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Sustainable Aquaculture System: Institutional Scientific Collaboration Network in Alborz Watershed, Iran

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ABSTRACT

The current research aimed to explore application of social network theory toward sustainable aquaculture system through Institutional Scientific Collaboration Network study conducted by interviews with key informants and follow-up organizational surveys at Alborz Watershed scale. The study was descriptive and explanatory, using social network analysis as a most analytical tool to systematically describe certain aspects of the social diversity and complexity of institutional scientific collaboration network. The needed data for social network analysis related to scientific collaborations in the form of research and scientific consulting, technical support, and implementation of joint project networks and was collected through a questionnaire. Research results revealed that the number of central actors in research and scientific consulting network was less than the other two networks. In this study, some powerful organizations such as the Institute of Ecology of the Caspian Sea and Shahid Rajai and Shahid Bahonar Reproduction Center had satisfactory research and scientific consultancy cooperation, as well as technical support for joint projects with other organizations, such as the Provincial Department of Fisheries, and Research Center for Agriculture and Natural Resources, which reflected dynamics of the organizations in the network. These three organizations can play a key role in the distribution of information, knowledge, and inter-sectoral cooperation among different institutions and can take responsibility of this process. If so, these organizations can develop a sustainable aquaculture in the basin of the Alborz Dam, based on scientific principles and in an interactive and dynamic path and, consequently, activate the implementation of projects and conducting scientific and executive studies by these organizations within the network. Although the approach is developed and tested using empirical social network data in the basin of Alborz watershed, the results can generally be useful for other regions and scales as well. Also, research finding could help in improving sustainable management through strengthening of intuitional scientific collaboration network and providing better understanding of the scientific needs and real interactions of diverse actors.

Keywords: Alborz basin, Betweenness centrality, Social diversity, Social network analysis.

INTRODUCTION

Aquaculture is one of the fastest-growing food production sectors, which has experienced significant developments in recent years, with the greatest part of this development taking place in developing countries (Ting *et al*., 2015). The experiences of different countries have shown that aquaculture can improve food security of the world and is known to be an important activity throughout the world, especially in developing countries (Choobchian *et al*., 2015). In the past decades, aquaculture quickly turned to a dynamic and growing industry (Jafarian, 2008). Rapid development of farmed aquaculture in Iran indicates a swift growth of aquaculture production in the past decade, such that aquaculture production in 2001 was reported to be about 73,645 tons. In 2011, this value reached

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285,351 tons (Iranian Fisheries Organization, 2011). Table 1 indicates the development trend of aquaculture and reduction in fishing in Mazandaran Province, as one of the pioneering provinces in the field of aquaculture.

Aquaculture is one of the productive activities that are considered destructive for natural resources, due to the release of a large amount of wastes in the surface and ground waters (Edwards, 2015). Therefore, it has been widely criticized by environmentalists due to its destructive use of resources and its negative effects on the environment (Salehi *et al*., 2018). However, some of the issues presented by environmentalists can be resolved through changing and improving aquaculture production practices. Fisheries and Aquaculture Department of Food and Agriculture Organization (2006) has announced that one of the basic procedures in order to manage a sustainable development in aquaculture is through better monitoring and control. Monitoring and control can be defined as a set of rules, institutions, and other factors that relate to exploitation of the environment and resources, evaluation and analysis of the problems and opportunities, acceptable and prohibited behaviors, and rules and restrictions related to the distribution and taking advantage of the natural resources. Accordingly, some organizations have made some changes in their managerial practices to address these constraints, which are acceptable and achievable by producers to reduce their negative impacts on the environment. In some countries, environmental management agencies have imposed laws and regulations related to aquaculture (Boyd *et al*., 2007).

In this regard, some approaches are presented to prevent degradation of the ecosystem (Folke *et al*., 2005). In these approaches, management of the ecosystem is discussed in terms of social and ecological systems (Bijani *et al*., 2017; Sabzali Parikhani *et al*., 2018), in which, in addition to ecosystem management, information regarding management of power relations, and cooperation in the scientific field are addressed (Roldan *et al*., 2015). Social network analysis is a useful tool in describing and explaining social phenomena in the form of an innovative framework for the sake of analyzing social dimensions of socio-ecological systems (Bodin and Crona, 2009; Crona and Bodin, 2010 cited in Roldan *et al*., 2015). Social networks can improve collaborative processes in sustainable natural resource management (i.e. governance) by facilitating the generation, acquisition, and diffusion of different types of knowledge and information about the systems under management (Bodin and Crona, 2009). Social network analysis has some indicators and each of these indicators represents an important social or political component. Centrality in degree shows reputation and authority of the actor; degree of centrality of the output shows social or policy influence (it means an actor's ability to affect legislative and management decisions of other actors (Weiss *et al*., 2012) of the actor and Betweenness Centrality shows the power control

Table 1. Aquaculture and fishing activities in the period of ten years in Mazandaran (Iranian Fisheries Organization, 2011)

The fish catches in the Mazandaran Province in the years 2001-2011 (Tons)											
Description	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Bony fishes	4837	5280	7983.5	6046.5	8316	11025	10244	9987.1	8500	7360	7251
Sturgeon	350	272	173	170	152	129	87	61.2	54	32	32
Kilka	14785	10200	8025	10260	13859	13538	10301	12260	20741	21216	15856
Total	19972	15752	16181.5	16476.5	22327	24692	20632	22308.3	29295	28608	23139
Level of Fish harvesting from water resources in Mazandaran Province in the years 2001-2011 (Tons)											
Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mazandaran	134	80	240	121	120	165	180	120	206	185	124
Level of growing cold-water fish in the Mazandaran Province in the years 2001-2011 (Tons)											
Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mazandaran	1195	1713	3187	4074	4662	6864	8097	9169	10514	12456	13294
Level of growing warm-water fish (carp fish and caviar) in the Mazandaran Province in the years 2001-2011 (Tons)											
Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mazandaran	2766	20844	22233	22825	24648	22959	30610	29140	35950	38391	41690

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of an actor, and these indicators are particularly important in the networks surveyed in this research. Because, through identifying the actors with high mediate power, one can transmit the data in the network and approve and implement appropriate policies, while spending less time and money (Ghorbani *et al*., 2013).

In the study, given the fact that decision making units (organizational context) cannot act in complete isolation, and their decision making pattern is a function of the interaction of their structural relations, the following question was raised:

How can structural relationships affect the success of this decisions making, i.e. what are the minimum definable network structural relations to achieve an institutional scientific collaboration?

The present study was the first in Iran in the area of aquaculture, and the key experts believed that the main reason for success in this field was the presence of scientific activities and collaborations among organizations. Therefore, the main aim of the present research was to determine the network arrangement in such a way that the results can be used successfully in other watershed areas and regions. Along with the research questions, two hypotheses were also tested. (Figure1, a)

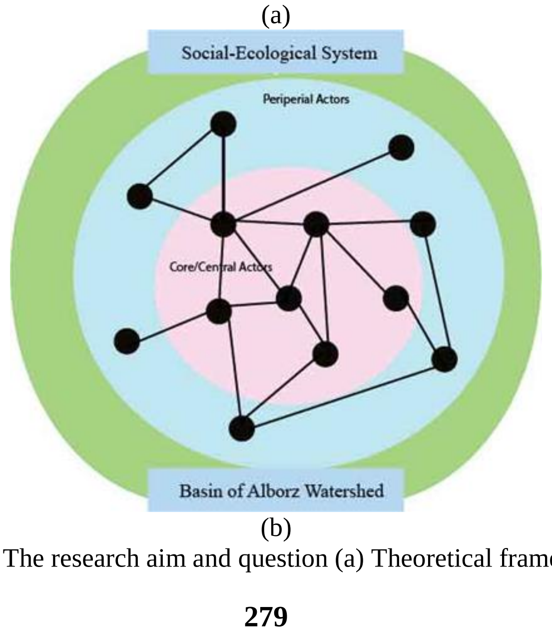
1. High centrality and low density indicate the asymmetry in the network under study, hence the emergence of high number of peripheral actors in contrast to smaller number of central actors.
2. There is a significant and positive relationship between the networks under study (research and scientific consulting, technical support, and implementation of joint projects) with policy influence network.

The Study Area

The area of Alborz Watershed, located in Mazandaran Province in northern Iran, is 1,347 km^2. It includes: (i) 346 km^2 upper catchments, mainly rangeland or forest covered; (ii)110 km^2 middle lands, which are gentle hills with irrigated valley bottoms and degraded or semi-degraded forests on hill sides; and (iii) 891 km^2 lowlands, mainly irrigated plains, down towards the Caspian Sea, which is about 25 m below oceanic sea level. The upper land ranges from mountain tops at 3,300 m asl down to the Alborz Dam site at 190 m asl. The middle land is defined as the area between the Alborz Dam and the start

The aim of the research was to explore how to use a social network theory to analyze the structural characteristics of the institutional scientific collaboration at the Alborz watershed scale. The study adopted descriptive and explanatory methods, using social network analysis as a most analytical tool to systematically describe certain aspects of the social diversity and complexity of institutional scientific collaboration.

(a)



(b)

Figure 1. The research aim and question (a) Theoretical framework (b).

of the main irrigation canal, at an elevation of 150 m asl. The lower land is densely-populated, predominantly irrigated, and lies between 150 to -25 m asl (Hoseini and Rezaei, 2013) (See Figure2, the study area).

In Iran, the tremendous development of aquaculture breeding (see Table 1) clearly supports the rapid growth relating to aquaculture production observed over the past decade. For instance, the amount of aquaculture production in 2001 reached about 73 thousand and 645 tons. In 2011, 10 years later, this amout reached 285 thousand and 351 tons. Table 1 indicates the development trend of aquaculture and reduction in fishing in Mazandaran Province, as one of the pioneering provinces in the field of aquaculture (Iranian Fisheries Organization, 2010).

MATERIALS AND METHODS

Social networks are comprised of actors tied up to one another through socially meaningful relations (Scott, 2003). These relations can

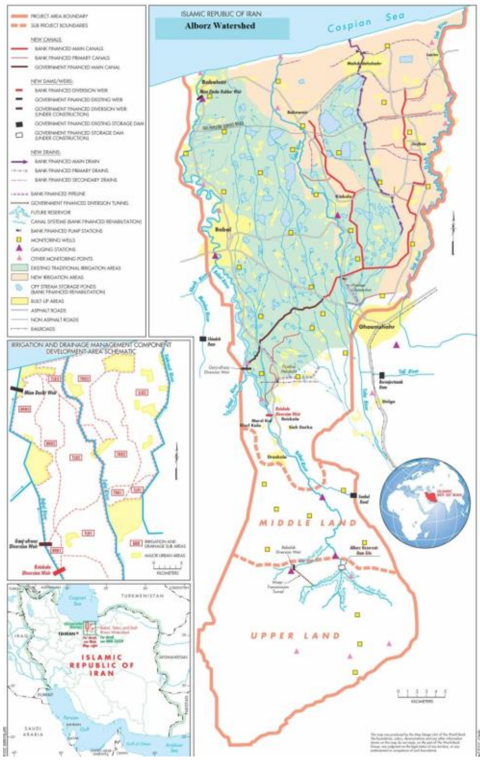


Figure2. Alborz Watershed Basin (Iranian Ministry of Agriculture, 2004).

then be analyzed for structural patterns that emerge among these actors. Thus, in social network analysis we look beyond attributes and characteristics of individuals or organizations for examining the relations among actors (e.g. individuals or organizations), how actors are positioned within a network, and how relations are structured into overall network patterns (Prell *et al*., 2009). In the present study, the required data for social network analysis were collected through combination of semi-structured interviews and organizational survey. Accordingly, complete network method, as a measurement method for analyzing the relations between the actors, was used. The complete network method can provide maximum information, but in a difficult and costly manner. To perform this procedure, we should have a complete list of all the actors, and the required information on the relationships between the actors must be collected. In this method, having collected the information on the relationship between the actors, a comprehensive and holistic image of the inter-population relationship is presented and, thus, it is possible to examine collaboration patterns, gaps, and challenges in the network, the gradual changes in network structure, and direct and indirect links between members of the network or system (Ghorbani *et al*., 2013; Hanneman and Riddle, 2005).

The current research uses the complete network sampling method to determine the nodes and actors in network analysis. Thus, all of the institutional actors relevant to sustainable aquaculture are considered based on the key informants' opinion. The actors are described in a pre-study, and the trend of work is described in the following parts. Accordingly, it is possible to present reliable and robust results on the relationships within the population.

To create social network data in the pre-study, based on 30 key informants with complete knowledge of organizations and their management levels and type of their activity in aquaculture, 27 organizations were identified. Use of such method (i.e. preparation of recall list in the pre-study) was confirmed by some researchers such as Stein *et al*. (2011) and Marsden (1990). The questionnaire was

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distributed in 27 organizations and they were asked to weight their current experience and communications with other organizations within the time period of the recent one year, and the extent of their communications with other organizations present in the list in three contexts of research and scientific consulting, technical support, and implementation of joint projects in the form of daily communications (1), weekly communications (2), monthly communications (3), four times per year (4), twice a year (5), once a year (6), and "zero" to express lack of communication. The data used to analyze the social network is relational data and unit of analysis is the relationship among the network actors, rather than the individual actors. Therefore, the collected data describes the relationships between actors (individuals, organizations, etc.) rather than the actors themselves. The data will be presented as two-dimensional matrices, eventually. The first row and column of the matrix and its cells represent network members and the relationships among them, respectively. In this matrix, as shown in Figure 3, initial matrix is a directed and weighted one. It should be noted that in a network where relationships are directed, relationship matrix is not symmetric, i.e. the relationship between groups A and B may be different from the relationship between groups B and A (Scott, 2003, See in Figure 1-b).

When each one of the organizations announced its communication with other organizations, numbers 1 through 6 for weighted networks and zero for lack of communication, the values were imported into Excel Software in the form of pairwise matrix, which was converted into a dyadic matrix (zero for lack of communication and 1 for presence of communication). Resulted matrix was used for data analysis. According to some subject specialists views and with regard to research objectives for comparing the results of existing network with standard network, weighted matrix Converted to Dyadic matrix (Carolan, 2013).

One of the weaknesses of the use of opinions proposed by only one person in the network analysis studies is that the communications relevant to the lower levels of organization that cover a wider network may be neglected, and this requires interviews with several people in an organization based on the size and duties of the relevant organization (Stein *et al*. 2011). This issue was out of the scope of the current research, and the research hypothesis was that collaborative activities in the studied organizations often was communicated by senior management to lower levels of the organization, and this issue, which was confirmed by the key informants, formed the basis for the current research. The collected data were analyzed using software Ucinet 6, which is one of most widely used softwares for analyzing social network data. Moreover, Net Draw software was used to draw the graphs. Table 2 indicates that the indices under evaluation of the intended network were proposed along with description. The indices will be categorized in three levels, including Macro level (density, concentration, reciprocity, and transitivity indices), Mid-level (center and peripheral index) and Micro level (In/Out Degree Centrality, Betweenness Centrality). In order to identify the key actors in institutional scientific collaboration network according to Boolean Combination, the data matrices of investigated networks were combined. This index were used to combine relationships (two or more) and the achievements will be to obtain a multiple relationships matrix to identify high score actors among scientific consultation, technical support, and implementation of joint projects. In the present research, Quadratic Assignment Procedure (QAP) was developed by Hubert (1987) and Krakhardt (1987) to test the null hypothesis where there is no correlation between two and more than two networks.

Weighted matrix					Dyadic matrix			
	A	B	C			A	B	C
A	0	6	3	Converted to	A	0	1	1
B	4	0	2	$\longrightarrow$	B	1	0	1
C	0	1	0		C	0	1	0

Figure 3. The process of converting weighted matrix to dyadic matrix.

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Table 2. Description and measurement of social networks (Roldán *et al*., 2015; Bodin and Crona, 2009; Scott, 2003; Ghorbani *et al*., 2013; Borgatti and Everett, 1999).

Measurement	Description
Density	Density is defined as the number of existing links divided by the number of possible ties. It indicates how connected a population is to another.
Centralization	Centralization indicates the tendency in the network for a few nodes to have many links, e.g. a wheel-star structure in which one central node is connected with all other nodes (Degree= n-1) which are not connected to each other (Degree= 1). Centralization expresses the degree of inequality or variance in the network as a percentage of that of a perfect wheel-star network of the same size.
Degree	The degree of a node, also called degree of centrality, indicates the number of links a node has (Freeman, 1979). A high degree of centrality for an individual node indicates that it has many links compared to other nodes and a central (powerful) position in the network. The number of direct relations between an actor and other actors in a network is called centrality. If we want to pay attention only to one aspect of the relation, we can focus on this issue that a central actor receives how many input links (which is also known as In-Degree Centrality) of how many output links a central actor has (which is also known as Out-Degree Centrality). The higher the centrality value of an actor, the more its access to the resources, and it will be considered more central. The centrality has only one form in undirected graphs and two forms in directed graphs (present paper): in and out (Carolan, 2013). The sociological interpretation of these two indices is as follows: Out-links represent providing some resources to the network and in-links represent receiving some resources from the network. A high value for an Out-Degree Centrality indicates high influence of the actor and a high value for In-Degree Centrality indicates popularity and power of the actor, such that many actors refer to this actor (Scott, 2003).
Betweenness	Betweenness is the measure that indicates how much a node is located in the path between other actors or how much a node connects other nodes with each other (Freeman, 1977). This measure can be applied to individual nodes, and can then be used to identify actors that contribute most to linking the network.
Reciprocity	A very important index in determining the stability and integrity of the network, which is achieved by examining the relationships between network actors.
Transitivity	The index is derived from the sharing links between three individuals that one of them acts as a connecting bridge between the other two. More persons transiting links lead to higher amount for this index and, as a result, more stability and durability are created between the actors.
Network size	This metrics suggests the number of links in a network of relationships. The more number of links leads to more density of the relationships network.
Core/Periphery Structures	The concept of the network core structure usually refers to a central AND densely, cohesive, connected set of network nodes, while the periphery structure of the network refers to a sparse, unconnected, usually peripheral set of nodes, which are linked to the core (center) (Borgatti and Everett, 1999).

Applying regression models and permutation tests for valued variables, also for a set of related models, this test predicts two-part (non-value-bearing) dyadic relationships among the actors in a directed graph (Carolan, 2013), which will be conducted by UCINET Software (Borgatti *et al*., 2002). In the present paper the latter is intended.

RESULTS

The results achieved from social network analysis are presented in two sections: (1) Investigating research and scientific consulting networks, technical support, and implementing

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joint projects, and (2) Comparison of the active actors of each network.

Investigating Research and Scientific Consulting Networks, Technical Support, and Implementation of Joint Projects among Related Institutional Actors

Linkage density of research and scientific consulting among constitutional actors related to sustainable aquaculture is equal to 40.31 percent, which is a medium density, and the institutional coherence based on this network is moderate. The other indicator is network centralization, which, according to the internal and external ties network in the matrix of research and scientific consulting in the surveyed area are about 49.01 and 53.99% for both ties. Another indicator is the reciprocity of the ties, which was examined among institutional stakeholders and shows a value of 43.65%. This value shows a medium interaction among the institutions in the network of research and scientific consulting, and it can be concluded that stability of the involved institutional network associated with the surveyed network has a medium sustainability. Of course, ties transitivity indicators reflect also the stability of the network, and its amount is equal to 63.34% for this network and shows a medium sustainability of the actors' network. On the other hand, network size indicator for research and scientific consulting network includes 283 ties from 702 expected ties (see Table 3).

In Table 4, indices of In-Degree Centrality, Out-Degree Centrality and Betweenness are calculated for each actor on the micro level of the network, and these actors are institutional actors related to sustainable aquaculture. According to Table 4 and Figure (4-a), it can be concluded that, in the surveyed area and in the network of institutional stakeholders involved in sustainable aquaculture and based on scientific and consulting research ties, Agriculture Ministry, Food and Natural Resources Engineering Organization, and Institute of Ecology of the Caspian Sea have a high reputation and authority, and Government, Fishing Cooperatives and the Institute of Ecology of the Caspian Sea have a great social influence. In addition, regarding Betweenness Centrality, three institutes including academic and educational centers, Center for Agricultural and Natural Resources Research, and the Institute of Ecology of the Caspian Sea have a very high control and intermediary power. Therefore, in institutional actors network, these institutes are considered as important institutes with high intermediary role, and are effective and key actors in research and scientific consulting among the institutions, and play a major role in the tenure process of sustainable aquaculture.

Linkage density of technical support tie among actors related to sustainable aquaculture is equal to 23.36 percent, which is a weak density, and the amount of institutional cohesion based on this network is at a low level. The other index is centralization of the networks, which was investigated according to internal and external ties in a technical support matrix and was 35.65 and 27.66%, respectively. Reciprocity of the ties showed a value of 35.54%, which indicates an average level of cooperation among the institutions in the network. Transitivity index of the ties, which shows stability of the network, is equal to 46.99 percent for this network and it indicates an average level of stability among

Table 3. Size of indicators in the network of organizations involved in sustainable aquaculture.

	Research and scientific consulting	Technical support	Implementation of joint projects
Organizations number	27	27	27
Expected ties number	702	702	702
Centralization (Internal)	46.01	35.65	52.1
Centralization (External)	53.99	27.66	32.1
Density (%)	40.31	23.40	19.1
Reciprocity	43.65	35.54	24.07
Network size	283	164	134
Transitivity	63.34	46.99	37.4
Centralization	46.0	27.7	52.1

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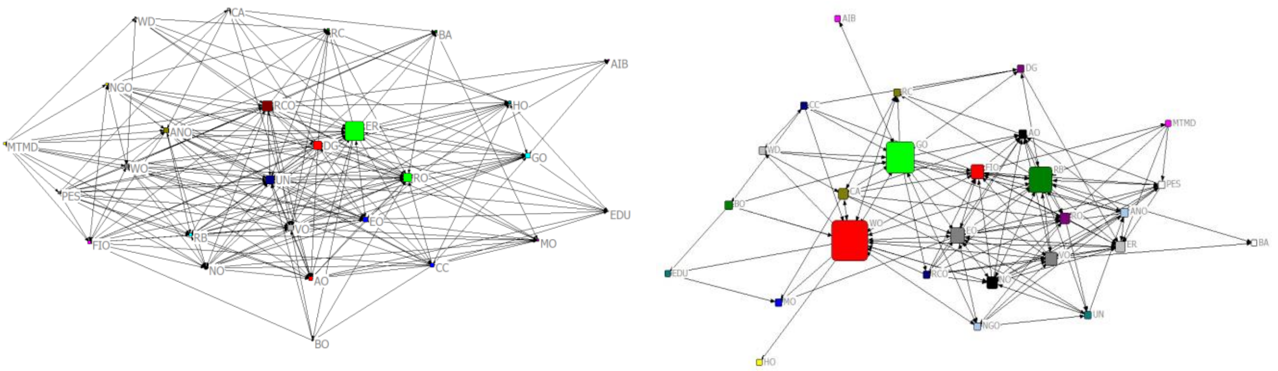
Table 4. Size of the indicators at a micro level: Analyzing cooperative network of institutional actors involved in sustainable aquaculture.

Name of the institutes related to sustainable aquaculture	Abbreviation name of the actors	Research and scientific consulting			Technical support			Implementing joint projects		
		Centrality (Out Degree)	Centrality (In Degree)	Betweennes	Centrality (Out Degree)	Centrality (In Degree)	Betweennes	Centrality (Out Degree)	Centrality (In Degree)	Betweennes
Agriculture Organization	AO	14.82	59.26	0.50	11.11	44.44	0.79	22.22	70.37	9.43
Department of Environmental Protection	EO	48.15	51.85	2.64	37.04	44.44	3.92	25.93	25.93	5.07
Department of Natural Resources and Watershed Management	NO	37.04	55.56	0.48	33.33	40.74	2.62	11.11	48.15	1.85
Regional Water Authority of the Province	WO	55.56	40.74	1.44	51.85	48.15	16.73	22.22	40.74	6.22
Provincial Department of Fisheries	FIO	37.04	55.56	1.73	33.33	48.15	7.48	29.63	33.33	9.81
Agriculture Bank and Operating Banks	BA	18.52	22.22	0.19	3.70	11.11	0.00	33.33	14.82	2.22
Research Center for Agriculture and Natural Resources	RO	59.26	74.07	9.01	33.33	29.63	4.10	18.52	11.11	1.42
Government House	GO	48.15	40.74	5.34	55.56	25.93	13.41	48.15	44.44	20.25
Environmental NGOs	NGO	48.15	48.15	5.01	25.93	25.93	3.62	18.52	18.52	4.64
Private Extension Services (Counseling Centers of Aquaculture)	PES	33.33	44.44	0.59	22.22	25.93	0.24	22.22	25.93	2.89
fishermen's Cooperative enterprise	RCO	74.07	40.74	3.12	33.33	14.82	0.22	29.63	11.11	7.44
Sari University of Agricultural Science and Natural Resources	UN	48.15	85.19	7.47	14.82	14.82	0.38	11.11	3.70	0.00
Agriculture and Natural Resources Engineering Organization	ANO	40.74	59.26	2.04	33.33	14.82	1.09	11.11	11.11	0.76
Department of Meteorology	MO	0.00	37.04	0.00	0.00	14.82	0.00	0.00	3.70	0.00
Department of Cooperatives, Labor and Social Welfare	CA	22.22	11.11	0.11	37.04	14.82	2.49	14.82	22.22	5.92
Department of Health	HO	11.11	37.04	0.87	0.00	3.70	0.00	0.00	7.41	0.00
Department of Education	EDU	11.11	18.52	0.21	3.70	7.41	0.08	7.41	3.70	0.73
provincial Veterinary Office	VO	62.96	55.56	3.85	40.74	25.93	2.20	25.93	11.11	3.63
Governor Office	DG	81.48	18.52	1.83	14.82	11.11	0.54	22.22	7.41	1.11
city Council	CC	51.85	11.11	0.36	18.52	11.11	2.34	7.41	7.41	0.08
Housing and Urban Development	BO	14.82	7.41	0.03	14.82	7.41	0.39	22.22	25.93	7.17
Provincial Water and Sewage Company	WD	25.93	25.93	0.92	18.52	18.52	1.20	14.82	14.82	1.48
Agricultural Insurance Fund	AIB	14.82	14.82	0.00	3.70	3.70	0.00	0.00	0.00	0.00
Department of Rural Cooperatives	RC	25.93	22.22	0.26	7.41	22.22	1.75	7.41	7.41	0.86
Institute of Ecology of the Caspian Sea	ER	88.89	62.96	17.89	0.00	44.44	0.00	44.44	11.11	7.99
Shahid Rajaei and Shahid Bahonar Reproduction Center	RB	48.15	51.85	1.34	55.56	44.44	13.15	22.22	18.52	3.36
National Research Center of the Caspian Sea	MTMD	44.44	14.82	0.48	18.52	3.70	0.04	11.11	3.70	0.00



(a) (b)

Figure 4. Network of research and scientific consulting in the studied area (a) Technical support network in the surveyed area (b) (a larger size indicates a higher level of Betweenness Centrality). 322×174 mm (96×96 DPI). Color squares represent different organizations. The larger square indicates the higher Betweenness Centrality. The abbreviation of the components of the figure is given in Table 4.

actors involved in the network. On the other hand, network size index includes 164 ties for technical support network (Table 3).

In Table 4, indices of In-Degree Centrality, Out-Degree Centrality and Betweenness were calculated for each actor and at a micro level of the network, suggesting that these actors were institutional stakeholders involved in sustainable aquaculture. According to Table 4 and Figure (4-b), it can be concluded that in the surveyed area and in network of the institutional actors in the network sustainable aquaculture, and according to the technical support network, Agricultural Organization, Department of Fisheries of the Province, and Regional Water Authority have a high reputation and authority, while Regional Water Authority, Provincial Veterinary Office, and Shahid Rajaei and Shahid Bahonar Reproduction Centers have a high level of social influence. Also, regarding Betweenness Centrality, Regional Water Authority, Provincial Veterinary Office, and Shahid Rajaei and Shahid Bahonar Reproduction Centers have a high intermediary and control power.

Linkage density among institutional actors related to sustainable aquaculture is 19.1 percent, which is a low level density and, consequently, institutional cohesion based on this indices will be at a low level. The other index is centrality of the network, which is, respectively, about 52.1% and 32.1 percent for the network and according to the internal and external ties in the implementation of joint projects matrix of the surveyed region. Reciprocity of the ties shows a value of 24.07 percent, which suggests a weak cooperation among institutions involved in the network. Transitivity of the ties index, which shows stability of the network, equals to 37.4 percent for the network, suggesting a low stability among network actors. On the other hand, network size indicator for implementation of joint projects network includes 134 ties from 702 expected ties (Table 3).

In Table 4, indices of In-Degree Centrality, Out-Degree Centrality, and Betweenness were calculated for each actor and in a micro level, where these actors are institutional stakeholders related to sustainable aquaculture. According to Table 4 and Figure 5, it can be concluded that in the surveyed area in the network of institutional actors involved in sustainable aquaculture and according to the network of implementing joint projects, Department of Fisheries of the Province, Regional Water Authority, Department of Natural Resources and Watershed Management, and Agricultural Organization have a high level of reputation and authority, while the Provincial Department of Fisheries, Institute of Ecology of the Caspian Sea, Agricultural Bank, and Operating Banks, and Government Office have a high level of social influence. Also, regarding Betweenness Centrality, three institutes including Provincial Department of Fisheries, Government Office, and Agriculture Organization have a high level of control power and mediation.

One of the most important indicators in a mid-level institutional network is central and

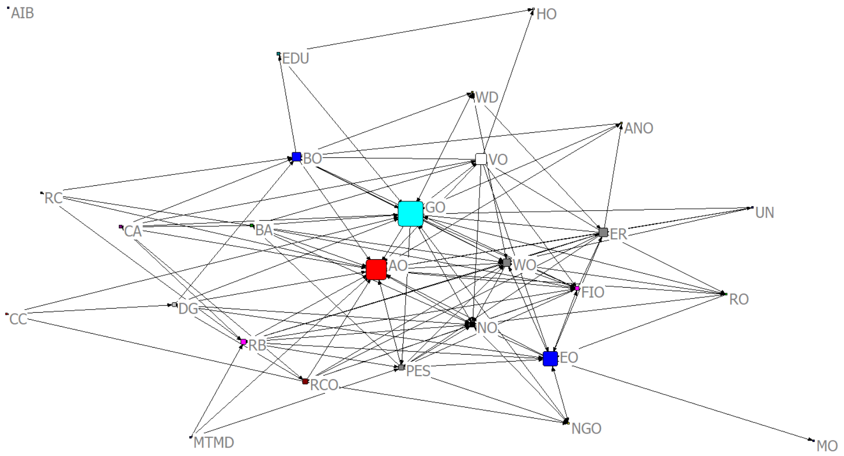


Figure 5. Network for implementing collaborative projects in the surveyed area (a larger size indicates a higher level of Betweenness Centrality). 322×174 mm (96×96 DPI). Color squares represent different organizations. The larger square indicates the higher Betweenness Centrality. The abbreviation of the components of the figure is given in Table 4.

peripheral index, which can accordingly determine institutions located in the center or around the network. According to the index, key actors involved in the network are divided into central subgroups, which enhance communication and will lead to close relations in network management, and despite peripheral actors that have a minor role, they play a major and influential role. In Table 5, groups are presented according to various ties and using peripheral center index.

Investigating the Role of Network Actors

In order to investigate the role of various organizations in the studied networks, the values of their In-Degree Centrality and Out-Degree Centrality are investigated (Figure 6, a-c).

This index represents the amount of provided or received research and scientific consulting, technical support, and implementation of joint projects networks. According to this index, in this section, organizations whose research and

Table 5. Central and peripheral actors according to the studied networks.

Research and scientific consulting	
Central actors	Peripheral actors
AO EO NO WO FIO RO GO NGO PES RCO UN ANO VO DG ER RB	BA MO CA HO EDU CC BO WD AIB RC MTMD
Density: 0.721	Density: 0.261
Number of central actors: 16	Number of peripheral actors: 11
Technical support	
Central actors	Peripheral actors
AO EO NO WO FIO RO GO NGO PES RCO ANO VO RB	BA UN MO CA HO EDU DG CC BO WD AIB RC ER MTMD
Density: 0.571	Density: 0.187
Number of central actors: 13	Number of peripheral actors: 14
Implementation of joint projects	
Central actors	Peripheral actors
AO EO NO WO FIO BA RO GO NGO PES BO ER	RCO UN ANO MO CA HO EDU VO DG CC WD AIB RC RB MTMD
Density: 0.455	Density: 0.133
Number of central actors: 12	Number of peripheral actors: 15

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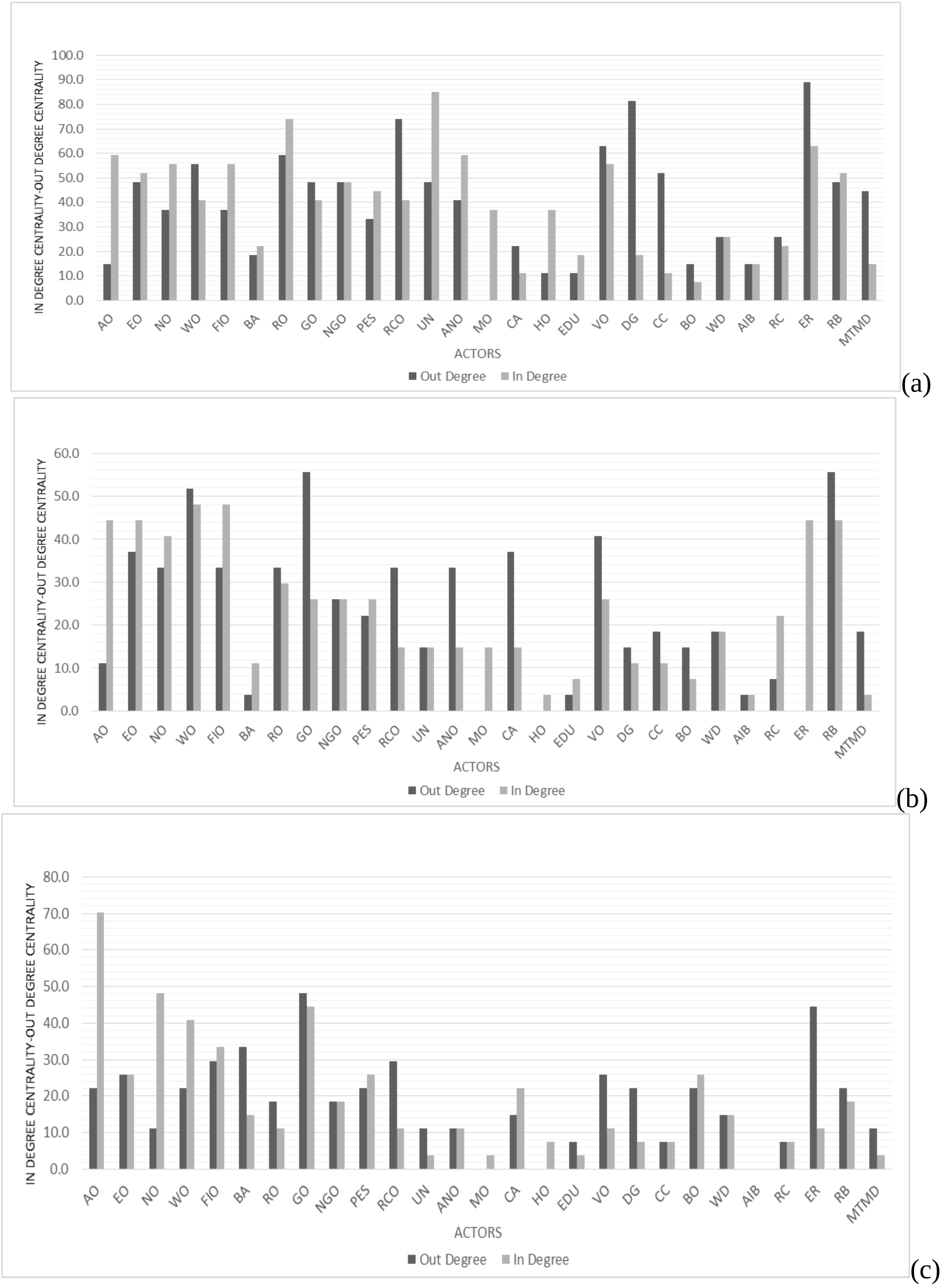

Figure 6. In-Degree Centrality-Out-Degree Centrality in: (a) research and scientific consulting network (b) technical support network (c) implementation of joint projects network
322×174 mm (96×96 DPI).

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scientific consulting In-Degree Centrality is less than their Out-Degree Centrality and have high Betweenness and based on type and nature of organization, namely, the consultancy they provide is more than the consultancy they receive, are called Consulting Organizations. For example, the Institute of Ecology of the Caspian Sea (ER), which has high Betweenness, in the first rank, and the National Research Center of the Caspian Sea (MTMD), in the next rank, are considered strong consulting organizations. Regarding technical support, national research center of the Caspian Sea and Shahid Rajai and Shahid Bahonar Reproduction Centers are considered active organizations in the field of technical inter institutional cooperation.

Regarding the third indicator, which is implementation of joint projects, among all organizations active in this regard, Technical Organization of the National Research Center of the Caspian Sea and Shahid Rajai and Shahid Bahonar Reproduction Centers, as well as National Research Center of the Caspian Sea in the sustainable management of aquaculture, have been active and are considered as executors of joint activities and projects. In addition, in order to investigate correlation between the surveyed networks and its effect on policy influence and cooperation networks, *QAP* (Quadratic Assignment Procedure) index was applied. The results show that, unless non-existence of correlation between cooperation network and implementation of joint projects, and between policy influence networks with technical support and research and scientific consulting networks, there has been no significant relation (Table 6).

Combined Network

Table 7 shows centrality of each actor in Boolean matrix (combined). This index was obtained from combination of three matrices, including research and scientific consulting, technical support, and implementation of joint projects. Accordingly, the central power of the actors involved in aquaculture institutional scientific collaboration can be identified. In order to identify these actors in the network, according to Boolean Combination, the three aforementioned matrices were combined according to the mathematical rules and using UCNet software. According to Table 7 and Figure 7, it is suggested that the actors including Agricultural Organization, Provincial Department of Fisheries, and Department of Natural Resources and Watershed Management have more authority to link research and scientific consulting, technical support, and consequently, implementation of joint projects. Because of their high social power, they can be used as the interface between institutional scientific authorities to plan sustainable development of aquaculture. Given In-Degree Centrality (Table 7), it is suggested that most actors are not powerful in terms of research and scientific consulting, technical support, and, consequently, implementation of joint projects links, while Agricultural Organization is the actor that has high authority and, based on Out Degree Centrality, Department of Environmental Protection and Regional Water Authority of the Province have high influence. These actors as key actors play a key role in strengthening trilateral relations among the actors and have an appropriate power and influence to improve consistency among stakeholders in the region. Also, due to the combination of the three abovementioned networks, some actors such as Agricultural Bank and Operating Banks (BA), Sari University of Agricultural Science and Natural Resources (UN), Healthcare

Table 6. *QAP* correlation index among surveyed networks, policy influence and cooperation networks.

	Cooperation	Policy influence	Research and scientific consulting	Technical support	Implementation of joint projects
Cooperation	1	-	-	-	-
Policy influence	0.206 *	1	-	-	-
Research and scientific consulting	0.278*	0.043 ns	1	-	-
Technical support	0.224*	0.062 ns	0.308*	1	-
Implementation of joint projects	0.058 ns	0.155*	0.1708	0.289*	1

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Table 7. Size of the indicators at combined networks (Boolean combination).

Name of the institutes related to sustainable aquaculture	Abbreviation name of the actors	Centrality (Out Degree)	Centrality (In Degree)	Betweenness
Agricultural Organization	AO	0.04	0.35	6.72
Department of Environmental Protection	EO	0.19	0.15	8.15
Department of Natural Resources and Watershed Management	NO	0.08	0.27	8.78
Regional Water Authority of the Province	WO	0.19	0.12	7.59
Provincial Department of Fisheries	FIO	0.15	0.19	13.03
Agriculture Bank and Operating Banks	BA	0.00	0.00	0.00
Research Center for Agriculture and Natural Resources	RO	0.12	0.08	8.58
Government House	GO	0.12	0.08	7.21
Environmental NGOs	NGO	0.04	0.04	0.00
Private Extension Services (Counseling Centers of Aquaculture)	PES	0.12	0.12	2.08
Fishermen's Cooperative Enterprise	RCO	0.15	0.00	0.00
Sari University of Agricultural Science and Natural Resources	UN	0.00	0.00	0.00
Agriculture and Natural Resources Engineering Organization	ANO	0.04	0.00	0.00
Department of Meteorology	MO	0.00	0.04	0.00
Department of Cooperatives, Labor and Social Welfare	CA	0.04	0.00	0.00
Department of Health	HO	0.00	0.00	0.00
Department of Education	EDU	0.00	0.00	0.00
provincial Veterinary Office	VO	0.15	0.04	3.04
Governor Office	DG	0.04	0.04	0.00
City Council	CC	0.08	0.04	2.31
Housing and Urban Development	BO	0.00	0.00	0.00
Provincial Water and Sewage company	WD	0.08	0.08	5.13
Agricultural Insurance Fund	AIB	0.00	0.00	0.00
Department of Rural Cooperatives	RC	0.00	0.00	0.00
Institute of Ecology of the Caspian Sea	ER	0.00	0.08	0.00
Shahid Rajaei and Shahid Bahonar Reproduction Center	RB	0.15	0.12	2.96
National Research Center of the Caspian Sea	MTMD	0.08	0.04	0.44

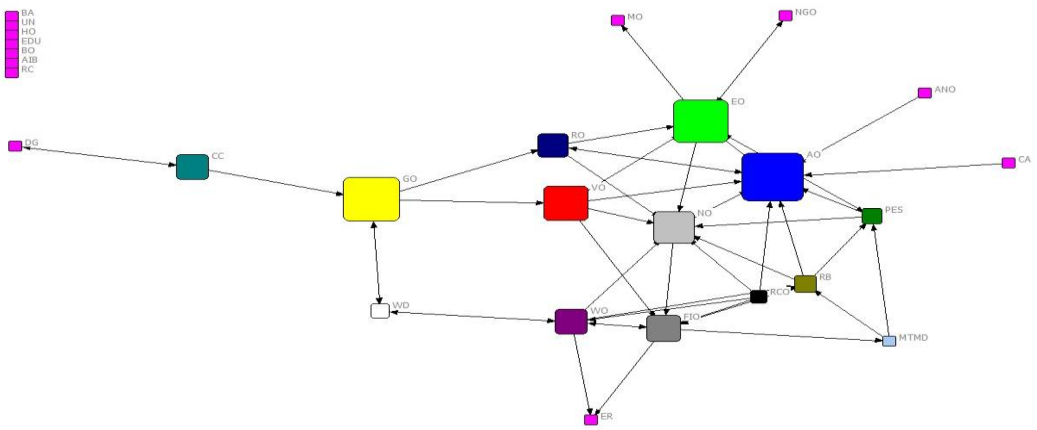

Figure 7. Combined network (Boolean combination in the surveyed area, 322×174 mm (96×96 DPI). Color squares represent different organizations. The larger square indicates the higher Between Centrality. The abbreviation of the components of the figure is given in Table 7.

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Organization (HO), Department of Education (EDU), Housing and Urban Development (BO), Agricultural Insurance Fund (AIB) and the Department of Rural Cooperatives (RC) have become isolated actors. In order to achieve the goals of a sustainable aquaculture, these actors should be encouraged to join the institutional scientific collaboration network.

CONCLUSIONS

The current research aimed to explore and analyze the network model used in the organizations active in the field of aquaculture in the Alborz Dam Watershed, in Mazandaran Province (as the holder of the first rank in aquaculture production in Iran). To this end, the social network analysis was performed to detect institutional scientific collaboration pattern in this top example of aquaculture production, and to find answers to the research questions and hypotheses, as below:

General state of inter-institutional relations through network analysis shows that this pattern has some weaknesses and strengths in the area of institutional scientific collaboration in the three studied contexts (research and scientific consulting, technical support, and implementation of joint projects), and by enhancing strengths and eliminating weaknesses related to the network, and transferring experiences and lessons learned from it to other areas, it would be possible to achieve proper institutional scientific collaboration at the local level in order to achieve the desired success in aquaculture production.

One of strengths of this network is the presence of some powerful agencies such as the Institute of Ecology of the Caspian Sea, Shahid Rajai and Shahid Bahonar Reproduction Centers, and National Research Center of the Caspian Sea had satisfactory participation and cooperation with other organizations regarding research and scientific consulting, as well as technical support for joint projects with other agencies such as the provincial Department of Fisheries, Research Center for Agriculture and Natural Resources and the governor office, which reflects dynamics of the organizations in the network. Thus, this result indicates that institutional scientific collaboration network can be successful in achieving its objectives in case there are some organizations with scientific expertise which are in a dynamic relationship with their administrative agencies. Fortunately, in the network under study, such organizations exist.

Based on the research findings, it was indicated that government agencies have more power and centrality in comparison to non-governmental organizations, which indicates a lack of co-management in the field of sustainable aquaculture. However, in order to achieve sustainability, involvement of all related actors is essential (Consistent with Sandström and Rova, 2010). On the other hand, investigating In-Degree Centrality and Out-Degree Centrality of non-governmental organizations shows that their Out-Degree Centrality is more than their In-Degree Centrality, which suggests that responsible organizations have paid less attention to knowledge and the information provided by non-governmental organizations closely associated with aquaculture (This finding is consistent with Ghorbani and Deh Bozorgi, 2014; Rezaei *et al*., 2015). The results are in line with those obtained from the interviews with the key informants and NGOs’ managers. One of the main concerns of NGOs in the field of aquaculture was the weakening of their influence in the network. And in case of establishing any relation, this connection is formed by NGOs. As it is well identified in combined network, NGOs set in whole network of Institutional scientific collaboration network with low and weak role. Also, due to the combination of the three abovementioned networks, some actors such as Agricultural Bank and operating banks (BA), Sari University of Agricultural Science and Natural Resources (UN), Healthcare Organization (HO), Department of Education (EDU), Housing and Urban Development (BO), Agricultural Insurance Fund (AIB) and the Department of Rural Cooperatives (RC) have turned to the isolated actors. In order to achieve the goals of a sustainable aquaculture, these actors should be encouraged to join the institutional scientific collaboration network.

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Accordingly, it is suggested that incentive mechanisms and procedures be adopted by decision makers and administrative organizations to make NGOs and isolated organizations more involved and active in the activities related to aquaculture, and ways to establish this two-way communication and interaction between these organizations be considered.

One of the hypotheses proposed in the research is to examine the relationship between the networks under study and policy influence of organizations over each other. In this respect, out of the three networks under study (i.e. research and scientific consulting, technical support, and implementation of joint projects), only the relationship between the implementation of joint projects and policy influence was significant. Based on the results and interview with key informants, it was revealed that if organizations can define their relationship more clearly and in a project-based manner, they can be more influential. Therefore, in order to implement plans and the activities relevant to aquaculture, whatever organizations are able to establish further collaboration in the area of joint implementation of projects, it would be easier to attract public funds for conducting further and accurate activities in this area. In a research by Weiss *et al*. (2012), it was concluded that the organizations with more policy influence are more capable of presenting information and knowledge to other organizations.

Core-periphery index is a type of blocking categorization of the institutions based on the different links in the network under study. In the research and scientific counseling's network, the number of central organizations is more than peripheral organizations and in technical support and implementation of joint projects networks, the number of central actors is less than peripheral actors. Based on the results, more progression toward definition and implementation of joint projects is tantamount to the reduction in the number of the organizations in central class. In addition, currently, lesser organizations are seriously involved in these activities; which calls for more investigations to identify the reasons. Thus, in order to make such activities more effective, these organizations should find opportunity to play a central role. As a result, the potentials and capabilities underlying these organizations can be further utilized in order to achieve more success in the area of aquaculture based on sustainability principle.

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نظام آبزی پروری پایدار: شبکه همکاری علمی ـ نهادی در حوضه آبخیز البرز

ا. قلی فر، ع. عباسی، و ع. رضایی

چکیده

هدف اصلی پژوهش حاضر کشف چگونگی استفاده از تئوری شبکه اجتماعی در راستای دستیابی به نظام آبزی پروری پایدار به وسیله مطالعه شبکه همکاری علمی ـ نهادی با مصاحبه با آگاهان کلیدی و پیمایش سازمانی در حوضه آبخیز البرز بود. این مطالعه یک کار توصیفی و اکتشافی با استفاده از تحلیل شبکه اجتماعی که یک ابزار تحلیلی که به صورت نظام مند جنبه های واقعی تنوع و پیچیدگی اجتماعی شبکه همکاری علمی ـ نهادی می باشد، صورت گرفته است. داده‌های لازم درخصوص همکاری‌های علمی، در قالب تحقیق و مشاوره علمی، پشتیبانی فنی و اجرای پروژه‌های مشترک در آبزی‌پروری، به‌منظور تحلیل شبکه اجتماعی از طریق پرسشنامه جمع‌آوری شد. نتایج تحقیق نشان داد که تعداد کنشگران مرکزی در شبکه تحقیق و مشاوره علمی کمتر از دو شبکه دیگر است. در این مطالعه، سازمان‌های قدرتمندی همچون مؤسسه اکولوژی دریای خزر و مرکز تکثیر شهید رجایی و شهید باهنر مشارکت و همکاری مطلوبی با سایر ارگان‌ها مانند اداره کل شیلات استان، و مرکز تحقیقات کشاورزی و منابع طبیعی در زمینه تحقیق و مشاوره علمی و پشتیبانی فنی برای پروژه‌های مشترک، داشته که نشان‌دهنده پویایی این سازمان‌ها در شبکه است. این سه سازمان می‌توانند در توزیع اطلاعات و دانش و ایجاد تعامل و همکاری بین بخش‌های مختلف نقش کلیدی داشته و مسئولیت این فرایند را بر عهده گیرند. دراین‌صورت، این سازمان‌ها می‌توانند با توجه به اصول علمی و در یک مسیر تعاملی و پویا، آبزی‌پروری پایدار را در حوضه سد البرز توسعه داده و در نتیجه اجرای پروژه‌ها و انجام مطالعات علمی و اجرایی توسط این سازمان‌ها و درون شبکه را فعال کنند. اگرچه این تحقیق با داده های تجربی حاصل از حوزه آبخیز البرز توسعه داده شده و مورد آزمون قرار گرفته است، ولی نتایج آن می تواند برای سایر مناطق و حوزه ها نیز مفید باشد. همچنین نتایج تحقیق می تواند در بهبود مدیریت پایدار به وسیله تقویت شبکه علمی ـ نهادی و درک بهتر از نیازهای علمی و تعاملات واقعی کنشگران متنوع، مفید واقع شود.

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