International Journal of the Commons
Vol. 4, no 1 February 2010, pp. 528–551
Publisher: Igitur, Utrecht Publishing & Archiving Services for IASC
URL:http://www.thecommonsjournal.org
URN:NBN:NL:UI:10-1-100223

ISSN:1875-0281

The network structure of adaptive governance: a single case study of a fish management area

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Abstract: The challenge of establishing adaptive management systems is a widely discussed topic in the literature on natural resource management. Adaptive management essentially focuses on achieving a governance process that is both sensitive to and has the capacity to continuously react to changes within the ecosystem being managed. The adoption of a network approach that perceives governance structures as social networks, searching for the kind of network features promoting this important feature, has been requested by researchers in the field. In particular, the possibilities associated with the application of a formal network approach, using the tools and concepts of social network analysis (SNA), have been identified as having significant potential for advancing this branch of research. This paper aims to address the relation between network structure and adaptability using an empirical approach. With the point of departure in a previously generated theoretical framework as well as related hypotheses, this paper presents a case study of a governance process within a fish management area in Sweden. The hypotheses state that, although higher levels of network density and centralisation promote the rule-forming process, the level of network heterogeneity is important for the existence and spread of ecological knowledge among the actors involved. According to the empirical results, restricted by the single-case study design, this assumption is still a well-working hypothesis. However, in order to advance our knowledge concerning these issues and test the validity of the hypotheses, more empirical work using a similar approach in multiple case study designs is needed.

Acknowledgement: We gratefully acknowledge the Swedish Environmental Protection Agency and the Adaptive management program for founding part of this work. Thanks also to the anonymous reviewers for valuable comments.

Keywords: Adaptive management; co-management; governance; social networks; social network analysis (SNA)

1. Introduction

Within the field of natural resource management, the search for appropriate institutions for governing the commons is an ever-challenging task (Dietz et al. 2003). Recently, the concept of adaptive management has gained significant attention in the literature. This has addressed the quality of the link between the management system and the socio-ecological environment into which it is embedded (Olsson et al. 2004; Smajgl and Larson 2006; Janssen et al. 2007). Drawing upon previous work by Pinkerton (1989), Pomeroy (1995), and Hanna (1998), Folke et al. (2002, 20) define adaptive management as "a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of trial-and-error". Thus, an adaptive governance process is sensitive to the ecosystem, perceiving its full complexity, and holds the capacity, ambition, and power to act in accordance with it. In adaptive settings, institutional rules are continuously reconsidered and adjusted to match the complex and ever-changing environment. At the same time, institutions should be stable enough to settle the rules of the game with some form of stability over time in order to enjoy legitimacy and trust among stakeholders (North 1990). This presents a paradox and a challenge for any governance system.

Parallel to the discussion about adaptability, concepts such as collaborative management and co-management have been suggested as enhancing the capacity of management systems. Despite divergences in how the concepts are comprehended, they all refer to multi-actor structures, spanning geographical as well as jurisdictional borders while regulating the state and transformation of natural resources (Walters 1986, 1997; Olsson et al. 2004; Plummer and FitzGibbon 2004; Carlsson and Berkes 2005; Sabatier et al. 2005; Koontz and Thomas 2006; Plummer and Armitage 2007, 2002). Such collaborative structures have been suggested as being better equipped to handle the problematic issues and challenges inevitably associated with common pool resource management (Carlsson and Berkes 2005).

As these notions incorporate an implied understanding of the existence of social networks, a network approach to the study of these governance systems has been suggested (Carlsson and Berkes 2005; Janssen et al. 2006). When a network approach is adopted, not only the characteristics of the involved actors, but also the pattern of their interactions, i.e. the network structure (Friedkin 1981) is considered an important analytical unit explaining various outcomes. In short, the network structure is assumed to affect the behaviour of the individuals and the quality of their interactions, consequently affecting the institutional arrangements regulating resource use. Thus, network structure may be linked to the performance of a governance system (Knoke 1990; Marsh and Smith 2000). Several empirical studies serve as examples for applying a network approach to the study of commons (Johnson 1986; Maiolo and Johnson 1989; Maiolo et al. 1992; Crona and Bodin 2006; Dougill et al. 2006; Frank et al. 2007; Prell et al. 2007). Yet empirical work searching for the kind of structural network features that characterise sustainable governance systems remains rare. This paper addresses the current knowledge gap concerning these issues.

By combining ideas from policy network theory, institutional theory, and social capital theory, Carlsson and Sandström (2008) sketched an analytical skeleton, suggesting how network structure can be related to various co-management structure outcomes. Hence, not merely the rise or existence of networks, but also their structural properties are considered important for the quality of the organising processes in these settings. Carlsson and Sandström (2008) approached the relationship between network structure and the qualities of natural resource management using two primary network concepts, namely, network closure and network heterogeneity. The concepts of closure and heterogeneity were adopted from Burt (2000). The concepts illustrate ideas that have been proposed by, for example, Granovetter (1973), Coleman (1990), Lin (2001), Reagans and Zuckerman (2001) and Reagans and McEviliy (2003). Network closure describes how well-connected a network is, either directly by the existence of many contact links or indirectly through a central actor coordinating the management activities. Network heterogeneity refers to the diversity of actors involved in the process and their level of cross-boundary exchange. More specifically, the concept reflects how many different organisations and/or sectors that are represented in the network and to what extent collaboration takes place among people with different affiliations. Both qualities are assumed to matter in the process of governing common pool resources.

Figure 1 suggests that network closure positively impacts on the achievement of collective action, i.e. "actions taken by members of a group to further their common interests" (Bogdanor 1987, 113) and the function of prioritising. This is a quality that essentially reflects the capacity of establishing, upholding, and maintaining the rules of the game. A closed structure might facilitate the ability to handle and solve divergences or conflicts among users. Thus, the transactions costs related to exchange situations (North 1997) are likely to decrease in well-connected structures. A low level of network closure, on the other hand, is likely to hamper the governance process by obstructing the prospect of dealing with problems related to collective action in an efficient manner.

Network heterogeneity positively relates to the function of resource mobilisation. Enhanced resource exchange is emphasised as a central asset and stressed as a key argument for the establishment of co-management systems (Carlsson and Berkes 2005). Other gains might result from heterogeneous structures. For example, a diversified network is probably better equipped to divide labour, increase specialisation and risk sharing and to acquire relevant ecological knowledge. Accordingly, a homogenous network is more likely to

Network Heterogeneity \ Network Closure	Low	High
High	In this type of network, access to various resources (e.g. knowledge) is improved. However, high transaction costs and difficulties in making priorities and managing conflicts between different interests hamper the policy process.	High levels of heterogeneity promote access to diversified knowledge. At the same time, high levels of closure improves the internal decision-making process by lowering transaction costs and fostering effective conflict resolution mechanisms.
Low	This kind of network structure hampers the governance process by obstructing the prospect of dealing with collective action problems in an efficient manner. It is also less likely to access knowledge and new ideas promoting innovative solutions to the problems faced.	The ability to make decisions and solve conflicts at low transaction costs is possible within this network. However, the process of knowledge mobilisation is likely insufficient, which affects the ability to find innovative solutions.

Figure 1: The relation between network structure and qualities of co-management systems (modified from Carlsson and Sandström 2008).

suffer from resource scarcity and less likely to access new ideas that promote innovative solutions to the problems faced. However, when it comes to achieving efficient collaboration and the process of setting, changing, and enforcing rules, homogenous networks might in fact have an advantage over heterogeneous structures. Thus, different types of structural features affect organising functions differently. Sandström and Carlsson (2008) have presented similar ideas related to policy-making processes in general.

By recalling the notion of adaptive management, as an active rule-forming process based upon prevailing ecological knowledge, the achievement and success of such a process might be associated with the two network features just described. The basic assumption is that network heterogeneity facilitates access to a diversified set of resources (e.g. ecological knowledge), while network closure improves the ability to set rules as well as to maintain and monitor these rules. This paper will question the accuracy of these ideas applying social network analysis to map and analyse the governance of a local fishery management system. Does a relation truly exist between network closure and the ability to set and enforce rules governing the resource? Does heterogeneity really promote the existence of ecological knowledge? Thus, do high levels of closure and heterogeneity increase the adaptive capacity of governance systems?

1.1. Aim

This paper examines a fish management area in Sweden. The study investigates the accuracy of the hypotheses regarding the relationship between network structure and performance. The aim is to challenge the idea that network closure and heterogeneity are important explanatory variables for failure or success in the adaptive management process. Empirical observations contradicting these hypotheses would be sufficient to question theory. For example, if the management system proves to be highly adaptive while having low levels of network closure and/or heterogeneity, the hypotheses must be reconsidered. On the other hand, if the empirical results concur with theory, the ideas of closure, heterogeneity, and adaptability in natural resource management systems will remain a well-working hypothesis.

2. Research methods

The resource system is situated in the northern and inland part of Sweden. The geographic area is large, with a radius of 130 km. It includes ~40 lakes, 20 brooks and tributaries, and 40 km of river. The area is home to a diversity of fish species, including pike (*Essox lucius*), perch (*Perca fluriatilis*), whitefish (*Coregonus* spp), grayling (*Thymallus thymallus*), and salmon trout (*Salmon trutta*). Within this area, different types of fishing activities such as sport fishing and net-fishing is common.

In administrative terms, the area constitutes a fish management area, which is a specific type of governance regime regulated by national law (The Swedish law 1981:533 on fish management areas; Dhyre and Edlund 1982). The area is a property-based fisheries co-management system, mandating the owners of the waters (those holding fishing rights), who have the communal authority to jointly manage the appropriation of the resource (Piriz 2005). The general purpose of fish management areas is to promote the common interests of the proprietors, making it possible to coordinate activities affecting the quality of the waters and the resource stock. All actors with fishing rights are incorporated in management as members of the association controlling the area. The operational work is managed by a board elected by the members. The rules stipulating the appropriation of the resource are set by the fish management area. In cases of rule-breaking, the organisation has the right to impose sanctions. Appeals with regards to the decisions made are directed to the County Administrative Board (The Swedish law 1981:533 on fish management areas). Thus, fish management areas have extensive rights to govern the resource; they have management rights to regulate how the resource is used and exclusion rights for regulating access (Ostrom 2003). These rights have been identified as critical, affecting users' ability to control the system as well as their incentives to invest time and effort into the process of problem solving (Ostrom and Schlager 1996). Considering the wide spectrum of authority divisions in co-management structures (Sen and Raakjoer Nielsen 1996; Carlsson and Berkes 2005; Njaya 2007), it can be deduced that regimes like fish management areas correspond to the category in which the community has far-reaching authority of control. However, in practice, the creation of operational rules often occurs in collaboration with the County Administrative Board making the state a partner in the co-management process. The fish management area studied in this paper operates in this manner.

The analytical unit of interest in this study is not the formal management structure described above. Although the formal rules stipulate power to the fish management area and to the elected board, the actual rule-forming network might in fact involve other actors and consequently depart from the formal arrangements. Applying a methodological bottom-up approach (Hull and Hjern 1987; Hjern and Porter 1997; Carlsson 2000), the relevant unit of analysis comprise the social network of actors who actually participate in management activities on a regular basis. Since it is not possible to identify these actors in advance, the boundaries of the management network must be defined inductively.

2.1. Data collection

The study was conducted in the autumn of 2006. Data was collected through interviews and a questionnaire asking sociometric (relational) questions. Consistent with the adopted bottom-up approach, the respondents were sampled using a snowballing interview technique (Miles and Huberman 1994). The snowballing started with the chairman of the board and from there allowed each individual interviewed to nominate new participants. The snowballing stops when no new actor, ascribed any central importance, is mentioned. The network was thus identified inductively. Twelve semi-structured interviews were conducted, lasting from 30 min to 2 hours. Two interviews were conducted over the phone, while the others were conducted in face-to-face situations. A tape recorder was used during most interviews, and all material was transcribed for analysis. The issue of confidentiality was discussed with all respondents. The interviews identified the actors involved in the management process and provided information regarding the level of adaptability (Appendix A).

After the interview study, a questionnaire was distributed in order to map the network structure, i.e. the patterns of relationships between individuals (Appendix B). The questionnaire was sent out to 48 persons, including those mentioned during the interviews as well as some persons on a contact list that belonged to the board of the fish management area. The questionnaire listed the names of these actors, and the respondents were asked to mark their collaborative partners. Respondents could also add new names to the list. The following question was asked: “Who do you usually talk to about the *goals*, *rules*, and *routines* of the fish management area?”. By asking this question, the structure of the rule-forming network was mapped. To refine the data, an additional type of communication link was mapped. Each respondent was asked: “Who do you usually talk to about the *ecological status*, i.e. the physical condition, of the fish and waters of the fish management area?”. This question sought to reveal the ecological knowledge network.

Social network analysis is sensitive to missing data. Forty-three questionnaires were returned. Two of these 43 questionnaires were not fully completed. It is not known whether these blank questionnaires should be interpreted as completed, reflecting the non-existence of links, or whether they were returned blank due to some other reasons. If the former is true, the response rate is 90%; otherwise, it is 85%. Regardless, the response rate is considered sufficient. Consequently, the research approach makes use of both qualitative and quantitative data.

The social network data were imported and analysed using UCINET6 and NetDraw (Borgatti et al. 2002; Borgatti 2002). The analysis presented in this paper was performed on a dataset including only the strongest links, in this case, defined as links that are reciprocated (Appendix C). Tie strength can be defined as "the combination of the amount of time, the emotional intensity, the intimacy (mutual confiding) and the reciprocal services which characterize the tie" (Granovetter 1973, 1371). Reciprocity is one empirical indicator of tie strengths. This approach stems from two main reasons. First, these stronger links better reflect the notion of networks as institutional entities (i.e. as stable structures forming the rules of the game). Second, problematic concerns regarding the reporting accuracy of sociometric questions are not as prominent when relations reflecting stronger links are analysed (Freeman et al. 1987; Marsden 1990; Wasserman and Faust 1994; Bell et al. 2007). Thus, the boundary of the network is empirically determined by the reciprocity condition.

2.2. Making the concepts measurable

2.2.1. Network closure

The level of network closure is empirically investigated using two measures, density and centralisation. Density refers to how many connections the structure is comprised of and centralisation to what extent these connections are indirectly channelled through a single actor, reflecting the level of hierarchy within the network. Density is calculated by dividing the number of connections present in the structure by the maximum number of possible connections (Scott 2000, 71).

$$\frac{l}{n(n-1)/2}$$

where: l = the number of links

n = the number of actors

A completely connected network has a density of 1 and a network in which one-third of the possible links are present will have a density of 0.33. However, certain issues regarding other structural properties, such as network size and the existence of subgroups, need to be considered when density is applied as an indicator of closure. Research has shown that "it requires a larger value of network density to achieve the same level of structural cohesion in a small than in a large network" (Friedkin 1981, 49). Thus, if networks of different sizes are compared, the size needs to be acknowledged before drawing any conclusions. The existence of subgroups, i.e. "subsets of actors among whom there are relatively strong, direct, intense, frequent, or positive ties" (Wasserman and Faust 1994, 249), might also complicate the interpretation. For example, a structure that consists of two very distinct subgroups might have a high density due to an intense activity occurring within each group; even so, the general notion of closure should be comprehended as low. However, if these limitations are properly acknowledged, density might still be a useful indicator of cohesiveness (Friedkin 1981; Wasserman and Faust 1994; Scott 2000). The subgroup structure will be examined using the concepts of cliques, k-plexes and by analysing the hierarchical clustering diagrams generated in UCINET6 6 (Borgatti et al. 2002).

Collaboration might also be channelled through a central coordinating actor, which is why centralisation is applied as an indicator of closure, interpreting highly centralised networks as well-connected structures. The centralisation index is calculated in two steps, starting with examining the centrality of each individual actor. Degree centrality and betweenness centrality are the versions relevant for this study. Degree centrality considers the numbers of direct links to and from an actor, giving the actor with the most links the highest centrality score. The measure of betweenness rests upon the idea that centrality is determined by how frequently an actor is situated between two other actors (Hanneman and Riddle 2005). The second step is to use these data on the individual level as a base for calculating the level of centralisation for the network as a whole. For *g* individuals a general measure of centralisation can be represented as (Wasserman, and Faust 1994)[1]:

$$C = \frac{\sum_{i=1}^{g}\left[C(n*)-C(n_i)\right]}{\max\sum_{i=1}^{g}\left[C(n*)-C(n_i)\right]}$$

where: C(n*) = the centrality of the most well-connected individual,
$C(n_i)$ = the centrality of the ith individual, and
maximum is taken over all possible graphs with g actors.

As a result, the centralisation measure illustrates how star-like the network is (Figure 2).

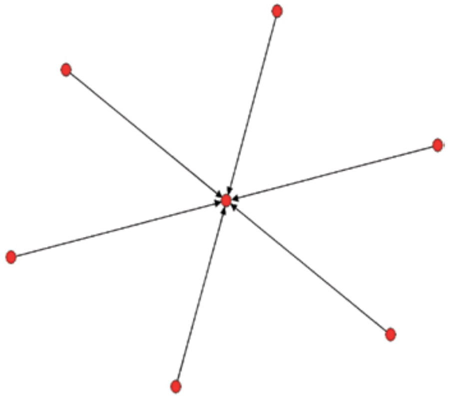

Figure 2: The star-shaped network illustrates a structure with the highest level of centralisation possible.

[1] The formulas for betweenness centralisation and degree centralisation are slightly different (Wasserman and Faust 1994), the equation above however serves to illustrate the general idea of centralisation.

Regardless of whether network centrality is calculated on the basis of actor betweenness or degree, a network formed as a star illustrates a structure with the highest level of hierarchy possible and a centralisation index of 100%. However, in certain situations different versions of centrality generate values that point towards divergent conclusions. Previous work has sought to clarify the theoretical power of the measures (Freeman 1978/79; Freeman et al. 1979/80; Bonacich 1987; Friedkin 1991; Wasserman and Faust 1994). In the current paper, degree centralisation is considered the primary indicator of network closure as a network with a high degree centralisation is that in which the communication flow is indirectly well-connected through a coordinating unit. Betweenness centralisation is extremely sensitive to the presence of long rows of indirect communications between the actors. This measure foremost reveals differences in the potential of withholding or distorting the flow of information (Freeman 1978/79). Such an imaginable network is considered less compatible with the idea of network closure adopted in the current paper. Even so, betweenness centralisation will be investigated as it might generate complementary information in the interpretation of closure.

Thus, higher levels of density and centralisation are interpreted as indications of network closure. Both measures describe how well-connected a network is in regards to the level of general activity and the hierarchy within a structure. The social network measures are context dependent and, as such, they might affect one-another. As such, it is not possible to identify any standard criteria or definite cut-off-values for when a density value, for example, should be interpreted as high or low. The interpretations regarding the structural properties of a network must be made based on several social network measures in order to obtain a comprehensive analysis.

2.2.2. Network heterogeneity

Heterogeneity is a far more complex concept than what is acknowledged herein. In the current paper, heterogeneity is understood as a reflection of actor diversity, assuming that a diversity of actors also promotes a diversity of perspectives, knowledge, and values in the process. Actors' diversity is measured by counting the number of organisations represented in the network. However, a network with actors from many different types of organisations does not necessarily imply that these actors exchange resources, knowledge, perspectives, etc. Therefore, the level of cross-boundary exchange, or the proportion of links connecting actors from different organizations, is examined. Simply put, the number of links connecting actors with different organisational belongings is divided by the total number of links in the network. Consequently, a highly diversified network with significant communication across organisational borders is perceived as heterogeneous.

2.2.3. Adaptability

The issue of adaptability, which constitute the dependent variable of the research design, is determined by studying the qualitative information generated from the interviews. In order to investigate this aspect, the respondents' experiences of the rule-forming process are analysed using the following questions as a frame of reference:

1. Does the institutional framework consist of rules that regulate access to, and appropriation of, the resource? Are these rules known and used, that is, are they accepted and followed (Appendix A: Questions 8–9, 15–19, 23–26)? The existence of access and appropriation rules will be analysed, studying the boundary rules, the choice rules, the scope rules, and position rules within the area (Kiser and Ostrom 1982; Ostrom 2005). The existence of rules regulating these issues is a precondition for an adaptive process to occur in the fish management area.
2. Do the actors involved in the management process consider the resource system as complex, non-linear, and characterised by significant uncertainty? Does the management process comprise elements of observations, experiments, and learning? These questions are essential for determining whether the foundation and necessary requirements for adaptive management exist within the fish management area (see Appendix A: Questions 10–14).
3. Are rules, regulating access and appropriation, continuously changed as a reaction to the generation of new ecological knowledge (see Appendix A: Questions 20–22)? This final question is asked in order to determine whether the fish management area adapts the rules to prevailing ecological knowledge.

The judgement regarding the adaptability of the fish management system is made based on the notions of the respondents. No external observation regarding if, when, and why rules are changed over time is conducted. If the empirical data affirmatively correspond to the questions posed above, the management system is regarded as adaptive. Selected citations have been incorporated into the subsequent presentation to exemplify the answers underpinning the interpretations.

3. Results

3.1. The structure of the management network

The management activities unite quite a diverse set of actors, representing various sectors of society and divergent interests (see Figure 3). However, the board of the fish management area and the sport fishing association (the blue and yellow nodes, respectively) constitute the two largest groups. The chairman of the fish management area, represented by the blue node in the middle of the network, is the most central actor. The network consists of 33 actors, linked by 49 symmetric relations, which generate a density of 0.093. The network is connected since links exist that bridge different groups in the network. At the same time, just 9% of all possible links are present. Figure 3 also implies the presence of at least one subgroup; a cluster of yellow nodes situated to the right in the graph is clearly

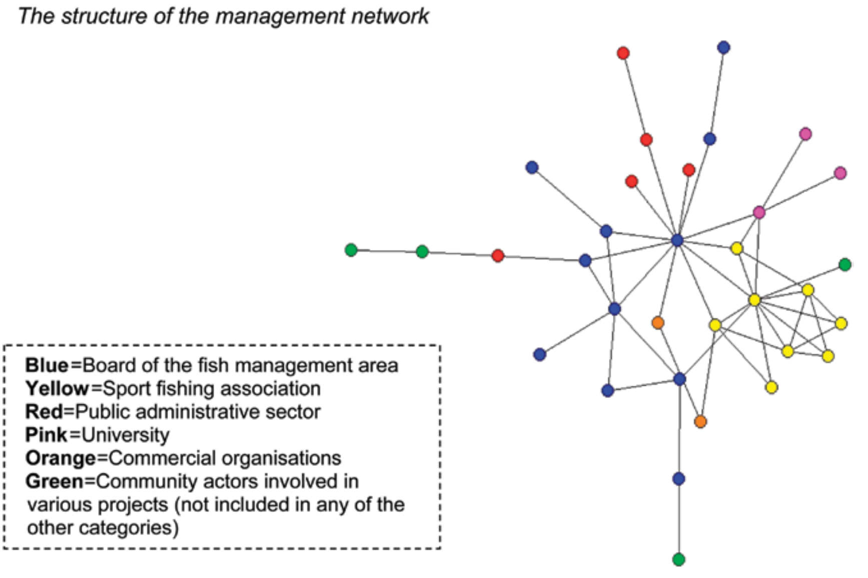

Figure 3: The social network reflecting the rule-forming process of the fish management area.

evident. The actors of this cluster are considerably more connected to each other than to the rest of the network. An analysis, investigating the existence cliques, k-plexes, and hierarchical clustering diagram generated in UCINET6 supports this observation.

The degree centralisation index is 30%. Based on the graph, significant indirect communication seems to occur in the structure, as suggested by the many lines of actors indicative for that type of communication flow.

This assumption is verified by the fact that the betweenness centrality is remarkably high at 56%. Consequently, numerous brokers exist, although they are to a large extent situated in the periphery, in this network.

Table 1 identifies the number of links connecting actors from the previously mentioned organisations. A considerable amount of the exchange occurs among actors from the same category, as in the large number of exchange links within the group of sport fishermen. However, 33% of the interactions are bridges between different organisations, reflecting cross-boundary exchange. The dominance by the board and sport fishing association is further underscored by the data in Table 1, which indicate that 64% of all links connect people within or between these two groups.

The network in Figure 4 consists of 28 actors connected by 90 connections, indicating a density of 0.12. The density value for the knowledge network is accordingly higher than for the rule-forming network presented in Figure 3. The difference in size must thus be considered. The picture in Figure 4 reveals

Table 1: Links crossing different categories of actors in the rule-forming process.

	Public adm.	FMA	Commercial	Projects	Sport fishing	University
Public adm.	2					
FMA	4	26				
Commercial		1	2			
Projects	1	1		2		
Sport fishing		4	1	1	30	
University		1			2	4

Note: FMA=Board of the fish management area.

a network composed of separate clusters, in which the chairman of the board is the most central actor. The social network measures support this observation. According to the subgroup analysis, one coherent group of sport fishermen, one group composed of the board, and one mixed group exist. The degree centrality is 35%, whereas the betweenness centrality is remarkably higher at 50%. Thus, although connected, the structure in Figure 4 is seemingly fragmented and consists of separate clusters coordinated by different actors.

Figure 4 demonstrates that the same categories of actors as in the rule-forming process are involved in the process of generating and exchanging ecological

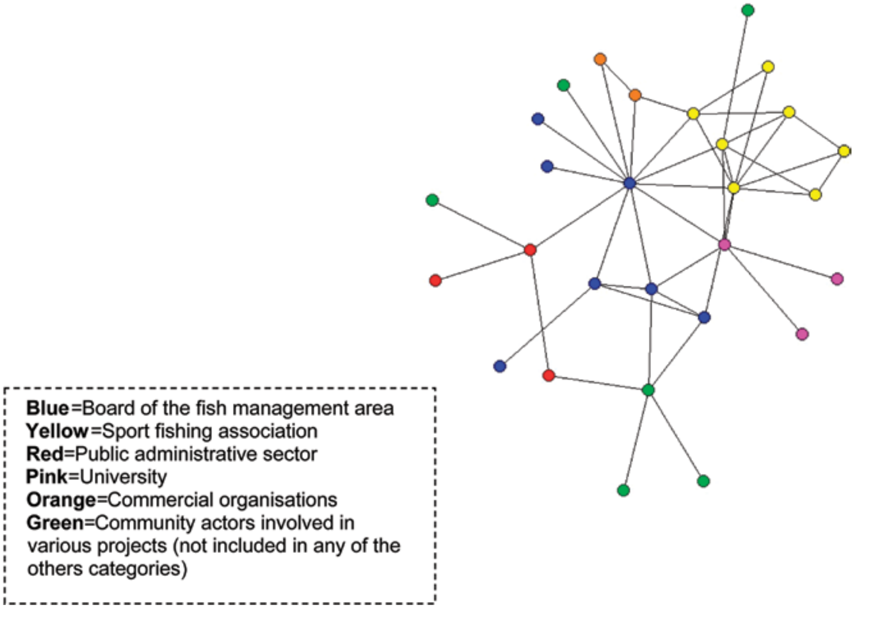

Figure 4: The social network reflecting the process of exchanging ecological knowledge within the fish management area.

knowledge. In addition, in this network, the actors from the fish management area and the sport fishing association dominate, being equally well represented in the structure. The cross-boundary exchange is 40%, which is higher than that found in the rule-forming network.

Figure 5 illustrates the social network comprising both types of relations. Different networks represent different functions of the management process; there are one structure for the process of rule-formation and one structure for knowledge generation (red and blue links). Yet the grey links indicate that input occurs with regards to the ecological conditions of the waters and fish directly in the management process.

The social network measures describing the management network are summarized in Table 2.

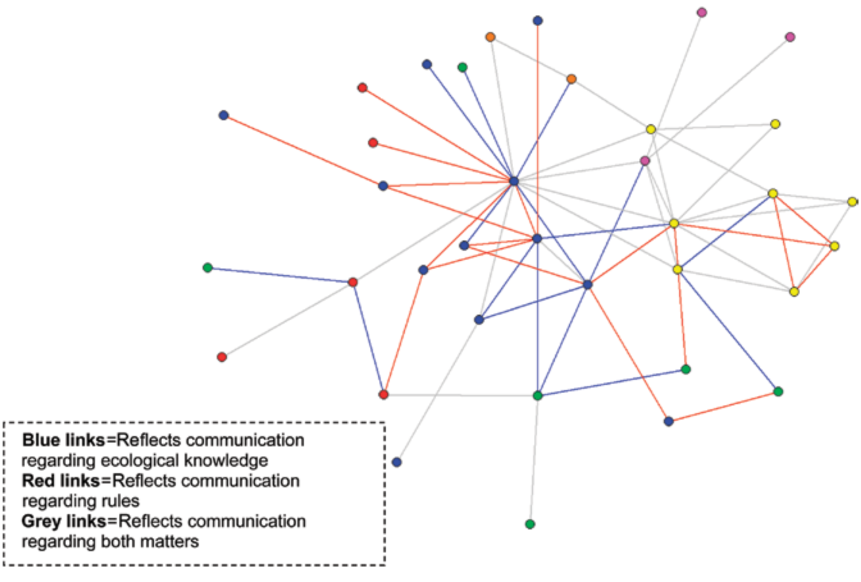

Figure 5: The social network reflecting exchange links concerning both the rule-forming process and ecological knowledge within the fish management area.

Table 2: The social network measures.

Type of social network	Size (No.)	Density (d)	Degree centralisation (%)	Betweenness centralisation (%)	Actors diversity (No.)	Cross-boundary exchange (%)
Rule-forming network	33	9.3	30	56	6	33
Knowledge network	28	12	35	50	6	40

The level of closure in the management network is moderate or even low. The modest density levels and degree centralisation indexes together with the high betweenness centralisation indexes underscore this interpretation. The management network is interpreted as heterogeneous since a diverse set of actors participates in cross-boundary interaction. No context independent standard for how to interpret social network measures exists. Still, some interpretations are more likely than others. An alternative interpretation, stating a high level of closure, would require significantly higher levels of density and degree centralisation and lower betweenness centralisation indexes than what was found in the empirical data.[2] A comparison of the two types of networks shows that the ecological knowledge network has slightly higher levels of closure and heterogeneity, respectively.

3.2 The adaptability of the management network

3.2.1. Access and appropriation rules regulating the area

Most rules originate from the establishment of the fish management area. Clear boundary rules identify who are entitled to utilise the resource. Fishing requires a licence, which is available to everyone in exchange for a small amount of money. The resource is also governed by a set of choice rules restricting the actions allowed. For example, in order to protect and secure regrowth, rules regulating what equipment to use and restrictions regarding the minimum size of the fish that can be taken from the waters exist. Catches above a certain size should also be reported to the fish management area in order to improve monitoring of and knowledge about the resource stocks. Scope rules specify in what geographical areas fishing is allowed. For example, fishing is sometimes temporarily prohibited in waters were hatchery produced fish has been released. In one brook, the discovery of a rare pearl mussel resulted in a total fishing prohibition. Consequently, the institutional framework stipulates who, how, and when fishing is allowed in the area.

For a long time, adherence to these rules was not monitored. Monitoring has been a highly debated issue. Some argued the absolute necessity of a control function: "I have long argued for supervision, however, many people thought that it would just cause disagreements". Others hesitated as they expected that supervision would in fact deepen disagreements and result in open conflicts: "I do not like to set rules and force them on others". However, since 2005, certain monitors are supervising the area. In cases of infringements, graduated sanctions are imposed, starting with information and ending with law enforcement. "We

[2] In a comparative multiple case study of policy networks within the higher education sector, a network of 37 actors (approximately the same size as the network in this case study) with a density of 0.11d and degree centralisation of 38% was regarded as having a low level of closure. The same network had a cross-boundary exchange of 61%, which suggested high heterogeneity (Sandström and Carlsson 2008). The authors' conclusions support the interpretation made herein. Still, validity problems arising in comparing networks from different settings should not be ignored.

believe in soft actions, to get everyone to understand what this is all about". This soft attitude is however debated: "What kinds of signals are actually communicated to the fishers? If the rumour is spread, that it does not matter [...], that it is just to continue as usual?"

Users have divergent viewpoints concerning the actual level of adherence to these rules. Still, the most common perception is that nowadays most users do have a licence. Fish poaching does exist, foremost among the older generation of users who had open access to the resource before the fish management area was established in its present form. Since sanction systems affect the set of pay-off rules, and thereby the calculated costs and benefits, it is likely that the imposed monitoring system may have changed users' behaviour in favour of rule-conformity. This assumption is verified by the respondents, who appreciate that the problem with rule-disobedience will be solved in the future, partly through supervision and partly as the older generation of fishermen is replaced by the younger one.

However, no common view emerged concerning what actions should be regarded as fish poaching, how seriously it should be looked upon, or how supervision should be performed. For example, one disagreement concerns the relevance and implementation of rules regarding minimum sizes; another debated issue is restrictions concerning equipment. It is widely doubted, within all groups, that the previously mentioned rules are actually followed. Another problem is that almost no one reports their catches to the fish management area, even though this is requested. Notable differences exist between the formal rules presented herein and the informal rules that actually regulate behaviour. These problems have a negative affect on adaptability.

3.2.2. The existence and spread of ecological knowledge

On a very general basis, the actors share a fairly common view concerning the status of the ecological system: "The water is of good quality". However, some divergences emerge in understanding, especially between the group of sport fishermen and the fish management board, when it comes to specific issues such as what fish stocks to release in what water and what rules would best enhance the stocks (e.g. the disagreements concerning minimum sizes and allowed equipment, as previously mentioned). An ongoing discussion regarding these issues and the controversies directly relates to how actors perceive the resource system.

The ecological knowledge in the management system is based on users' experiences and scientific expertise. Certain respondents claimed that they can see how healthy the fish stocks are: "I have lived in the area since the 70s and I am really into fishing. Thus, I dare to say that I know every pool of water". With this information as a base, judgments regarding the quality of the waters are made: "You talk with other fishers if something seems strange". Through contacts with expertise and science and through participation in scientific projects managed by the university, the users have gained a deepened understanding about the complexities of the ecosystem. For example, systematic investigations and experiments have been performed on certain fish stock in some lakes: “We have a good contact network, so we are able to work out the troublesome issues, when we need help from the municipality, the county administration or the university”. “The contacts with the university have contributed to a widening perspective. I have learned new things [...]”. “I had never really considered the fact that the ways we fish have effects on the whole resource stock”.

Disparate views exist concerning the reliability of information that aims to capture the condition of the resource system. The process of mobilising knowledge is complicated by several factors. The essential complexity of ecosystems in general is emphasised as one factor: “We know too little in order to adapt the rules”. Other difficulties are more associated with the design of the management system. First, the large size of the geographical area makes it practically impossible to successfully monitor the resource and how it is utilised. Second, the deficient reporting system provides no feedback about actual catches in the area: “People today, they take up a lot of fish, but do not bother to report it”. However, despite such difficulties, the actors acknowledge and emphasise the importance of understanding the resource as part of a complex system. They also agree that it is imperative to deepen their knowledge about the ecosystem as a whole in order to improve the adaptability of the management process. This perspective is a necessary foundation and prerequisite for adaptive management.

3.2.3. The connection between ecological knowledge and the rule-forming process

Developing a truly adaptive management system is a clear ambition of the network. The fundamental idea that good management will result in high quality fishing and healthy waters is also widely adopted. “We have that vision: to change the rules according to the conditions of the waters”. Yet no general agreement exists regarding to what extent these high ambitions are realised. Some actors claim that ecological criteria do steer the process of rule-formation, referring to the fact that fishing or certain types of fishing is prohibited in some fishing grounds. Others claim that no solid connection exists between the rules set and the prevailing information about the ecological conditions. “The rules have not been set with the health of the resource as a base”. “The experiments with the university have not changed the rules; however, they have given rise to discussions regarding these matters”. The actors point to other lines of actions that, with regard to the status of the system and the existing fish stock, ought to be implemented in order to transform the state of the resource to the better. Net-fishing, for example, is one controversy. Disregarding differences, the common denominator among the users is that much more could be done in order to increase the adaptability of the management system. The rules governing the resource system have, in fact, been rather constant during the recent past. This situation indicates problems related to adaptability.

Thus, the analysis above indicates a poor relationship between prevailing ecological knowledge on the one hand and the management process on the other. Evidently, it is hard to achieve adaptive management. Some main obstacles were identified by the interviewed actors; the trouble of getting reliable knowledge regarding the health of the ecosystem, the difficulty of achieving a common picture regarding the status of the resource, and the creation, maintenance, and enforcement of rules. These circumstances affect adaptability negatively.

4. Discussion

The primary empirical findings, and interpretations, regarding both network structure and aspects of adaptability are summarised in Figure 6.

The network is heterogeneous and has a moderate level of closure (see the left side of Figure 5). According to the hypothesised relationship between structure and performance, this type of structure should generate a process with a fairly unproblematic process of resource mobilisation, i.e. an input of ecological information into the management system will occur. However, theory also suggests that a management system with moderate levels of closure is likely to struggle with problems related to collective action, such as finding common agreements and establishing rules. Thus, adaptability in this type of network presumably suffers because of an insufficient relationship between current ecological knowledge and the process of forming and enforcing rules. Do these expectations correspond to empirical observations?

The empirical analysis does demonstrate problems regarding the adaptability of management (see the right side of Figure 5). The actors share an ecosystem perspective and the processes contain elements of both observation and learning. There is also a clear ambition for letting this prevailing knowledge base affect the criteria for when and how rules should be changed. Relating to theory, the heterogeneous structure might indeed explain this aspect of management. The actors claimed that the contacts or the cross-scale linkages (Berkes 2008) with

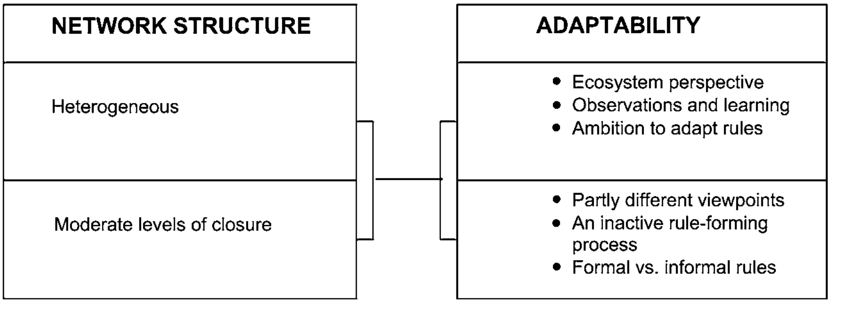

Figure 6: Empirical findings concerning network structure and adaptability of the fish management area.

experts and academic actors have changed their understanding of the ecosystem. Their perception of complexity has increased.

The social network analysis demonstrated a certain overlap between the rule-forming network and the ecological knowledge network. Consequently, a knowledge input to management exists, which is a crucial prerequisite for adaptive management. Furthermore, the ambition to establish a process in which this knowledge supports the decisions made is clearly articulated by the actors. However, despite this ambition, the current analysis indicates that the fish management area has not been particularly active in changing and developing new rules regulating appropriation. The problematic concern could, in line with theory, be related to the moderate level of closure within the network. A network structure like the one found in this case is more likely than a very dense and centralized structure to result in a situation in which different views regarding both the importance and actual substance of certain rules are competing. The existence of divergent understandings concerning these fundamental issues obstructs both rule conformance and the rule-forming process. Differences with regards to the state of the ecosystem among the two largest groups (i.e. the board of the management area and the sport fishing association) were also emphasised by the actors as a reason for the experienced inactivity. This situation has probably paralyzed the process.

Adaptive management requires management structures in which a diverse set of actors with dissimilar knowledge bases and opposing interests can unify and conciliate around a common policy problem, adjust and adapt in order to prioritise and achieve common action. The importance of closure and heterogeneity in achieving such a process has proven a well-working hypothesis. Theory and observation are consistent. This notion has implications for policy. The bottom line is that this insight can improve the governance of these management networks (for governance theory see Kickert et al. 1997; Koppenjan and Klijn 2004; Sorensen and Torfing 2007). Tentatively, the studied network would presumably benefit a structure that is better, more densely and hierarchically, connected. A closer interaction between the two most important sub-groups of actors would enhance the function of forming and enforcing rules. It should be acknowledged that the causal direction might be the other way around, i.e. that divergent understandings enforce the structural gaps within the network. From a governance perspective, however, the implication would be to foster the communication channels within the structure in order to merge the different understandings concerning the status of the ecosystem into one general picture, in order to create the necessary foundation for an adaptive process.

This study generates new questions and new tentative ideas regarding the relation between structure and performance in resource management systems. For example, do any optimum values exist regarding network closure and heterogeneity? Does a trade-off effect exist between the two? As dense structures promote homogeneity in values, researchers have warned about systems being too dense as they might reduce knowledge diversity incorporated in the management process (Bodin 2006). Applying these thoughts to this empirical case, the proposition would be that, although closure is a desirable feature within rule-forming networks it could in fact be hampering the function of the ecological knowledge network since diversity and the promotion of different views are important for the creation of new knowledge. Thus, in the best of worlds, management structures should have a 'closed' rule-forming process and a knowledge network characterised by fragmentation and sub-groups with different centres. This information has implication for how to govern management networks.

The case study presented here has limitations that call for further research. It is a single case study and the fact that no general standard exists for how to interpret the values of the social network measures complicates the analysis. Furthermore, the management system is only studied at one point in time. Other concerns include the limited ability to control for hidden variables and the ever-prevailing issue of cause and effect in relation to network's structure and adaptability. The causal relationships in resource management settings are presumably contingent relationships, they are interrelated and contextual (Agrawal 2003). Thus, efforts to clarify how different variables affect one another are needed. For example, what is the relation between density and centralisation? Perhaps, centralisation alone is the important network feature for success? How could other aspects of heterogeneity (for example, differences in wealth, power, etc.) be related to adaptability? More case studies would reinforce our understanding regarding the structural impacts on our capacity to deal with challenges related to the commons. In particular, comparative case studies would have the potential of inductively identifying the design principles of successful systems as they would enable the testing of hypotheses. Moreover, longitudinal studies would be interesting given that such data could shed some light on how different variables interact over time, thereby clarifying the issue of cause and effect. Another issue to be dealt with is how these research questions could be approached in larger and more complex systems. What kinds of methodological challenges would be associated with the study of social networks governing large-scale resource systems? More work on this topic should be pursued.

5. Conclusion

Empirical studies have assigned collaborative arrangements, or co-management structures, enhanced capacities to deal with the commons (e.g. Pinkerton 1989; Ostrom 1990; Bromley 1992; Baland and Platteau 1996; Rova 2004). However, the expectations regarding what these structures might achieve are perhaps sometimes too high. Co-management is a broad concept that covers a wide range of ways in which to organise management. Therefore, any attempt to formulate statements regarding the consequences of co-management in more than very general terms will be unsuccessful. Indeed, local-level collaboration structures are not a panacea.

These structures face the same challenges as other kinds of management structures and we still know too little about how they operate. In this paper, the hypothesis that certain types of network features, network closure and heterogeneity, affect the adaptability of a fish management area was challenged and discussed. The conclusion is that the idea remains an effective hypothesis. The next step for research is to test the validity of the hypothesis by undertaking comparative multiple case studies. Such research would certainly enhance our knowledge about the impacts of social networks in natural resource management.

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