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Impacts of aquaculture on social networks in the mangrove systems of northern Vietnam

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Abstract

Mangrove systems are one of the most complex and productive ecosystems on Earth, providing crucial livelihood support to coastal communities in developing countries. However, mangrove systems are being degraded and lost at an alarming rate globally. In Vietnam, the principal threat to mangrove systems is their conversion to aquaculture. Historically, mangrove system dependent communities (MSDC) have responded to change through their livelihoods and social networks, using social capital to self-organise and access crucial livelihood resources. However, little is known about the impact of different degrees of aquaculture on MSDC livelihoods and social networks, and what this means for the resilience of these communities and their ability to self-organise in response to change. Using a quantitative approach based on empirical household survey data, we assess the association between aquaculture and the livelihoods and social networks of three coastal communities of northern Vietnam. Results indicate that greater degrees of aquaculture are associated with: greater income inequality and lower livelihood diversity; and larger and less dense social networks. The increased influence of market-based relations associated with greater degrees of aquaculture has implications for resilience through the socio-economic differentiation and fragmentation of MSDC networks, which reduces social capital and the ability to self-organise in

response to change. A diversity of network ties is required in order to connect various groups within MSDC. This can enable shared identification and understanding of the issues facing mangrove systems in order to facilitate self-organisation, and foster the resilience necessary for the sustainable governance of mangrove systems.

Highlights:

- Aquaculture impacts coastal livelihoods and social network structures
- Low degrees of aquaculture are associated with small and dense networks
- High degrees of aquaculture are associated with large and diluted networks
- Networks based on productivity of aquaculture are more efficient but less resilient
- Networks based on spreading risk are less productive but more resilient

1. Introduction

Mangrove systems are among the most productive and biologically important ecosystems in the world (Giri et al., 2011). They form a crucial component of the livelihoods of coastal communities in developing countries (Joffre and Schmitt, 2010), providing: fish, crustaceans and other sea life for food and income; wood for fuel and energy; protection of shorelines from erosion, flooding and storm damage; and a filter for pollutants to help maintain water quality (Spalding et al., 2010). However, mangrove systems have experienced rapid change in the form of degradation and loss due to increased human activity (cf. Ellis, 2000), particularly from intensive and extensive commercial aquaculture (Gopal, 2013; Barbier, 2006). These changes undermine their ability to support coastal livelihoods (Primavera, 2006). Aquaculture has also contributed to changes in mangrove system access and livelihood opportunities within coastal communities, which can cause conflict in mangrove system use (Van Hue and Scott, 2008). This impacts social capital through alterations in the networks that coastal communities draw upon to access the resources necessary to pursue their livelihoods (i.e. financial, human, physical, and natural), and which facilitate cooperation, trust, and the ability of communities to self-organise in response to change (Misra et al., 2014; Speranza, 2014; Nath et al., 2010). In order to increase resilience to change, communities require sufficient capacity within their social networks to self-organise and generate the necessary social capital to support livelihoods (Djalante et al., 2013).

The rapid rise of large scale, intensive aquaculture in Vietnam has been facilitated by the transition from a centrally planned to a socialist-orientated market economy (Adger, 2000; Tri et al., 1998). Subsequently, Vietnam has lost 69% of its 269,000 hectares of mangrove forests held in 1980, with an estimated 77% of this loss due to aquaculture (Hamilton, 2013). Social networks have long been central to household responses to change in Vietnam, being used to pool risk and promote security and stability (Luong, 2003). However, the political and economic reforms experienced have altered relations within mangrove system dependent communities (MSDC) (Van Hue and Scott, 2008) as they become increasingly influenced by market processes, particularly for aquaculture goods, altering the ways in which communities interact with one another and the wider world. Growing income inequalities, changing livelihood opportunities, and alterations in access to mangrove system resources have the potential to significantly impact the social network structure of coastal communities. The changing structure of social networks will influence the resilience of MSDC through alterations in social capital and the ability to self-organise.

As the complexity of coastal livelihoods increases due to increased pressure on mangrove systems from aquaculture, understanding the structure of the social networks that sustain livelihoods is critically important in order to understand the resilience of MSDC to change. However, despite the importance of social networks in fostering resilience through supporting rural livelihoods and self-organisation, social network analysis has gained little attention in livelihood research (Misra et al., 2014), particularly in Vietnam. This paper addresses this gap. It aims to assess the impact of differing degrees of aquaculture on the livelihoods and social networks of three MSDC in northern Vietnam to provide insights into the resilience of these communities to change. The objectives are to: (1) assess and compare livelihood contexts at each degree of aquaculture; (2) assess and compare social network structures at each degree of aquaculture; and (3) examine the relationship between social network structures and livelihood characteristics at each degree of aquaculture. We find that a greater degree of aquaculture weakens community networks as livelihoods are more market orientated and social networks are larger and expand beyond the local community. This can lead to divergent understandings of mangrove functions and processes that impact the ability of communities to self-organise. Supporting network diversity through a balance of internal bonding and external bridging ties is required in order to facilitate self-organisation through the sharing and increased understanding of divergent perceptions of mangrove systems, and to foster resilience for future mangrove system planning.

The next section outlines the central concepts related to resilience and social network analysis, followed by details of the research process. Quantitative analysis then offers insights into the influence of aquaculture and resulting livelihood alterations on social networks between and within communities. Lessons from these insights are discussed, drawing out key conclusions that could be used to inform future mangrove planning.

1.1 Central concepts

1.1.1 Livelihoods, vulnerability and resilience

A livelihood comprises the capabilities, assets and activities necessary for a means of living (Chambers and Conway, 1992), and is sustainable when it is able to cope with perturbations and maintain its capabilities while not undermining the natural resource base (Scoones, 1998). Vulnerability is defined as "…*the degree to which a person, system or unit is likely to experience harm* *due to exposure to perturbations or stresses*" (Kasperson et al., 2002: p253), and is a function of exposure, sensitivity and capacity to respond (Gallopin, 2006). Perturbations and stresses encompass disruptions to household livelihoods in response to changing circumstances (Adger, 2000), such as the change observed in Vietnams mangrove systems in the shape of degradation and loss due to increased aquaculture (Tri et al., 1998). For vulnerable households, change is often intractable and related to underlying socio-economic factors such as income (Fisher, 2001), livelihood diversity (Ellis, 2000), and dependency on and access to natural resources such as mangroves (Chambers, 1989; Shackleton and Shackleton, 2004).

Although much debate surrounds the link between vulnerability and resilience (i.e. that the concepts are not simply linear antonyms of each other), they do generally have an inverse relationship (Cassisy and Barnes, 2012). Research suggests that vulnerability to stress can be reduced through strengthening social resilience (Nelson et al., 2007), defined as "…*the ability of individuals and communities to absorb external changes and stresses…while maintaining the sustainability of their livelihoods*" (Adger et al., 2002: p358). In Vietnam, a large portion of the population is rural and living in coastal areas with highly variable environmental conditions (Adger, 2000). Households living within these communities are engaged in a range of primarily natural resource based livelihoods which are being severely impacted by mangrove system change related to the rapid growth of aquaculture (Van Hue and Scott, 2008). This in turn is leading to considerable divergence in the vulnerability context within communities due to changes in the livelihood opportunities available to households (Orchard et al., 2014). The resilience of communities to such change is embedded within and available to them through the social networks, which households use to gain access to the necessary livelihood resources required to respond to change (Cassidy and Barnes, 2012; Nath et al., 2010; Bodin et al., 2006).

1.1.2 Social capital, social networks and resilience

Historically, natural resource dependent communities have self-organised to manage changes to the resource base on which their livelihoods depend, with social networks shaping access to the necessary resources to respond (Adger, 2003). Social networks are constituent of two or more actors (e.g. individuals, households or organisations) that are connected through one or more relations (Abbasi et al., 2012). The structure and function of social networks shapes the trust, norms and reciprocity that forms a crucial part of social capital and enables people to act together to pursue shared goals (Putnam, 1995; Pretty and Ward, 2005). Social networks are also an attribute of self-organisation, which refers to the autonomy, freedom, and power of actors to coordinate themselves (Pelling, 2011). Self-organisation relates to resilience through the ability of communities to reorganize in the face of change (Whaley and Weatherhead, 2014). Hence, communities endowed with social capital will have greater resilience through their ability to self-organize in order to understand and tackle environmental challenges (Bunting et al., 2010; Fleischman et al., 2010; Sanginga et al., 2007; Folke et al., 2005; Pelling and High, 2005). Hence, aspects of resilience reside in the social networks of natural resource dependent communities through: facilitating access to livelihood resources in order to respond to change (Smit and Wandel, 2006); social connectedness that increases the ability of communities to self-organise and build social capital (Crona and Bodin, 2010). In Vietnam, social networks have long been central to household responses to change, being used to pool risk and promote security and stability (Luong, 2003). Analysing how aquaculture impacts social network structure and the ability of MRDC to self-organise is crucial for improving our understanding of the factors that shape resilience. Vietnam provides a highly relevant context for this research, having experienced rapid social, economic, political and mangrove system change due to aquaculture expansion following transition.

This paper uses an egocentric approach (i.e. analysis of individual household networks rather than whole networks) to assess social network density, degree and betweenness centrality, efficiency, effectiveness and constraint. These measures provide indicators of how information and resources may flow through particular types of network (e.g. large or small, dense or sparse, open or closed).

They also help analyse the opportunities and constraints that actors experience, and the potential for self-organisation, as a result of social network structures.

Degree centrality is simply the number of contacts a household has and is an important indicator of how integrated a household is within the network (Valente and Foreman, 1998). Network density is the number of existing contacts divided by the number of possible contacts. Network density relates to bonding social capital in that it involves strong social linkages within localised networks (Barnes-Mauthe et al., 2013) which can lead to the creation of trust and the promotion of norms for acceptable resource use (Pretty and Ward, 2001). High degree centrality and network density can increase resilience by providing a number of redundant contacts (Magsino, 2009). However, too much degree centrality and network density may constrain a household's behaviour due to homogenisation of knowledge and perspectives and reduced flexibility, and hence reduce resilience (Frank and Yasumoto, 1998; Bodin and Crona, 2009). Betweenness centrality refers to households that connect other households who would otherwise not be linked (Burt, 2004). Betweenness centrality has similarities to bridging social capital, although it does not differentiate between households within or outside a community. High betweenness centrality provides the potential for a household to control the flow of and access to a variety of resources between the households it connects (Bodin and Crona, 2009). However, bridging capital is characterised by weaker linkages, and networks with high levels of betweenness are vulnerable to fragmentation should bridging households leave the network (Borgatti, 2003).

Burt (1992) states that, in terms of productive capacity, using the least number of ties to access as wide a range of resources as possible increases the effectiveness and efficiency of social networks. Figure 1 illustrates an inefficient network (A) comprising a large number of redundant contacts (i.e. duplicated ties) accessing the same cluster of resources, compared to an efficient network (B) with low levels of redundancy as only one tie is used to access each cluster. Burt (1992) uses the term effective size to denote the number of clusters that an actor can receive benefits from, so network A and network B both have an effective size of 4. Network efficiency is calculated by dividing the effective size of the network by the total number of ties: in the case of network A giving a low score of 0.25 (i.e. 4/16 = 0.25), whilst in network B we observe perfect efficiency of 1 (i.e. 4/4 = 1). Network constraint measures the degree to which a household's contacts are connected to each other. In terms of network productivity, if a household's potential trading partners are all connected and have one another as potential trading partners, that household is highly constrained (Hanneman and Riddle, 2005). Research on network productivity demonstrates that high efficiency and low constraint are useful indicators of an individual's ability to 'get ahead' in terms of performance and ideas (Burt, 2004; Podolny and Baron, 1997). However, a more in-depth analysis of the nature of the relationships in the social networks of natural resource dependent communities is required to assess how they affect resilience (Brockhaus et al., 2012).

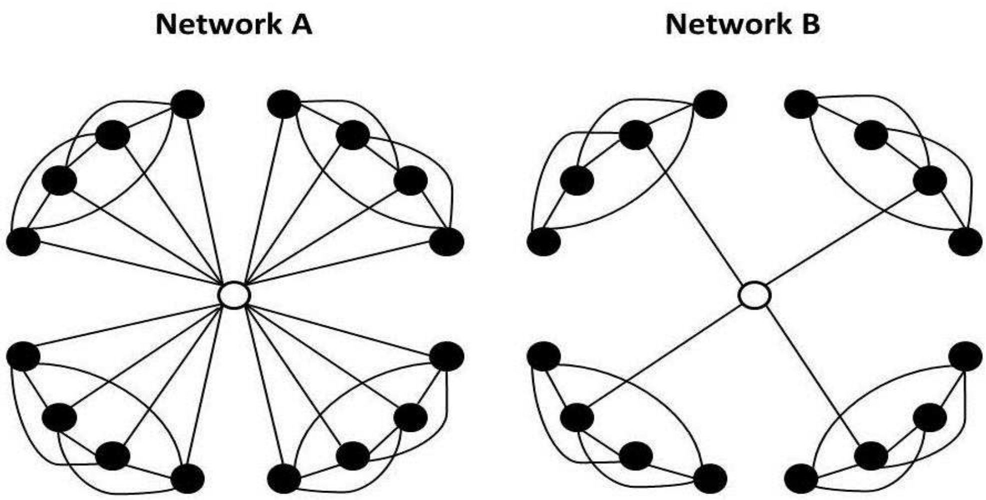

Figure 1: Inefficient (A) and efficient (B) networks. *Adapted from Burt (1992)*

By focussing on productive capacity rather than resilience in social networks, resilience can be compromised by a narrow focus on efficiencies (Walker et al., 2006). Increasing network efficiency results in a loss of redundancy, which represents buffering capacity in the case of loss (i.e. if one or more actors are weakened or lost, others can fill the position and continue to perform the necessary functions (Janssen et al. 2006)). Hence, social networks assessed purely from a productive capacity standpoint might be considered efficient by having low or no redundancy, but in terms of resilience the system requires redundancy so that the network does not fragment if a household leaves. There is growing recognition that governance of natural resources such as mangroves requires a deeper understanding of social structures, and the ways in which relationships among different actors facilitate or constrain the way natural resources are managed (Henry and Dietz, 2011; Crona and Hubacek, 2010). Management efforts often fail due to inadequate attention to the role of social relationships in shaping environmental outcomes (Pretty and Ward, 2001).

Social network analysis is employed here to analyse three MRDC in northern Vietnam with different degrees of aquaculture, providing a snap shot of the social structures at the local scale. This approach does not provide a time dimension (e.g. as with social-ecological system approaches (Folke et al., 2005)), consideration of network links to higher levels of governance (e.g. as with network governance approaches (Carlsson and Sandström, 2008)), or the power dynamics related to each respective social network (e.g. as with political ecology approaches (Escobar, 2006)), as these are beyond the scope of this research. Rather, by analysing the current structure of social networks in MRDC with differing degrees of aquaculture, it is expected that crucial insights will be gained into the impact of aquaculture on resilience in order to support future mangrove system planning and to guide appropriate policy development.

2. Materials and methods

Three coastal communities in northern Vietnam were selected for data collection during February-August 2012: Giao Xuan (Nam Dinh province); Da Loc (Thanh Hoa province); and Dong Rui (Quang Ninh province) (Figure 2). A community is distinguished here as a sub-set of the lowest administrative level of Vietnam's government, the commune, and defined as the socio-economic impact area of a mangrove system (Glaser, 2003). Communities were all situated on the northern coast of Vietnam, yet they represented distinct mangrove systems, geographically separate and with different histories. All three communities were located on the brackish shoreline in river estuaries where mangrove systems comprise mangrove trees, intertidal wetlands and mudflats that provide provisioning goods for local livelihoods. Research participants in all study communities had some degree of access to surrounding mangrove systems. For the purpose of this research, mangrove system provisioning goods (MSPG) refer to wild fish, clam, shrimp, crab and other shoreline animals collected from mangrove system areas held in common.

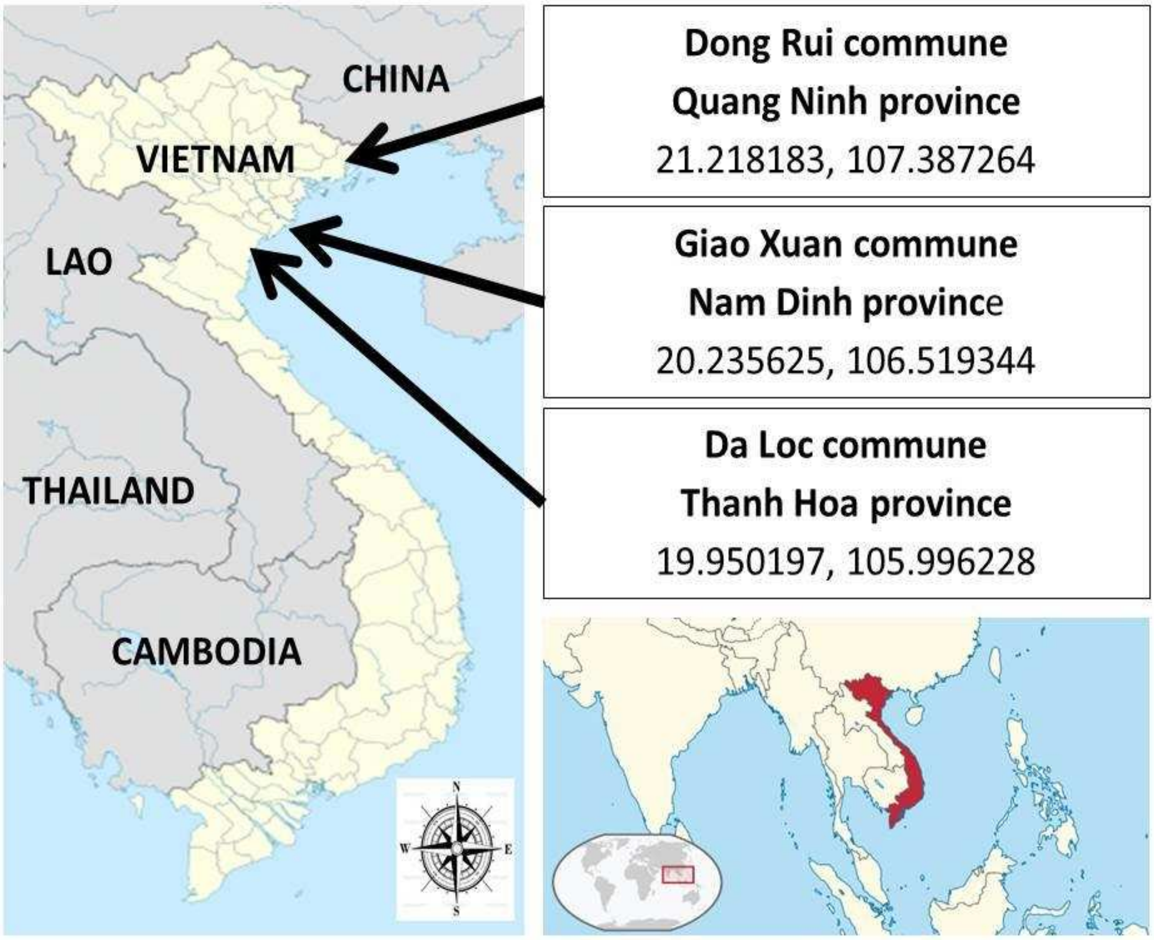

Figure 2: Study site locations and coordinates (*source: Wikipedia, 2014*)

Each community exhibits different degrees of aquaculture: Giao Xuan has a greater degree of aquaculture involvement; Da Loc has a moderate degree of aquaculture; and Dong Rui has a lower degree of aquaculture. Degree is used here to indicate "*the amount, level, or extent to which* *something happens or is present*" (Oxford English dictionary, 2011: 142), and involvement indicates "*the fact or condition of being involved with or participating in something*" (Oxford English dictionary, 2011: 296). Giao Xuan has a highly developed clam aquaculture sector which was established in the early 1990s. The sector was facilitated and supported by emerging trading connections between local households and aquaculture investors from China following market liberalisation (1986). Since then, the number of aquaculture farms developed by people external to the community has increased, and Giao Xuan is now one of the largest producers of clams in Vietnam, supplying domestic and international markets. Aquaculture farms are situated in the mudflat area located beyond the mangrove forest and covering the full extent of the coastline adjacent to the community. In Da Loc the clam aquaculture sector is in the initial stages of development, having been started by local households in 2010 who observed the success of a neighbouring community's clam aquaculture ventures. Aquaculture farms have been developed by locals who have little experience, knowledge or support to guide them but productivity is rising quickly and markets are rapidly growing domestically. As with Giao Xuan, the aquaculture farms are situated in the mudflat area located beyond the mangrove forest, but do not cover the full extent of coastline adjacent to the community.

Dong Rui experienced a short, intense and highly productive period of shrimp and fish aquaculture during the late 1980s/early 1990s. Large scale commercial aquaculture enterprises were initiated and implemented by external investors from a neighbouring province that had experienced recent success in the industry. These powerful and influential investors were able to use their connections in local authorities to acquire land for aquaculture farms, often illegally, and exclude the local community. Dong Rui is situated on an island archipelago, and aquaculture enterprises were located in adjacent areas surrounding the community on all sides. After an initial 2-3 years of high productivity the sector collapsed due to mismanagement, which resulted in severe environmental damage and the abandonment of the farms by investors. Hence, considering the minor impact on community livelihood opportunities and social networks, and the time elapsed since the collapse of the sector, aquaculture can be deemed as having limited influence on the community. Throughout this research each community is used to examine the impacts of different degrees of aquaculture on aspects of resilience related to the research objectives.

A quantitative approach to data collection was taken. Household surveys (n=248: Giao Xuan, n=79; Da Loc, n=70; Dong Rui, n=99) were conducted with household heads to identify: (i) livelihood characteristics regarding income, mangrove dependency (i.e. per cent of total income coming from sale of MSPG), and livelihood activity diversity; and (ii) social connectivity through name-generator questions. Name-generator questions were designed to produce a list of individuals with whom that particular household communicated regarding issues relating to mangrove systems. Each individual listed in the name-generator represented a communication tie of that household, and the full set of individuals on the name-generator list comprised that household's full ego-network. Local partners and key informants helped identify an initial set of key households engaged in mangrove system related livelihood activities. These key households then identified further respondents for the subsequent snowball sampling (Luttrell, 2006; Pereira et al., 2005). Sampling continued in a respondent-driven way until saturation of target areas had been reached (i.e. until the same names started to reoccur in the list of names provided by respondents). Although it was recognised that this approach may miss households unconnected to the network of the initial respondents, respondent-driven sampling did permit less well-known households to be identified, as those best able to access members of hidden populations are their own peers (Heckathorn, 1997). Reaching saturation also meant that the configuration of the total sample was fully independent from the initial key respondents, hence yielding an unbiased sample (Heckathorn, 1997). In addition, this approach also prevented time being wasted talking to respondents that were not engaged in mangrove system use, thus permitting more focussed data collection. Household names were removed and replaced with a number to maintain confidentiality throughout this research.

Data for social network analysis were collated using quantitative methods to produce numerical data on the presence or absence of ties (Edwards, 2010). Such an approach enabled the measurement of network structure properties of density, degree and betweenness centrality, efficiency, effective size, and constraint. Although quantitative methods can overlook culture, agency and the processes through which relationships are created, maintained or reconfigured over time (Emirbayer and Goodwin, 1994), employing a quantitative approach in this study permitted the analysis of large sets of data using statistical techniques in order to identify patterns and connections in the data, which would not have been possible with qualitative information. Furthermore, the structure of networks was able to be analysed from the perspective of all actors in the network at the same time, and not just one individual perspective (Scott, 2000).

Data analysis first involved the identification of livelihood variables, i.e. total household annual income, mangrove dependency and livelihood diversity. Name-generator data, representing connectivity, were entered into UCINET 6 software to produce degree, density and betweenness scores for each household. For objectives 1 and 2 (assess the difference in livelihood diversity and social network measures across communities), once livelihood and connectivity measures and scores were obtained for each household, descriptive statistics were produced using SPSS v19 software. Objective 3 (identify differences within communities in livelihoods and social connectivity) involved the categorisation of livelihood diversity variables using two-step cluster analysis (Table 1). Inferential statistics, with livelihood diversity categorisations being the independent variables tested against the dependent connectivity measures, were produced using Kruskal-Wallis and Mann-Whitney tests (Ahenkan and Boon, 2011; Cox et al., 2010).

Table 1: Categorisation of livelihood diversity variables

	Dong Rui	**Da Loc**	**Giao Xuan**
Income ($per capita)	Low: 0-572 (n=32)	Low: <350 (n=23)	Low: 0-730 (n=17)
	Middle: 573-1,156 (n=34)	Middle: 350 – 800 (n=24)	Middle: >730-<1,330 (n=28)
	High: >1,156 (n=33)	High: >800 (n=23)	High: >1,330 (n=34)
MSPG dependency	Low = 0 - <33 (n=44)	Low = 0 - <33 (n=47)	No = 0 (n=53)
	Medium = 33 - <66 (n=27)	Medium = 33->34 (n=16)	Low = <32 (n=18)

	High = >66 (n=28)	High = >66 (n=7)	High = >33 (n=8)
Livelihood diversity	Low: <3 activities (n=5) Med: 3-4 activities (n=47) High: >4 activities (n=47)	Low: <5 (n=22) Med: 5 (n=28) High: >5 (n=20)	Low: <2 activities (n=15) Med: 3 activities (n=31) High: >3 activities (n=33)

3. Results

3.1 Comparing livelihood diversity characteristics across communities

In relation to objective 1, establishing a set of livelihood characteristics and values for each household allowed us to explore the similarities and differences in the relationship between livelihoods and aquaculture in each of the study communities (Table 2). A significant difference was observed in the mean income values between Giao Xuan and both Da Loc and Dong Rui, indicating that higher incomes are associated with greater degrees of aquaculture. The link between income inequality and degree of aquaculture is illustrated by observing the distribution of data in the descriptive statistics tables (Tables S1 and S2), whereby the 5% trimmed mean and income range are both considerably higher in Giao Xuan, followed by Da Loc, then Dong Rui.

Table 2: Livelihood characteristic measures between communities (*GX = Giao Xuan, DL = Da Loc, DR = Dong Rui*)

	Livelihood characteristic measures		
	Test statistic	**Degrees of freedom**	**Post-hoc r score**
Income	22.97*	2	0.148 (GX>DR)
Mangrove dependency	89.25*	2	0.485 (DR>GX)
Livelihood diversity	72.2*	2	0.405 (DL>FGX)

* Kruskal-Wallis test score significant at p = 0.025

A significant disparity occurred in the mean mangrove dependency values, suggesting an inverse relationship between aquaculture prevalence and mangrove dependency. The 5% trimmed mean indicates that omitting the lowest 5% and highest 5% values from the data had less influence in Dong Rui than in Giao Xuan and Da Loc. However, the lower level of mangrove dependency observed in Giao Xuan, with a well-established aquaculture industry, combined with greater skewdness and kurtosis values (Table S1), suggests that greater degrees of aquaculture were associated with lower mangrove dependency.

A significant variation was noted in the mean livelihood diversification values between Giao Xuan and both Da Loc and Dong Rui, suggesting that degrees of aquaculture has an inverse relationship with household livelihood diversification. Although there is no notable deviation from the mean value observed in the 5% trimmed mean and range values in all three communities, a greater range of livelihood activities available to households in Giao Xuan but a lower mean value of livelihood activities undertaken suggests that households are specialising their livelihoods in response to greater degrees of aquaculture. This is supported by the kurtosis values which suggest that households cluster around the mean in Giao Xuan, with a flatter distribution found in Da Loc and Dong Rui. Hence, in communities with high degrees of aquaculture, household livelihood activities are lower and concentrated into that industry.

3.2 Comparing social network characteristics across communities

Establishing a set of social network measures and values for each household allowed us to explore the similarities and differences between community networks (objective 2). Analysis of social network measures (Table 3) indicated a statistically significant difference was observed in mean degree centrality values between Dong Rui and both Giao Xuan and Da Loc, with larger network sizes observed in communities with high degrees of aquaculture. However, a significant disparity was also observed in mean density values, suggesting that higher degrees of aquaculture are associated with networks of lower connectivity. This could be due to the changing structure of social networks, from close-knit and family based networks associated with low degrees of aquaculture, and wider reaching commercial networks associated with high degrees of aquaculture. Although there was no significant difference between mean betweenness values, the lower value observed in Dong Rui supports the previous finding from network density values, i.e. Dong Rui networks are more closely connected with a household's contacts all having many connections to each other.

Table 3: Difference in social network measures between communities

	Social network measures		
	Test statistic	**Degrees of freedom**	**Post-hoc r score**
Degree	32.64**	2	0.178 (DL-DR)
Density	8.64*	2	0.076 (GX-DL)
Betweenness	0.241	2	- Ω
Effective size	31.08**	2	0.172 (DL-DR)
Efficiency	9.45**	2	0.081 (DL-GX)
Constraint	15.15**	2	0 (GX-DR)

*****Kruskal-Wallis test score p = 0.026, ** p = 0.05

Ω = no significant relationship observed, therefore no score provided

A significant difference was observed in the mean value of the effective size of networks between communities. The lower value observed in Dong Rui suggests that low degrees of aquaculture are associated with a greater redundancy among a household's contacts, which is supported by the greater network density observed in the community. Although this may be detrimental to the productivity of a household's social network, the increased redundancy can increase resilience. A significant disparity was detected in the mean value of network efficiency. The greater network efficiency observed in Giao Xuan than in either Da Loc or Dong Rui suggests that households in Giao Xuan obtain greater productivity from their social network for each unit of effort invested in their contacts, but the observed lower levels of redundancy (i.e. network density) may translate into lower resilience. A significant difference was also observed for the mean value of network constraint, with a greater constraint observed in Dong Rui suggesting that the high density of networks can constrain household's behaviour in terms of productivity, but increase resilience in terms of the greater number of redundant contacts.

3.3 Comparing livelihood diversity and social network characteristics within communities

Having established a set of livelihood and social network characteristics and values, we can determine whether there is a relationship between livelihood characteristics within communities and their social connectivity (objective 3) (Table 4). In Dong Rui there were no significant differences in mean degree, density or betweenness values according to livelihood diversity. However, there was a significant difference in scores according to network density, with higher income households having greater network density than lower income households. Although not statistically significant, a difference was noted in betweenness scores according to mangrove dependency. There was no significant difference found in mean social network values of effective size, efficiency or constraint according to mangrove dependency or livelihood diversity. However, a significant difference was observed in efficiency values according to income, with lower income groups having more efficient networks, suggesting that they have more non-redundant ties in their networks.

Table 4: Results of Kruskal-Wallis tests for significant differences in social network scores according to livelihood measures in the three study communities

			Dong Rui			
	Density	**Degree**	**Betweenness**	**Effective size**	**Efficiency**	**Constraint**
Income	9.15***	3.26	0.91	1.11	10.78*	0.66
Mangrove dependency	1.88	1.82	4.66*	2.46	1.85	4.55
Livelihood diversity	0.7	0.49	1.48	0.71	0.35	1.1
			Da Loc			
	Density	**Degree**	**Betweenness**	**Effective size**	**Efficiency**	**Constraint**
Income	0.51	0.54	1.67	0.21	0.431	0.59
Mangrove dependency	2.92	3.71	5.92*	4.54	3.13	3.04
Livelihood diversity	4.45	2.33	0.02	1.69	0.94	1.68
			Giao Xuan			
	Density	**Degree**	**Betweenness**	**Effective size**	**Efficiency**	**Constraint**

Income	1.63	0.31	0.96	0.46	1.22	2.24
Mangrove dependency	4.66*	0.85	0.28	0.26	3.88	0.19
Livelihood diversity	4.49	0.75	3.01	0.54	4.36	5.93*

***p = 0.025, ** = 0.05, *= 0.1 (*nb: *** and ** are statistically significant, while * is apparent but not statistically significant*)

In Da Loc, there were no significant differences in degree, density or betweenness values according to all livelihood diversity measures. However, there was a difference in betweenness according to mangrove dependency, with more dependent groups scoring lower in betweeness. There were no significant differences in effective size, efficiency or constraint according to any of the livelihood measures. In Giao Xuan, there were no significant differences in mean values of degree, density or betweenness values according to livelihood income and diversity. There was a small but not significant difference in network density values according to mangrove dependency, between groups with no dependency and those with low and high dependency. No significant differences were observed in mean effective size, efficiency and constraint values according to livelihood income and mangrove dependency measures. There was a small but not significant difference in constraint according to livelihood diversity, with lower livelihood diversity groups possessing less constrained networks.

4. Discussion

4.1 The impact of aquaculture on livelihoods

This study found high degrees of aquaculture are associated with lower resilience in coastal communities through greater income and inequality, lower mangrove system dependency and lower livelihood diversity. Adger et al. (2006) show how income inequality can negatively impact resilience as the concentration of resources among a small number of individuals reduces resource access for the rest of the community. Allenby and Fink (2005) suggest that reductions in the regenerative ability of ecosystems are undermining the resilience of those with greater levels of natural resource dependency by reducing their ability to effectively respond to change in order to sustain their livelihoods. Turning to livelihood diversity, findings correspond with those from Cinner and Bodin (2010) in their study of fishing communities in Kenya. They found that households in more developed communities were less likely to have supplementary livelihood activities than households in less developed communities. The divergence observed in aggregate livelihood diversity measures between communities is important because livelihoods are the means by which households in MSDC interact with one another and give value and meaning to the changing environment around them (cf. Frost et al., 2006; Wiesmann, 1998), which greatly influences resilience (Vincent, 2007). Cinner and Bodin (2010) argue that increased levels of development are associated with changes in livelihoods which influence the structure of social networks.

4.2 The impact of aquaculture on bonding social capital and resilience

High degrees of aquaculture are associated with low community bonding social capital, with negative impacts on resilience through lower levels of network redundancy and potential for self-organisation. Results indicate that different degrees of aquaculture involvement are associated with distinct livelihood contexts, and subsequent variation in bonding social capital with regard to the size and density of social networks. Communities with low degrees of aquaculture are associated with smaller and denser networks than communities with high degrees of aquaculture. This suggests that such communities are characterised by a larger stock of bonding social capital and higher degrees of resilience due to a greater number of redundant network ties. Furthermore, Djante (2013) argues that high levels of network density can foster greater interaction and trust between individuals and groups in natural resource dependent communities. Previous research suggests that greater levels of trust have the potential to increase the resilience of MRDC in a number ways: first, it reduces the risk and cost of collaborating with others which is crucial for self-organisation to occur (Bodin et al., 2006);

second, it fosters shared identification and understandings of environmental issues necessary for self-organisation to occur (Petty and Ward, 2001); third, it facilitates the creation of and compliance with mutual norms with regards to acceptable behaviour in resource use (Barnes-Mauthe et al., 2013); finally, it reduces the potential for network fragmentation (Coleman, 1998).

Communities with high degrees of aquaculture were found to be associated with larger and less dense networks, with a greater number of non-redundant ties suggesting lower levels of resilience. Sandstrom and Rova (2010) argue that less dense networks can exhibit conflicting interests and perceptions, lowering resilience through a lack of common understanding and problem identification, such as resource condition, quantity/quality of stocks and rules of use, that are necessary for self-organisation to occur. Results presented here concur with that of Baird and Gray (2014) in their study of the influence of economic transition on Maasai communities in Tanzania, which indicate that: livelihood opportunities are low and social network interactions are high prior to transition; livelihood opportunities increase with development, which prompts changes in the traditional use of social networks; subsequently, households reduce their engagement with traditional social networks.

Research from our study suggest that communities differentiate subsequent to the transition process, leading to reduced levels of resilience in MRDC by hindering the potential for self-organisation (cf. Cumming, 2011). King (2000) suggests that actors who are successful in furthering their goals will actively seek ties with others to continue the pursuit of their goals. For example, in communities with high degrees of aquaculture, wealthy households with little mangrove system dependency and large and expansive market oriented networks are typically more concerned with market demands and less aware of the degradation of local mangrove systems. This could act as a barrier to self-organisation within MRDC as it could reduce shared understandings of natural resource issues and the support of wealthy and influential households (cf. Bodin and Crona, 2009). In light of this, Sandstrom and Rova (2010) argue that denser community networks made up of heterogeneous actors and groups within MRDC can promote the reconciling of conflicting perspectives, and facilitate the development of common understandings of natural resource issues and dilemmas.

4.3 The impact of aquaculture on bridging social capital and resilience

The large and expansive social networks associated with high degrees of aquaculture can reduce resilience through less redundant ties and potential for self-organisation. Communities with higher degrees of aquaculture are associated with larger and less dense social networks, indicating greater access to external sources of capital, skills and knowledge, market opportunities and social networks. The social networks of these communities were found to exhibit greater effectiveness and efficiency and less constraint, indicating a high number of non-redundant ties. Previous research on organisational networks advocates this type of network with regard to increasing productivity and gaining competitive advantage in market settings (Burt, 2004). However, resilience can be compromised by a narrow focus on efficiencies (Walker et al., 2006). The increased reliance on a small number of weak market based bridging ties can lower resilience by reducing the number of redundant ties required to buffer networks against the loss of any particular actor (Prell et al., 2009). Furthermore, in line with findings from Baird and Gray (2014) in their study of traditional social networks and household livelihood strategies in northern Tanzania, market forces may increase household economic independence in communities with high degrees of aquaculture involvement. This can reduce resilience through lower capacity to self-organise in response to change.

Previous research indicates that only a small number of households in communities with high aquaculture have bridging social capital due to their engagement in aquaculture market networks (Orchard et al., 2014). These households are able to maintain their advantageous network position through bridging ties that facilitate their access to and command over external resources (cf. Isaac et al., 2007). Research suggests that as local networks become increasingly integrated into market orientated networks, it is the local social networks that largely determine who benefits (Frank et al., 2007). Furthermore, results show that households with high dependence on MSPG that are unable to access new market opportunities maintain their traditional bonding networks as a resource to respond to change (cf. Busby et al., 2010; Cassidy and Barnes, 2012; Baird and Gray, 2014). Hence, it is possible that bonding capital within successful socio-economic groups is reinforced over time, and the resources attained through bridging ties become captured within these groups (cf. Isaac et al., 2007). Reduced community cohesion, in this case through disengagement in community-level networks due to large and expansive aquaculture networks, can reduce the ability of communities to self-organise in response to change (Adger, 2000).

Whilst communities with high degrees of aquaculture have built bridging ties to other communities to develop and maintain aquaculture, this could be at the expense of bridging among different socio-economic groups within communities. Although self-organisation may occur within distinct socio-economic groups, either among high income groups seeking to maximise their power and wealth, or among marginalised groups pooling resources in order to respond to change, the subsequent homogenisation has fractionalised communities with high degrees of aquaculture. A lack of bridging among socio-economic groups obstructs the opportunity for self-organisation and prevents the creation of shared understanding of environmental issues (cf. Crona and Bodin, 2006). This highlights the need to balance the bonding and bridging ties of communities to help build trust across diverse groups, encourage a diversity of ideas, increase network flexibility and foster resilience (Baird and Gray, 2014). This should link marginalised groups who have rich knowledge of mangrove systems due to their high dependence, with those from higher socio-economic groups that are integrated into external networks of diverse actors and resources other than those based solely on market relations (e.g. NGOs, governments) (Bodin and Crona, 2009).

5. Conclusion

By analysing the impact of aquaculture on livelihoods and social networks, our findings illustrate the importance of considering how these interacting elements have shaped resilience in three mangrove system dependent communities in northern Vietnam. By employing an approach that provides insights into social capital in communities with differing degrees of aquaculture, we have discussed how the livelihood context and the structure of social networks shape the ability of communities to self-organise in response to change. Whilst efforts to increase social capital in natural resource dependent communities in order to increase resilience are welcomed, the various ways in which aquaculture impacts the structure of social networks and the ability to self-organise must be acknowledged.

Findings demonstrate how economic transition alters mangrove system governance through the increasing influence of market mechanisms on the structure of social networks. For example, small and dense social networks based on kinship have traditionally played a crucial role in rural Vietnam, representing a component of social capital used as an asset and coping strategy for households with few alternative assets. However, our findings show that communities with a greater degree of aquaculture are associated with larger and less dense networks that are shaped by market relations for aquaculture goods that extend beyond the immediate community. We have demonstrated how market relations can negatively impacted resilience by: (1) lowering the level of redundancy in social networks, reducing buffering capacity in the event that ties are lost; and (2) reducing the level of connectedness within communities as networks become less dense, compromising the ability of communities to self-organise.

Hence, it is crucial that the impact of aquaculture on livelihoods and social networks is acknowledged if policies to sustainably manage mangrove systems are to be successful. In particular, understanding how aquaculture impacts the structure of social networks is vital in order to provide targeted support to community networks to increase resilience. Building and supporting social networks among MSDC can help foster self-organisation to effectively manage and respond to external shocks through shared understanding, not only of the resource itself, but of the perspectives of divergent mangrove system stakeholders. This is crucial in transition economies as the state is rolled back and traditional community networks (i.e. bonding capital) are replaced by external networks (bridging capital) oriented towards markets and commerce. Further research will be necessary to identify the specific kinds of support communities will need, and also to understand the structure and role of networks that extend beyond the community and across governance levels.

Findings presented here highlight important features of communities that should be considered within environmental governance more widely. For example, the increasing influence of external market relations means that community networks risk becoming fractionalised among groups with differing needs regarding networks of productivity or adaptability, and priorities for responding to market or mangrove system changes. While networks that extend beyond the immediate community present an opportunity to access external resources, they are fragile and have the potential to extract resources away from communities. How mangrove system change affects resilience depends on the impact of aquaculture on livelihood contexts and social network structures, and will manifest differently depending on the diversity and balance of social networks necessary for the sustainable governance of mangrove systems.

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