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ARTICLE

How stakeholders structure their collaborations to anticipate and tackle the threat of mountain pine beetle in the Jasper–Hinton (Alberta, Canada) area[1]

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Abstract: The resilience of resource-based communities facing natural disturbances partly depends on the capacity of a wide diversity of stakeholders to share their expertise, articulate their efforts, and develop solutions that are both effective and equitable. Structural methods from network theory can be used to measure how efficiently and thoroughly collaborations happen among stakeholders and to identify ways to improve information flow. We applied network theory to represent and analyse the collaborations between individuals dealing with a significant mountain pine beetle outbreak in the Jasper–Hinton area of Alberta, Canada. For this, we interviewed and collected relational information from 90 respondents officiating in the area. Our results show unbalanced collaboration patterns among federal, provincial, and municipal institutions, as well as the forestry sector and research institutions, leading to clusters and, as a consequence, to gaps in the flow of information that are only partially bridged by a few actors. Such siloing of information is a key barrier to sustainability in natural resource management that may be addressed more transparently using network theory.

Key words: network analysis, mountain pine beetle, stakeholder networks, social–ecological systems, resilience.

Résumé : La résilience des communautés qui dépendent des ressources face aux perturbations naturelles dépend de la capacité d'une grande diversité d'intervenants de partager leur expertise, d'articuler leurs efforts et d'élaborer des solutions efficaces et équitables. Les méthodes structurelles qui découlent de la théorie des réseaux peuvent être utilisées pour mesurer à quel point les collaborations entre intervenants sont efficaces et complètes et pour identifier les façons d'améliorer la circulation de l'information. Nous avons appliqué la théorie des réseaux pour représenter et analyser les collaborations entre les individus aux prises avec une importante épidémie de dendroctone du pin ponderosa dans les régions de Jasper et Hinton en Alberta, au Canada. À cette fin, nous avons interrogé 90 répondants travaillant dans la région et collecté des informations relationnelles à leur sujet. Nos résultats montrent des schémas de collaboration déséquilibrés parmi les institutions fédérales, provinciales, municipales, ainsi que les institutions du secteur forestier et de celui de la recherche, engendrant des regroupements et, par conséquent, des lacunes dans la circulation de l'information qui sont seulement partiellement comblées par quelques acteurs. Un tel compartimentage de l'information constitue un obstacle important pour l'aménagement durable des ressources naturelles qui peut être abordé de façon plus transparente en utilisant la théorie des réseaux. [Traduit par la Rédaction]

Mots-clés : analyse de réseau, dendroctone du pin ponderosa, réseaux d'intéressés, systèmes socio-écologiques, résilience.

Introduction

The resilience of resource-based communities facing a natural disturbance such as a mountain pine beetle (MPB) outbreak depends on many factors. One of them is the capacity of a wide diversity of stakeholders with a common interest in containing, or adapting to, the disturbance, to articulate their efforts and develop joint mitigation and adaptation solutions (Ostrom 1990; Magis 2010; Berkes and Ross 2013). Indeed, these social–ecological challenges are often so complex (entangling ecological dynamics with deeply rooted social, cultural, and economic interests) that timely, well-informed, and fair local management decisions requires sharing of knowledge, skills, capital, and ideas across a diversity of interest groups, companies, and institutions. Each of these stakeholder groups has their own prerogatives in terms of resource management and capacity to take on different initiatives (Ostrom et al. 1992; Olsson et al. 2004; Armitage 2005; Tyler 2006; Magis 2010; Berkes and Ross 2013).

However, institutional, geographical, ideological, or economic boundaries may, in many settings, hinder this well-accepted necessity for collaborations (Powell 2010; Fischer et al. 2016). These boundaries tend to make stakeholders who are like-minded, who belong to the same institution or geographical entity, or who have aligned economic interests to collaborate more closely with each other than they do with other stakeholders. This phenomenon, called homophily (McPherson et al. 2001), lowers the overall sense

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of trust among stakeholders, as well as the diversity of knowledge and skills made available at the landscape scale (Rickenbach and Reed 2002).

To counter this systemic tendency for siloed collaborations and decision-making, it has been shown that improving social capital (among, and between institutions) can help with building bridges between otherwise unacquainted stakeholders (Borg et al. 2015), as well as, more generally, improving trust, recognition of expertise between stakeholders, better knowledge sharing, and ultimately, collective decision-making (Abell and Reyniers 2000; Gass et al. 2009; González Bailón 2006; Stern and Coleman 2015).

Because cooperation, or lack thereof, can be conceptualized with networks of interactions, different network-related frameworks have been developed to help analyse them. Although some frameworks are qualitative (Murdoch 1994; Doyon 2009), others have more recently taken advantage of metrics from social network analysis. The latter have shown that a quantitative approach can be very effective in grasping the subtleties, complexity, and emerging patterns of cooperation networks (Berkes et al. 2006; Ernstson et al. 2008; Bodin and Crona 2009; Crona and Bodin 2010; Marín and Berkes 2010; Stein et al. 2011; Matouš and Todo 2015; Fischer et al. 2016; Mbaru and Barnes 2017). Indeed, structural metrics related to social capital (i.e., density of communications and collaboration between individuals, bridging capacity) are all very well documented in social network theory (Scott and Carrington 2011).

The main objective of this research is to use network analysis to identify strengths and gaps in information flow between stakeholders that might either increase or decrease system resilience and adaptive capacity in a forest-resource dependent region. Starting from the postulate that a collaboration network displaying a higher social capital, with denser sustained collaborations between the different stakeholders, would breed better informed and accepted solutions at the landscape level, we focus on identifying how the flow of information is articulated across the region's diverse spheres of interests and influence, on where the potential gaps are in the patterns of information sharing, and on which groups of stakeholders best help close these gaps.

Study area

Our study area encompasses the towns of Jasper and Hinton in the foothills region of Alberta, Canada. The Jasper–Hinton area is at the eastern edge of the current MPB infestation, which is significantly affecting pine forests in the region. The two communities are located approximately 70 km apart as the crow flies, along the Athabasca River, which flows eastward out of the Rocky Mountains. Although Jasper and Hinton have highly contrasted institutional and economic profiles, they share the same forest resource and are part of the same ecological system at the landscape scale. We have thus chosen to study them as a single system. The town of Hinton has a population of nearly 10 000 people, and its economy is mainly based on natural resources extraction. This includes coal mining, oil and gas extraction, and forestry. The latter is represented by two separate divisions of West Fraser Inc.: Hinton Wood Products (which holds the Hinton Forest Management Area and operates a sawmill) and Hinton Pulp (a pulp and paper mill). Together, the forestry sector counts as a major local employer, and the proximity of the MPB infestation is a great matter of concern at the local and provincial government levels. The Municipality of Jasper has a population of close to 4500 people and is located within the boundaries of Parks Canada's Jasper National Park (JNP), which covers 10 878 km² and is visited by more than 2 million people each year. As per its geographic location, the town has a specialized status under Canada's National Parks Act and its governance is shared between an elected municipal council and Parks Canada. The town's economy is largely tourism-based and the MPB infestation does not have a direct economic impact on the residents. Nevertheless, the increased risk of wildfires, as dead, MPB-infected trees accumulate in the forest surrounding the town's buildings, is a matter of concern for the council. As an agency of the Federal Ministry of Environment, JNP's mandate includes maintaining the ecological integrity of the park and educating visitors on its ecological processes, which the region's indigenous MPB is a part of. However, considering the potential economic and public safety consequences of an outbreak on the region, JNP has, together with the Provincial Government of Alberta and the Municipality of Jasper, worked on a mitigation plan (Parks Canada 2016) with the goal of slowing the spread of the MPB. The plan includes conducting conservation-oriented prescribed fires, removing targeted trees or patches, and facilitating community protection programs related to wildfires. However, some forestry-sector stakeholders east of Jasper voice concerns in regards to the scale of the plan and whether it will be sufficient to truly mitigate the effect of the outbreak and its spread east of the park. This raises the sensitive subject of territorial prerogatives in terms of MPB management and the perceived key geographical position of Jasper National Park as a gateway for the infestation into Albertan forests. There is thus clearly a need for coordination and cooperation between stakeholders working at different levels of government (federal, provincial, county, and municipal) and in different jurisdictions inside and outside of the park to manage the MPB outbreak as it progresses across the landscape.

Methods

This research consisted in the collection of relational data of individual stakeholders working directly or indirectly on the threat of MPB's infestation in the Jasper–Hinton area, in mapping the network of interactions, and in analyzing the structure of this network.

To collect relational data, a broad range of stakeholders involved in community leadership, in the forestry sector or in forest management related activities in both towns was targeted. This included, for example, representatives from municipal, county, provincial, and federal level government agencies, First Nations, industry and community groups, and scientific researchers from academic and other institutions. Data collection began by reaching out to a few key individuals (e.g., town Mayors) and a snowball sampling approach was used to identify additional individuals in the network, as described in further detail below.

Data collection was done through in-person interviews, telephone interviews, and an online questionnaire. The question asked to interviewees was as follows:

> "Who do you feel is, or has been (in the last 3 to 4 years), a valuable resource when it came to helping you anticipate, manage, develop new knowledge or plan adaptation to mountain pine beetle infestations in the Jasper/Hinton area? These individuals could be from your community or from elsewhere in Alberta, in Canada, or in the rest of the world. They could work, for instance, in forestry companies, government agencies, academic institutions, research groups, they could be elected officials, independent consultants, students, or even concerned citizens from your community. The help that these individuals may provide you with could take the shape of information and knowledge sharing (i.e., who informs you about the progress of the beetle in the landscape? Who provides you with ideas or options on how to deal with it? etc.) or in terms of actual, on-site help in dealing with the issue."

The questionnaire itself consisted of a website with a list of the names and affiliations of individuals who were identified by us or other interviewees as potential stakeholders. For each of these individuals, the interviewee had the choice to select a frequency of interactions between daily, weekly, fortnightly, monthly, quarterly, bi-yearly, yearly or less often, and never. Additionally, interviewees were asked to fill-in new names that were not already in the list, hence directing us to new potential interviewees (in a

Table 1. The groups, categories, and the corresponding number of individuals surveyed.

Group	Category	No. of individuals
Alberta Ministry of Agriculture & Forestry	Alberta Government Agencies	16
West Fraser	Industry	12
Parks Canada	Federal Government Agencies	11
University of Alberta	Academia	10
Municipality of Jasper	Local Government	9
fRI Research	Multi-Actor Research Partnership	5
Yellowhead County	Local Governments	4
Town of Hinton	Local Government	3
Canadian Forest Service	Federal Government Agencies	3
University of British Columbia	Academia	3
Private Consulting	Private Consultant	2
Forest Growth Organization of Western Canada	Multi-Actor Research Partnership	2
Saskatchewan Ministry of Environment	Saskatchewan Government Agencies	1
Jasper Environmental Association	Recreational & Environmental NGO	1
Alberta Innovates	Private Consultants	1
Federal Legislature	Other	1
Alberta Forest Product Association	Industry	1
Alberta Newsprint Company	Industry	1
BC Ministry of Forests, Lands, and Natural Resource Operations	British Columbia Government Agencies	1
University of Montreal	Academia	1
University of Northern British Columbia	Academia	1

snowball sampling fashion) and contributing new names to the list for the next interviewees to choose from. The constant updating of the questionnaire led us to develop a website and a series of tools to automate these repetitive tasks.

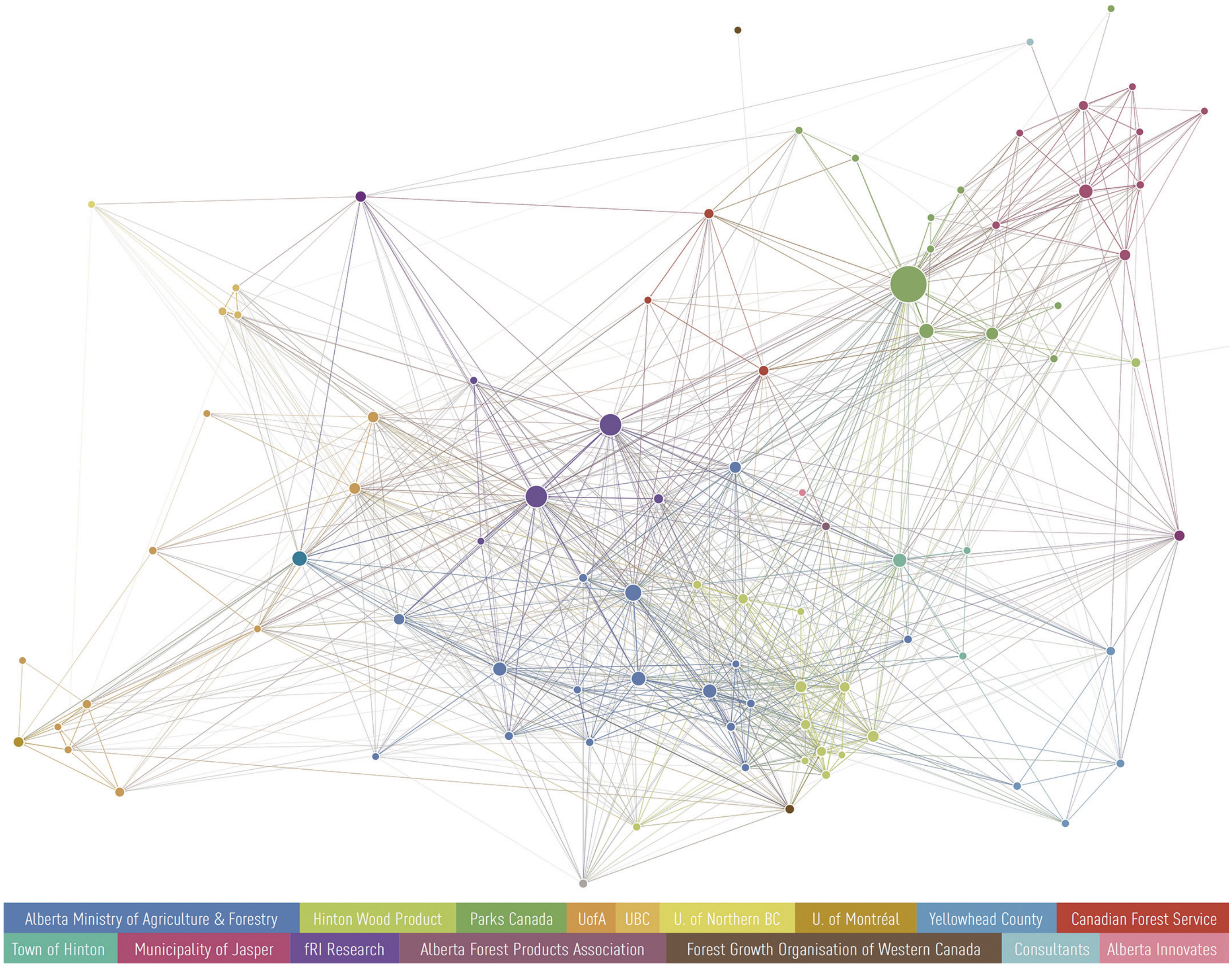
Data collection lasted over a period of four months between December 2016 and March 2017 and was organized around four steps. The first step consisted in a series of meetings organized by the Foothills Research Institute (fRI Research), an independent research institute located in Hinton, during which we were given the opportunity to present our project to a number of key stakeholders, as well as to discuss their roles and stakes surrounding the MPB issue in the area. During this phase, we were introduced to the mayors of the municipality of Jasper and town of Hinton, the chief administrative officer of Jasper, the superintendent and fire team from Jasper National Park, and the two directors of woodland and mill operations at Hinton Wood Products (based in Hinton). The meeting helped us establish important local contacts and outline an initial list of potential stakeholders. The second step consisted of a series of in-person meetings with select stakeholders to fill out the questionnaire and resolve potential misunderstandings in the formulation of the question. This was done during two field trips to Jasper, Hinton, and Edmonton and resulted in the completion of 20 questionnaires. During the third step, we sent the online questionnaire to all remaining identified stakeholders (around 180 individuals in total), while conducting some of the interviews over the telephone. Finally, the online questionnaire was sent once again to all stakeholders who had filled it in to give them a chance to consider the names added after they were interviewed. Between the face-to-face interviews, the phone interviews and the online questionnaire, we collected data about how 90 respondents (corresponding to 45% of the total identified stakeholder population) receive information that helps them in their job dealing with the MPB threat in the Jasper–Hinton area. As Table 1 shows, these respondents belong to groups related to the forest industry, to federal, provincial, county, and municipal governments, to academia, to groups organized under research partnership umbrellas, and to an independent expert and a member of a local environmental NGO. However, although our field research suggested the importance of the region's First Nations as potential stakeholders, our attempts to reach these communities proved unsuccessful. This should be seen as an important gap in our sampling.

This dataset was analyzed using the formalism of graphs, which can model different kinds of interactions with simple nodes and edges. Nodes represent one interviewee (anonymized by a random number) and are associated with a group and a category (see Table 1 for a list of both). Edges, which represent a flow of information between two nodes, are directed and weighted according to the inverse of the lapse of time (in days) between to communication events (e.g., a daily interaction would result in a weight of 1/1 = 1, whereas a weekly interaction would result in a weight of 1/7 = 0.14).

From this simple and intuitive model, we drew the interactions as a network map and used graph theory metrics to quantify the topology of our datasets. The network map was done using a force-directed layout algorithm (Kobourov 2012), which arranges the position of nodes in the figure using the physics analogy of weights attached together with springs (where the weights represent nodes, and springs, set with a tension related to the strength of the relationship between nodes, represent edges). Starting from a random distribution of the nodes in the figure, the algorithm finds a layout of nodes in which the forces in the network are close to optimally balanced. This leads to visualization where topological features such as clusters, hubs, and outliers are clearly represented. It also gives an idea of a nodes' centrality in the network, as more central groups of nodes tend to settle around the centre of the figure.

In terms of topological features quantification, we focused on bridging capacities and emission of information. The bridging capacity was computed with both (*i*) classic betweenness centrality (which measures the node's topological centrality as the frequency of a given node to fall on shortest paths between all pairs of other nodes, i.e., an individual who is structurally standing in the middle of most other individuals exchanging information would have a higher betweenness centrality) (Freeman 1978), and (*ii*) a modified betweenness centrality that we dubbed "reachability" (Gonzalès 2016), which measures, using the same principle as betweenness centrality, the capacity of a node to function as a bridge between groups that are different from each other (including two particular cases in which we focus on the capacity of individuals to build bridges between groups in Jasper and groups from outside of Jasper and the capacity of individuals to build bridges between the academic world and the rest of the network), hence giving a better idea of who best brings potentially different

Fig. 1. Layout of the entire network at the individual scale. Each dot represents an interviewed individual. The colours represent the group to which the individual belongs, and the sizes of the dots are proportional to the betweenness centrality (or bridging capacity) of the individual. Interactions between individuals are represented by edges (the thicker the line, the more frequent the interaction is). [Colour online.]



knowledge and interests together. The emission of information was measured with out-degree centralities (a simple count, at the node level, of how many connections come out of any given individual). All these metrics were measured at the node level (i.e., at the individual level) but aggregated into the groups they are associated with to protect the anonymity of participants.

Results

Our results consist of two network maps (Figs. 1 and 2) and five figures (Figs. 3–7) each representing a topological feature of the network. The two network maps differ in only one aspect. In Fig. 1, each of the interviewed individuals is represented by a coloured dot (where the size corresponds to the individual's bridging capacity through the network metric of betweenness centrality). In Fig. 2, individuals are aggregated according to the group they belong to (in this case, the size of the dot corresponds to the groups' bridging capacity). Figure 1 shows how individuals receive and transmit information through the network. Individuals appear to agglomerate not only according to their groups, but also, in an instance at least, according to the geography of the region, as nodes from Jasper (represented by JNP and the Municipality of Jasper) seem relatively weakly integrated to the rest of the network.

Figure 2 shows the same network as in Fig. 1, but the nodes are aggregated into the groups they belong to. This provides a less granular, but clearer view of the dynamics at play among stakeholders at the group level. It highlights a central cluster of just a few groups (Hinton Wood Products and the Alberta Ministry of Agriculture and Forestry, as well as fRI Research) taking centre stage in the information flow.

Figure 3 shows the betweenness centralities of individuals agglomerated by groups. fRI Research overall appears as the group where individuals are the most central, topologically speaking. However, medians do not tell the whole story, and distributions need to be considered. For instance, the Alberta Ministry of Agriculture & Forestry has the stronger outlier, and the University of Alberta has the wider spread. Additionally, the overall high median of Yellowhead County should be balanced by the fact that only three individuals from this group answered our survey.

Figure 4 shows the out-degree centralities of individuals agglomerated by groups. The Alberta Ministry of Agriculture & Forestry and fRI Research host the individuals who share the most information. Importantly, Parks Canada, which is ranked low in terms of median, is home to an individual who is a very strong sharer of information in the network.

Fig. 2. Layout of the network at the group scale. All interviewed individuals are aggregated according to their group (see Table 1), which are represented as dots on this figure. The colours represent the group to which the individual belongs, and the size of the dots are proportional to the betweenness centrality (or bridging capacity) of the group in the network. Interactions between groups are represented by the sum of edges between individuals belonging to each group (the thicker the line, the more frequent the interaction is). [Colour online.]

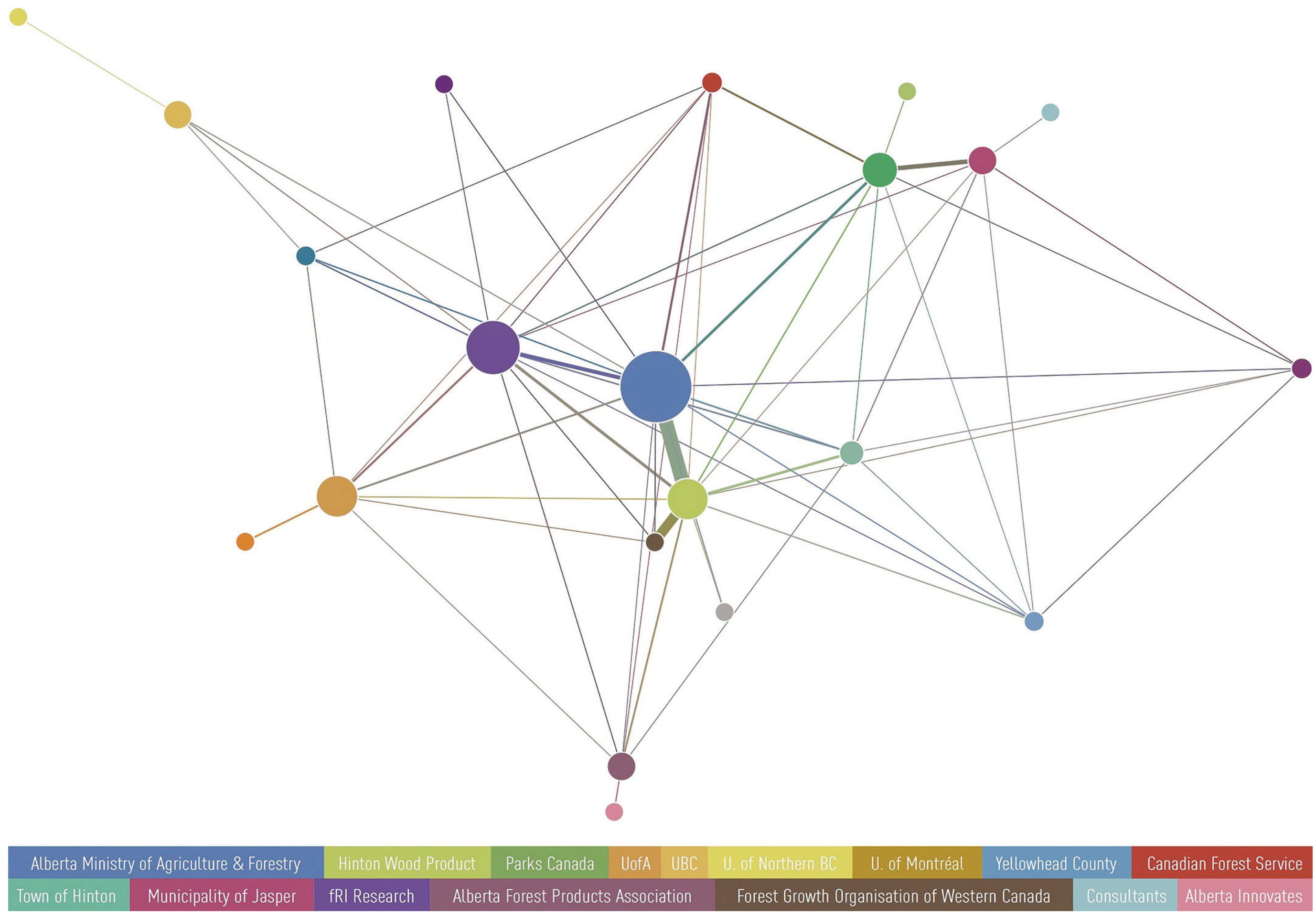


Figure 5 shows the capacity of individuals (agglomerated by groups) to connect to other individuals belonging to different groups. Although Parks Canada has a very strong outlier, fRI Research appears as the group that counts the individuals who best act as bridges in the information network.

Figure 6 shows the capacity of individuals (once again agglomerated by groups) to serve as geographical bridges between Jasper and the rest of the network. As for Fig. 5, fRI Research, as well as, in this instance, one individual from Parks Canada, are strong bridges to help connect Jasper to the rest of the network. Likewise, the Canadian Forest Service, albeit with relatively few in the number of respondents, ranks as a very strong bridge.

Finally, Fig. 7 shows the capacity of individuals (agglomerated by groups) to serve as bridges between the academic world and the rest of the network. fRI Research clearly appears as the strongest bridge in this case.

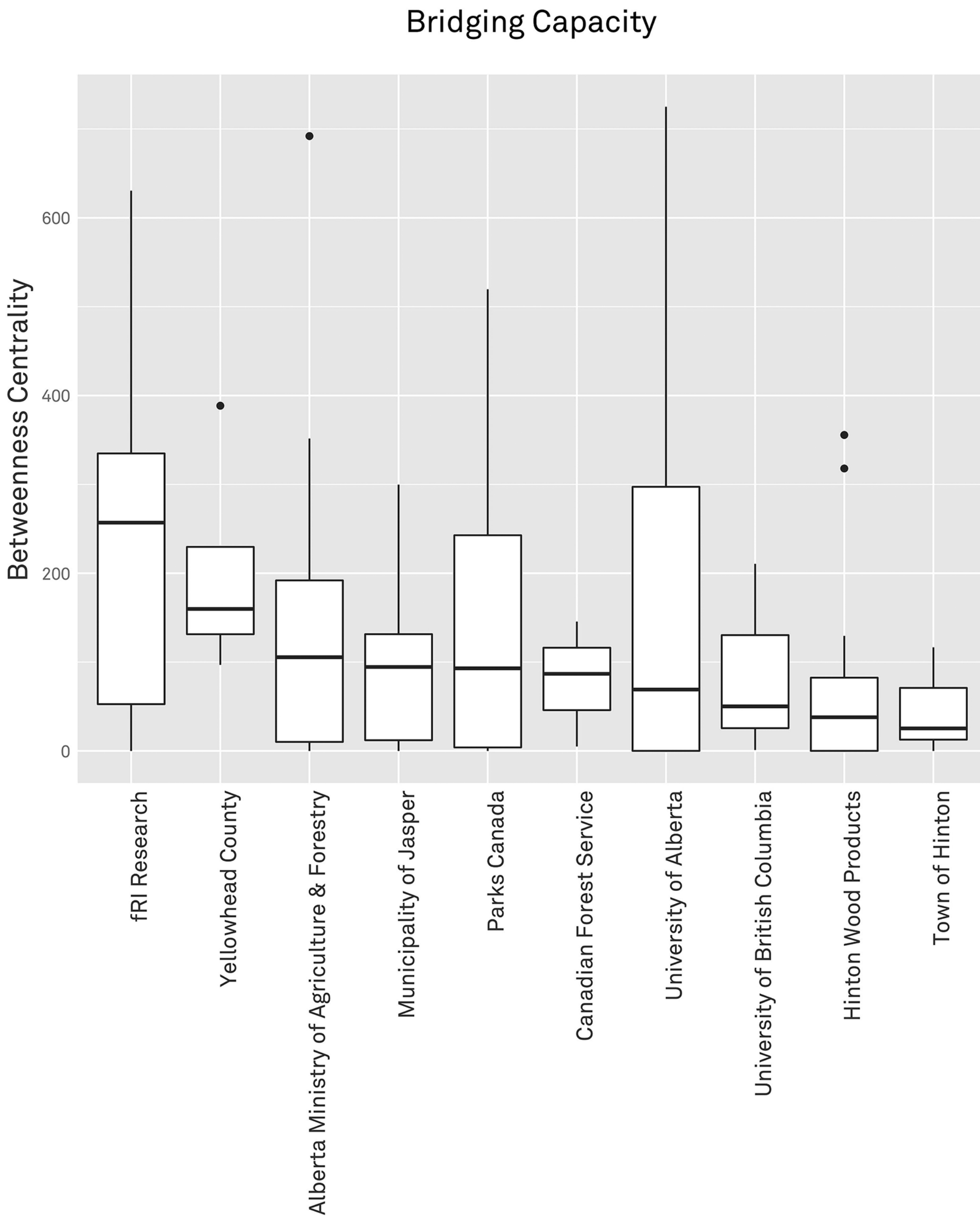
Discussion

Our results highlight non-trivial structural patterns in the flow of knowledge within the stakeholder network. Together, Hinton Wood Products, the Alberta Ministry of Agriculture & Forestry, and fRI Research constitute the pivotal point of the network as a large portion of the collaborations happen within and around this joint entity. Jasper, as a geographical entity (represented by JNP and the Municipality of Jasper), is somewhat separated from the rest of the network, and this spatial (and arguably institutional) divide is only bridged by a handful of individuals from fRI Research, Canadian Forest Service, and a small number of respondents from Parks Canada. When it comes to disconnect between institutional academics and practitioners, fRI Research provides, by far, the main information avenues to the rest of the network. Together, these points suggest that despite the multi-objective landscape management setting of the area (the National Park on one side, with its mandate of conservation and education, and Hinton's wood industry on the other side with economic objectives), the stakeholder network is heavily shaped by geographic, institutional, economic, and perhaps ideological homophily. The heterogeneity in the densities of interactions leads to clusters and, as a consequence, to gaps in the flow of information.

Jasper's relative isolation

For the most part, geography is not strongly reflected in the structure of this network, with the notable exception of Jasper (Parks Canada and Municipality of Jasper), which forms a group that is structurally isolated from the rest of the network. Within this group, the Municipality of Jasper is even further isolated and is mainly connected to other actors in the network through JNP (this is most likely a structural translation of the specialized status of the Municipality of Jasper, which leaves the landscape-scale management of MPB to officials at JNP). As a consequence, although Parks Canada seems to be self-sufficient in the production of its knowledge regarding the management of MPB in JNP, the

Fig. 3. Betweenness centrality by groups as box plots. As with Figs. 4–7, the boxes represent the spread of the distribution (from first quartile at the bottom to third quartile at the top), the horizontal lines within the boxes represent the median of the distribution, and individual dots represent outliers. Groups are sorted in descending order of their medians (for significance considerations, we only kept groups from which at least three individuals responded to our survey).



Municipality of Jasper makes its local management decisions by seeking external expertise from consultants (Fig. 2), as well as with knowledge developed by JNP (ibid.). More importantly yet, Fig. 6 shows that, although Canadian Forest Service and fRI Research do play a significant role in bridging Jasper to the rest of the network, the strongest connection relies on only one individual at Parks Canada (as seen also in Fig. 1).

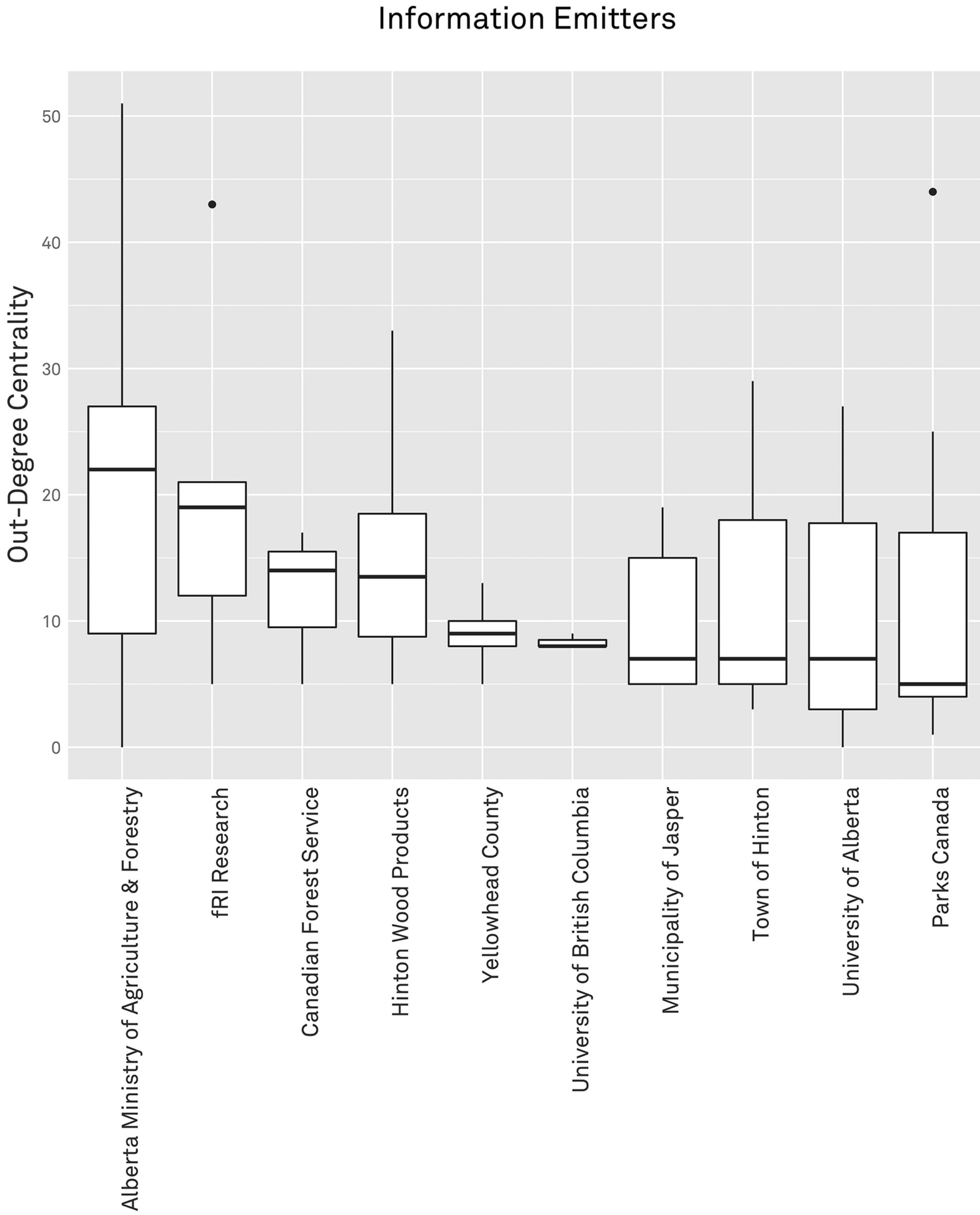
Provincial government and forestry sector's strong bonds

The Alberta Ministry of Agriculture & Forestry is both very central in the network and tightly connected to Hinton Wood Products (Figs. 1 and 2). Although still topologically distinct, the two groups are the most strongly connected in the network (for reference, this bond is 3.7 times as strong as the relationship between Parks Canada and the municipality of Jasper). Importantly, the Alberta Ministry of Agriculture & Forestry is a significant source of knowledge in the network (Fig. 4), which makes this close relationship particularly meaningful, and possibly illustrating a strategy by the Provincial Government to prioritize direct collaboration with local natural resource users. Altogether, their centrality in the network (position and size of nodes in Fig. 2) puts them in a powerful spot in terms of information sharing.

Producing knowledge at the periphery

Academics are quite present in this network, and among all of them, the University of Alberta is the most represented academic

Fig. 4. Out-degree centrality by groups.

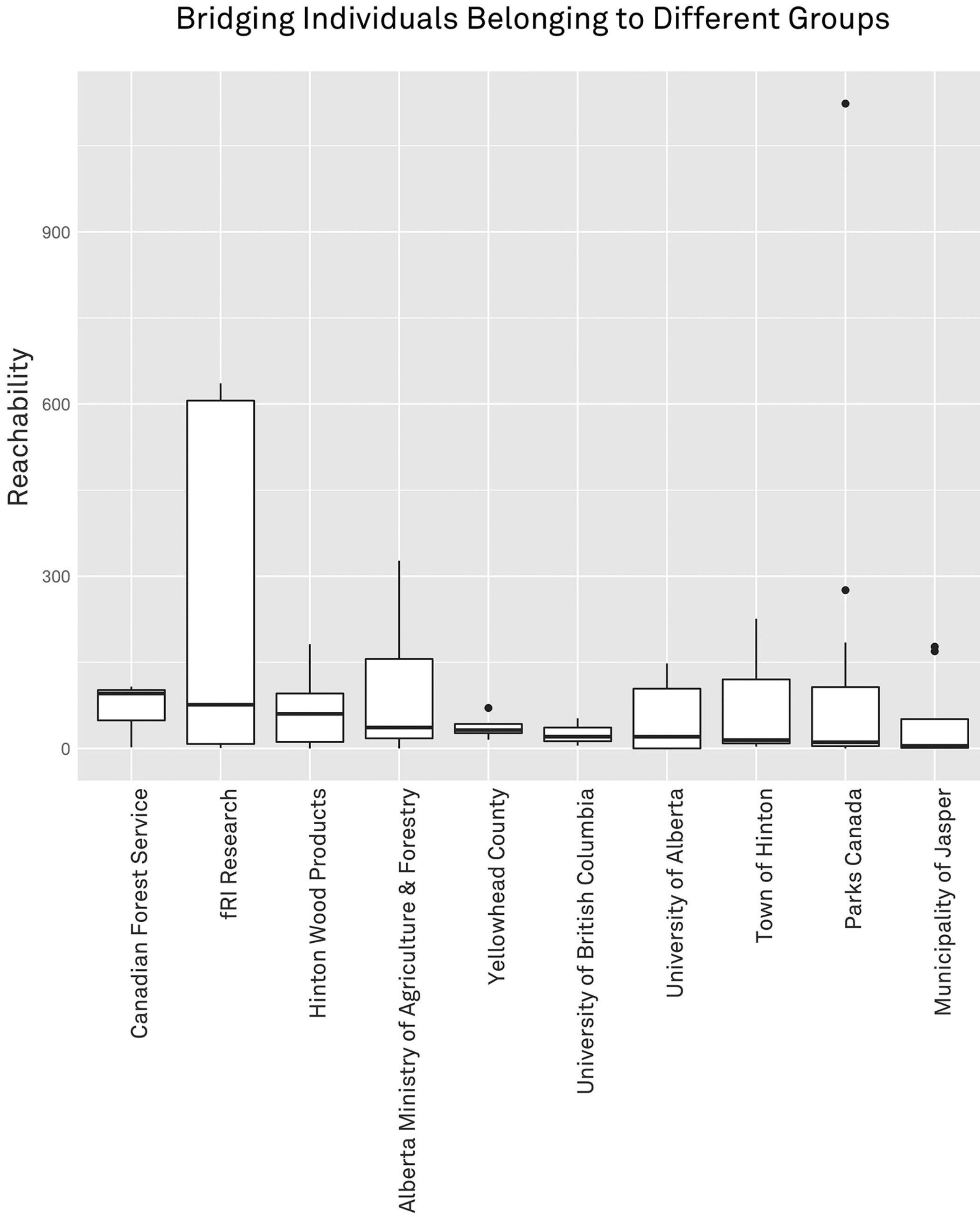


group. Interestingly, this group is divided into two smaller subgroups: the first group gathers geneticists (bottom leftmost in Fig. 1), also including a researcher from the University of Montréal, whereas the second group gathers ecologists and entomologists. Although not as tightly interconnected as the former group, the latter group connects more to fRI Research and the rest of the network. Researchers from The University of British Columbia shape a small substructure by themselves, connecting with the sole interviewed individual from the University of Northern British Columbia. Topologically speaking, academics are at the periphery of the network. From this position, they do not act as knowledge bridges but rather as knowledge producers, hence fulfilling one of their expected functions. Their research is spread across the network for the most part by respondents from fRI Research (Fig. 7), which once again, acts as a strong bridging actor in the network. Interestingly, the Saskatchewan Ministry of Environment also serves as a local channel between many academics and the rest of the network (most particularly with the Alberta Ministry of Agriculture & Forestry).

Bridging and facilitating collaborations

Our results highlight two main forces at work in the stakeholder network. The first one isolates Jasper (park and municipality alike) from the rest of the network, whereas the second one attracts around a cluster mainly shaped by provincial government agencies and the forestry sector. The former could be explained by both the relatively narrow decision-making power of the Municipality of Jasper and the disconnect in land management objectives between JNP and the forest management area east of the park. This translates into JNP having few incentives to sustain strong connections outside of the park. The provincial government–forestry sector cluster may be a structural product of neoliberal

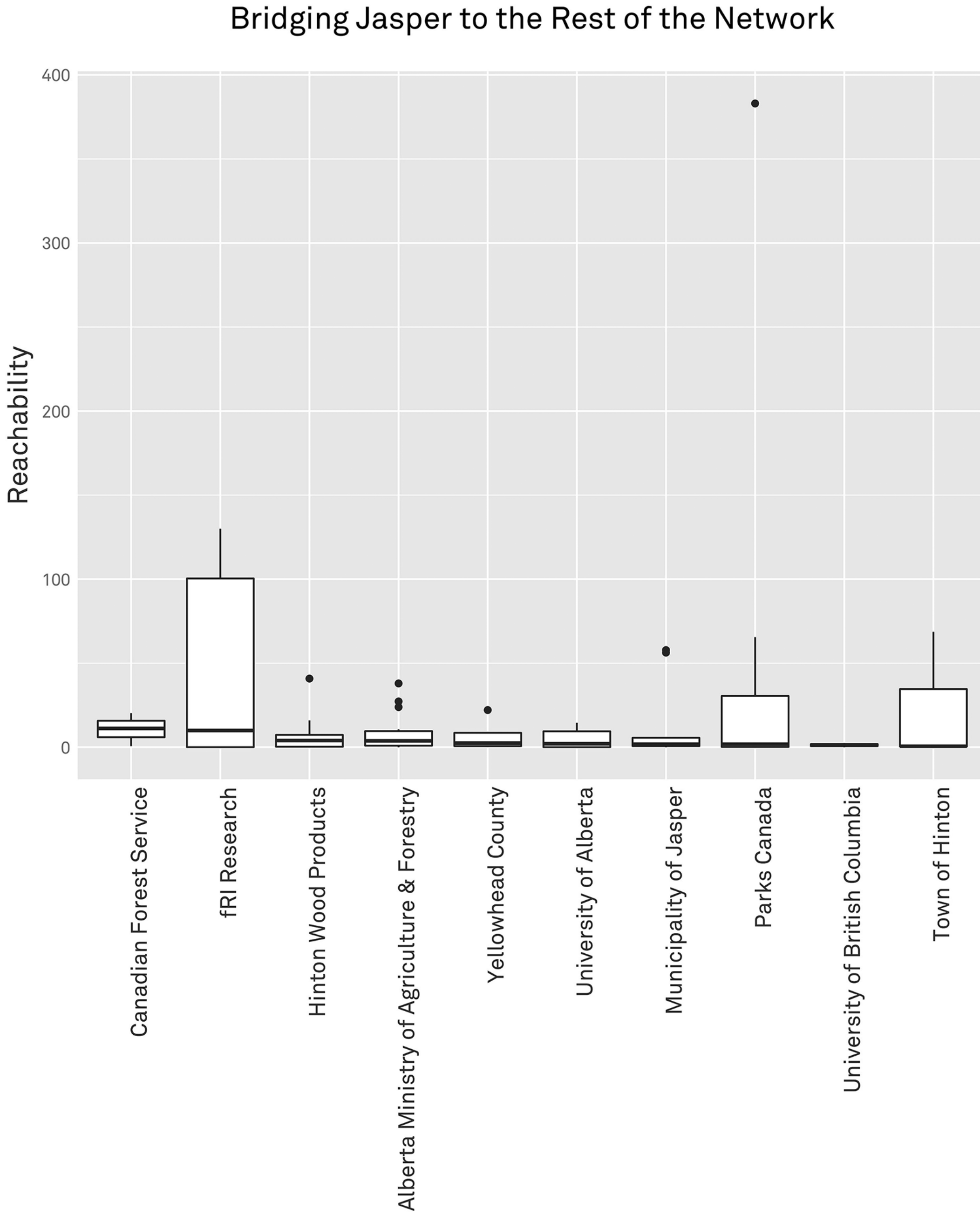
Fig. 5. Capacity of stakeholder groups to function as bridges between groups that are different from each other.



policies, according to which governmental bodies choose to transfer many societal responsibilities to the private sector and thus place efforts on direct relationships and collaborations with this sector (Ilcan 2009). Although there may be good reasons for governmental bodies to team up with industrial actors whose activities are closely tied to local economies, this bias means that other stakeholders may be, or at least feel, alienated. As a consequence, this central cluster of such strong stakeholder groups, together with JNP's institutional isolation, could (*i*) be detrimental to the overall social capital of the system (reducing trust levels and recognition of expertise between stakeholders), (*ii*) organically align local resource management decision-making, outside of the park, towards the interests of the forestry sector rather than society as a whole, and (*iii*) possibly hinder the emergence of broadly accepted and sustainable planning solutions to the MPB threat.

Practically, this implies that bridges need to be built to establish lasting relationships between a wider variety of stakeholders. Doing so would support sustainable forest management that more effectively includes the interests of a broader spectrum of society and includes more diverse forms of knowledge. Efforts in this direction seem to be underway. For example, Figs. 3, 5, 6, and 7 highlight fRI Research as an instrumental organization that facilitates the flow of information across the network. These brokering initiatives happen mainly outside of Jasper geographically but still count as a significant part of the links between Jasper and the rest of the network (Fig. 6). Although likely not yet sufficient to balance collaborations between Federal and Provincial entities, channeling knowledge and collaborations is very valuable to better include the Jasper perspective, and expertise, into the rest of the network. These initiatives should be taken advantage of, and

Fig. 6. Capacity of stakeholder groups to function as bridges between groups located in Jasper and groups located outside of Jasper.

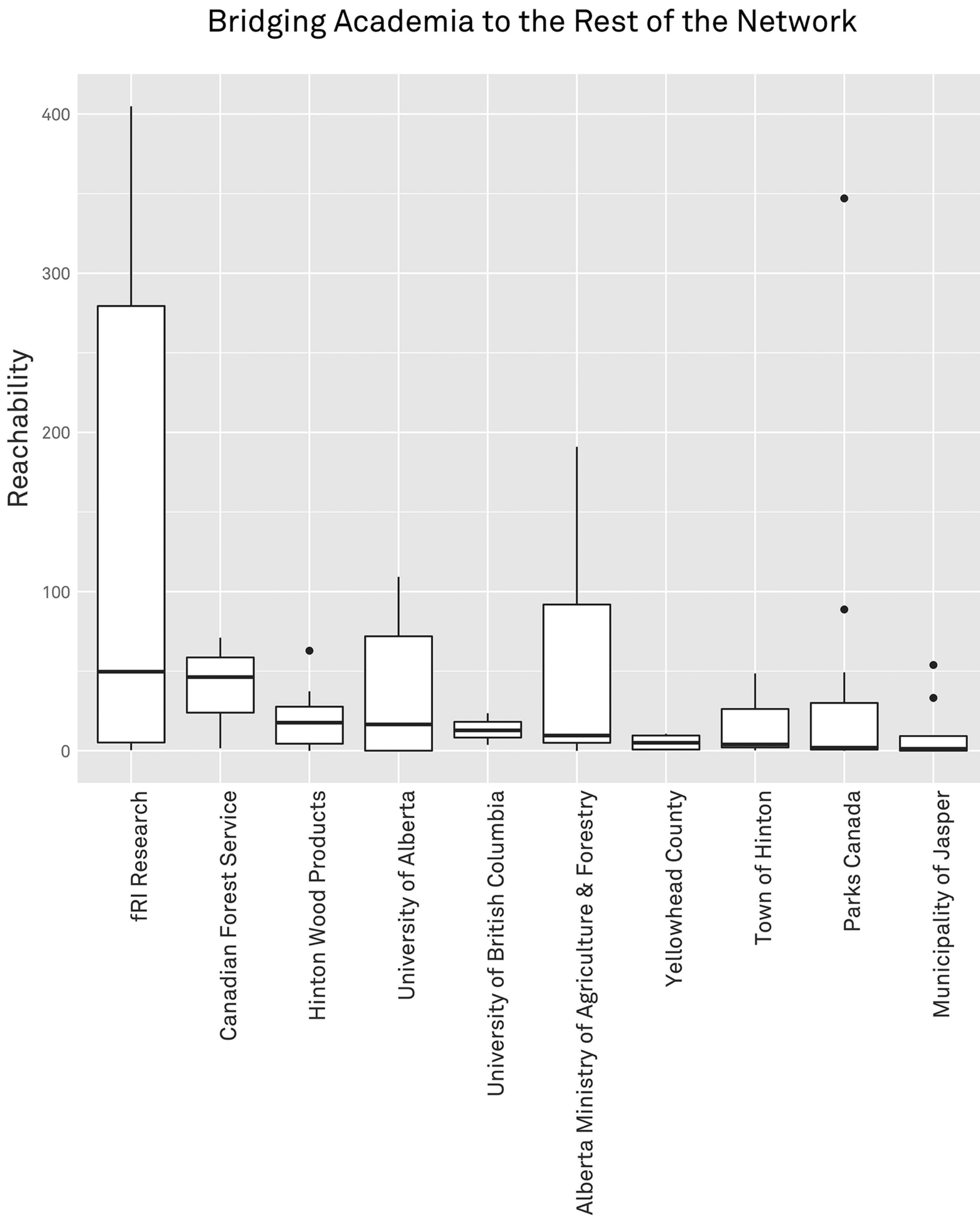


be further encouraged, as a significant part of social capital is built through brokers such as this one (Burt 2000). However, more direct channels of collaboration between the provincial and federal levels should be initiated as well; as noted by Abell and Reyniers (2000), level of trust and positive feedback loops of reciprocity between unaligned stakeholders can also be sparked by simple direct first moves from one of the parties to the other.

Key players

Our results also identify a number of key players in the network. Although we cannot speak of individual names, Fig. 1 shows only a few nodes whose sizes indicate higher-than-average betweenness centrality (hence strong bridging capacity). Two of these individuals belong to fRI Research, which illustrates our precedent discussion point. However, the most notable one belongs to a group considered structurally more isolated than others: JNP. This single individual assumes most of the connections between JNP and its vicinity. Although this situation is not uncommon in this type of network, stakeholders across the network should be aware of such structural fragility and attempt to add redundancy to their relationships with other groups, since (1) such de facto gate-keepers are, whether the individual is aware of it or not, in a very powerful position of so-called information control in a network (Barzilai-Nahon 2008), and more importantly, (2) the loss of such key individuals would be extremely detrimental to the overall flow of information in the network. Additionally, because these individuals can also be considered as instrumental entry points in the network (Mbaru and Barnes 2017) and brokers of large amounts of information from diverse sources, their loss would be detrimental to the achievement of sustainable conservation or resource management goals.

Fig. 7. Capacity of stakeholder groups to function as bridges between groups belonging to academia and the rest of the groups.



Conclusion

In this research project, we focused on identifying how collaboration (through information sharing) is articulated in a complex stakeholder network related to the management of the MPB threat in the foothill region of Alberta. Our results show the complex relationships between key stakeholders, each operating, with their own objectives, toolsets, and levels of power, on a shared landscape threatened by a common perturbation.

Among the main stakeholder organizations, Hinton Wood Products is the focus of most of the local and provincial government's efforts to contain MPB. This is particularly clear in its strong bond with the Alberta Ministry of Agriculture & Forestry. Together, Hinton Wood Products and the Ministry constitute the pivotal point of the network, as a large portion of the collaborations happens within and around this double entity. Although it may be highly effective with regards to management of resource extraction, this type of close government and private sector partnership can potentially result in isolation and disempowerment of local governments and other public sector and community groups in the stakeholder network.

Parks Canada appears as an equally central actor but in a different way. Although its influence on the landscape is undeniable and its structural position in connecting Hinton and Jasper is significant, it is at the centre of a much more modest network of collaborations. This position in the network might be explained by the difference in landscape-management objectives between Parks Canada and the forest industry, as well as the fact that Parks Canada is a federal organization operating within a network of largely regional and provincial organizations.

Notably, it is surprising that so few connections are made with organizations from the neighbouring province of British Columbia (except for The University of British Columbia), as a number of stakeholders in the Jasper–Hinton network could likely import valuable knowledge from the experience of communities and parks in British Columbia that have gone through similar perturbations in the past.

Finally, the lack of participation of the region's First Nations in our research should account as an important caveat of our methodology. Although several respondents to our study mentioned First Nations individuals as people with whom they share information and these individuals were subsequently contacted and invited to participate in the study, they were not included in the final network map due to a lack of response. Our methodology was designed from a Western scientific point of view (Smith 1999), and data collection was carried out in a relatively short time frame, which did not facilitate relationship building with potential indigenous participants. In a study providing recommendations on how stakeholders should work on building trust between parties, it is ironic that our research constraints made us fail to apply our concepts to our own work. Further work on the subject should be more sensitive to this issue and implement early relationships with indigenous people.

Stakeholder network analysis such as the one done here can help communities and governments identify where to strengthen ties and flows of information. Although it is obvious that groups with similar objectives and mandates should form structural clusters (Webb and Bodin 2008; Gonzalès and Parrott 2012), an efficient flow of information should nonetheless be fostered to strike a balance between clustering and knowledge sharing (ibid.). This case study identifies an imbalance between these two features, with a large number of connections on one side of the network (the Alberta Ministry of Agriculture & Forestry and Hinton Wood Products) and structural gaps on the other side of the network (Jasper and the rest of the network). This situation could contribute to tensions between levels of governance and to slowing the efficient flow of local knowledge, hence hindering community resilience at the landscape scale. In the larger context of small, resource-based communities across Canada, our research suggests that social network analysis is an effective way to analyse the structure of stakeholder relationships, and to begin dialogue around how that structure might be leveraged and (or) modified to support collaborative decision-making. Such approaches will lead to greater community resilience and adaptive capacity in response to future change.

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