Title:
Bridging Collaboration Gaps in Fragmented Environmental Governance Systems

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Highlights:
- "Collaboration gaps" among interdependent actors complicates environmental governance
- Third-party actors tend to bridge gaps, but gaps were prevalent in the governance system
- Actors without capacity to implement policy were more likely to bridge gaps
- Actors who could more readily access the benefits of coordination also bridged gaps

Abstract:
Recent research highlights the challenge of achieving environmental governance goals in the absence of collaboration among interdependent policy actors. This article explores factors contributing to the likelihood of "collaboration gaps" among actors who are interdependent because their jurisdictions overlap. Analysis of data on collaboration among organizations involved in wildfire risk governance in Oregon indicates that interdependent actors are more likely to collaborate. Despite this tendency, nearly 75% of possible collaborations between interdependent actors were absent. In turn, these collaboration gaps tended to be brokered by third-party actors, especially those lacking the authority to manage land themselves and those for whom the benefits of brokerage may be more immediately apparent. Taken together, these findings shed light on actors' strategies for navigating fragmented governance systems and highlight opportunities to improve risk mitigation outcomes by enabling greater coordination among interdependent actors.

1. Introduction

How do policy actors collaborate to address natural hazards in decentralized governance settings? Risk mitigation commonly requires collective action, especially among actors who are interdependent because they are jointly exposed to common sources of risk (Kapucu, 2006; Nohrstedt and Bodin, 2019) and an active literature highlights the role of decentralized collaborative relationships in risk governance systems (Fischer and Jasny, 2017; Hamilton et al., 2019; Kelly et al., 2019). More generally, scholars have emphasized the importance of understanding how governance systems self-organize via collaborative interactions among policy actors (Berardo and Scholz, 2010; Feiock and Scholz, 2009; Lee et al., 2012). A central premise of this vein of research is that evaluating "micro-level" processes such as partner selection are crucial for understanding "macro-level" outcomes such as the performance of complex governance systems, given the decentralized distribution of authority as well as the numerous and diverse sets of policy actors (Barnes et al., 2016; Berardo and Lubell, 2016).

This article focuses on one particular form of complexity that manifests when multiple actors' jurisdictions (i.e., territories over which responsibilities or authority extends) overlap in geographic space, resulting in physical interdependence because actors are mutually affected by one another's actions. Overlapping spheres of authority are well-recognized as a reality of governance (Lubell, 2013). We argue that accounting for the interdependence among actors whose jurisdictions overlap is necessary for understanding governance processes that play out at both the actor- and system-level. In particular, jurisdictional overlaps highlight the need for collective action among actors who jointly manage or bear responsibility for outcomes within a common geographic space. However, not all actors whose jurisdictions overlap may interact. Such situations—or "collaboration gaps"—point to the potentially important role of third-party actors that indirectly broker between these actors and thereby help to reduce inefficiencies, moderate conflict, and improve governance outcomes in other ways (Bodin et al., 2014; Kininmonth et al., 2015). Consequently, an understanding of the tendency for collaboration gaps to manifest—as well as the characteristics of actors that bridge collaboration gaps—can contribute to theories of policy processes in fragmented governance settings.

In this article, we develop and test a set of hypotheses about (1) the likelihood of collaboration between organizations whose jurisdictions overlap, (2) the tendency for third-party organizations, i.e. those that do not have jurisdictions, to broker collaboration gaps, and (3) how such brokerage varies as a function of actor attributes. We test these hypotheses through inferential network analysis of data on collaborative interactions among organizations seeking to address wildfire risk within a fire-prone region of Oregon, USA. Wildfire risk governance provides an ideal setting for studying collaboration gaps. Globally, including in our study region, wildfires are becoming increasingly frequent and severe (Perry et al., 2011; Stephens et al., 2014; Westerling et al., 2006). Given the tendency for fires to burn across increasingly large areas, research has highlighted the importance of undertaking risk planning and response at scales that span the jurisdictions of multiple organizations (Fleming et al., 2015; Monroe and Butler, 2016). In particular, an active literature examines how collaborative networks can allow organizations to address hazards at multiple spatial scales, which may not necessarily align with any single organization's jurisdiction (Abrams et al., 2015b; Butler and Goldstein, 2010; Fischer and Jasny, 2017). However, in the specific context of wildfire risk governance as well as the more general context of environmental governance, there is limited understanding of the conditions that shape direct and mediated (i.e., brokered) interaction among policy actors who are interdependent

based on their responsibility and/or formal authority for managing the same lands. Such understanding is crucial for crafting policies to improve governance outcomes in settings characterized by extensive fragmentation of authority and capacity to mitigate hazards.

2. Collaboration gaps in complex governance systems

Interdependence is a defining feature of complex systems (Simon, 1976), and research on the structure and function of governance systems explores the implications of interdependence among policy actors based on their joint participation in multiple decision-making processes (Berardo and Lubell, 2016; Lubell, 2013). While this literature primarily focuses on interdependence from social interaction, we consider spatial interdependence as well. Actors may also be interdependent if their jurisdictions overlap, which is common in landscapes managed for multiple objectives. For example, one organization may depend upon the provision of timber or other natural resources from a tract of land, while another organization may bear responsibility for preventing fires from spreading from that land to neighboring homes. In such cases, multiple organizations have a stake in forest or fire management outcomes within the same tract of land because their jurisdictions overlap.

Such overlaps create interdependence among land managers, whose actions jointly affect one another by way of their joint use or dependence upon ecosystem processes and functions. For example, one organization may be reluctant to use mechanized equipment to reduce fuel densities in tracts of forest that provide habitat to endangered species. Such decisions may complicate efforts of another organization with a legal obligation to prevent fires from spreading from those tracts to residential communities. Overlapping jurisdictions may likewise create interdependence among organizations with similar mandates or goals. For example, multiple fire response organizations that may be jointly responsible for protection of homes and other assets within a certain tract of land. In these situations, one organization's fire-fighting strategy can increase or decrease safety of personnel from the other organization (Faas et al., 2017).

Consequently, to the extent that interdependent organizations do not collaborate, they risk duplicating efforts or implementing conflicting actions that result in mismanagement (Bodin and Nohrstedt, 2016). Collaboration gaps may preclude coordinated management of the same resource base, resulting in inefficiencies. Indeed Bodin et al. (2014) show that desirable conservation outcomes depend in part on social interaction among organizations jointly managing the same resources. Additionally, collaboration gaps may increase the likelihood that organizations independently implement management actions that are incompatible with one another (e.g., one landowner planting dense vegetation to improve habitat while the adjacent owner thins vegetation to prevent the spread of fire), which may result in conflict (Fleming et al., 2015).

Although interdependent organizations may not directly collaborate, they may be indirectly linked via third-party intermediary organizations that perform a brokerage role (Kininmonth et al., 2015), which may mitigate inefficiencies. For example, intermediary organizations may distribute information and resources among organizations that are otherwise not connected. Eventually, holding the same information and resources may foster complementary strategies for forest or fire management, or otherwise facilitate effective decision-making processes by encouraging bilateral relationships between organizations that do not previously interact directly.

3. How partnership selection shapes collaboration gaps

Research on governance systems characterized by fragmented authority that constrains top-down policy implementation has highlighted the importance of understanding actor-level strategies, and particularly the factors that influence how policy actors select collaborative partners. A common thread in this literature is that actors evaluate prospective partners based on how well partnerships may allow them to capture payoffs from solving collective action problems, subject to transaction costs (Berardo and Scholz, 2010; Feiock, 2013; Lubell, 2013). Importantly, organizations may weigh the prospective value of each relationship relative to other relationships (Scott and Thomas, 2017a). Given capacity constraints, organizations may pass up a beneficial relationship in favor of an even more appealing relationship. The following five hypotheses reflect our expectations for why actors select partners in ways that do or do not mitigate collaboration gaps.

> **Interdependence hypothesis** (H1): Actors are more likely to select collaboration partners whose jurisdictions overlap their own.

Just as overlapping jurisdictions creates interdependence among actors, interdependence can spur collaboration by providing conditions favorable to social interaction. The relationship between proximity and social interaction has been well documented in diverse empirical settings (Gerber et al., 2013; Greenbaum and Greenbaum, 1985; Ponds et al., 2007). We focus on the special case of proximity defined by overlaps in actors' jurisdictions, which can provide opportunities for in-person interaction. In turn, greater familiarity among such actors can foster trust (Lubell, 2007), thereby lowering the transaction cost of collaboration (Torre, 2008; Wondolleck and Yaffee, 2000). Furthermore, among interdependent actors, collaboration may enable actors to influence one another's activities, thereby limiting negative externalities.

> **Brokerage hypothesis** (H2): Actors preferentially broker collaboration gaps in overlapping jurisdictions.

Although actors may preferentially collaborate with partners whose jurisdictions overlap their own, not every such potential collaboration may be realized, and our remaining hypotheses relate to expectations about the likelihood that other actors, or certain types of other actors, mediate between actors who do not collaborate even though their jurisdictions overlap (i.e., broker collaboration gaps). In particular, consistent with research from sociology and political science, we recognize brokerage as a strategy that simultaneously presents opportunities as well as liabilities (Burt, 2005; Stovel and Shaw, 2012; Uzzi, 1997). We contend that collaboration gaps present an opportunity for would-be brokers. By creating an indirect linkage between unconnected actors, brokers can improve efficiencies (e.g., by aligning management actions) in ways that advance their own goals (e.g., encourage a particular form of management).

Building on this baseline expectation that organizations will tend to broker collaboration gaps, the appeal of this strategy for social interaction may additionally vary as a function of organizational attributes of would-be brokers, including their capacity to implement management actions themselves, their legitimacy, and the timescales at which they gain payoffs from solving collective action problems.

> **Brokerage and capacity hypothesis** (H3): Actors without jurisdictions are more likely to broker collaboration gaps.

Among actors participating in a governance system, some can directly implement policies, while others lack the capacity to do so and must advance their goals by influencing other actors. Organizations without jurisdictions may not have the authority to carry out management activities themselves but may still affect management by collaborating with land managers or by contributing to landscape-level decision-making processes. For these organizations, collaboration gap brokerage may be especially appealing because they may utilize their bilateral relationships with land managers to promote preferred management actions. Scott and Thomas (2017b) observe that public agencies that lack the authority to implement certain management actions on their own may be drawn to collaborate with organizations that do have such authorities. In a study of health policy, Fernandez and Gould (1994) found that government organizations gained benefits from brokerage when they played the 'outsider' role. Here, we argue that organizations without jurisdictions play a similar outsider role and may consequently be more trusted as brokers (Stovel and Shaw, 2012), which may enable them to more effectively advance policy goals.

> **Brokerage and legitimacy hypothesis** (H4): Non-local organizations are more likely to broker collaboration gaps.

While H3 posits that brokerage may serve as a mechanism for organizations to indirectly achieve management goals despite lacking the *capacity* to directly implement management actions (i.e., because they lack jurisdictions), H4 examines the role of *legitimacy*, and specifically the form of legitimacy derived from local affiliations. Successful implementation of land management policies hinges upon the support of local stakeholders throughout large regions of the American West (Molden et al., 2017). In these settings, local organizations are often better able to draw upon longstanding relationships with residents, community organizations, and locally based enterprises to gain the "social license" necessary for policy implementation (Edwards et al., 2016). For non-local organizations, engagement with local networks provides opportunities to gain legitimacy as they seek to advance policy goals through local environmental management projects (Abrams et al., 2015a; Maier and Abrams, 2018).

> **Brokerage and discernable payoffs hypothesis** (H5): Actors concerned with rapid-onset hazards are more likely to broker collaboration gaps.

Consistent with H5 is our expectation that the benefits of brokering collaboration gaps may be more obvious for actors that address risks that manifest more rapidly. In the context of wildfire risk governance, fire management organizations that respond to hazard events may expect to realize the benefits of coordinated risk mitigation at short timescales, including during specific wildfire events (Bodin and Nohrstedt, 2016; Nowell et al., 2017). By contrast, for forest management organizations concerned with slow-onset hazards (e.g., accumulation of flammable vegetation in forests), the benefits of brokerage may be obscured by time lags. Even when forest managers respond to rapid-onset crises such as pest and disease outbreaks, they experience greater uncertainty about how to achieve their goals, relative to fire response organizations (Moynihan, 2008). Likewise, forest as well as fire management can be challenging due to diverse stakeholder preferences for management outcomes. However, fire response tends to be guided by a narrower set of high-profile objectives, including the safety of responders and community

members, and the protection of homes and other assets (Spies et al., 2014; Wibbenmeyer et al., 2013). In landscapes characterized by diverse groups of actors with wide-ranging policy preferences, the goals of forest management can be contested by stakeholders, which constitutes a transaction cost.

4. Materials and methods

4.1. Study site

We tested these hypotheses using data about the collaborative interactions among organizations concerned with wildfire conditions within the Eastern Cascades Ecoregion (ECE) in Oregon, USA. The ECE includes the slopes and foothills of the eastern, and drier, side of the Cascades mountains and extends to the California border (figure 1). While wetter mountainous forests historically received high severity fires, much of the lower elevation forests are adapted to frequent but low-severity fires (Agee, 1993; Merschel et al., 2014).

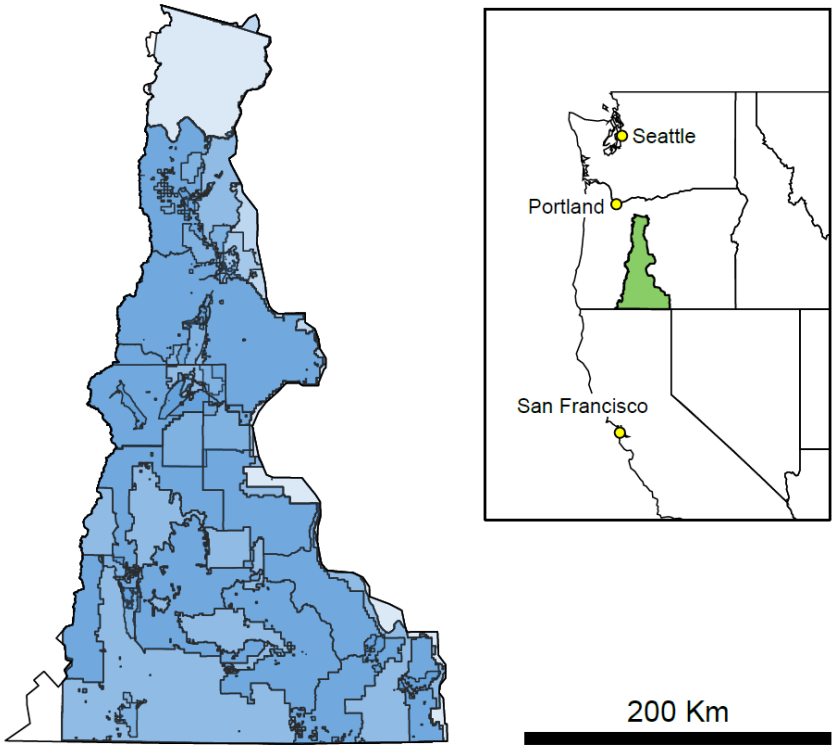


Figure 1. Map of the Eastern Cascades Ecoregion (ECE) in central Oregon. Polygons show jurisdictional boundaries of organizations, with darker shading indicating greater overlapping.

Increasingly aggressive fire suppression and exclusion practices over the past century reduced the frequent fires that once cleared small-diameter trees and understory vegetation, leading to the accumulation of flammable material. In recent decades, these conditions have contributed to fires that overwhelm suppression efforts (Stephens et al., 2014; Williams, 2013). Demographic trends have compounded the challenge of changing wildfire hazard conditions as communities have grown within or adjacent to dense forested lands (Hammer et al., 2007; Olsen et al., 2017).

Growing wildfire risk has spurred efforts to address hazard conditions at larger scales and with new approaches, which commonly requires collaboration among federal, state, and local agencies, fire response organizations, environmental groups, and other stakeholders. These groups may participate in multi-stakeholder risk mitigation decision-making processes, which can lead to long-term collaborative relationships (Cheng and Sturtevant, 2012). Likewise, government programs that incentivize fuels reduction projects at the interface of private and public land can also spur collaborative partnerships among local land managers (Schultz et al., 2018).

4.2. Data collection

Data were collected through semi-structured interviews. Based on their familiarity with key actors in the region, the research team identified a snowball sample seed of 45 organizational representatives concerned with wildfire and fire prone forests in the ECE. These individuals were prompted to describe where their organizations work to address wildfire management issues in the ECE, their organizations' goals with respect to fire and forest management, and their beliefs about how wildfire should be addressed, among other topics. Respondents were also asked to identify individuals from other organizations with whom they had interacted on forest and/or wildfire-related activities, including individuals with whom they planned, funded, or implemented fire-prone forest or wildfire risk management work. Individuals nominated through these network questions were included in successive waves of snowball sampling. No new individuals were identified during the third wave of sampling. Altogether, 154 respondents of 86 organizations were interviewed [Footnote 1].

Although respondents described the region in which their organization worked, we also sought more detailed spatial information about organizations' jurisdictions. Local experts with extensive familiarity with forest and fire management organizations in the ECE identified from the roster of 86 organizations a subset of 36 that either owned or managed land or had formal responsibilities to address wildfire hazard conditions (or respond to wildfires) within specific tracts of land. Using a combination of publicly available data from the Oregon Spatial Data Library (OSDL, 2016) and the Oregon Department of Forestry Maps and Data clearinghouse (ODF, 2016), as well as other data provided by local experts, we delimited the jurisdictional boundaries of these 36 organizations.

4.3. Analytical approach and variables

We created a network based on respondents' nominations of collaborative partners. The network was composed of 697 collaborative relationships among the 86 organizations represented by the interviewees. Importantly, the network was "directed", meaning that a pair of organizations *i* and *j* could be related in one of four ways: *i* nominated *j* as a collaborator, *j* nominated *i* as a collaborator, both *i* and *j* nominated each other, or neither *i* nor *j* nominated the other. While collaboration is sometimes treated as a bilateral (i.e., undirected) relationship, we considered it to be directed because organizations do not necessarily invest equally in a collaborative relationship or may otherwise value a common relationship differently (Henry et al., 2012; Robins et al., 2011). Indeed, of the 697 relationships between organizations, only 161 were reciprocated (i.e., both organizations nominated each other).

We then estimated a series of estimated exponential random graph models (ERGMs) to assess the likelihood of direct (H1) and brokered (H2) interaction among policy actors with overlapping jurisdictions, as well as how the likelihood of brokerage varies according to the

attributes of brokers (H3-5). As an approach for modeling social selection, ERGMs allowed us to evaluate how actor-level strategies constitute the social processes that structured our empirical network. ERGMs use Markov chain Monte Carlo simulation to estimate coefficients for parameters that generate networks with similar patterns as the observed network (Lusher et al., 2012; Robins et al., 2007). In our case, parameters included attributes of organizations (e.g., the region in which they operate), attributes of pairs of organizations (e.g., whether organizations from the same region collaborate), and structural characteristics of the network (e.g., brokerage).

Among the 36 organizations with jurisdictions, there were 420 pairs of organizations (i.e., dyads) with overlapping jurisdictions, presenting the possibility for collaboration gaps (table 1). Of these 420 cases, 111 featured a direct collaborative relationship between organizations. Of the remaining cases, there were 188 dyads brokered by at least one organization. Many collaboration gaps were brokered by multiple organizations. There were 371 instances of an organization brokering a collaboration gap. Finally, 121 collaboration gaps were not brokered by any organization.

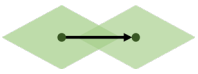
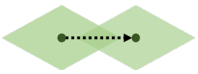
Configuration	Diagram	Count
Overlapping jurisdictions		420
Overlapping jurisdictions with directed collaboration		111
Collaboration gaps		309
Brokered collaboration gaps		188
Collaboration gap brokers		371
Unbrokered collaboration gaps		121

Table 1. Descriptive statistics of network configurations associated with collaboration gaps. Points: actors; green diamonds: actors' jurisdictions; solid arrows: collaborative relationships; dotted arrows: absence of a collaborative relationship; dashed arrows: absence of at least one collaborative relationship.

Our ERGM included five parameters that each served to directly test one of our hypotheses. *Overlapping jurisdictions* (H1) measured the tendency for collaboration between organizations whose jurisdictions overlap, thereby preventing a collaboration gap (CG). *CG Brokerage* (H2) measured the tendency for organizations whose jurisdictions overlap. *CG Brokerage: Has jurisdiction=No* (H3) measured the tendency for organizations without jurisdictions to broker collaboration gaps. *CG Brokerage: Local=No* (H4) measured the tendency for organizations operating at the county level or higher to broker collaboration gaps.

CG Brokerage: Goal=Fire protection (H5) measured the tendency for organizations whose goals primarily related to fire protection rather than forest restoration to broker collaboration gaps [Footnote 2]. We also included a set of parameters to control for organizations' collaborative behavior given their attributes, as well as to control for network structural characteristics typically used in inferential network models to represent common social tendencies (see Supplemental Information for details).

We estimated the all models using the "statnet" suite of packages (Handcock et al., 2008) in R (R Core Team, 2018). Models converged well, and we provide evidence of goodness of fit in figures A1 and A2.

5. Results

ERGM results (table 2) provide support for our expectation that organizations were more likely to seek partners whose jurisdictions overlap their own, providing support for H1. The *CG Brokerage* estimate in Model 2 indicates a tendency for organizations to broker collaboration gaps, as expected (H2). Interestingly, the *CG Brokerage* estimate is negative (but not significant at the 0.05 level) in Model 3, which includes three parameters that specify the attributes of brokers of collaboration gaps. This means that the significant parameters in this model (*CG Brokerage: Has jurisdiction=No* and *CG Brokerage: Goal=Fire protection*) measures the significant tendency for brokerage of collaboration gaps. The remaining tendency for brokerage by the reference categories of these three parameters (e.g., organizations with jurisdictions, local organizations, and organizations that emphasize forest management) cannot be distinguished from chance.

		(1) Direct ties	(2) Brokered ties	(3) Full model
Collaboration gap parameters	Overlapping jurisdictions (H1)	1.16 (.12)*	1.17 (.11)*	1.45 (.19)*
	CG Brokerage (H2)		.07 (.03)*	-.08 (.08)
	CG Brokerage: Has jurisdiction=No (H3)			.20 (.06)*
	CG Brokerage: Local actor=No (H4)			-.07 (.06)
	CG Brokerage: Goal=Fire protection[a] (H5)			.21 (.05)*
Attribute parameters	Popularity: Has jurisdiction=No	.21 (.07)*	.27 (.08)*	.27 (.08)*
	Activity: Has jurisdiction=No	.48 (.08)*	.55 (.09)*	.56 (.10)*
	Popularity: Local actor=No	.17 (.08)*	.17 (.08)*	.19 (.09)*
	Activity: Local actor=No	-.06 (.08)	-.08 (.08)	-.06 (.09)
	Popularity: Goal=Fire protection[a]	-.17 (.06)*	-.18 (.06)*	-.28 (.07)*
	Activity: Goal=Fire protection[a]	-.16 (.06)*	-.17 (.06)*	-.27 (.07)*
	Homophily: Region	.48 (.06)*	.49 (.06)*	.50 (.07)*
Structural parameters	Edges	-4.76 (.22)*	-4.80 (.22)*	-4.72 (.24)*
	Anti-centralization (GW in-degree θ=0.7)	.81 (.37)*	.79 (.37)*	.80 (.38)*
	Anti-centralization (GW out-degree θ=0.7)	.48 (.34)	.45 (.33)	.45 (.34)
	Transitivity (GW edgewise shared partners θ=0.7)	1.36 (.07)*	1.34 (.07)*	1.32 (.08)*

Brokerage (non-edgewise shared partners)	-.07 (.01)*	-.07 (.01)*	-.07 (.01)*
AIC	3281.86	3279.82	3264.89
BIC	3371.52	3376.38	3382.13
Log Likelihood	-1627.93	-1625.91	-1615.44

Notes: Standard errors in parentheses. *p < .05; [a] Reference category: Goal=Forest management; CG: collaboration gap; GW: geometrically weighted.

Table 2. ERGM parameter estimates.

Organizations without jurisdictions were more likely to broker collaboration gaps, relative to organizations with jurisdictions, providing support for H3. We did not find support for our expectation (H4) that non-local organizations would be more likely to be brokers. The *CG Brokerage: Local actor=No* parameter was negative and not significant at the 0.05 level. The estimate for *CG Brokerage: Goal=Fire protection* indicates that organizations working to improve fire protection are more likely to be brokers compared with organizations whose primarily goal is forest restoration, providing support for H5.

To help contextualize model results, we compare collaboration gap brokerage with generic brokerage, normalizing both measures to account for the number of opportunities each organization can broker ties (figure 2). These results provide additional insight into which organizations could be prioritizing collaboration gap brokerage as a strategy for collaborative wildfire risk mitigation. For example, the organization labeled “A” in figure 2 brokers only four collaboration gaps, but the collaborative relationships that bridge these gaps comprise all of the brokerage activities undertaken by that organization.

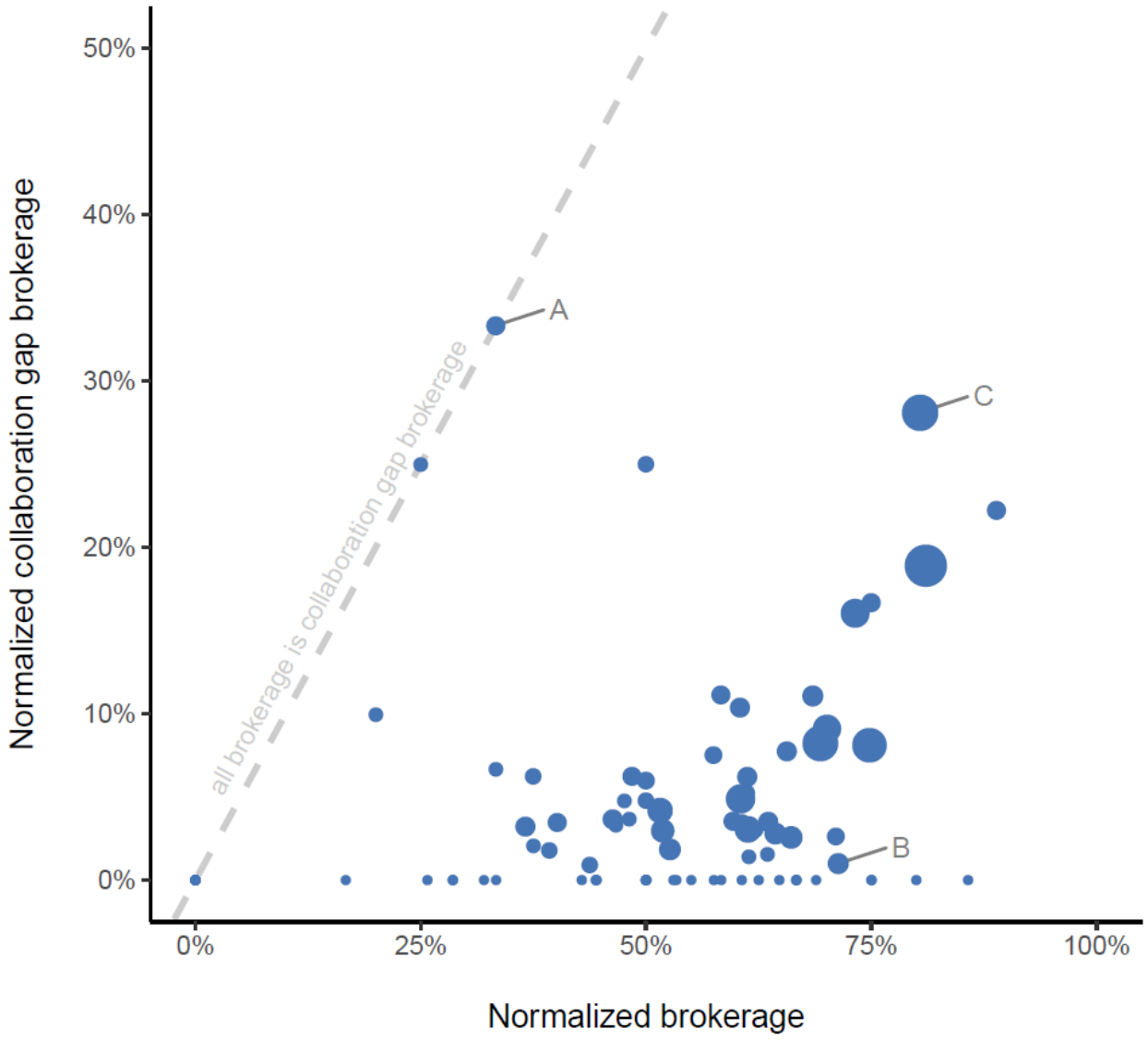


Figure 2. Comparison of collaboration gap brokerage to generic brokerage. Each measure of brokerage is normalized by the number of possible opportunities to broker (incoming ties * outgoing ties). Points represent organizations in the network. Point size corresponds to the number of collaboration gaps brokered, ranging from 0 to 54.

By contrast, organizations in the lower right corner of figure 2 seem to prioritize forms of brokerage that do not bridge collaboration gaps. For example, in figure 2, the organization labeled "B" links 428 dyads of organizations that do not interact, making it the most active broker in the network. However, only six of these instances of brokerage span organizations whose jurisdictions overlap. These six instances of collaboration gap brokerage constitute just 1% of the organization's 600 opportunities for brokerage, given its 25 incoming ties and 24 outgoing ties.

Finally, we observe organizations that seem to emphasize generic as well as collaboration gap brokerage, several of which also broker a large number of collaboration gaps. For example, the organization labeled "C" in figure 2 brokers 103 dyads of organizations, including 54 whose

jurisdictions overlap. These linkages comprise 80% and 28% of all opportunities for generic and collaboration gap brokerage, respectively, given the organization's number of incoming and outgoing ties.

Although actors vary in their capacity for investing in partnerships (e.g., due to differences in resources), figure 2 demonstrates significant variation in the degree to which actors emphasize collaboration gap brokerage, even after accounting for differences in actors' capacities for generic brokerage. Additionally, among actors that emphasize brokerage of collaboration gaps over generic brokerage, some bridge numerous gaps and may play crucial coordination roles within the governance system as a whole, while others' contributions are relatively modest.

6. Discussion

This paper highlights how self-organizing networks can inhibit or mitigate collaboration gaps via actors' strategies for partner selection, which vary depending on actor-level attributes. In particular, while actors may not form partnerships for the express purpose of reducing collaboration gaps (thereby contributing to desirable outcomes at the level of the overall governance system), our results suggest that such partnerships are more likely when they allow actors to capture greater payoffs from solving collective action problems and/or when associated transaction costs are lower (i.e., actor-level net benefits are greater). One of this article's core contributions is our extension of this theoretical perspective to account for the interplay between partner selection and the interdependence that results when actors' jurisdictions overlap geographically.

Our finding that actors preferentially select partners whose jurisdictions overlap their own provides support for a more general proposition that interdependence increases the value of collaboration. For example, Weible and Sabatier (2005) suggest that interaction among marine resource governance actors with divergent policy core beliefs can be explained in part by their reliance on one another to achieve common goals, while Bodin and Nohrstedt (2016) find that collaboration is more likely among wildfire responders who are interdependent based on their responsibilities to carry out the same task. Our study extends this vein of scholarship by showing that collaboration is also more likely among actors who are interdependent because they jointly manage the same lands and are mutually affected by each other's actions.

However, despite this tendency, not all interdependent actors collaborate, and we further hypothesized that such collaboration gaps presented opportunities for brokerage by third-party actors. Results revealed a tendency for actors to broker collaboration gaps, which provided support for our expectation that brokerage provides a mechanism for actors to address collective action problems—arising from the lack of coordination between interdependent actors—in ways that advance their policy goals. A crucial future test for this hypothesis will be whether brokerage of collaboration gaps enables actors to encourage the implementation of preferred policies.

A hallmark of environmental governance is the involvement of diverse policy actors, and we expected that certain types of actors would benefit more from brokering collaboration gaps. In particular, our finding that actors without jurisdictions were more likely to mediate between actors whose jurisdictions overlap is consistent with expectations that such a strategy provides opportunities to indirectly influence management decisions for actors that lack the capacity to do so directly.

We also expected collaboration gap brokerage to be more appealing to non-local actors, as it would offer them the opportunity to bolster their legitimacy as "matchmakers" for interdependent local actors. This hypothesis was not supported, and our model actually indicated that non-local actors were less likely to broker collaboration gaps, though not significantly so. It is possible that because fire risk mitigation requires extensive knowledge of local social and ecological factors, local actors are better positioned to acts as brokers. However, more research will be needed to evaluate this proposition.

Additionally, our finding that actors concerned with fire management, rather than forest management, were more likely to broker collaboration gaps supported our expectation that the value of brokerage depends on whether its benefits are more immediately apparent. When coordinated wildfire responses are successful, benefits are realized during discrete fire events (Nowell and Steelman, 2015). By contrast, the outcomes of forest management may not be discernable for years, during which time they may be contested by stakeholders with diverse management preferences (Abrams et al., 2017; Cheng and Sturtevant, 2012).

From a management perspective, our results should be encouraging to practitioners who believe that addressing wildfire risk requires greater coordination among actors who share responsibilities and authorities for the management of fire-prone forests. In particular, interventions that facilitate direct interaction among interdependent land managers may be welcomed if such actors are inclined to collaborate. The same can be said of efforts to encourage third-party actors to bridge collaboration gaps, given the tendency for actors to preferentially intermediate between land managers who do not collaborate.

However, despite the tendency for joint managers to collaborate, we still observe that nearly 75% of possible collaborations between interdependent actors were absent, and that nearly 40% of these collaboration gaps were not brokered. Consequently, there are significant opportunities to improve wildfire risk outcomes through greater coordination of jointly managed fire-prone forests. Of particular relevance to practitioners is our finding collaboration gaps are more likely to be brokered by actors concerned with fire management rather than forest management. This result highlights the need to more strongly integrate forest management organizations in the governance network, and in particular, to increase their capacity to bridge collaboration gaps. For example, initiatives such as stewardship contracting, the Good Neighbor Authority program, and the Collaborative Forest Landscape Restoration Program, which each incentivize partnerships to address forest management issues through coordination by multiple managers (Abrams et al., 2017; Charnley et al., 2020; Mattor and Cheng, 2015; USDA Forest Service, 2018), could enable forest managers to bridge collaboration gaps.

7. Conclusions

This study advances a view of environmental governance systems that embraces the reality that such systems are complex not only because of the participation of numerous policy actors, but also because these actors commonly have responsibilities and authorities that overlap geographically. A growing body of research indicates that desirable governance outcomes depend upon collaboration among organizations that are interdependent because of their relationships to the biophysical landscape (Bodin et al., 2014; Kininmonth et al., 2015; Sayles and Baggio, 2017). However, the question of why actors collaborate in ways that may improve governance outcomes has received limited attention (Hamilton et al., 2019).

To address this gap, we developed a series of hypotheses about the incentives that may prompt actors to seek partnerships that prevent or mitigate collaboration gaps. Results supported

our expectations that collaboration is more likely among actors that are interdependent because their jurisdictions overlap. We also found that third-party actors were more likely to broker interactions between interdependent actors that did not directly collaborate. We further found that certain types of actors were more likely to broker collaboration gaps, including those who lacked the authority to manage land themselves and those for whom the benefits of brokerage may be more immediately apparent (based on their interest in fire protection versus forest management).

We encourage future research on how actors navigate environmental governance networks to build upon our work by explicitly measuring the outcomes of collaboration at the actor- and governance system-level. Specifically, data on actors' perceptions of the relative benefits of individual partnerships, or approaches for engaging in collaborative networks (e.g., brokerage) will be crucial for clarifying why actors pursue different collaborative strategies. Such research will not only advance theoretical understanding of the processes that shape collaborative governance but may also enable interventions that achieve elusive policy goals because they better account for the behavior of diverse policy actors.

Footnotes

1. Prior publications based on these data have analyzed a network of 87 organizations. Here we regard the Bureau of Land Management Central Oregon Fire Management Service (COFMS) and the Forest Service COFMS as a single organization, because staff from both federal agencies work together in the same offices and only differ based on their affiliation.
2. To test Hypothesis 2-5, we used the "ergm.userterms" R package (Hunter et al., 2013) to develop two custom ERGM parameters. The parameter used to test Hypothesis 2 counts the number of non-edgewise shared partners for dyads that have a non-zero value of an edge covariate (e.g., 1 for overlapping jurisdictions, and 0 otherwise). The parameter used to test Hypotheses 3-5 was identical except it allowed specification of an attribute (e.g., "Manage Land") and value (e.g., "No") of non-edgewise shared partners. Both new parameters are geometrically weighted, like the non-edgewise shared partner parameter, and accept a decay parameter. In our models, all we set this decay to 100 to count every non-edgewise shared partner (i.e., every broker).

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