Fragmentation and integration in Swiss water governance

Understanding a complex system through the study of organizational networks

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Introduction

Throughout history, successful natural resource management has always required collaboration and collective action. In many cases, from collective water management in ancient Egypt to grazing cattle in alpine regions, formal or informal institutions and organizations regulating the use of natural resources have emerged as a result. Mostly, these emerged to address typical problems of collective action that can arise in the joint use of resources, such as overharvesting (Pretty and Ward 2001; Ostrom 2000). This need to effectively structure human interaction with natural resources and environmental life-support systems is no less urgent today than it was in the past (Folke et al. 2005). In many ways, it is even more pronounced in the 21st century due to the ongoing degradation of ecosystems and recognition that economic and social development depends on a stable and resilient biosphere (Guerry et al. 2015).

The interactions between humans and a given single or set of natural resources constitute a social-ecological system (Ostrom 2009; McGinnis and Ostrom 2014). In the social part of a social-ecological system, social actors interact with a resource mainly in two general ways. These include the use (consumptive or non-consumptive) and governance of the resource. This thesis deals with the latter, governance, which is a complex activity for all involved. Besides being a complex activity in the sense of the myriad of complicated considerations required, the governance of natural resources also takes place in a complex system structure. These two things, a complex activity and a complex system, are not the same. In effect, governance is made complex because it takes place in a complex system. This thesis introduces different ways of understanding the complex system of natural resource governance from a background of complex system thinking.

Complex system thinking represents a distinct, multidisciplinary way of approaching science in general and the study of social phenomena in particular. A common denominator among theories influenced by complexity thinking is the recognition of emergent properties within systems, produced by non-linear interactions between the parts of a system; and between the system and its parts. The semi-colon in the preceding sentence is maybe the most simple way to differentiate two main types (Byrne and Callaghan 2014) of complexity theory. The first, restricted complexity, approaches emergence as the sole product of the interaction of parts, of micro-level interactions. The second, general complexity, goes beyond this and looks in detail at the possible ontological repercussions of studying the interaction between parts and system. In marked contrast to restricted complexity, social actors are recognized not as the rule-following caricatures of agent-based modelling, acting within constraints and rules placed on them by the system, but as having agency and being capable of transcending these rules. The emergent system itself is recognized as being socially real, endowed with causal power (Byrne and Callaghan 2014, p. 56), and more than the sum of the interaction of its parts.

Natural resource governance as a complex social system

The theoretical underpinnings provided by generalized complexity theory provide a well suited angle from which to approach questions of natural resource governance. Natural resource governance as a social system, closely intertwined with the biophysical systems it refers to, fulfills the key requirements of a complex system. It comprises social actors with agency, adhering (or not) to a set of institutional rules, and interacting with a natural system often governed by further emergent, non-linear dynamics.

Governance as a practice in such a system is understood in the following to comprise of networks of governmental and non-governmental organizations (Rhodes 1996), who form, apply, interpret and reform rules (McGinnis 2011, p. 171) in interaction and referral to each other. These rules regard a set of substantive collective action problems, called issues. The combined set of organizations and issues active within a geographical boundary (Lubell 2013a) is a governance system.

The quintessential definition of the phenomenon of governance itself used in this thesis borrows from Rhodes (1996, p. 660), who defines it as self-organizing, interorganizational networks. More concretely, Rhodes (1996) lists the presence of both governmental and non-governmental organizations, game-like interactions among them and a degree of autonomy from the state (that can, however, still attempt to steer networks) as defining characteristics of governance. Rhode's descriptive empirical claim of an increased presence of networks or a shift "from government to governance" has been disputed (Börzel 2011). However, his conceptual definition of governance is still a valuable vantage point from which to grasp the complexity of modern societal steering and self-steering.

Many of Rhode's points on the nature of governance, especially the emphasis on interorganizational interactions (which in turn create interorganizational networks) and the analogy of repeated games between organizations, are reflected in the ecology and games (EG) framework (Lubell 2013a). The EG framework is a theoretical development within the policy sciences, which underpins the previously introduced definition of a governance system developed in this thesis. This definition of a governance system is an extension of the EG framework's definition of a policy system.

The extension, defining the scope of governance systems compared to policy systems, is based on concepts developed within the Institutional Analysis and Development (IAD) framework (Ostrom 2011), another school of thought within the policy science literature. This is no far-fetched combination of theoretical developments, as the IAD and EG are already closely related. The younger EG framework borrows the emphasis given to different types, rules and rule-making from the IAD. Given this, the IAD proves helpful in precisely defining the scope of activity considered relevant within a governance system. Governance in the IAD is defined as encompassing the formation, application, interpretation and reformation of rules (McGinnis 2011, p. 171). Governance activity does therefore encompass a larger set of activities than often considered within policy studies, which often focus more narrowly on rule-making. This larger set of activities might for example extend to the implementation or evaluation of policy issues. A governance system must in conjunction also encompass these activities.

A key step in understanding a complex system is the careful analysis of the relationships between its components. This necessarily entails boundary setting, the identification of such components, which is in itself crucial. We "(...) know systems by defining them in terms of boundaries (...)" (Byrne and Callaghan 2014, p. 33). Together these steps are not only essential for the scientific study of complex systems, but also necessary to inform practitioners working in complex system settings (Haynes 2015). Structural features of complex systems do not only act as constraints upon the activity of organizations, but also interact among themselves. For example, if the exchange of information within a governance system happens within fragmented subsystems with little cross-subsystem exchange, this very feature of the system might lead to a self-reinforcing dynamic of increased conflict between subsystems. Understanding such interactions can help organizations who are active in complex systems to navigate their surroundings and understand possible repercussions of their actions, which are often hard to predict.

Water governance is an especially poignant example of the limited capacity to predict outcomes of governance actions in a straightforward manner. Water is something to be used; to be protected; and to be protected from. These simultaneous properties of the resource are at the heart of the complexity inherent to the governance system that revolves around it. The use of water raises, for example, a set of issues related to water supply and wastewater treatment, but also another set of issues concerning hydroelectric energy. Both sets of issues are also intertwined with issues regarding the protection of water and watercourses. On the one hand this relates to pollution control. On the other hand, the ecological quality of water bodies and watercourses is key in maintaining biodiversity. Lastly, humans and human infrastructure need to be protected from the destructive capabilities of water in the form of flooding and erosion, which raises a new set of issues ranging from the upkeep of warning systems to the building and maintenance of protective infrastructure. And again, all of these issues related to protection from water can have profound effects on biodiversity and water use. The result is a system where changes in one issue can reverberate through the whole system, as a large number of water governance issues are tightly interlinked. Action in one area can thus have unforeseen consequences, a classic complex system property. It is not surprising that the need for coordination and integration with regard to water governance has therefore been stressed in the past (Hering and Ingold 2012).

Understanding a complex system through the study of the organizations that perpetuate it

Having established some key properties of a complex social system; that natural resource, and specifically water governance fit this description; and the importance of understanding the interdependencies between components of complex governance systems for both research and practice, the next question is epistemological: How can we get a grasp of a complex water governance system? The approach taken to do so in this thesis is based on the study of organizational networks. In essence, this means the study of organizational activity with a clear recognition of the relational character of such activity.

Complexity theory based on a critical realist approach (Byrne and Callaghan 2014) emphasizes the agency of social actors that make up complex social systems such as water governance. This is crucial. A complex systems approach for the social sciences cannot disregard a key element of the social - the agency of actors, which needs to be clearly acknowledged in its ontological foundations. If not, the approach risks becoming overly structuralist at best, teleological at worst, but definitely invalid regarding the lived experience of the actors active in governance. Streeck (2018) puts is most eloquently in its exploration of the ways in which social theory can learn from evolutionary biology, which is remarkably similar to the ontological position taken in the critical realist approach to complex social systems:

> ”Social theory, this suggests, can (...) reassure itself that it is not its fault if its objects as it represents them appear noisy, fuzzy, restive, eventful, transitory, temporary, surprising, and always more or less out of balance and that there is no need for a theory of society to take their life out of them for social science to become possible.“ (Streeck 2018, p. 663)

A key differentiation in this regard lies in the difference between activity and agency, regarding the relationship of both to the overarching structure. Activity can be shaped to a large extent by underlying constraints. Agency is what remains after all that is largely determined is accounted for. Activity thus contains both agency and structure in complex systems.

It is therefore fitting to turn to the activity of social actors in order to understand the structure of a complex governance system, given the ontological necessity of acknowledging the agency of social actors. Governance is reified in the activity of organizations that are active in the various substantive issues it entails. Analyzing the resulting structure of organizational relations and activity patterns makes it possible to understand key properties of complex natural resource governance systems.

Organizations are not the only category of actors relevant to governance. Indeed, the most common association with the term actor most likely relates to individual human beings.[1] Whether organizations, if narrowly understood as hierarchical agglomerations of individuals should be considered actors has been debated. In essence, this rests on the contention that only individuals can be real social entities. However, the existence of social collectives is undisputed in many areas of sociology (Byrne and Callaghan 2014, p. 46). Further, the narrow understanding of organizations as mere products of individual-level interactions is not shared in this thesis, as such interactions can themselves lead to emergent properties of organizations. This requires considering them as a special kind of real social entity. The study of organizations as actors with agency forming an "organizational state" (sic) also has a long tradition in political science literature (Laumann and Knoke 1987), not least in the understanding, fundamental to this thesis, of governance within the tradition established by Rhodes (1996) as organizational networks. Thus, while it cannot be denied that the activity of individuals plays a role in governance systems and within organizations, it is still likely that an approach centred on organizations alone will suffice to highlight a wide set of crucial governance system characteristics.

Network concepts in the study of organizational relations

A common theme throughout this thesis is the use of network concepts to study organizational activity and relations. The use of network concepts in general political science dates back to more allegorical uses of displaying hierarchical power structures in the 1970s. This was very removed from the elaborate descriptions of social networks mathematically grounded in graph theory

[1] Some ontologies also explicitly extend the term to non-human actors (Latour 2017). This touches upon a relevant point with regard to general thinking about complex systems composed of both social and biophysical parts. However, the practical implications (both for informing policy-makers and carrying out empirical research) of this line of thought for governance systems as understood here are not readily apparent. It is thus not pursued further.

used by sociologists such as Harrison White in Chicago around the same time (Ward, Stovel, and Sacks 2011). However, network concepts have come a long way since then in political science and are now a blooming topic (and method) in the discipline (McClurg et al. 2011). The same holds for the specific subfield of policy analysis. Policy analysis has sometimes focused more on the content of policy problems and solutions than the actors that are involved in their production and has been criticized in the past for this. Policy network analysis can be seen as a partial answer to this criticism, because it has the study of policy actors and their interactions in policy networks at its core (Hermans and Thissen 2009).

Network concepts also fit the complex systems perspective taken as the ontological foundation for this thesis. Relational sociology has highlighted time and time again that social actors are embedded in a web of social relations (Granovetter 1985). This recognition even pervades social phenomena such as markets, which are often and short-sightedly studied based on assumptions of methodological individualism (Granovetter 2005). What constitutes a social phenomenon can only be understood from a relational standpoint and governance is a case in point. The social real is relational and complexity theory concepts such as emergence are well served in relational concepts and accompanying empirical methods emphasizing networks (Byrne and Callaghan 2014, pp. 76, 85).

Fragmentation and integration: Two key system properties

This thesis leverages the study of organizational activity to mainly explore two properties of natural resource governance, which can be subsumed under the twin properties of fragmentation and integration. These two concepts offer a compelling way of exploring complex governance systems.

In the following, fragmentation is defined as a separation between different components of a governance system, which is judged undesirable from a given normative point of view. Gathering information about separation is thus a prerequisite to understanding fragmentation and amounts to gathering information about the different components that exist within a complex governance system.

As with all things normative, the point at which separation is judged detrimental to the functioning of a governance system will be subject to debate. Arguments in such a debate can differ on two levels, which are not unlike the separation between deep core beliefs and policy beliefs in Sabatier's (2007) Advocacy Coalition Framework. At the most profound level, akin to deep core beliefs, differences can occur related to what a functioning governance system should strive to achieve. This refers to the relative preferences assigned to a set of outcomes such as effectiveness, efficiency, legitimacy, adaptability or sustainability, which may or may not be in conflict with each other (Hogl et al. 2012; Schulz, Lieberherr, and Zabel 2016).

A second level, which is akin to policy core beliefs, refers to the ways in which separation enhances or impedes this set of desired outputs. This relates for example to debates about governance network characteristics attuned to overcoming specific collaborative challenges such as solving contested problems (Bodin, Sandström, and Crona 2017) or the network characteristics that foster resilience (Moore, Grewar, and Cumming 2015; Newman and Dale 2005). In these debates, the desired output is given (solving contested problems, resilience) and the point of contention is the way in which to achieve it.

To illustrate the importance of the inherent normativity within any definition of fragmentation further, one should consider that most of the separation within a governance system is likely to reflect a division of labor between different organizations around different sets of issues. Some issues may require the activity of specialized organizations and institutions. If these issues are not intrinsically linked to other issues, separation around these issues is desirable from a point of view emphasizing efficiency. Aspiring for a governance system to be completely devoid of separation would engender enormous transactions cost. Simply put, not everyone should be doing everything. However, for example, from a point of view stressing adaptability, a certain amount of efficiency might have to be sacrificed to ensure involvement of a more diverse set of actors in issues, which can improve learning capabilities (Walker et al. 2004). A careful analysis of a governance system as it is should therefore point out first separation and then, while being explicit about normative assumptions and goals, fragmentation in a second step.

When informing practice, highlighting fragmentation is thus a key contribution that a complex system perspective can make when dealing with a governance system. Most likely, practical suggestions to policy makers will involve suggestions for integration. Integration is defined in the following as the outcome of efforts to reduce fragmentation. Approaches to achieve integration differ in the literature, not only in the way solutions to fragmentation are presented but also on a more fundamental level in the amount of normative assumptions that go into the conceptualization of integration.

A compelling way to conceive integration concepts can be found in the umbrella term of fit. It is compelling because normativity can be initially kept at a minimum level if fit is rephrased as a system state where governance structure reflects underlying interdependencies in the problem structures of issues. Such a definition is a generalization of the concept of functional fit (Folke et al. 2007), which was originally introduced to describe a state where governance matches the properties of an underlying ecological system. Further developments in this area are explicit in this regard in their reference to the exact fit concept in question. These include social-ecological fit (Bodin and Tengö 2012), spatial fit (Bergsten, Galafassi, and Bodin 2014) or overcoming scale mismatches (Sayles and Baggio 2017a).

Engaging the complex system of Swiss water governance empirically

All three articles featured in this thesis explore both fragmentation and integration, and center on organizational activity and relations for the case of Swiss water governance. They all do so empirically, as the understanding of science reflected in this thesis puts a firm emphasis on empirical research. This follows the Gulbenkian Commission in understanding science as "systematic secular knowledge about reality that is somehow validated empirically' (Wallerstein et al. 1996, p. 2). This is not to argue that purely theoretical work should be branded non-scientific. However, it cannot be detached from empirical engagement with the social world following its formulation. As such, all articles contained in this thesis aim to make theoretical concepts apparent in the complex system of Swiss water governance more tractable through empirical research and owe a debt of gratitude to those.

All three articles explicitly and implicitly explore the concepts of fragmentation and integration in natural resource governance from different angles. They also differ in placing more or less emphasis on identifying fragmentation and separation versus studying ways of integration. This becomes apparent by studying the articles as a combined set.

The first article, *Bottom-up identification of subsystems in complex governance systems*, accepted for publication in the Policy Studies Journal (Angst 2019a, forthcoming), focuses on identifying fragmentation by providing the conceptual and methodological foundation needed to identify separation within the Swiss water governance system in the form of subsystems. It does so through the development of a methodology to identify subsystems in the complex system of Swiss water governance based on patterns of organizational activity.

The second article, *Networks of Swiss water governance issues. Studying fit between media attention and organizational activity*, accepted for publication in Society & Natural Resources (Angst 2019b, forthcoming), studies a particular kind of fragmentation within Swiss water governance. In a slight shift of perspective, it conceptualizes Swiss water governance as a network of governance issues. This enables it to study a novel concept of fragmentation by comparing two different ways in which relations between issues can be conceptualized in a governance system. These two relations are media attention, as the way in which the media pays attention to issue interdependencies, and, befitting the overall context of this thesis, organizational activity, measuring the way in which actors reflect issue interdependencies in practice. Analyzing the fit between the two, the article shows that mismatch between them highlights particular kinds of fragmentation. Mainly, fragmentation between media attention and governance activity is related to issue relations that are either newly appearing on the agenda or conflict-laden.

The third article, *Connectors and coordinators in natural resource governance: insights from Swiss water supply*, published in Ecology & Society (Angst et al. 2018), places the most emphasis on mechanisms of integration. In line with the focus of the thesis on organizations and their practice as the epistemological foundation for understanding governance, the study explores the way in which single organizations contribute to overcoming fragmentation based on their network positions. Connectors and coordinators are highlighted as two important network positions in this regard through a case study of regional water supply governance in a setting of institutional fragmentation. A key finding in this regard is that even in a situation where the formalized institutional landscape is not favorable to integration, actors can achieve integration through their agency.

Methodological considerations

The methodological choices made in all three articles reflect the focus on organizations and their relations, but also a background of critical realism. The former is reflected in the use of survey methods among organizational representatives for data gathering, the use of graph theory, and the tools of inferential network analysis. The latter might be less apparent, but lies in the rejection, in the first two papers of this thesis, of the narrative structure and ontological background usually provided by the hypothetico-deductive framework. Instead, these papers focus on the thorough exploration of a social phenomenon, recognizing its situation in place and time. Quantitative analyses of governance subsystems and issue networks are thus followed up by qualitative discussions of findings related to the specific setting of Swiss water governance. Obviously, this leads to a proportion of insights that are idiosyncratic (without totally rejecting a claim for inter-subjectivity, the realist part of critical realism).

Like politics, governance is more clouds than clocks (Almond and Genco 1977). Social phenomena such as governance are profoundly shaped by the agency of actors and emergent properties of complex systems. The result is the indeterminism taken seriously in complexity theory. A clock-like understanding of governance as a set of fundamental, rigid laws waiting to be discovered by the social scientist is a useless ontological foundation from this perspective. The scientific study of governance should reflect this in its methods. In the context of this thesis, the key consequence lies in a focus on valueing medium-range and place-/ time-specific statements, based on thorough empirical methods, but foregoing unnecessary attempts of formulating unboundedly generalizable laws.

However, it is important to stress that this does not preclude a set of more generalizable findings generated in this thesis, which remain in conjunction with insights specific to Swiss water governance. Thus,taking a core tenet of complexity theory to the heart, an important question that remains is one of emergence. What is there to be learned from the combined study of all articles presented in this thesis that is more than the sum of its parts?

In terms of methodology, this thesis generally shows how a combination of rigorous graph theoretic, clustering and inferential network analysis methods together with qualitative case knowledge can be leveraged to gain an understanding of complex governance systems. Taking a birds-eye view of all three articles also shows that such systems can only be understood based on different perspectives. All three articles share an emphasis on organizational activity and relations, but situate their analyses both on different levels (local as well as large-scale, national) and approach the system from different angles (via issues, subsystems or local collaboration). This shows not only the nested, interdependent nature of governance structures, but also that their mechanics can and need to be untangled by studies at different levels.

Some of the analytical approaches taken in this thesis are clear children of the time this thesis is written, making use of the possibilities made available by the advances in collaborative, open source programming languages and cheap computing power. For example, the analysis of a large dataset containing more than 20'000 newspaper articles in the second paper of this thesis uses machine learning techniques to filter out relevant articles. Still, these were later manually coded, making use of case knowledge and cultural sensitivity a computer can (probably) never attain. A second example is the use of clustering algorithms to identify patterns of organizational activity to identify subsystems. The resources available to the inclined researcher in the form of online tutorials, open access journals and active open source software development in languages such as R (R Core Team 2017) or Python can be both mindblowing and overwhelming at times. Thus, this thesis is an encouragement for social scientists dealing with complex systems to make use of new technical developments in the form of machine learning or clustering algorithms putting such systems in reach of systematic analysis (often for the first time), while not forgetting their unique capabilities as human beings.

The methodological contributions of this thesis are disciplinary in various aspects, but mostly, as befitting an ontology of complexity, interdisciplinary. A key disciplinary contribution to the policy sciences lies in the establishment of a methodology for subsystem identification developed in the first article of this thesis. The methodology is widely applicable as a basis for policy science theories using subsystem concepts and puts ubiquitous subsystem concepts on a firm empirical footing. The methodology used to identify fit and misfit between media attention and organizational activity developed in the second paper is an interdisciplinary contribution, which could be used in a variety of purposes, as many governance and management situations can be understood as issue networks. The methodological contribution of the third article lies in linking concepts of actor roles to possible network operationalizations, which is again useful both disciplinary for the specific study of governance networks, but also for the per se interdisciplinary situation where a social network is engaged in natural resource management.

Fragmentation and integration in Swiss water governance

Besides methodological contributions, what can be said about fragmentation and integration in Swiss water governance, after the tour d'horizon undertaken in this thesis? In sum, three key insights stand out. These are the high potential for fragmentation among high-visibility, high-conflict issues surrounding agriculture, biodiversity and hydropower, the key integrative role of administrative agencies, especially on the cantonal level, and the essential role of local level implementation.

All three articles in this thesis provide evidence that Swiss water governance has two distinct modes of operation in terms of visibility and conflict. On the one hand, a lot of water governance is "quiet politics" related to the implementation and upkeep of water supply, waste water management and flood prevention measures and infrastructure. These areas are highly technical and relatively uncontroversial among the self-selecting set of actors involved. On the other hand, there is a second mode of more controversial issues, which are also more strongly reflected in media attention. At the heart of the matter lies the unwelcome fact that there are zero-sum games surrounding some water issues. Protecting aquatic biodiversity cannot avoid clashing with a reliance on agricultural methods based on pesticide use. Freeing up riverbeds and streams at some point comes at the cost of agricultural land. Large-scale hydropower concepts cannot be built outside of the landscape they are situated in and completely without impacting the dynamics of aquatic ecosystems.

To overcome conflicts in these areas, administrative agencies have emphasized synergies to resolve the perception of zero-sum games. Revitalization projects are the prime example of this strategy. Arguments in favor of such projects sometimes go to great lengths in emphasizing how they do not only serve nature protection purposes, but can also improve flood prevention and increase the quality of life for residents by creating an inspiring landscape for recreational purposes (Göggel 2012). However, strategies of highlighting synergies can only go so far. Tellingly, many revitalization projects in Switzerland have tackled not necessarily areas where ecological improvements would have been maximized (Holinger AG and stadtlandfluss GmbH 2015), but areas of least resistance, which in the Swiss context often means areas of a minimum amount of confrontation with agricultural interests. In the future, such areas will become more scarce. A key challenge for integration will thus relate to integrating agricultural organizations into the water governance system. In order to further improve the situation of aquatic habitats in Switzerland, any other way seems unrealistic. As agricultural interests are deeply entrenched within the political system, a more confrontational approach is only likely to lead to a stalemate and a patchwork of ecological improvement measures.

Interestingly, also the first mode of operation in Swiss water governance, the more technocratic area of water supply and waste water management has been in more flux recently. It will need to find answers to the two key challenges of drought and micropollution in the future. Both require integration, sometimes involving an engagement with more controversial issues. How the challenges posed by increasing drought risks and micropollution are addressed in the future will thus be informative in order to judge the adaptive capacity of the Swiss water governance system, and the area of "quiet politics" identified in this thesis will be crucial in this regard. There is good reason to be optimistic about this capacity for adaptation, not least due to the entrenched role of reputed cantonal level administrators and the presence of low-conflict local level networks within the areas of water supply and wastewater management.

In overcoming fragmentation, cantonal level administrators emerge time and time again as a key player in Swiss water governance. They stand out as a hub connecting lower-level actors such as municipalities and regional service providers either to other lower-level actors or higher-level ones such as federal administrators. However, this thesis also shows that the networks of local level actors consisting of municipalities, service providers, and engineering and consulting firms are key in getting things done in the end (Fischer et al. 2017). The studies assembled within this thesis indicate that they are part of distinct governance subsystems, integrate issues through their often generalist approaches to water governance within their territory, and show remarkable capacity for self-organization.

The preceding three key points about Swiss water governance harbour theoretical insights for natural resource governance systems elsewhere. Much of natural resource governance is implementation and "quiet politics", such as the water supply and flood control subsystems in Swiss water governance. In these non-adversarial areas, phenomena such as actor coalitions based on belief differences or "devil shifts" (Fischer 2016) are not likely to occur. Instead, as the regional water supply management network studied in the third article of this thesis shows, actors have a high capacity to organize and overcome fragmentation in such areas. In dealing with such subsystems, it thus seems advisable to establish conditions that retain a maximum amount of agency for organizations to self-organize. The most compelling argument for anarchy as a model for network governance (Wachhaus 2011) thus somewhat ironically applies to cases where a degree of order in terms of a non-conflictive subsystem exists.

Another general insight of this thesis is that integration comes in different forms. On the actor level, it can range from explicit coordination to providing bridges between different communities and access to outside knowledge. On an institutional level it can range from legislative, administrative or executive action, such as policy integration, to organizing venues for exchange, such as forums (Fischer, Angst, and Maag 2017).

If integration comes in different forms, the same can be said about fragmentation. Some of it is caused by the slow speed of adaption of a governance system to new challenges or lack of knowledge about relations between issues. Such fragmentation is easier to address. The more problematic kind of fragmentation has a root in more fundamental conflicts of values and interests. Setting up more institutional venues and disseminating knowledge can only go so far in overcoming it. In the end, there is no other legitimate and long-term effective way of resolving such fragmentation than the appropriate level of democratically legitimate debate and decision-making procedure. Social science based on complexity thinking can play an important role in this by informing debates and empowering actors based on an understanding of social systems appropriate to their nature.

Bottom-up identification of subsystems in complex governance systems

Theories of policymaking often focus on subsystems within a larger, overarching governance system. However, subsystem identification is complicated by the complexity of governance systems, characterized by multiple, interrelated issues, multi-level interactions, and a diverse set of organizations. This study suggests an empirical, bottom-up methodology to identify subsystems. Subsystems are identified based on bundles of similar observed organizational activity. The study further suggests a set of three elementary criteria to classify individual subsystems. In order to prove the value of the methodology, subsystems are identified through cluster analysis, and subsequently classified in a study of Swiss water governance. Results suggest that Swiss water governance can be understood as a network of overlapping subsystems connected by boundary penetrating organizations, with high-conflict and quiet politics subgroups. The study shows that a principled analysis of subsystems as the interconnected, constituent parts of complex governance systems offers insights into important contextual factors shaping outcomes. Such insights are prerequisite knowledge in order to understand and navigate complex systems for researchers and practitioners alike.

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Introduction

Theories of policymaking often focus on an analysis of subsystems within a larger political system (Cairney and Heikkila 2017, p. 305). Depending on the theoretical background they have been labeled differently. Prominent concepts include the policy subsystem in the advocacy coalition framework (Weible and Sabatier 2007), policy areas in applications of punctuated equilibrium theory (True, Jones, and Baumgartner 2007), or policy domains (Laumann and Knoke 1987; Burstein 1991).

While conceptualizations of policy subsystems differ and serve different theoretical needs, they have in common that the empirical identification of subsystems is a complicated task. Subsystems are primarily meant to simplify the study of a complex policy area, but are themselves ambiguous, nested, dynamic, and interdependent constructs containing multiple components (Nohrstedt and Weible 2010). This study suggests a widely applicable, systematic procedure for subsystem identification to inform the application of policy process theories, with specific advantages in identifying different types of subsystems. In the light of the complex diversity in actors, activities, and issues, which characterizes modern governance (Rhodes 1996), the identification of subsystems is treated as an empirical question (Weible and Sabatier 2009). Thus, subsystems are not defined a priori but are identified given an observed empirical reality, based on a generalizable, systematic procedure. Subsystems are defined as bundles of similar observed organizational activity, and approached from a bottom-up, data-driven perspective.

The focus of policy analysis on the conduct of analyses within well-defined subsystems has long been challenged to incorporate more adequate representations of the complex empirical reality of governance. To do so, some have proposed to extend subsystem approaches. Proposed extensions include detailed concepts of sector-subsector relationships (Rayner et al. 2001), linked subsystems with trans-subsystem dynamics (Jones and Jenkins-Smith 2009) or the possibility of nested or overlapping subsystems (Zafonte and Sabatier 1998; Nohrstedt and Weible 2010). These extensions all implicitly reflect some of the complex system properties (Byrne and Callaghan 2014) of governance systems.

This article contends that the study of subsystems still provides a useful focal point for the application and development of governance theory. Subsystems provide a comparable frame of reference within which the predictions of different theoretical frameworks can be tested and compared across studies. As context-rich, meso-level constructs, they represent one of the most powerful ways to inform policy analysis approaches (Cairney and Kwiatkowski 2017, p. 624). Similarly, public management that harnesses complex systems thinking, which depends on developing an understanding of the interaction of constituent parts of an overall system (Haynes 2015), can profit from knowledge about subsystem properties.

This makes it all the more essential that the way in which subsystems as a common frame of reference are identified and conceptualized reflects the reality of complex modern governance systems. Otherwise, studies based on the study of subsystems risk to draw invalid, or at least incomplete conclusions. A bottom-up identification of subsystems based on the observed activity of actors mitigates this risk. Subsystems that are identified inductively based on observed empirical patterns within a common methodology are more likely to allow comparison and allow for valid statements about single subsystems and their interconnections. This encourages cross-fertilization and comparison between theories, which is increasingly important, not least due to the proliferation of policy process theories (Weible 2017).

Besides systematizing the empirical task of subsystem identification or boundary setting, the complexity of governance also suggests that subsystems should be conceptually classified according to a set of criteria that allows differentiating different types of subsystems. A classification of subsystems provides information about a crucial element of the all-important context within which policy choices take place (Cairney and Weible 2017). Predictions from some policy process theories might better apply to specific types of subsystems. For example, theories such as the Advocacy Coalition Framework (ACF) have mostly been applied and proven useful in adversarial subsystems (Weible 2017, 13), but to a lesser extent in collaborative ones (although exceptions exists, see Weible and Sabatier (2007)). Fitting the scope of a policy process theory to a specific type of subsystems thus increases the theorys explanatory power.

Thus, there are two main research aims of this study. First, it aims to develop a systematic, broadly applicable procedure for subsystem identification within a complex governance system. Second, the study aims to develop a starting set of criteria to classify subsystems, which are generally applicable and relevant to governance outcomes.

The methodology for subsystem identification is based on three dimensions of organizational activity. Substantive issues that organizations deal with, the levels on which they are active, and the type of activity they engage in draw up a three-dimensional space where organizations can be active at every possible junction. The space each individual organization occupies within these three dimensions represents its specific organizational activity profile. Comparing different activity profiles makes it possible to identify clusters of similar organizational activity profiles, in order to identify subsystems. The methodologys distinct advantage lies in its minimalist definition, which focuses solely on organizational activity. This allows for the identification of a broad range of different subsystems, as subsystems can be identified in any case where some sort of organizational activity exists.

To characterize different types of subsystems, the study makes use of three criteria. These relate to substantial properties of modern governance systems that have the potential to influence processes within the subsystem. First, areas of substantial overlap between subsystems are highlighted as an important criterion, which measures the extent to which organizations in a subsystem are also present in other subsystems. Interlinkages and spill-over effects, which can be gauged by subsystem overlap, are essential knowledge for organizations navigating a complex landscape. They can also help in assessing potential and need for cross-sectoral policy coordination. Second, the degree of conflict within subsystems is compared, distinguishing adversarial and collaborative subsystems. The degree of conflict can play a crucial role in shaping outcomes in a subsystem. High conflict can lead to blockages and low problem-solving capacity, but also to implementation problems, if outcomes are not considered legitimate by a large portion of organizations in the subsystem. Third, issue multidimensionality classifies subsystems based on the extent to which they contain multiple, substantially different issues. This basic feature is crucial, as it is a direct reflection of the complexity of the issue configuration within a given subsystem, which influences the potential for change and collective problem-solving.

To prove the value of both the methodology for identification and the criteria for classification of subsystems, they are utilized to analyze subsystems of the Swiss water governance system. The analysis demonstrates how a bottom-up identification of subsystems can reveal insights into the structure of governance, which would not have been possible otherwise. It also reveals the extent to which different types of subsystems are present in Swiss water governance. The results provide evidence for the validity of a theoretical conception of governance systems as networks of subsystems, and the focus of trans-subsystem dynamics that comes with it (Jones 2009).

Theoretical background

Subsystems in policy theory

Empirical case studies of a policy process and applications of policy theory usually feature some variant of subsystem identification. The development of theories about the policy process has rested on studies of subsystems for a long time. Laumann and Knoke (1987) studied how policies were made in health and energy policy domains in an influential study that emphasized the importance of organizational networks for the modern state. Theirs and further explorations of organizational activity in politics focused on policy domains as parts of a larger political system that revolve around substantive political issues (Burstein 1991).

Current state-of-the-art theories of the policy process, which evolved from such earlier work, also rest on highlighting processes and patterns within subsystems. The advocacy coalition framework (ACF) is the foremost example in this regard, as it focuses exclusively on statements about subsystem dynamics. It generally defines a policy subsystem by a territorial boundary, a substantive topic, and the organizations that are part of it. Acknowledging the vagueness of this definition, Weible and Sabatier (2007) recommend to identify subsystem boundaries empirically through preliminary interviews with policymakers to identify the relevant the territorial and substantive boundaries of an issue as well as the set of other relevant organizations within a subsystem. The ACF thus treats the definition of subsystems as an empirical question. Still, in a review of ACF applications, Weible, Sabatier, and McQueen (2009) found that a large proportion of studies relied on unsystematic data collection and did not specify methods clearly. This indicates that subsystem definition is unlikely to have followed a rigorous procedure. Further, exploratory interviews with policymakers, if thoroughly applied, are likely to be useful in defining valid subsystem boundaries as perceived by participants within the subsystem, as many ACF applications show. However, interviews may not suffice to understand subsystem interdependencies, which are an important area of theory development regarding the ACF (Weible, Sabatier, and McQueen 2009). Also, exploratory interviews risk to neglect the diversity in issues and levels that may characterize a subsystem, if they focus on single issues that are specified by the researcher in advance.

Another theoretical development, which focuses heavily on subsystems, is punctuated equilibrium (PE) theory (True, Jones, and Baumgartner 2007). PE theory studies how changes in policy originate in policy subsystems, or sometimes policy areas (Epp and Baumgartner 2017) or niches (Givel 2010). Subsystem identification in PE theory is not as extensively discussed as in the ACF, and mostly rests on identifying a single issue and observing policy change over time based on the tone of media coverage or policy output (Givel 2010; Mortensen 2007).

As the ACF and PE theory examples demonstrate, a key advantage of the focus of policy theories on subsystems is that in doing so, they can generate statements relating to a well-defined scope. As such, hypotheses derived from a theory are transferable. They can be tested in different contexts by referring to the intended scope of the original theory. The focus on subsystems further generates immediate substantive context to an application of policy theory. Studies can be compared within similar subsystems, such as floodwater protection in different countries. Similarly, studies can compare substantively different subsystems, asking, for example, if results obtained from studying processes of public health policymaking transfer to energy policymaking.

Theoretical models, which aim to give structure to the social space in which policymaking happens, have to achieve a certain level of abstraction in doing so. The various subsystem concepts applied in practice thus disregard some of the complexity in empirically observed governance (Nohrstedt and Weible 2010). This is necessary as it in turn enables these theoretical concepts to serve as a stepping-stone from which to posit more general principles governing the policy process. However, the abstraction of policy systems into subsystems becomes problematic if it does fail to capture key aspects of the complexity of these systems. On the one hand, this can result in missing important processes, which characterize a policy process but happen across the boundaries of subsystems. On the other hand, analyses of interactions between subsystems (Jones and Jenkins-Smith 2009) can also be compromised, if these interaction do not actually represent a genuine interaction between different parts of a governance system, but should rather be seen as a misspecification of boundaries between subsystems, which should be considered a single subsystem.

This problematic becomes even more pressing in the study of modern governance structures, which have been described as becoming increasingly more complex, fragmented and dynamic (Torfing 2005). Broadly, such systems satisfy the definition of complex systems in Simon (1962, p. 468), in that they are made up of a large number of parts that interact in a nonsimple way. More specifically, complexity in policy systems manifests itself in systemic behaviour that emerges from interdependent, interacting parts that are hard to predict, path dependence, local level interactions that lead to global changes and periods of punctuated equilibria (Cairney 2012). Faced with this, scientific inquiry into governance needs to acknowledge the differing explanatory roles of multiple theoretical approaches (Byrne and Callaghan 2014), depending on the context in which choices are made, of which subsystems are an essential part (Cairney and Weible 2017). Given the oftentimes singular complexity of subsystem settings, a generalized methodology to identify them can also be the basis for further qualitative inquiry based on methods such as process tracing (Beach and Pedersen 2013), which are uniquely suited to understand the peculiarities of a single subsystem in more depth.

The value in organizing governance systems along the lines of subsystem concepts that reflect their complex nature goes beyond the provision of a common reference for research alone. For practitioners in the public sector, the lack of clear relationships of cause and effects in the complex governance systems they face call for a holistic understanding of the environment they operate in. Understanding patterns and influences permeating system boundaries is needed to arrive at management decisions with improved outcomes over such based on overly simplified understandings inappropriate to complex systems (Haynes 2015). Illuminating the properties of subsystems, together with their interrelations within a complex governance system provides essential knowledge needed in this task.

Criteria for subsystem classification

Subsystems can differ in substantial ways. These differences affect the processes within them. In the following, three crucial, although not exhaustive criteria for subsystem classification are introduced, which have been shown to influence subsystem dynamics. These are subsystem overlap, the degree of conflict, and issue multidimensionality.

Overlap between subsystems is a key component complicating the study of governance. A given subsystem is unlikely to exist in a vacuum. Instead, it is embedded in a nested and overlapping structure of larger, as well as smaller subsystems. In the ACF framework, Zafonte and Sabatier (1998) already built upon a long tradition of research stressing the various ways in which subsystems can influence each other. For example, minority organizations in one subsystem may seek allies in another subsystem to make their voices heard. Another interesting example combining a multi-level conceptualization of governance and subsystem interdependency is the way in which subsystems far removed on higher political levels and addressed by specialized organizations can substantially overlap on the local level, where generalist administrators typically cover a broader variety of issues. Some authors conceptualize a network of linked subsystems, where links between subsystems allow changes to ripple through different subsystems. Subsystems can be linked in various ways, including communication or transaction links between actors from different subsystems, or actual boundary penetration, wherein actors are present in multiple subsystems (Jones and Jenkins-Smith 2009, 46). Subsystem interaction can therefore play an important role in explaining change in subsystems. Interaction can also explain blockages in subsystems, as Rayner et al. (2001) highlight in a discussion of so-called critical subsectors, which have an outsize influence on whole sectors.

The degree of conflict in a subsystem is a key differentiating factor among subsystems and influences decisionmaking processes (Fischer 2014). Theories of the policy process differ in the degree to which they incorporate conflict. Applications of the ACF framework often focus on subsystems with a high degree of conflict, which is understandable since the ACF-inherent notion of coalitions implies a set of competing interests within a subsystem. However, the ACF does not in itself predetermine this, as the distinction between collaborative and adversarial subsystems in an ACF application regarding Lake Tahoe water quality policy shows, which also outlines a number of ways in which a predominantly adversarial or collaborative subsystem setting can influence overall processes within the subsystem (Weible and Sabatier 2009). For example, in collaborative subsystems, the role of science in informing the policy process is likely to be different, as science is less likely to be used as a weapon and more likely as a tool for policy learning. PE theory as another example of a policy process theory is characterized by its explicit differentiation of common, stable and low-conflict, and rare, high-conflict subsystems where punctuated equilibria may occur (Baumgartner 2006). Generally, a high degree of conflict raises the profile of a subsystem and profoundly shapes the way in which rules are negotiated within it. In low conflict, low salience subsystems, quiet politics, shaped by experts and private interests, and less touched by public contestation, is much more likely (Culpepper 2011).

Issue multidimensionality characterizes the extent to which a subsystem revolves around multiple, substantially differing issues. The presence of multiple issues increases the internal complexity of a subsystem. Issue multidimensionality has been recently highlighted as a key contributing factor for the instability of a subsystem (Epp and Baumgartner 2017). In simple subsystems dominated by single issues, problems can be solved by incremental adjustments. Epp and Baumgartner (2017) cite snow removal as a prime example, where agreement on the solution for solving a recurring problem is the straightforward and widely understood and agreed upon deployment of snowplows. A snow removal subsystem is therefore unlikely to undergo drastic changes. On the other hand, in complex, multidimensional subsystems, the demands on the information processing capabilities of subsystem members are often too high for them to deal in detail with all subsystem dimensions. This makes them more likely to focus on a single aspect of a problem. However, if attention then switches to a different aspect, subsystem members are more likely to undertake drastic changes to accommodate it.

Research design and methodology for subsystem identification

A bottom-up identification of subsystems within a governance system requires a clear definition of the scope of a governance system itself. In the following, a governance system is defined as a system of governmental and non-governmental organizations, which engage in the formation, application, interpretation and reformation of rules (McGinnis 2011, p. 171) concerning one or multiple policy issues within a geographic boundary (Lubell 2013b).

Further, the definition of subsystems as bundles of similar organizational activity introduced in this study requires that the dimensions of the conceptual space in which organizational activity takes place need to be established. In order to characterize activity of organizations involved in governance, three dimensions are utilized. These are issues, levels and the type of ruleoriented activity.

First, policy issues, defined as substantive collective action problems (Lubell 2013, 541), define the varying substantive content that activity in governance is related to. For example, this might be floodwater protection.

Second, a number of levels that are involved in a governance system can be defined. Multilevel governance has been extensively studied as a normative concept, suggesting that multi-level structures increase the flexibility of governance, but also as a descriptive tool to understand modern governance (Scharpf 1997; Hooghe and Marks 2003; Bache and Flinders 2004). It suggests that modern governance is ever more removed from command-and-control systems and distributed across multiple centers or levels of authority. As this is an important dimension structuring the space where governance happens, a definition and partition of a governance system should therefore take multi-level structures into account. To continue the example, organizational activity in floodwater protection might be differentiated between activity located at the national level (such as the planning of national strategy) or the local level (such as the building of a dam by a municipality).

Third, organizational activity can be divided into different activity types, approximately based on distinct phases of governance processes. This is not to return to a strict cyclic model of the policy process that is descriptively inaccurate, but simply to acknowledge that there are different distinct types of activity in policymaking in the lived experiences of policymakers (Howard 2005), as well as other types of actors not usually considered policymakers (Cairney and Weible 2017, 621). Phases are therefore used as a starting point to typify organizational activity, but without an implication of temporal order. Activity types should be seen as distinct sets of similar substantive organizational activity, which are related to each other in multiple path-dependent ways. For example, the application of rules (such as the implementation of a law) governing the use of a natural resource implies a set of activities that is sufficiently distinct from the formation of these rules to constitute a different activity type. To illustrate path-dependency, the implementation of rules is in most cases dependent on their crafting. Concluding the example, the type of organizational activity in floodwater protection on the local level might range from application of rules (building a dam based on legal requirements) to their formation (if local stakeholders are involved in the crafting of laws).

The activities of organizations within a governance system can be summarized as the properties of the space they occupy within the resulting three-dimensional matrix. Figure 1 illustrates this for a single organization. The overall distribution of occupied space within this matrix for all organizations structures the governance system as a whole. For a bottom-up identifi-

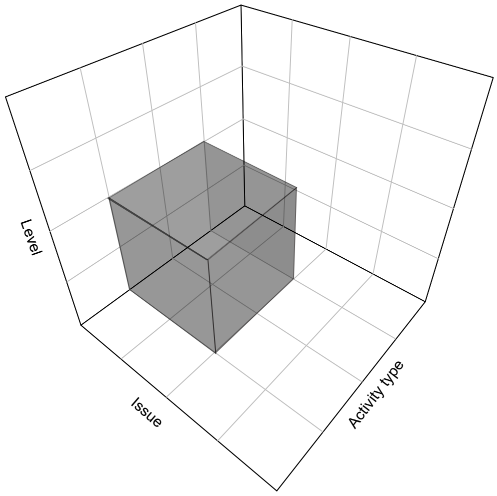


Figure 1: Simplified example of organizational activity of a single organization, summarized as the space taken up by it within a three-dimensional matrix, drawn up by the dimensions issues, levels and type of activity. The grey cuboid indicates that the exemplary organization is active on two issues, two levels and involved in two types of activity.

cation of subsystems, related organizational activity within this matrix can be grouped together. Subsystems can thus be multidimensional in issues, include various levels, and cover multiple types of activity, if this reflects observed patterns in the activity of organizations.

Data Collection and Methods

Case

The governance of water resources makes for a compelling case of a complex governance system. Most systems of even small-scale natural resource governance are characterized by a complex interplay of bio-physical and social parts (Ostrom 2009). Water governance is no exception. Institutional fragmentation indicated by interconnected issues that are dealt with separately by different institutions, has been called one of its defining characteristics (Lubell 2015, p. 37).

To gather empirical data on the overall make-up of Swiss water governance, 467 organizations in water governance were surveyed through an online-survey about water issues they regularly work on. 326 organizations responded, resulting in an overall response rate of 68 percent. A logistic regression model used to model total non-response (Sax, Gilmartin, and Bryant 2003) as a function of the type of respondent organization only identified the organizational types politics (mostly political parties) and private sector organizations as statistically significant predictors of non-response (compared to interest groups as a baseline, see model results in table A1 in the appendix). Thus, even while the differences in non-response rates are not drastic, it is still worth noting that the subsystem identification undertaken in the study could potentially be biased if a group of private sector organizations or political parties with distinct activity profiles were missing from the analysis. However, based on the relatively large number of respondents, as well as to the best knowledge of the organizational landscape of the author, this seems unlikely.

The issues and organizations included in the survey were identified based on an extensive manual content analysis of newspaper articles and parliamentary hearings related to water topics in a companion study (Brandenberger et al. 2015). The content analysis used to identify issues and organizations followed a bottom-up model. It started with the delimitation of water as the only common concept that the documents analyzed in the manual content analysis had to share. Beyond this, all possible organizations and issues were considered. This increased that chance that the sets of organizations and issues were representative of Swiss water governance as a whole. Also, sources from the national level (a national-level newspaper and the federal parliament), as well as on the level of a constituent state, called canton (a cantonal newspaper and parliament), were used. This ensured that the set of organizations and issues also reflects the multi-level structure of Swiss water governance.

The subsequent survey asked organizations whether they had regularly been involved in projects in the three years prior to 2016 regarding 26 issues aggregated from the content analysis. For every issue chosen, the survey presented organizations with a list of levels within the federal setting (municipal, cross-municipal, state, cross-state and national). The survey then asked organizations to indicate on which of these levels they normally dealt with each issue. Some organizations were, for example, involved in the protection of aquatic ecosystems exclusively on the municipal level, such as local nature protection interest groups. Other organizations, such as state nature protection agencies, were involved in projects on all levels ranging from working with municipal stakeholders to providing input on national regulation. Similarly, the survey asked organizations to indicate the phases where they normally would engage with each issue. Phases included initiation, planning, decision-making, implementation and evaluation. Of these phases, the initiation and decision-making phases relate to the formation, planning to the interpretation, implementation and evaluation to the reformation of rules governing organizational activity (McGinnis 2011, 171). Finally, for every issue chosen by an organization, a name generator question (Bien, Marbach, and Neyer 1991) asked organizations to provide a list of other organizations they considered allies or opponents regarding each issue.

Identification of subsystems

The technical procedure to identify subsystems based on organizational activity can be summarized in four steps. Figure A1 in the appendix provides an illustrated overview over all steps, starting from an example of the initial survey questions used. To further encourage reproducibility the (anonymized) dataset of organizational activity in Swiss water governance used in the analysis for this study, as well as a set of scripts to replicate the clustering procedures used can be found in a public online repository [2].

First, the data gathered in the survey was formally represented in a two-dimensional binary incidence matrix with organizations as rows and the set of all observed unique triplet combinations of issues, levels and activity type (called triplets in the following) as columns. Cell entries specify for each organization if it is involved in a given unique triplet.

Second, the identification of subsystems is based on identifying clusters of triplets in the transposed incidence matrix in terms of common organizations. In other words, this means that triplets become observations, while the indications of organizational activity become features of each triplet. Every unique triplet is thus characterized by a binary vector specifying organizational activity. In this binary vector, a one indicates that a given organization is active in the given triplet. The similarity between two such vectors indicates the degree to which the corresponding triplets share organizations, a measure of their relation in terms of organizational activity.

Third, to identify clusters of triplets, a k-medoids algorithm from the family of k-means clustering procedures (Lloyd 1982) implemented in the R package cluster is used (Maechler et al. 2017; R Core Team 2017). The resulting clusters of triplets represent the patterns of organizational activity that characterize different subsystems.

[2] https://doi.org/10.25678/000055

Clustering is an inherently subjective procedure as the choice of clustering algorithm as well as the choice of parameters for clustering algorithms determines the clustering results. This subjectivity however also has advantages as it forces the researcher to substantively consider the clustering problem and evaluate the results. With regard to the clustering problem in the present study, the first difficulty lies in choosing a suitable clustering algorithm. The k-medoids procedure was chosen due to its simplicity, speed and the widespread use of k-means based clustering, which facilitates replication of the analytical procedure. The binary, relatively sparse incidence matrix, which is clustered in this application, is not an ideal case for simple k-means clustering as k-means clustering relies on minimizing the euclidean distance between observations and cluster centroids (means of features). For binary vectors these means do have a substantive meaning (the proportion of a given feature) but are not means on the scale of the input data, as intended by the algorithm.

The k-medoids procedure mitigates these problems by operating directly on a similarity matrix, which can be constructed using an adequate similarity measure for binary vectors (for an overview, see Seung-Seok, Sung-Hyuk, and Tappert (2010)). Sokal-Michener similarity was chosen to represent the similarity between triplet vectors, as it includes matches in the absence of attributes between vectors, which includes additional information about organizational activity. The k-medoids procedure further minimizes distances to medians, instead of means, which is more adequate for binary vectors. As an additional robustness check, density-based spatial clustering of applications with noise (DBSCAN) (Ester et al. 1996) implemented in the R package dbscan (Hahsler and Piekenbrock 2017) was also used on the data, to see if results would be approximately similar using an alternative, starkly differing clustering approach.

Besides the choice of clustering algorithm, the choice of parameter settings for the algorithm is equally important. The main challenge for k-means and k-medoids algorithms lies in choosing a sensible value for k, which determines the number of subsystems. The difficulty lies in the fact that there is no objectively correct choice for k. Instead, to an extent, different values for k allow to probe for different aspects of the structure of the governance system, providing more general, but coarse-grained, or more fine-grained results.

In this study, the optimal number of clusters k was identified based on the data, by calculating the gap statistics (Tibshirani, Walther, and Hastie 2001a) for different numbers of clusters. The optimal number is chosen by identifying the smallest k such that the value of the gap statistic function for k is not more than one standard error removed from the first local maximum of the function, as implemented in the R package cluster (Maechler et al. 2017). This procedure formalizes the intuitive notion of the optimal number of clusters as the point from which the marginal improvement in the fit of clustering to the data through the addition of a new cluster decreases significantly.

In a fourth and final step, organizations that were active in one of the triplets contained in a subsystem were assigned to the respective subsystem, leading to a list of subsystems containing disjoint sets of triplets and partially overlapping sets of actors for each subsystem. It should be noted that clustering triplets into disjoint sets is not strictly necessary, but in this case a result of the clustering procedure chosen. However, depending on the application, a fuzzy clustering method, which can assign triplets to multiple clusters, might be deemed more appropriate. This could for example be the case for studies where some triplets are believed to be highly crosscutting throughout most subsystems.

Results

The k-medoids clustering procedure resulted in 9 subsystems. Figure A2 in the appendix displays the results of gap statistic calculations leading to this number. The k-medoids procedure starts from a random draw, which means that clustering results vary slightly between successive runs. In order to check for large variations between results, the procedure was run multiple times and results compared. While small variations occurred, no changes in the broad overall pattern of results could be detected.

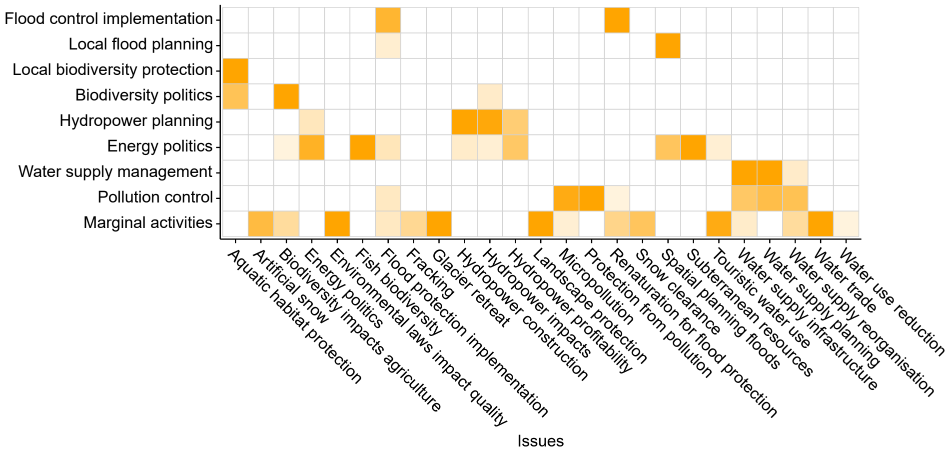
Figure 2 graphically illustrates the composition of each subsystem, based on the issues, levels and activity types present within it. Eight subsystems identify meaningful and nuanced clusters of organizational activity in Swiss water governance. A ninth can be seen as a residual category, which clusters together a broader set of diverse, mostly marginal activities, which are grouped into a common subsystem mainly not due to their similarity but dissimilarity to all other clusters. This conclusion is further justified by the fact that DBSCAN clustering either classifies most of these activities as outliers or groups them into individual clusters (see figure A5 in the appendix). Results from the DBSCAN algorithm were substantially very similar to k-medoids clustering, which illustrates the validity of the general statements that can be derived from the clustering procedure. In the following, all subsystems are shortly discussed.

The flood control implementation subsystem contains organizational activity regarding the implementation of technical flood protection measures as well as renaturation measures for flood control. Activities in the subsystem focus primarily on the local (municipal and intermunicipal) and cantonal levels, and on planning, decisionmaking and implementation of measures. The subsystem is heavily dominated by local and cantonal administrative agencies (mostly municipalities and local associations set up to implement flood control measures), and engineering firms.

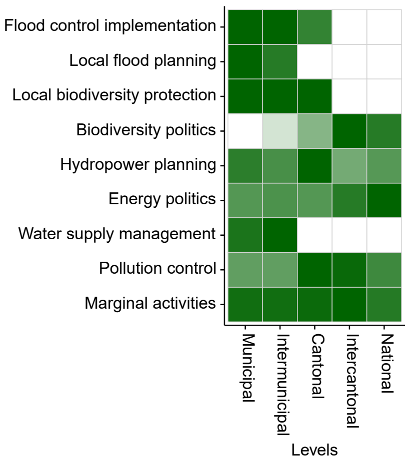
The local flood planning subsystem is the conjoint part to the flood control implementation subsystem. It is however sufficiently different to be categorized as its own subsystem. This is mostly evident in the fact that it does not contain any activity on the cantonal level. The subsystem also almost exclusively contains activities regarding spatial planning for flood protection, especially on the municipal level. It is dominated by local municipalities. This reflects the fact that spatial planning is a task undertaken at the municipal level in the setting of Swiss federalism. The federation only sets general guidelines, which are implemented by the cantons, which in turn often delegate a large proportion of responsibilities to municipalities.

The local biodiversity protection subsystem concerns projects regarding aquatic biodiversity on the sub-national level. It is shaped mostly by local municipalities, cantonal agencies, and a mix of mostly local nature protection interest groups. Beyond this, scientific actors, such as research groups at universities, are most prevalent in this subsystem, compared to all other subsystems. This is most likely due to the fact that projects regarding nature protection often require expert input concentrated at research institutes and that scientific groups conduct research projects themselves on the local level.

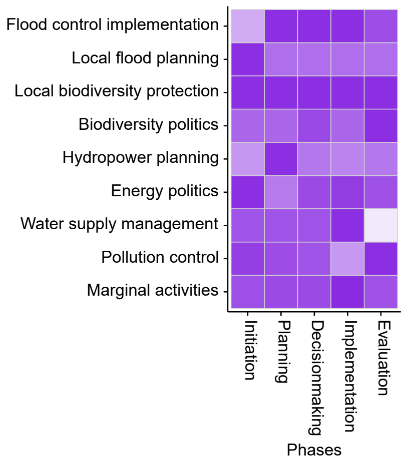
The biodiversity politics subsystem includes predominantly evaluative activities regarding the issue of general protection of



(a) Issue incidence



(b) Level incidence



(c) Phase incidence

Figure 2: Composition of subsystems derived from k-medoids clustering illustrated in three incidence matrices. Non-white colors indicate the prevalence of issues, levels and activity types in a subsystems. The strength of colors indicates the relative frequency of a given issue, level or activity type in organizational activity characterizing the subsystem. Reading example: In the level incidence matrix, if some cells are white, one is light green and two dark green (such as the flood control implementation subsystem), this implies that the two white levels are not present, there is a small amount of activity triplets that include the level indicated by the light green color, and most subsystem activity focuses on the three levels indicated by dark green level to the same extent.

aquatic habitats and two main threats to aquatic biodiversity in Switzerland. These are the impacts of hydropower operations and the construction of new hydropower plants on biodiversity, as well as the impacts of agricultural practices on biodiversity. The intercantonal level is the most important level in this subsystem. This reflects the fact that nature protection in Switzerland is mostly carried out by the cantons, with incentives set by the national government. The subsystem is much more politicized than other subsystems, as it contains a large number of political parties, as well as interest groups representing different views on aquatic biodiversity. These are mostly national level organizations such as the largest Swiss nature protection organization Pro Natura, Aqua Viva (an interest group specializing in water topics), the Swiss farmers association, or industry associations.

The hydropower planning subsystem is centered on the planning stage in the construction of hydropower facilities. This includes explicit construction issues, but also biodiversity impacts of hydropower, cantonal energy politics and the profitability of hydropower. The fact that activity in the subsystem mostly takes place on the cantonal level illustrates the important role of the cantons in Swiss hydropower. Cantons (and sometimes municipalities) need to approve new hydropower construction, but also own many facilities themselves.

The energy politics subsystem is the second subsystem besides biodiversity politics, which is heavily focused on the highest political level. It mainly revolves around the two main issues in the political discussions regarding water and energy, which are the regulation of hydropower and the use of subterranean resources (geothermal energy and fracking). The political discussion regarding hydropower regulation have been dominated by the call for subsidies due to decreased profitability of hydropower and to a lesser extent by the influence of hydropower construction on biodiversity associated issues such as fish biodiversity, which is evident in the issues present in the subsystem. Hydropower dams may block migration routes of fish, and the operation of hydropower plants directly affects the dynamics of aquatic ecosystems and the health of fish populations. Activities in the subsystems take place on the national level, where the general guidelines regarding regulation in the energy domain are set. They mostly involve the initiation phase, which reflects that the subsystems contains a large number of interest groups, which aim to influence the political agenda. The water supply management subsystem is exclusively focused on the local (municipal and intermunicipal) level and contains all issues directly related to water supply. This subsystem is comparable to the flood control implementation subsystem in its focus on implementation of a specific task on the local level, which is mostly carried out by local level administrators.

The pollution control subsystem mostly

contains organizational activity related to protection against pollution. To a lesser extent, it also contains activities regarding water supply management. Most of the activity takes place on the cantonal level and regards evaluative activity. The proportion of activities that relate to implementation is remarkably low. Thus, this subsystem is about controlling the framework within which rules regarding pollution control and water supply are implemented, but not the implementation itself. As to be expected in a subsystem focused on regulative overview of activities carried out by municipalities, the subsystem contains a large number of local and cantonal administrative agencies.

The marginal activities subsystem on the one hand contains issues which are treated by small groups of focused organizations and are not high or only emerging on the political agenda (such as glacier retreat, artificial snow production, trade in water, or touristic water use). On the other hand, it contains outlier combinations of issues, levels and activity types, which were only rarely chosen by organizations (such as energy politics on the municipal level or water supply planning on the national level). These outliers either represent genuine outliers in that they represent unique activities of some organizations, but could also be erroneous entries. Based on the results of alternative clustering approaches, the first possibility seems more likely.

Discussion

In the following, the eight identified meaningful subsystems are classified based on the initially introduced three criteria issue multidimensionality, overlap, degree and conflict. Much as evoked by Jones and Jenkins-Smith (2009), the overall system of Swiss water governance can be seen as a network of partially overlapping subsystems. This is graphically illustrated in figure 3, which displays both the overlap among subsystems and their respective degree of conflict.

Subsystem overlap was measured for every pair of subsystems as the proportion of actors present in both subsystems compared to the total number of actors in both subsystems. This captures the boundary penetration types of ties between subsystems introduced in Jones and Jenkins-Smith (2009, 46). Overlap between subsystems ranges from six to sixty percent (exact proportions for every pair of issues can be found in figure A3 in the appendix). A certain amount of baseline overlap should be assumed due to the fact that the set of organizations contains a number of organizations that are active in a wide variety of water issues, such as cantonal and national government agencies, large environmental interest groups, but also local municipalities, which often manage all issues related to water on their territory. High amounts of overlap are also generally found in thematically similar subsystems. The highest amount of overlap exists between the flood control implementa-

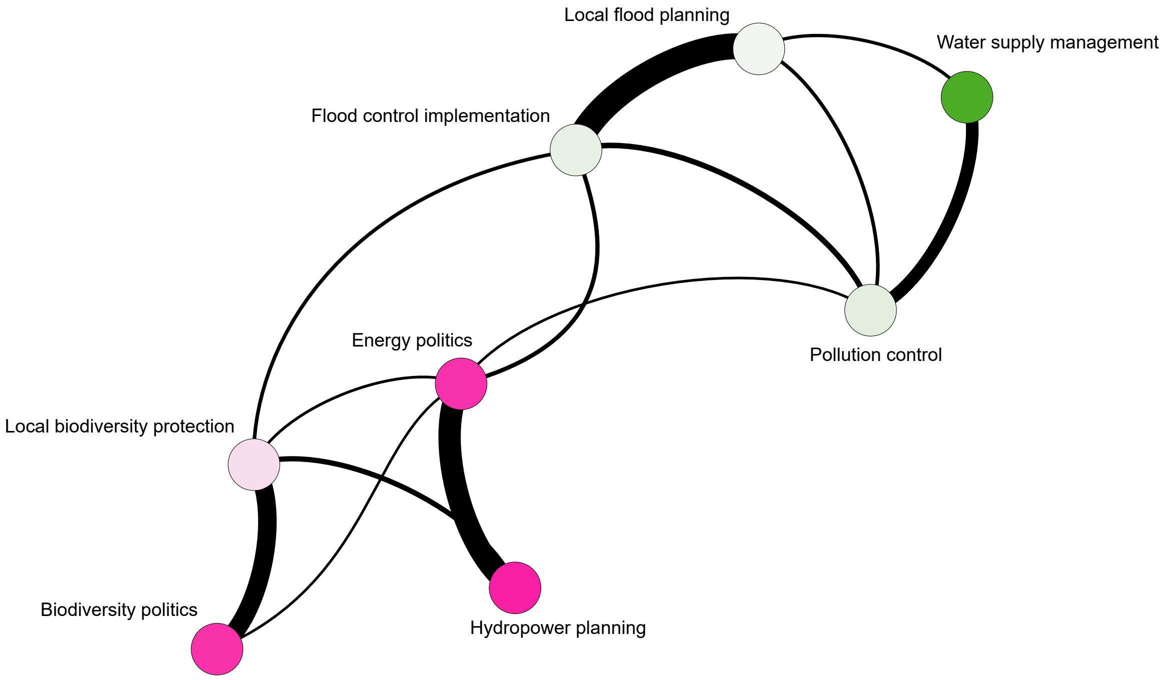


Figure 3: Subsystem network of Swiss water governance. Circles indicate subsystems. Overlap between subsystems is indicated by links. Links indicate that more than 30 percent of actors between subsystems are shared. The size of links is proportional to the number of actors shared. The color of circles indicates the degree of conflict within a subsystem. Red circles indicate high, green circles low conflict.

tion and local flood planning subsystems. Therefore, many organizations who participate in flood control implementation are also involved in planning and vice versa. This indicates a high level of coordination between these two activities. The high respective overlap between the higher-level pollution control and the lower-level water supply management subsystems, and the higher-level biodiversity politics and lower-level biodiversity protection subsystems are similar in this regard. However, they also further indicate a high amount of cross-level interaction in these issues.

In general, the overlap between subsystems matches functional interdependencies between issues. For example, biodiversity subsystems overlap with hydropower planning and energy politics, which represent factors strongly influencing aquatic biodiversity, to a relatively high degree. However, biodiversity politics almost has no overlap with water supply management, which is not directly related to aquatic biodiversity in a way other subsystems are. One area where the amount of overlap is surprisingly low, based on what would have been expected due to functional interdependence, is between pollution control and biodiversity subsystems. This could however be a reflection of the fact that discussions around impacts of pollution on biodiversity have recently been more focused on the impact of agricultural practices, and much less on waste water treatment, which makes up a large proportion of the pollution control subsystem.

The different levels of overlap serve to illustrate a further more general point about subsystems in complex governance systems. These subsystems are likely to overlap to a large extent due to the nature of complex functional relations between issues. A bottom-up identification of subsystems can highlight the nature of this overlap and indicate related subsystems that need to be taken into account in the analysis of a given subsystem. For example, studying processes of biodiversity regulation should also analyze consequences on energy politics and flood control subsystems.

The level of conflict in each subsystem was measured as the ratio of opponents to allies indicated by members of a subsystem regarding issues that were part of the subsystem. Figure 3 points out the main differences among subsystems in terms of conflict (exact numbers can be found in table A2 in the appendix). The three most conflictive subsystems are biodiversity politics, hydropower planning and energy politics. The fact that energy and biodiversity politics are among the most conflictive is not surprising and illustrates the validity of the partition. These subsystems contain the most salient discussions in Swiss water politics and are both centered on higher levels, focusing on rule-making, where different interests clash. The planning of hydropower facilities has also been particularly contentious in Switzerland. One of the most relevant examples in this regard is the proposed extension of the large Grimsel hydropower facility, which would inundate an area of disputed protected status, and has subsequently been fought by nature protection organizations for years.

Combining the classification criteria overlap and conflict as illustrated in figure 3 shows that Swiss water governance can be conceptualized as consisting of two parts, which are similar in their degree of conflict and represent network subgroups, in that they are more strongly connected internally than between them. On the one hand, the four subsystems dealing with water supply, pollution and flood control issues form an area of quiet politics, dominated by administrative organizations and low levels of conflict (Culpepper 2011). On the other hand, the two most contentious issues in Swiss water governance, biodiversity and hydropower engender their own subgroup of four subsystems, which is characterized by higher levels of conflict, high issue salience, and the presence of a higher number of non-administrative organizations.

Subsystems in Swiss water governance are multidimensional in issues (in that they feature very dissimilar issues) to a varying degree. The eight meaningful subsystems center around four common overarching themes. These are flood control, aquatic biodiversity, hydropower and water supply/ pollution. Among those, aquatic biodiversity is the most multidimensional.

Besides habitat protection, the aquatic biodiversity subsystem touches on issues related to hydropower and farming, two topics which would not readily be grouped together at the first sight. Their presence in the same subsystems shows that both are essential factors influencing aquatic biodiversity in Switzerland and organizations active in this topic reflect this in their activity. Further, the hydropower subsystem also includes the issue of fish biodiversity, which further reflects the intricate interconnections between nature protection and most other issues in water governance. The subsystems revolving around flood control are relatively focused on these topics, but also include renaturation as an issue related to nature protection. The two water supply/ pollution subsystems are relatively unidimensional but give different weights to water supply and protection against pollution respectively.

Generally, higher issue multidimensionality of subsystems is associated with increased conflict, which is in line with recent findings in the literature (Epp and Baumgartner 2017). For example, the biodiversity politics subsystem involves different sets of organizations, which have substantially different interests. These range from hydropower firms, over nature protection groups to farmers associations. These organizations are affected by biodiversity protection in different ways. While nature protection groups generally favor strict regulation of residual flows, hydropower companies may face reduced production capacity due to this. Similarly, farmers can be restricted in their operations due to limitations on pesticide use advocated by nature protection groups. Conversely, unidimensional subsystems, such as water supply management, consist mostly of organizations that implement existing rules on a given, narrowly defined issue. This reduces the chance for conflict.

The subsystems demonstrate that Swiss water governance is heavily influenced by multi-level structures. Activity broadly differs between higher (cantonal, intercantonal and national) and lower (municipal and intermunicipal) levels. This is also apparent in the alternative clustering solution (see figure A5b in the appendix). This separation of some governance issues into distinct higher and lower level subsystems illuminates a key feature of Swiss water governance. Swiss water governance is characterized in many areas by strong decentralization and local autonomy (Hill Clarvis and Engle 2015).

The split between lower and higher levels is most apparent in the relatively unidimensional subsystem that revolves around water supply/ pollution. The aquatic biodiversity and hydropower subsystems include a broader variety of levels but nonetheless show a tendency toward a similar structure. The pollution control, biodiversity politics and hydropower planning subsystems are further strongly dominated by a focus of activities on the cantonal level. This illustrates the key position of this level as a hub of activities in Swiss water governance. Lower level subsystems tend to focus on implementation, while higher level subsystems bundle more evaluative and initiative activities. However, the subsystems are not as clearly split on activity type as they are on levels, which is also likewise repeated in the alternative clustering solutions. This is substantially interesting, as it shows that subsystems are generally bundling most types of organizational activities regarding the issues they contain. A special case in this regard is the water supply management subsystem, which does not contain any activity regarding evaluation. The energy politics and biodiversity politics subsystems are also interesting cases. Judging by the organizations, as well as the levels and issue-specific activities they contain, these subsystems are the most political subsystems identified in this study, containing the highest numbers of political parties and interest groups, and mostly concerned with rule-making and the crafting of higher-level legislation. Theories of the policy process that focus on political decision-making are therefore most likely to apply directly to these subsystems.

These observations regarding the predominant levels and types of activity across subsystems are empirical evidence illustrating that care needs to be taken in studying subsystems in two further ways, beyond taking into account issue multidimensionality, conflict, and subsystem overlap. First, governance subsystems are likely to be heavily influenced by multi-level structures. On different levels, different dynamics are therefore likely shape outcomes, which is further evidenced by the differences in activity type between subsystems. Identifying subsystems without taking account of multi-level structure thus risks to disregard a key feature of organizational activity. Second, the fact that many subsystems contain a broad variety of different types of activity suggests that further care needs to be taken if studies of subsystems focus on only a single type of activity, such as decision-making, as there is a high likelihood that organizations in a subsystem also engage in various other activities. This is relevant as actions of organizations during initial stages of a project, for example, may influence their considerations in later stages.

The subsystem partition based on the methodology presented in this study resulted in a nuanced set of subsystems. These subsystem differ along the criteria proposed for their classification. This shows the added value of a bottom-up identification of subsystems, based on a minimal criterion for subsystem identification (distinct groups of organizations with similar activity profiles). A procedure based on this type of empirical data can pick up patterns that might have been ignored otherwise. One such example is the differentiation between subsystems which involve the same issues, but on different levels. The fact that the methodology for identification only makes minimal initial presumptions about what should be considered a subsystem, enables it to pick up subsystem of vastly differing types. As the empirical results show, these range from conflictive and high-level, to local and quiet politics subsystems, providing an adequate representation for the complex, messy reality of governance.

Conclusion

The identification of subsystems in complex governance systems has many advantages. It provides a clear scope for the application of theoretical concepts, makes results comparable across cases and simplifies the sometimes bewildering complexity of governance to manageable proportions. Especially the last aspect is an essential prerequisite for public management concerned about the likely results of actions reverberating within complex system structures (Haynes 2015). However, these advantages rest on a valid procedure to identify and classify subsystems. This article has suggested a bottom-up way to identify and classify subsystems in complex governance systems, based on similar patterns of observed organizational activity.

The suggested methodology to identify subsystems proceeds in three general steps. First, relevant issues and organizations pertaining to a certain governance topic are identified based on document analysis. Second, data on organizational activity in three dimensions is gathered. The resulting information specifies for each issue an organization is active in the levels and types of activity the organization focuses on. Third, the resulting data structure can be clustered to identify subsystems as patterns of organizational activity.

A key advantage of identifying subsystems based on minimal initial presumptions regarding the grouping criterion (similar organizational activity) is that they can then be more easily classified according to a wide-ranging set of criteria. In this study, issue multidimensionality, overlap, degree of conflict and predominant type and level of organizational activity have been highlighted as key criteria, based on the fact that they have been shown as influential in shaping subsystem processes and outcomes in the past. However, depending on the substantive interest of the researcher, other criteria, such as the maturity of a subsystem (Nohrstedt and Weible 2010; Ingold, Fischer, and Cairney 2017) can easily be envisioned.

This article has applied this procedure to identify subsystems in Swiss water governance. The resulting partition of Swiss water governance is substantially interesting in its own right in illuminating three main characteristics of the complex system of Swiss water governance. First, the subsystems in Swiss water governance can be thought of as a network connected by boundary penetrating organizations. This network broadly consists of two subgroups. In a first subgroup, issues of biodiversity and energy politics are addressed in conflictive subsystems, while a second subgroup of "quiet politics" dominated by administrative agencies, contains issues of water supply, pollution and flood control. Second, this "quiet politics" subgroup shows that there are a number of subsystems, generally perceived to be well-functioning, which feature only moderate or little conflict. Such subsystems are less likely to be noticed by analysts, but are likely to be as crucial for governance outcomes as conflictive ones. Third, there is a clear difference between local and higher-level (cantonal and national) activity in almost all issues. The level at which organizations are active therefore emerges as an influential dimension partitioning Swiss water governance. The existence of clear local-level subsystems in most governance issues highlights one of the most crucial points in order to understand Swiss water governance. Processes of implementation and interpretation of rules at the local level are absolutely important in order to understand how governance works in a given area. Analyses and policy design should therefore not only account for the most visible, high-level subsystems, but also consider their conjoint parts at lower levels and the interaction between the two.

These empirical results illustrate more general properties of subsystems in complex governance systems, which become apparent through the use of a bottom-up procedure. The analysis suggests that governance subsystems are likely to be more multidimensional and more interdependent than often conceived. The identified subsystems in Swiss water politics are mostly not centered around a single issue, level, or activity type. As the complex nature of large-scale governance systems implies, subsystems of organizations who engage in similar governance activities revolve around unique configurations of multiple issues, multiple levels, and multiple types of governance activities. This is a stark reminder for analyses that focus on the analysis of individual subsystems to carefully specify the delimitation of subsystem boundaries and beware of potential bias regarding the overall structure these subsystems are situated in. Further, the network-like structure between subsystems supports analytical efforts that try to assess the influence of betweenand trans-subsystem dynamics (Jones and Jenkins-Smith 2009).

The variance in the degree of conflict between subsystems and the existence of unidimensional and low-conflict, or less politicized subsystems further points toward a need for theory that focuses more explicitly on such subsystems. Most concepts in policy theory apply most fruitfully to subsystems focused on rulemaking on higher governmental levels. Two instances of such subsystems could empirically be found in the case of Swiss water politics. However, the results reported in this article suggest that the interplay of such political subsystems with other types more strongly focused on implementation, or the local level, should be more extensively researched, in order to gain a more detailed understanding of governance processes.

The extensive overview of a large-scale

governance system undertaken in this article is likely not feasible in many applications. A study trying to focus in more depth on a given policy subsystem, where a large-scale system overview is not available from previous research, would face unresolvable challenges in balancing a large overview of a governance system with the analytical depth required for a thorough study of a single subsystem. However, in many cases, subsystem research undertaken with an increased awareness of multi-level structures, local level implementation, and adjacent, overlapping subsystems should already strongly mitigate the danger of inadequately determining subsystem boundaries and neglecting important contextual conditions. Even the sole exercise of more precisely situating the activities of organizations in a given policy area within the three dimensions outlined in this study alone has merit. On the one hand, it should provide an appreciation for how appropriate it is to treat the policy area as single subsystem. On the other hand, it can illuminate the extent to which comparisons with other subsystems are possible.

This study suggests a way forward to establish a common subsystem procedure identification procedure to serve the needs of different theoretical frameworks as a shared frame of reference. While it demonstrates a methodology that yields viable results, further research should explore the implications that arise from implementations in different contexts. Be it as an entrance door for in-depth qualitative studies of single subsystems, as a way to relate features of a multitude of subsystems to policy outcomes, or to inform policymakers about the structure of the ecosystem they are active in, the possibilities of a shared subsystem identification procedure should be exploited and debated.

Networks of Swiss water governance issues. Studying fit between media attention and organizational activity

This study analyzes Swiss water governance as a network of interrelated issues. It compares how organizations reflect relations between governance issues in their activity with the way issue relations are depicted by the media (issue attention-activity fit). To do so, a media data analysis, supported by machine learning, is combined with a nation-wide survey. Prominent areas of misfit relate to the coordination between water saving measures and drought risks; the exploitation of subterranean resources and drinking water protection; and issues of micropollutants. The study demonstrates that comparing organizational activity with media attention is particularly well suited to recognize newly emerging, currently neglected areas of governance.

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Introduction

Natural resource governance often deals with a complex network of interconnected governance issues. Governance issues are substantive collective action problems (Lubell 2013b), for example regarding the sustainable use or effective protection of a given resource. They form a network of issues, as addressing one issue often affects one or more other issues.

This study investigates organizational activity and media attention as two distinct ways in which to conceptualize relations between issues in this network. It then highlights the insights that can be gained by studying fit and misfit between them (issue attention-activity fit) in a case study of Swiss water governance. Organizational activity reveals how actors in a governance system treat issues as interconnected in practice. Comparing this to the way in which media data depicts relations between issues is shown to particularly identify newly emerging, neglected areas of governance, and areas of present or future conflict.

Studying fit and misfit in natural resource governance is generally motivated by the explicit or implicit normative goal of aligning governance with an underlying systemic structure, such as the one captured by issue relations. The concept of fit describes the outcome of this process. Prominent fit concepts have usually focused on how to fit governance structure to ecological systems (Folke et al. 2007; Bergsten, Galafassi, and Bodin 2014; Sayles and Baggio 2017b). This study departs from this social-ecological approach and highlights fit between media attention and organizational activity as a distinct, complementary approach to assess complex natural resource governance systems.

The conceptualization of fit based on comparing issue networks builds on a number of recent studies (Ekstrom and Young 2009; Kininmonth, Bergsten, and Bodin 2015; Treml et al. 2015; Sayles and Baggio 2017b), which have demonstrated the emergence of networks as an established conceptual basis for the empirical study and refinement of many types of fit concepts (Bodin, Sandström, and Crona 2017). By studying issue attention-activity fit, the present study advances the study of fit based on a network perspective. It adds to the theoretical richness of fit by expanding it to encompass a type of fit not based on ecological links, but the perception and debate about issue relations in the public sphere. As a complement to social-ecological models, this approach allows for the study of large-scale governance systems with a wide variety of issues. In emphasizing the particular nature of issue relations that appear in the media arena, it allows for the identification of specific, otherwise potentially neglected types of misfit.

Fit between organizational activity and media attention on governance issues

Most fit concepts as originally developed, such as functional fit (see Folke et al. (2007)), describe the challenge of linking ecosystems and socioeconomic systems to achieve coherent management. Thus, they traditionally measure the extent to which governance matches the ecological system structure.

This study extends the notion of fit to an approach that investigates the way a governance system reflects publically perceived relations between issues. A governance system is defined as a geographically defined territory that contains multiple issues (such as flood protection or hydropower construction), institutions (rules such as minimum residual flow regulations) and actors (organizations such as government agencies, private firms or interest groups) (Lubell 2013). Governance itself is then a process taking place within this system by which the repertoire of rules, norms, and strategies that guide behavior (...) are formed, applied, interpreted, and reformed (McGinnis 2011, p. 171).

Governance issues can represent a wide range of problems that actors confront. For example, in a water governance system, increasing hydropower production capacity can represent one issue, while the protection of aquatic biodiversity is a second issue, and floodwater protection a third. These three issues are intricately linked. The regulation of residual flow in hydropower production influences aquatic biodiversity. Hydropower dams can be used to regulate river systems to mitigate the consequences of flooding. Further, revitalisation measures designed to protect aquatic biodiversity in rivers can contribute to floodwater prevention by establishing buffer zones. If organizations are active on any of these issues, high fit would imply that they are aware of these interconnections and reflect this awareness in their activities by either tackling related issues simultaneously or coordinating their actions with other organizations active on the issues.

The example above shows that studying fit based on issue relations makes it possible to analyze relevant properties of complex, large-scale governance systems. For the purpose of this study, governance systems are considered large-scale systems if they contain issues operating on multiple levels of spatial and jurisdictional scales (Cash et al. 2006). Such systems can involve a very broad and heterogeneous variety of issues. An issue-based representation offers a way to deal with this by understanding issues as collective action problems, which is seen as their common denominator.

However, even the relatively simple example of a water governance system with three issues shows that the empirical operationalization of issue relations in large-scale, complex governance systems is a hard problem to solve. The exact way in which issues depend on each other is often singular to the exact pairing of issues. As the number of issues increases, this makes it unfeasible to consider the exact content of a relation between issues in detail for every relation. Every abstract representation of issue relations is thus only one of a number of possible representations, and the possible insights it can engender depend on the particular conceptualization utilized.

In light of this, this study explores organizational activity and media attention as two possible ways of studying relations between issues. In combination, this enables a study of fit with distinct properties. The way organizations consider multiple issues in their activity represents a manifestation of governance, as it exists in the lived practice of actors, who form the interorganizational networks that governance implies (Rhodes 1996). In comparison, how relations between issues are picked up and portrayed in the media represents a socially constructed (Hilgartner and Bosk 1988) landscape of issue relations.

The way issues are given attention by media is not neutral but influenced by processes endogenous and exogenous to the media system. These include news cycles (Downs 1972; Djerf-Pierre 2012), journalistic values and news routines, properties of organizations seeking attention (Andrews and Caren 2010) and news values (Galtung and Ruge 1965). The latter describe a perceived inherent quality to content that shapes the answer to the question of whether or not it is news, emphasizing some issues over others (Harcup and ONeill 2017). In the context of this study, this suggests that media attention will systematically overemphasize some relationships between issues compared to the way organizations do so in their activity. This study posits that it is likely that such overemphasis applies especially to issue relations in two main dimensions. First, based on the news value of conflict, media attention is likely to focus strongly on issue relations that are contentious, unresolved or normatively charged. Second, based on the news value of surprise and exclusivity, issue relations that are new on the agenda are also likely to be given emphasis.

Analyzing fit between the relations among issues as evident in the practice of governance against their portrayal in the media (issue attention-activity fit) therefore offers a unique possibility of highlighting a set of governance areas of interest. Given the two types of relations between issues that are likely to be emphasized more strongly in the media arena than in actor activity, this relates to two main areas. First, areas where relations between emerging, new issues portrayed as such in the media are not reflected in organizational activity can suggest a need for adaptation in the governance system. Second, where relations between contentious issues highlighted in the media are not reflected in increased actor activity surrounding this issue relation, this might point toward areas where conflict obstructs coordination.

Data and methods

The case of Swiss water governance

To demonstrate the value of studying issue attention-activity fit, a suitable case should be representative of a situation where it can substantively add to understanding a complex governance situation. This is primarily the case for situations where multiple, interdependent and thematically wide-ranging issues exist surrounding the governance of given resource. Swiss water governance is such a case for two main reasons.

First, water is a good example of a resource where the need for taking into account complex system properties in its governance is evident. Water typically fulfils a variety of functions (Tropp 2007). Water resources thus cannot be satisfactorily managed through fragmented and localized structures. The nature of the resource introduces complex dependencies, where management in one place directly affects subsequent management situations. Complex linkages and ecological interrelations need to be factored into water management, even on the most basic level.

Second, this multi-functional nature of water as a resource leads to a variety of different actors who deal with interdependent, at times overlapping issues. In Switzerland, this kind of fragmentation is especially found between different sectors, where actors are split between different, but interconnected issues such as biodiversity protection or flood prevention. It is also evident in the complex interplay between different administrative levels (Schmid et al. 2014). Swiss water governance can thus be understood as a complex governance system that revolves around multiple, interrelated issues. The nature of complex interdependencies between issues in such a wide-ranging case cannot easily be approached based on ecological modelling. For an adequate physical modelling procedure, each issue would likely need to be effectively modelled on its own. In Switzerland, this has recently been done for the case of micropollutants (Ingold, Fischer, and Cairney 2017), and fish decline (Burkhardt-Holm and Zehnder 2018), but extends to other issues such as invasive species management, or habitat protection for amphians. Single-issue social-ecological models are crucial in order to obtain precise knowledge about the situation regarding a single issue. A larger mapping of how issues themselves interrelate complements single-issue models by taking into account the larger setting of water governance.

Data structure

For the analysis, issue attention-activity fit Swiss water governance is analysed based on comparing two networks of issues. These networks are each formally represented in an undirected, unipartite and valued graph. Nodes in both networks represent the same complete set of salient issues in Swiss water governance. Differing sets of valued edges in the networks represent the strength of relations between issues based on organizational activity and media attention, respectively[3].

Organizational activity

To represent organizational activity, the study makes use of data gathered in a national level survey of 476 actors involved in Swiss water governance. The survey gathered data on the participation of actors in a set of 56 predefined issues in Swiss water politics. Actors were asked to indicate the issues they had been involved in through projects in the previous three years.

Crucially, the set of predefined issues and actors included in the survey were not defined by the researcher in a top-down way, but identified through an extensive document analysis of newspaper articles, parliamentary discussions and scientific papers covering water issues within the borders of Switzerland. A complete description of this initial procedure can be found in Brandenberger et al. (2015). The actors identified in this way include a wide variety of government (such as municipalities or cantonal offices), interest-group, private (such as engineering firms or power plants) and scientific organizations, reflecting the cross-sectoral nature of governance (Rhodes 1996).

The bottom-up data gathering process applied avoids falling into the trap of predefining policy fields along pre-conceived notions of sectoral silos which may not be adequate for a fragmented policy field such as water. Following this bottom-up logic, the set of actors gathered through the document analysis was later extended through a snowballing procedure in the survey. Organizations were asked to name other organizations they were interacting with on given water issues and these were subsequently included in the actor set. The survey was started in summer 2016 and the snowballing round finished in spring 2017. The response rates for the initial survey and the snowballing round were 69 percent and 64 percent, respectively. This lead to a dataset containing information on organizational activity in Swiss water governance for 313 organizations.

Table 1 displays the distribution of non-response and response among different categories of organizations in more detail. To assess potential bias in response across organizational categories, a logistic regression model was used to model total non-response (Sax, Gilmartin, and Bryant 2003) as a function organizational type, using the categories displayed in table 1. Using interest groups as a reference category, only the organizational categories politics, which mostly includes political parties, and private sector, which includes mostly engineering firms, were statistically significant predictors of non-response (see model results in the appendix, table A1). Thus, the results of the study potentially underestimate the way in which political parties and private firms connect water governance issues, while the

[3] All data and code needed to replicate the analysis can be found in an open online repository under https://doi.org/10.25678/000077

Group	Percentage nonresponse compared to group	Number of respondents	Number of non-respondents
Politics	0.64	16	28
Private sector	0.43	50	38
State and national administration	0.35	53	29
Interest Groups	0.25	63	21
Service Providers	0.25	33	11
Local Administration	0.24	61	19
Science	0.15	17	3
Other actors	0.09	20	2

Table 1: Distribution of survey non-response among organizational groups

coverage of all other organizational groups does not appear to show bias.

The information about the set of issues each organization indicated to have been active in was represented in an actor-issue incidence matrix. The two-mode actor-issue network drawn up by this incidence matrix was projected to a weighted one-mode network of issues connected by actors, based on (Newman 2001). To do so, every shared actor k between a pair of issues i and j is weighted by w_{ij} and added. If x_{ik} equals 1 if the actor k is active in issue i or zero otherwise, this weight is calculated based on

$$w_{ij} = \sum_k \frac{\delta_{ik}\delta jk}{n_k - 1}$$

where n_k is the number of other issues the actor k is also active in. In determining how issues are connected through the activities of organizations, this gives more weight to organizations that focus on a smaller, specific sets of issues. It formalizes the intuition that organizations have a limited number of issues they can pay complete attention to. Organizations that are active in many issues also connect many issues, but these connections are not given as much weight for indicating the connectivity between issues as the connections created by specialized organizations working in a smaller subset of issues.

Media attention

To gather the way in which issues are depicted as related in the media arena, newspaper articles that discussed subjects relevant to Swiss water governance were analysed. These articles raised individual or multiple governance issues. Fundamentally, the more often issues appeared together in the same newspaper article, the more likely they were considered to be perceived as related in public perception.

The analysis of the media data followed a two-step approach, using a combination of machine learning and manual coding. In a first step, for the year 2013, all articles in the Swiss newspaper Neue Zürcher Zeitung (NZZ) that contained the German words for lake, water, or water body were downloaded and manually filtered to identify relevant articles in relation to Swiss water governance (see Blinded).

This data set was used to train a binary classifier to extend the dataset to identify relevant articles for the time span between 2007 and 2017. The training set included 1497 articles judged irrelevant and 100 judged relevant. Four models based on Bernoulli naive Bayes, linear support vector machines, multinomial naive Bayes and neural networks as implemented in Scikit-learn (Pedregosa et al. 2011) were built. In building the models, focus was laid on minimizing false negatives, in order to not miss potentially relevant, weakly determined issues. To further emphasize this, articles were included in the relevant final set if they were present in at least two out of four classifications. In the subsequent filtering of new data, a total of 21'597 articles, which contained the search terms, were classified. 685 articles were identified as relevant.

The Neue Zürcher Zeitung was chosen as the data source for this study because it is generally considered the highest quality newspaper in Switzerland (Hänggli and Kriesi 2010) and reliably reports on issues from a national perspective, taking into account all four linguistic regions. The NZZ has thus been previously used to study media data on the national level (Tresch, Sciarini, and Varone 2013). Still, the choice of a German language newspaper is likely to bias the analysis toward issues occurring within the territory of the German-speaking majority of Switzerland. This was considered acceptable, as this territory covers the majority of the country and crucially includes the three main geographic regions of Switzerland (Alps, Jura and Plateau). Due to this, there is little reason to expect a decisive bias in issue relations regarding water issues due to cultural differences. The choice of a single newspaper as a data source could also make the analysis susceptible to particular kinds of issue framing. However, as the analysis focused on the pure co-occurrence of issues, and not on their framing, such framing would need to occur in the selection of issue coverage itself and not in the content of articles. This is likely mitigated by the long time period and large number of contributing journalists covered in the analysis, but remains a possibility. The long time period further makes it more likely that very recent fluctuations of attention on some issues over time are attenuated.

Another key problem of the approach taken in this study is that the coding of general issues without reference to their exact spatial location does neglect a very important dimension of natural resource governance. This is due to a fundamental trade-off required in order to make general statements about fit on a country level, which is less sensitive to variations in issue interdependence on the local level. For example, the fact that articles often mention landscape protection in conjunction with the construction of hydropower facilities is seen as pointing toward a general trend, which indicates that these issues are perceived as related on average. In extension, this suggests that organizations should consider approaching these two issues as interrelated in their activity. However, the general scope of such statements entails that in some locations, this might not be the case.

In a second step, the articles in the extended dataset were manually coded by the researcher for the presence of the 56 issues related to water governance included in the organizational survey. 456 articles contained at least one issue. This coding procedure resulted in a document-issue incidence matrix specifying which issues were mentioned in every article coded.

Multiplying this document-issue matrix with its transpose creates an issue co-occurrence matrix. In this matrix, for every pair of issues, a number specifies how many times they were mentioned together in the same newspaper article. This matrix was projected to a weighted network of issue relations, where edge values represent the strength of association between two issues. To derive the strength of association, the raw co-occurrence matrix was normalized using the Ochiai coefficient. It is given by:

$$Ochiai(x, y) = \frac{C_{xy}}{\sqrt{C_x C_y}}$$

where C_x describes the sum of occurences of x and C_{xy} the sum of co-occurences of x and y. The projection method used to create this network notably differs from the method used to create the network based on organizational activity due to theoretical considerations given the nature of issue co-occurrence in documents. The Ochiai coefficient is equivalent to applying Saltons cosine similarity directly to the incidence matrix. Due to this, it has been found an appropriate measure to determine association between features of documents, as it addresses problems of skewness in their distribution and the prevalence of large numbers of zeros in most matrix cells (Zhou and Leydesdorff 2016).

Thus, the use of the Ochiai coefficient to establish a measure of issue relation based on media data represents a normalization procedure chosen due to the expected properties of the data under study (documents). The Newman (2001) projection method used to create the organizational activity network however was chosen to more substantive considerations about the nature of what constitutes an issue relation rooted in organizational activity. It gives more weight to edges created by exclusive co-occurrence in the second (actor) mode of the network, which was seen as desirable to establish issue relations based on governance activity, because it emphasized the contribution of expert, focused organizations and reduced the influence of very active organizations creating spurious relations. Contrary, this feature of the Newman (2001) projection method would have been less desirable for measuring media attention on issue relations, where exclusive co-occurrences of issues in articles were not considered to have the same substantive interpretation in indicating a substantially higher amount of interrelation and articles mentioning a very large number of issues were less common.

Fit assessment

The two weighted issue networks were combined to create a fit assessment for every pair of issues they contain. Issues mentioned by four or less organizations or documents were removed from both datasets, as making general statements based on such a small number of data points was deemed inappropriate. To combine the networks, the edge weights of both networks were uniformly scaled to range from zero to one, to make them comparable while conserving the original weight distribution. Diagonals of both matrices were set to zero as self-ties among issues do not have a substantive interpretation in this context. Afterwards, the weighted adjacency matrix of the media-based issue association network was subtracted from the weighted adjacency matrix of the organizational activity network. For every pair of issues this created a value between -1 and 1.

An important consideration regarding this procedure relates to the endogeneity that arises due to the fact that organizational activity is likely to be reflected in media data reporting on it, which in turn engenders subsequent activity. In the context of this study, this is most likely to lead to an overestimation of fit, while it should affect the diagnosis of misfit to a lesser degree. As the assessment of misfit is the main interest of the study, the influence of the endogeneity problem is thus reduced, but should be kept in mind in the interpretation of the results.

Results and Discussion

Figure 4 shows the network of issue relations evident in organizational activity, contrasted with the network specifying issue relation based on the media attention. The fit diagnosis combines the information derived from these two networks. Figure 5 displays the results in a heatmap. High negative values indicate that high attention on an issue relation in the media data is not replicated likewise in actor activity (misfit). Values around zero indicate fit. High positive values indicate that actors do relate issues in their activity in a way not picked up by the media data, which is informative regarding the types of connections between governance issues that are covered less or ignored in the media, but are reflected in organizational activity.

Figure 5 shows that organizational activity in Swiss water governance matches the way issue relations are publically perceived in most cases. This is especially the case for the generally strictly regulated and uncontroversial areas of flood protec-

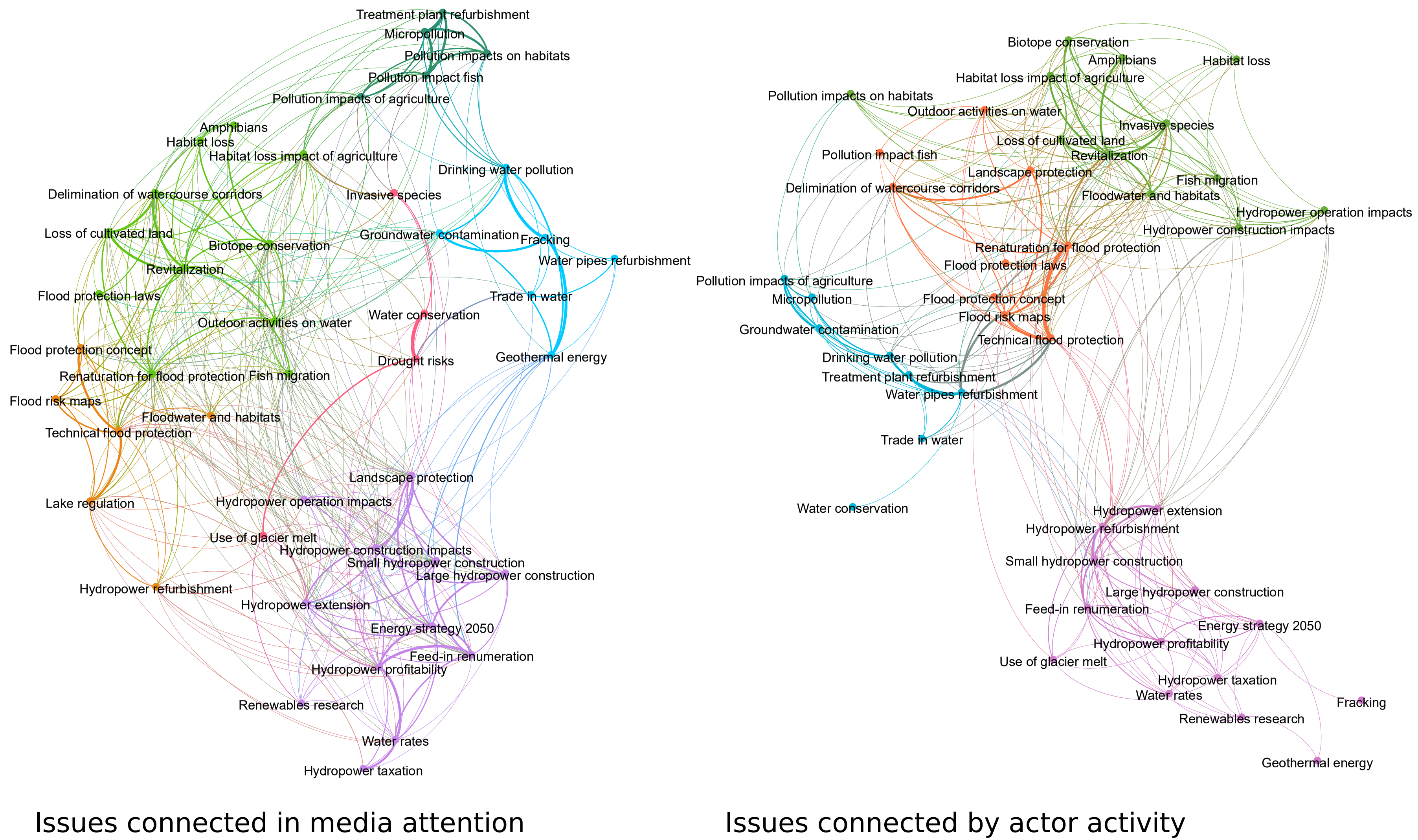

Figure 4: Networks of issue associations in Swiss water governance based on co-occurence in media data (link size based on Ochiai similarity) or actor activity (one-mode projection of two-mode actor-issue network, link size based on Newman (2001) projection). Nodes are colored based on modularity classes identified using the algorithm described in (Blondel et al. 2008), as implemented in the software Gephi (Bastian, Heymann, and Jacomy 2009).

tion, municipal water supply, and waste water treatment. Issues in these areas are often not very politicized, highly technical, and focused on the implementation of existing laws. Beyond the majority of issue relations where fit is generally high, the fit diagnosis also points out specific areas of misfit. These are discussed in the following. Table 2 shows the issue pairs with the ten highest negative fit scores.

The most striking area of misfit exists between issues related to the exploitation of subterranean resources (mostly fracking) and drinking water protection, which feature three times in the five highest negative fit scores. This is most likely due to the fact that the issue of subterranean resources is a relatively new and so far incoherently regulated issue in Switzerland (Ingold, Fischer, and Cairney 2017). While some organizations are active in the field, there have only been a small number of projects. However, as the issues are strongly related, it points to a potential area of future conflict. Should the exploitation of subterranean resources become more widespread, organizations that are active in drinking water protection will need to become more involved in an issue that they currently are likely to have little expertise in. This points to a way in which the concept of issue attention-activity fit can operate as a method for recognizing potential future areas of necessary coordination or regulation i.e. if the public discussion relates two issues, but this is not yet reflected in organizational activity.

The misfit between drought risks and water conservation further illustrates this point. Considered one of the main adaptation challenges due to climate change for Switzerland, drought has been on the agenda of administrative agencies in Switzerland for a number of years. In a study of the social capacity to adapt to drought risks in Switzerland, Kruse and Seidl (2013) find that preconditions for capacity building are generally present, mostly due to previously successful ad-hoc management strategies. However, institutional fragmentation and lack of financial resources have so far hampered more long-term strategic adjustments. The results of this study are in line with this assessment. Actors involved in water conservation did not indicate that they consider drought risks regularly in their projects. This shows that the recognition of drought as a potential problem, while on the public agenda, has yet to reach most organizations. A potential reason for this is the fact that Switzerland, considered Europes water castle for a long time, is historically unused to drought events. The fit diagnosis in this case thus interestingly illustrates a case of slow adaption of the governance system to change.

The value of an issue attention-activity fit measure in identifying future areas for improving coordination is illustrated a third time in the misfit between micropollution, pollution impacts on fish, and the refurbishment of treatment plants. The issue of micropollutants, chemical substances of very low concentration levels, represents a com-

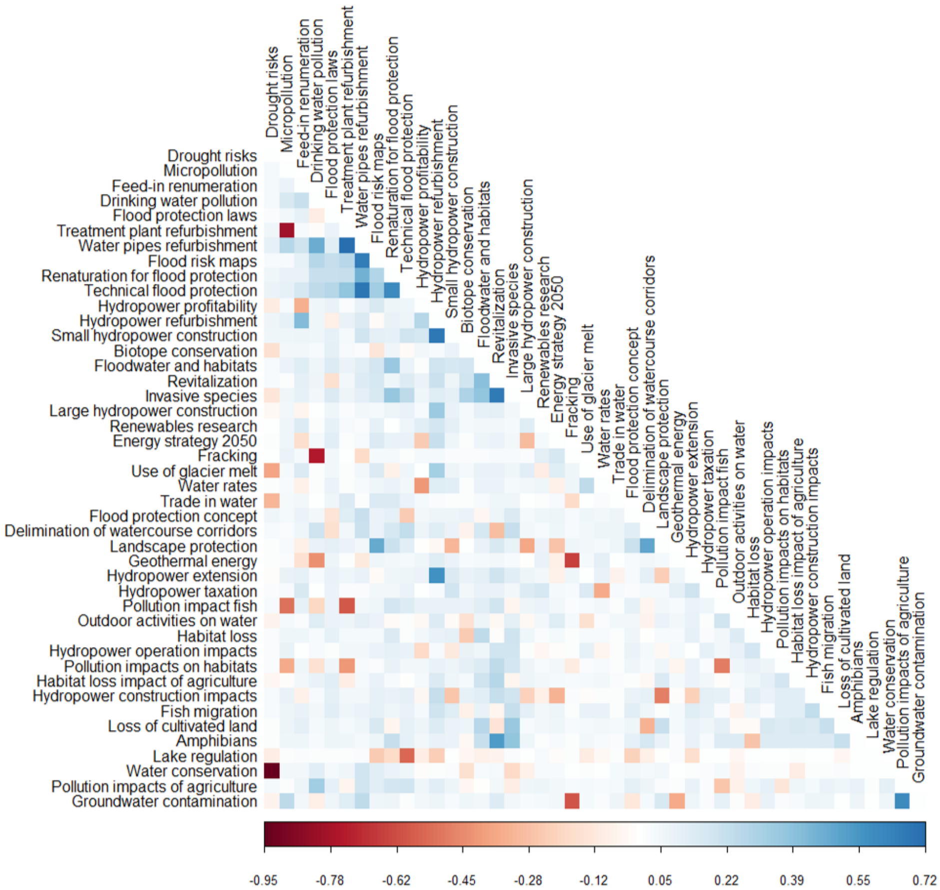

Figure 5: Results of issue attention-activity fit diagnosis for all pairs of issues in Swiss water governance. Red colors indicate misfit in that the emphasis given to relations between issues in media data is higher than the way in which actors treat issues as related in their activity. Absence of color indicates fit. Blue colors indicate relations between issues apparent in actor activity not reflected in media coverage.

Issue 1	Issue 2	Fit measure
Drought risks	Water conservation	-0.95
Treatment plant refurbishment	Micropollution	-0.8
Fracking	Drinking water pollution	-0.75
Fracking	Geothermal energy	-0.66
Fracking	Groundwater contamination	-0.59
Treatment plant refurbishment	Pollution impact fish	-0.59
Technical flood protection	Lake regulation	-0.55
Micropollution	Pollution impact fish	-0.51
Pollution impact fish	Pollution impacts on habitats	-0.49
Landscape protection	Hydropower construction impacts	-0.48

Table 2: Ten issue pairs with highest absolute values of negative fit scores, indicating media attention to an issue relation is not matched by organizational activity.

plicated policy problem (Metz and Ingold 2014). Policy-makers have only recently addressed it with a decision to upgrade the biggest Swiss municipal sewage treatment plants. The low fit between treatment plant refurbishment and micropollution indicates that this process has not yet led to projects tackling the issue for most organizations. It can be expected that this will change in the near future, at least for bigger treatment plant operators.

Another area of misfit surrounds the issues of landscape protection and hydropower construction, which is interesting because comparable levels of misfit cannot be found for the biodiversity impacts of hydropower construction and operations. Landscape protection (related to preserving the aesthetic and cultural value of the landscape) and biodiversity protection (more specifically targeting individual species and habitats) are strongly related. Most measures targeting landscape protection also have beneficial effects on biodiversity, and vice versa (Gerber and Knoepfel 2008). However, while biodiversity impacts of hydropower are strongly regulated in Switzerland, the impact of hydropower projects on landscape quality has become a contentious political issue.

The federal act on the protection of waters of 1991 and the accompanying water protection ordinance, which was enacted in an updated version in 2017, introduced strong regulation regarding the biodiversity impacts of hydropower operation. It regulates issues such as minimum residual flows and fish migration. Media articles show that this has led to an increased activity and inclusion of nature protection organizations in hydropower projects, who can claim a firm legal footing for complaints. Likewise, hydropower operators had to initiate new projects to restore facilities that did not meet prescriptions. An exemplary case includes the construction of the Rhone Oberwald power plant in the canton of Wallis, where the inclusion of nature protection organizations in the planning of the project in 2013 led to a compromise to compensate the impacts on residual flows by ecologically restoring another section of the river.

Landscape protection areas on the other hand have come under pressure in Switzerland. Switzerland decided to put in motion a process to restructure its energy system, phasing out nuclear energy to replace it with renewable energy after the nuclear disaster in Fukushima in 2011 (Fischer 2015). This has raised the possibility of a substantial increase in hydropower production capacity. In order to do so, the relaxing of restrictions on the construction or extension of hydropower projects in landscape protection areas has been particularly controversial (Gurung et al. 2016), especially within the most widespread landscape protection areas catalogued in the federal inventory of landscapes and natural monuments of national importance (BLN). An exemplary case was the proposal in 2013 to build a new hydroelectric power plant near the Rhine falls in Schaffhausen. Due to fears that it would diminish the landscape value of the falls, the proposal was rejected in a popular referendum in 2014.

The different regulatory backgrounds regarding landscape and biodiversity protection therefore explain why organizations involved in hydropower projects tend to consider biodiversity issues much more than questions of landscape protection. It also suggests that organizations focused on landscape protection could switch to contesting projects based on their biodiversity impacts in the future, as these issues often overlap.

Lastly, the misfit between lake regulation (where water levels in lakes are adjusted to provide a buffer in order to prevent or mitigate flooding) and technical flood protection, such as the building of dams, illustrates that an apparent misfit can also be due to the formal regulatory framework. Lake regulation is controlled by the federal administration, while the implementation and upkeep of technical flood protection measures often takes place at the municipal level. It is therefore not surprising that organizations involved in technical flood protection projects (mostly municipalities and engineering firms) did not tend to indicate that they encountered the issue of lake regulation in their projects as well. Given that the federal office for the environment indicates a high awareness of the interconnection between lake regulation and a whole range of other water governance issues, the apparent misfit between lake regulation and flood protection is thus most likely not an area of substantive misfit. However, it also points toward a top-down process, where an inclusion of lower-level stakeholders is lacking at the moment and might be more advisable in the future. On a more general level, this further illustrates that fit diagnoses should always be followed up by a careful consideration of the substantive issues they reflect, in order to properly interpret them.

The results of the case study of Swiss water governance discussed here show that issue links present themselves as a useful way to analyse a set of relevant properties of a complex, large-scale governance system. However, it remains important to stress that an issue based approach may ignore important ecological interdependencies that are not recognized as collective action problems by social actors. In the end, governance issues need to be recognized as socially constructed representations of probable underlying ecological system properties and discussed from this perspective. This is also especially important in contexts where, for example, state censorship influences and restricts public discussions of issues.

Still, actionable research may often be better served with a system representation that is not complete but sufficient for the task at hand (Dee et al. 2017). In this vein, it is conceivable that an analysis of fit rooted in relations between governance issues could be well applicable to local-level, small-scale governance situations, such as the management of regional protected areas. If stakeholders have a rough approximation about how governance issues related to natural resources in their domain are linked, data gathering procedures such as mental maps (Özesmi and Özesmi 2004), participatory mapping (Brown et al. 2017), collaborative modelling (Morisette et al. 2017), or qualitative, expert-driven assessments of task relations (Bodin and Nohrstedt 2016) are promising options for establishing issue links in these situations and might even provide an acceptable proxy for ecological ties. Comparing issue linkages based on such assessments with a detailed analysis of organizational activity could, for example, be used to point out a need for increased cross-scale governance if organizations address related issues on different jurisdictional levels.

Conclusion

Investigating Swiss water governance as a network of interrelated issues and combining media data with data on organizational activity has illustrated a way to put a highly complex system within the reach of systematic analysis. Pre-eminent areas of issue attention-activity misfit found in Swiss water governance relate to the coordination between water saving measures and drought risks; the exploitation of subterranean resources and drinking water protection; and issues of micropollutants.

For the case of drought risks, the challenge is how to overcome the apparent inertia in the governance system in recognizing an unusual problem for Switzerland, fraught with uncertainty. Drought risk issues seem to be sufficiently studied and discussed by scientific and higher-level administrative organizations, but as this study shows, they are not considered in actual governance practice yet. Strategies to deal with drought risks should thus consider a pivot toward putting emphasis on information dissemination. For the relation between emerging issues surrounding the exploitation of subterranean resources and drinking water protection, the apparent misfit is due to gaps in the formal regulatory framework. The establishment of such a framework can lead to improved fit, as comparing the high fit between biodiversity protection and hydropower construction, compared to the misfit between landscape protection and hydropower construction, has shown. Issues surrounding micropollutants represent a harder problem to solve. Switzerland is ahead of most European countries in upgrading waste water treatment plants to address the problem. Still, a holistic approach should also include preventive measures, which requires increased coordination between organizations from different sectors. Crucially, governance also needs to be coordinated with neighbouring countries, as the problem is transboundary, adding to its complexity (Ingold et al. 2018).

Fit concepts present themselves as useful conceptual tools for analysing the alignment of human action and interaction with the natural world. Since the initial introduction of functional fit, fit concepts have matured greatly (Folke et al. 2007). The adoption of the concept by network researchers is a particularly interesting avenue in this development. The present study gives further evidence that network concepts provide a stable basis to carry out fit assessments (Bodin, Sandström, and Crona 2017). It also shows that the potential of fit concepts goes beyond social-ecological models and demonstrates the complementary value of considering relations between governance issues in the study of natural resource governance.

A crucial area of future research should put emphasis on consequences of quantified measures of fit. This study has assessed fit based on an implicit normative assumption that increased fit improves governance outcomes. However, the causal links implied by this assumption need to be better established. A key question concerns what could be called the optimal level of fit. This becomes especially relevant under the assumption of decreasing marginal benefits of adding more coordinating actors between connected components of governance. Put another way, it is hardly optimal for every organization involved in collaborative governance to be involved in every issue. The question for future research must thus revolve around finding the right kind of actors to create fit, balancing both efficiency and legitimacy.

Finally, relations between issues in governance are neither static nor are their relationships always clear. The key to considering this in the study of fit are models that see fit as a dynamic concept, including an assessment of adaptive capacity. In doing so, the consequences of uncertainty in issue relations and (nonlinear) changes over time on fit should be explored, potentially in conjunction with recent studies of network resilience in natural resource governance (Moore, Grewar, and Cumming 2015). Adaptive capacity and flexibility are crucial in this respect and include not only the formation, but also the conditions for the maintenance and severance of ties.

To explore such questions, formalized measures of fit, as developed in this study and others (Bodin, Sandström, and Crona 2017; Sayles and Baggio 2017b), need to be compared across cases and contrasted with outcomes or, even better, compared over time, while keeping in mind the needs of policymakers and practicioners for actionable evidence.

Connectors and coordinators in natural resource governance: insights from Swiss water supply

Fragmentation across scales in natural resource governance can impede coordinated action and decrease innovation capacity. Bridging actors who connect others within governance networks helps to overcome this challenge. We analyze two bridging positions for actors in governance networks. First, periphery connectors integrate otherwise unconnected actors and provide access to new knowledge. Second, central coordinators efficiently connect actors at the center of the network and thus facilitate coordinated action. We propose a way to identify periphery connectors and central coordinators within governance networks and formulate expectations about types of actors that are likely to occupy these positions. An analysis of three actor networks in the water supply sector in Switzerland suggests that periphery coordinator positions are more likely to be occupied by organizations at higher jurisdictional levels. Central coordinator positions are more likely to be occupied by governmental actors as compared to nongovernmental actors. Thus, in addressing challenges of fragmentation, higher level governmental actors continue to play an important role, even when they delegate responsibilities to lower level and private actors.

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Introduction

Coordination in natural resource governance is a difficult task because of the involvement of many governmental and non-governmental actors operating at different levels of spatial and jurisdictional scales (Cash et al. 2006; Ostrom 2009; Pahl-Wostl 2009). Changes in institutions and policy designs that emphasize self-organization of actors in governance networks are one way to address the challenge of coordination (Folke et al. 2005). Collaboration between individual actors in governance networks can thus mediate the challenges of fragmented natural resource governance (Bodin and Crona 2009).

Actors within such governance networks, intentionally or inadvertently, take up different positions, which potentially contribute to coordination. For example, McAllister, Taylor, and Harman (2015) examine how organizations influence climate change adaptation planning in Australia by playing a select set of roles within governance networks. One type of role includes organizations that interact with many other different types of organizations and are thus important for disseminating knowledge throughout a fragmented governance landscape. The study of Ernstson, Sörlin, and Elmqvist (2008) demonstrates that a lack of organizations that integrate peripheral groups with valuable ecological knowledge into the management of urban green areas could have constrained more collaborative management. In a similar vein, Vignola, McDaniels, and Scholz (2013) identify so-called bridging organizations, which transmit information across scales and policy areas, as key actors in a study of watershed management in Costa Rica.

This analysis focuses on actors who occupy bridging positions in natural resource governance networks in further detail. In general, actors in bridging positions connect other actors who would not be connected otherwise (Granovetter 1973). We focus on two types of bridging that each address an essential governance challenge resulting from fragmentation. First, bridging ties can connect peripheral actors to the network. This integrates a more heterogeneous set of actors into the network, which provides access to new knowledge to the rest of the network (Carlsson and Sandström 2008). Second, bridging ties can efficiently connect actors who need to coordinate their actions across levels of scales (Ernstson, Sörlin, and Elmqvist 2008; Rathwell and Peterson 2012). Based on these two types of bridging ties, we analyze two actor positions in governance networks: periphery connectors and central coordinators. We then ask which actors are likely to occupy these positions.

Answers to our research question contribute to the literature in three ways. First, on a theoretical level, we develop a precise understanding of periphery connectors and central coordinators as two important bridging roles. The theoretical value of this distinction extends to the existing literature in policy studies and natural resource governance, where concepts of bridging roles are ubiquitous (Ernstson, Sörlin, and Elmqvist 2008; Bodin and Crona 2009; Christopoulos and Ingold 2015). Our study answers the demand for a more profound analysis of individual actors occupying critical positions in natural resource governance (Bodin and Crona 2009). Second, on the methodological level, we propose a straightforward operationalization of both role concepts. Especially, we identify periphery connectors by adapting a bridging measure developed in the social network analysis literature (Valente and Fujimoto 2010). Third, on the empirical level, we provide insights into governance settings with a very high potential for fragmentation. An empirical analysis of three regions in Switzerland with different socioeconomic contexts allows us to identify the actors that are most likely to occupy periphery connector and central coordinator positions in these settings.

The role of actors in overcoming fragmentation in natural resource governance networks

Fragmentation in natural resource governance

Following (Jasny and Lubell 2015), we define fragmentation as a setting where actors have overlapping responsibilities for issues that span across multiple levels of a relevant scale of governance, or work independently on interconnected issues. Fragmentation impedes effective governance (Carlsson and Sandström 2008; Ekstrom and Young 2009; Bodin et al. 2014) especially because of competing responsibilities between different actors (Jasny and Lubell 2015). Such competing responsibilities are a fertile ground for collective action dilemmas (Berardo 2014, p. 238). By contrast, reducing fragmentation by integrating new and nonpublic actors in the governance system has the potential to include new views, information, and perspectives (Prell, Hubacek, and Reed 2009) and enhance creativity and innovation (Betsill and Bulkeley 2004).

Institutional adjustments have been suggested to reduce fragmentation. For example, the concept of institutional fit (Folke et al. 2007) suggests to better match ecological system structure with formal and informal rules (Ekstrom and Young 2009). Although adjusting institutions is thus a way to address issues of fragmentation, individual actors can also contribute to overcoming fragmentation in a governance network without institutional change.

Overcoming fragmentation through bridging

Among actors who can contribute to the reduction of fragmentation, actors in bridging positions play an important role. The literature on social networks in natural resource governance has highlighted different forms of bridging (Fernandez and Gould 1994; McAllister, Taylor, and Harman 2015), such as cross-scale brokerage (Ernstson et al. 2010; Rathwell and Peterson 2012), within- and across-type bridging (McAllister, Taylor, and Harman 2015), or brokering across venues or issues (Lubell 2013b; Fischer, Angst, and Maag 2017). Although these analyses have addressed specific sources or problems of fragmentation (levels, actor types, and issues), we provide a more general division of bridging activity in regard to two main problems of fragmentation. These problems are the loss of access to new knowledge and inefficient coordination and we suggest distinguishing two essential bridging positions that can help to overcome them: periphery connectors and central coordinators.

Periphery connectors integrate otherwise unconnected actors to the core of the network. Many studies observe a core-periphery setting in governance situations, where a well-connected group of core actors can be distinguished from a loosely connected periphery (Ernstson, Sörlin, and Elmqvist 2008; Luthe, Wyss, and Schuckert 2012; Hirschi et al. 2013; Angst and Hirschi 2017). Periphery connectors maintain contact to the margins of the network and support access to and integration of new knowledge. Peripheral actors are often sources of information heterogeneity in a network because they are likely to be less prone to groupthink, sticky information (Burt, Kilduff, and Tasselli 2013) and homophilous processes (where actors who interact often become more similar over time) acting among strongly connected actors. Furthermore, heterogeneity has also been associated with effectiveness and adaptability in natural resource governance networks (Carlsson and Sandström 2008).

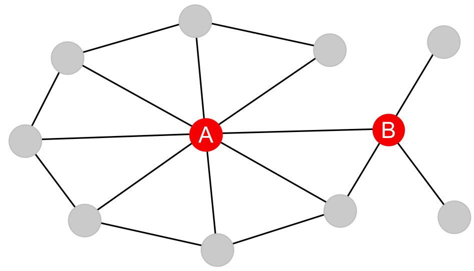

Figure 6: Illustrations of network positions of periphery connector (A) and central coordinator (B) positions.

Central coordinators play a different bridging role than periphery connectors. They do not reach out to the periphery, but rather can facilitate coordinated action because of their central position. The defining characteristic of central coordinators is that they connect a great number of other actorswho might be connected to each other but over longer pathsin a very efficient way. This means that they provide the shortest network paths between many other actors, making them logical choices if one actor wants to reach other actors. Central coordinators are thus key actors if it is necessary to coordinate action and disseminate information. We focus on bridging centrality in this study, but there are various other ways actors can be central in a network. Bodin and Crona (2009) highlight several examples of how central actors can contribute to governance outcomes through information distribution and leadership that go beyond our specific focus on overcoming fragmentation. Figure 6 illustrates ideal-typical periphery connector (A) and central coordinator (B) positions.

Hypotheses about distribution of positions

Some types of actors have been shown to be more likely to occupy specific positions in natural resource governance networks. For instance, Kininmonth, Bergsten, and Bodin (2015) conclude that large municipalities are crucial to enhance the compatibility between the governance network structure and ecological interdependencies in wetland management. Fliervoet et al. (2015) show how nongovernmental actors depend on the resources and connections of governmental actors in new governance approaches to natural resource management. Exploring the role of local actors in regional land use planning, Ingold (2014) concludes that mainly intermediate-level actors, in contrast to local or national actors, connect different parts in multilevel networks. By contrast, Angst and Hirschi (2016) show that higher level actors such as the national administration provide stable and lasting connections and thus play a crucial role in network development over time.

Hypothesis 1: Periphery connector positions are more likely to be occupied by actors at a higher jurisdictional level than by lower level actors.

Actor attributes are thus likely to influence which actors take up periphery connector and central coordinator positions. There is a line of argument within the environmental governance literature that stresses that directly affected, local level stakeholders are best suited to resolve resource degradation problems and thus need to be included in the decision-making process (Ostrom 2000). The involvement of actors on higher levels in a polycentric arrangement has, however, also been shown to positively affect governance outcomes, provided that these actors do interact sufficiently (Newig and Fritsch 2009). The concept of periphery connectors relates to this discussion, as it highlights a mechanism through which higher level actors can influence the effectiveness of governance in terms of ensuring sufficient interaction. Periphery connectors represent a network position that is important for assuring integration of diverse knowledge but is not necessarily (but can be) involved in the direct management of a resource. We posit that higher level actors, who are less affected by the mostly local or regional environmental problems and the related solutions, are more likely to be such periphery connectors. These actors tend to be involved in many different governance processes, compared to local level stakeholders focused on local problems. This involvement allows them to gain experiences, to transfer knowledge from one setting to another, and to access a wider network of different actors.

Hypothesis 2: Central coordinator positions are more likely to be occupied by governmental actors than by nongovernmental actors

Whereas forms of self-regulation with only little direct involvement of public authorities and governmental actors became prominent steering arrangements in environmental governance (Ostrom 2009), public actors still play an important role. Effective (environmental) governance often results from actors interaction in the shadow of hierarchy (Bolleyer and Börzel 2010, p. 182). Even in settings where they surrender formal power, governmental actors can exert substantial influence by putting themselves into coordinating positions (Fliervoet et al. 2015; Fischer and Schläpfer 2017). This enables them to pursue their interests without having to rely on strategies of top-down enforcement. A similar argument is made by the literature on network management and meta-governance of networks, referring to the capacity of governmental actors to steer networks by facilitating interaction processes, mediating conflicts, and reallocating resources (Klijn and Koppenjan 2000). Besides, government and its administration are also more likely to have the necessary resources to occupy central coordinator positions, as compared to other actors. They often employ a larger, specialized workforce than other actors but most importantly, governmental actors in most cases still maintain the formal responsibility to initiate and structure policy processes. Consequently, they are often the preferential targets for collaboration for other actors (Leifeld and Schneider 2012; Ingold 2014; Bursens, Beyers, and Donas 2014) and can draw upon sources of power such as the setting of collaborative agendas and institutional capacities (Brisbois and Loë 2016) that other actors often do not possess. Thus, we expect governmental actors rather than nongovernmental actors to occupy central coordinator positions.

Case, Data, and Methods

Case characteristics and data

Our empirical cases cover collaboration networks in water supply governance of three administrative regions in the Swiss canton of Basel-Landschaft. Water governance is a setting that is generally prone to fragmentation (Jasny and Lubell 2015). In Switzerland, the water supply sector is strongly shaped by the federalist structure of the country: water supply is a formal responsibility of the subnational states (so-called cantons), respecting general national laws and the regulation of water quality and provision as laid out in the Constitution. When it comes to operational tasks of water distribution, provision, and infrastructure however, responsibilities typically are delegated to the municipalities.

More recently, several reforms have been initiated to regionalize water supply; that is, to encourage municipalities to comanage water supply tasks, often also involving new actors such as private companies.

Consequently, regionalization increases the potential for fragmentation. Moreover, new challenges such as an increasing number of extreme events or aging infrastructure demand the inclusion of further organizations such as scientific experts or planning and engineering firms. This reorganization further increases the need for coordination and collaboration in the water sector.

In terms of case selection, studying three cases within a single subnational state holds many intervening factors constant. Reforms in terms of reorganization and regionalization of water supply, encompassing the comanagement of and shared responsibility for service supply tasks, finances, and infrastructures have been proposed in the three selected cases. The three regions represent an urban, a peri-urban, and a rural area, respectively. Whereas the first two are located in flatland areas with industrialized sites, the latter region is characterized by mountainous landscape and agriculture.

Data for our analysis of the collaboration networks stem from a survey carried out between September and December 2015 among public authorities and stakeholders involved in the water supply sector. For actor identification, we started with a preliminary interview with the subnational lead-agency. Through scoping interviews and snowball sampling conducted in late 2013 and early 2014, the full actors list was first drawn, then validated by seven public officials and key stakeholders from the three regions. For each of the three regions, the actor list included state and federal offices, municipal authorities, waterworks, engineering companies, water providers, local water technicians, and relevant interest groups. Survey participants were considered as representatives of public or private organizations, thus answering the survey questions on behalf of a corporate actor (Coleman 1974). The only exceptions were local water technicians: though a majority were public actors, they typically carried out their task as individuals.

Respondents were asked to indicate with which other actors on the actor list they regularly collaborated in water supply management in the region. Regular collaboration was defined as either the repeated exchange of information or the joint implementation of projects. We surveyed 64 actors in the urban, 56 actors in the peri-urban, and 52 actors in the rural region. Response rates were 93%, 86%, and 92%, respectively. Based on the survey responses, we found three collaboration networks with 79 actors in the urban, 73 actors in the peri-urban, and 59 actors in the rural region. The collaboration networks include more actors than surveyed because some actors indicated nonrespondents as collaboration partners. There were many actors that were involved in all three regions. These were generally actors situated on higher administrative levels, such as state and national agencies or interest groups. However, their collaboration patterns were assessed for every region separately. Actors were manually assigned a dummy variable to indicate their status as governmental or nongovernmental. They were also manually assigned one of four jurisdictional levels based on an organizations main focus of operations. The four jurisdictional levels considered were local (single municipality), regional (multiple municipalities), state (across the whole state), and national (extending beyond the state of Basel-Landschaft).

We symmetrized all three networks in our analysis based on a weak criterion, establishing an undirected tie whenever one actor indicated another actor as a collaboration partner. We symmetrized the data in order to remove directed ties because the conceptual meaning of directed ties in a collaboration network is hard to interpret, given that collaboration is a process that always involves the participation of both parties. We chose weak rather than strong symmetrization because it also captures lower forms of collaboration where actors are not equally willing to call their relationship collaboration. However, such forms of collaboration capture phenomena such as access to information or sporadic contact that we expect to be a more likely form of interaction among actors of the periphery and the core.

Operationalizing periphery connectors and central coordinators

The operationalization of periphery connector positions was based on assessing the number of actors that are solely connected to the network by a given actor. To do so, we assessed the effect of the removal of every actor on its own on the number of actors in newly created components apart from the main component of the network because of the actors removal. We thus estimated the effect of node-wise deletion on an overall structural network characteristic akin to the procedure suggested by Valente and Fujimoto (2010) who locate critical connectors via edge-wise deletion.

For central coordinators, we relied on betweenness centrality (Borgatti and Everett 2006). Betweenness centrality measures how often an actor lies on a shortest path between any two actors it is connected to. A shortest path is defined as the connections with the minimal number of connections that an actor needs to reach another actor. For each shortest path that passes through a node, if there exist other paths that bypass the node, the contribution toward the nodes betweenness centrality score of this shortest path is divided by the total number of shortest paths. Betweenness centrality measures exactly what we understand as central coordination, namely, the provision of efficient pathways within a network captured in the relative number of shortest paths running through a node.

We computed betweenness scores based on an actors position in its respective ego network of order 2 (this includes cross-connections between all other actors an actor is connected to). This means that all other actors connected to the ego by paths of length 1 or 2 were included in our computation. Betweenness scores thus reflected an actors position within a local ego network. The reason for focusing on ego networks is that for collaborative activities it is difficult to attach substantive meaning to path lengths longer than 2 (Gould and Fernandez 1989).

Analytical steps

In a first step, we identified the actors that were positioned within the network according to our operationalization of periphery connector and central coordination positions. We extracted ego networks and calculated betweenness scores using the R packages statnet (Handcock et al. 2003) and igraph (Csardi and Nepusz 2006). In order to check whether our networks exhibited a core-periphery structure, we also partitioned the network datasets using the CORR algorithm implemented in UCINET (Borgatti 2002) to assign actors to two distinct sets by maximizing the correlation between the observed and an ideal core-periphery structure.

In a second step, we carried out a statistical analysis to assess our hypotheses about the distribution of positions. It compared our observed networks to a large number of simulated networks in a permutation-based approach. In social network analysis, permutation-based approaches are used to construct null models that provide a baseline against which to compare the empirically observed networks. These permutation models aim to preserve the network structure while allowing for individual actor positions to vary (Spiro, Acton, and Butts 2013). For this analysis, we specified a pooled exponential random graph model (ERGM), which fit the set of parameters that on average best represent the data generating process throughout all three regions.

The pooled model was used to simulate a baseline distribution of positions that takes into account the main processes that shape the structure of the networks under study. We then compared this distribution against our observed distribution of network positions. We modeled both dyad-independent and dependent processes we theoretically expected to play a role in shaping network characteristics in our cases. We deemed the use of a pooled model, resulting in the same set of parameters for every region, to be superior to the estimation of a separate model for every case. It increased our confidence in comparing inferences based on baseline distributions generated through a process that is identical for every region because we saw no theoretical reason why the basic underlying processes shaping network structure should vary significantly between our cases.

We considered two dyad-independent processes in our model. First, we expected the respective activity of different actor types to vary. In this regard, we included terms that model activity for actors on different jurisdictional levels because we expected intermediate and lower-level actors to be more active in the network in general.

Second, we also expected homophilous processes based on actor type to shape the networks. This encompasses a potential tendency for actors to favor similar actors in collaboration. In this regard, we modeled homophily among actors situated on the same jurisdictional level. We expected networks to be strongly shaped by this process because state-level actors in particular are often formally mandated to collaborate among themselves. Further, we also considered dyad-dependent processes that include the propensity for triadic closure and the shape of the degree distribution because these processes are generally expected to play a role in shaping governance network structure (Robins, Lewis, and Wang 2012).

After achieving a satisfying fit, our pooled model was used to simulate 1000 random networks for every region. These simulated networks, by the virtue of being based on a fitted model, captured many of the basic processes inherent in our empirical cases and therefore reflected theoretically important processes shaping network structure we wanted to control for. This enables us to assess whether our empirically observed position patterns were more likely to occur than by chance, while controlling for our modeled effects. We did so by comparing the empirically observed distribution of positions to the related distribution in the simulated networks. We analyzed two distributional patterns based on our hypotheses about factors shaping the distribution of positions. We assessed the likelihood for (a) higher level (state and national level) actors to be periphery connectors, and (b) governmental actors to be central coordinators. For reasons of comparison, we further analyzed the distributional patterns and related likelihoods of (c) governmental actors to be periphery connectors, and (d) higher level actors to be central coordinators. We estimated, simulated, and assessed goodness of fit of ERGMs using the R package xergm (Leifeld, Cranmer, and Desmarais 2016).

Results and Discussion

Distribution of positions

All networks show a more-or-less pronounced core-periphery structure with within-core densities between 0.55 and 0.67 and within-periphery densities between 0.04 and 0.05. This result indicates that the networks can be partitioned in a strongly connected core and a weakly connected periphery, which corresponds to our observation, based on previous studies, that in many governance situations, a well-connected group of core actors can be distinguished from a loosely connected periphery (Ernstson, Sörlin, and Elmqvist 2008; Luthe, Wyss, and Schuckert 2012; Hirschi et al. 2013).

Figure 7 shows all three collaboration networks. The identified periphery connectors and central coordinators are indicated by color. We consider an actor to be a periphery connector if the actor connects a minimum of two peripheral actors that would otherwise not be connected to

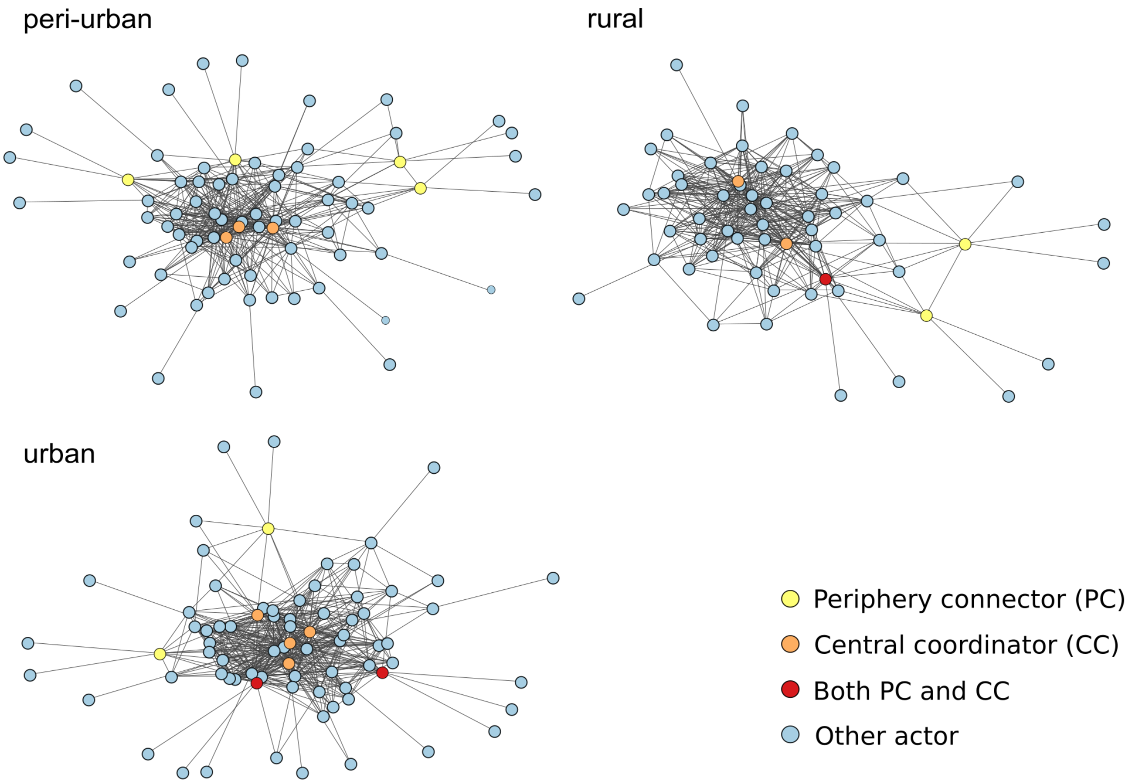

Figure 7: Collaboration networks in water supply for three regions in the Swiss canton of Basel-Landschaft. Colors indicate periphery connector and central coordinator positions.

the network. Further, we consider actors to be central coordinators if their betweenness scores within their respective ego network exceed a cut-off value of two standard deviations of the scaled distributions of these measures in their respective networks. We chose this cut-off value based on a sensitivity analysis (see figure A6 in the appendix), balancing the need of having a comparable cut-off value across regions and choosing a cut-off point at a value where small variations do not create large jumps in the number of central coordinators.

We identify four periphery connectors in the urban and peri-urban regions and three in the rural region. Six central coordinators are present in the urban region, and three in the peri-urban and rural regions. The distribution of these actors by jurisdictional level and governmental/nongovernmental status is detailed in table 3.

The comparison of simulated distributions of actor positions versus observed values for the interaction with the set of actor attributes covered in our hypotheses is shown in Figure 8. Generally, our results are stable in their tendency across regions. This suggests that the processes generating the distribution of positions are similar across socioeconomic contexts, even though these regions differ with respect to the challenges to water supply governance.

	periphery connectors			Central coordinators		
Attribute	Urban	Peri-urban	Rural	Urban	Peri-urban	Rural
Governmental	2	2	2	2	2	2
Non-governmental	2	2	1	4	1	1
Federal level	1	1	1	1	0	0
State level	2	2	2	4	3	3
Regional level	0	0	0	0	0	0
Local level	1	1	0	1	0	0
Total	4	4	3	6	3	3

Table 3: Number of periphery connectors and central coordinators per region and by type (governmental/ non-governmental) and jurisdictional level

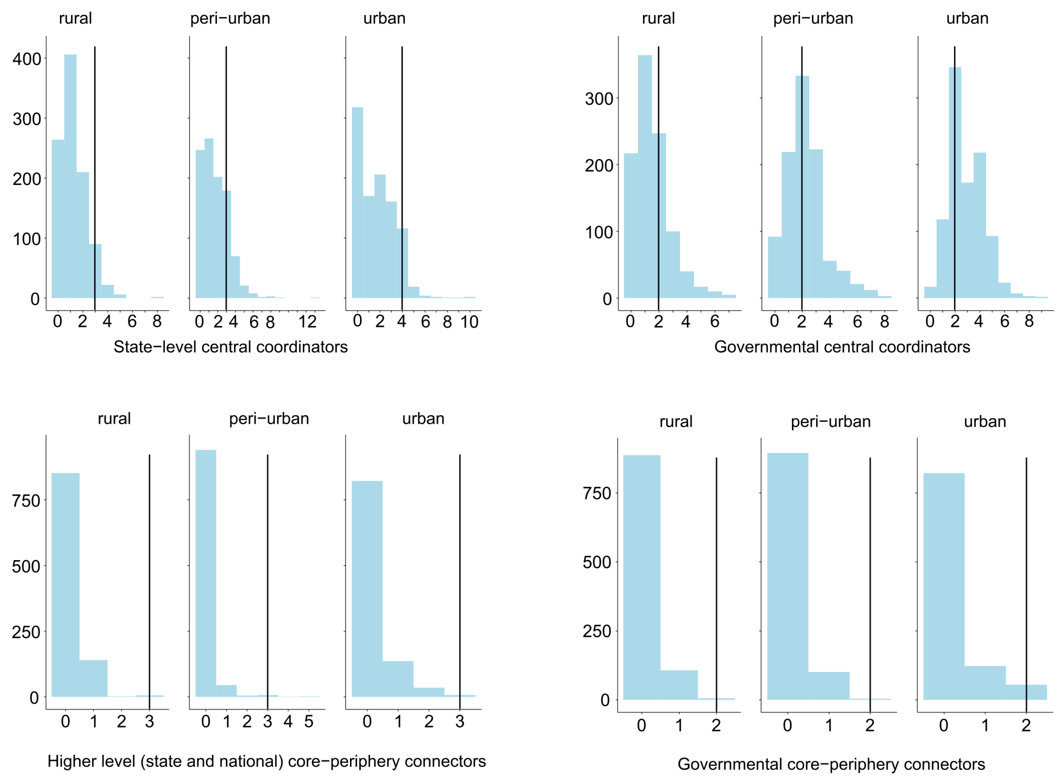

Figure 8: Frequency (count) of the occurence of four actor types in three Swiss water supply governance networks. The solid lines show the real, observed number of each actor type. The bars illustrate the distribution obtained from 1000 simulated networks based on a pooled exponential random graph model of the networks. The more the solid line deviates to the right from the distribution, the more likely it is that the given actor type is observed more often than by chance.

The exact model specifications of the pooled ERGM used for baseline simulations can be found in the appendix (table A3). Model fit throughout all three regions is sufficient to generate networks that are better in recreating networks of the type we observed than a model controlling only for network density. Goodness of fit plots that illustrate how far the model replicates a set of not modeled network statistics can be found in the appendix (figure A7). The model is biased in two main ways because it generally creates networks that are more clustered than the observed networks and tends to produce a smaller number of isolates. This inadequacy can be expected because it reflects the minimal theoretical assumptions about drivers of network structure we incorporated into our model for all three regions. However, this issue does not present a major concern because the main purpose of the model is to create a viable baseline distribution against which to compare each observed network, and we consider the fit to be adequate for this purpose.

Periphery connectors

As compared to the simulated networks, higher level actors (national/state) are more likely to occupy network positions associated with periphery connector positions. These results thus support our first hypothesis that periphery connector positions are more likely to be occupied by higher level actors. We expected this to be the case because of the range of operations of national and state-level actors that often encompasses a broader set of other actors than it is the case for lower level actors. The empirical evidence based on the statistical models and on our analysis of specific individual roles adopted by actors such as the Federal Office for the Environment supports this idea. The integration of peripheral actors to the natural resource governance network allows for the access of sources of information heterogeneity, which has been claimed to contribute to effectiveness and adaptability (Carlsson and Sandström 2008). Some studies have stressed that sources of new and diverse knowledge need not come from outside but can also be found among local level stakeholders (Knapp et al. 2014). However, we found no evidence that periphery connectors in our cases interact with peripheral local-level actors. This is most likely due to the fact that there were few peripheral local-level actors in the cases we studied. It would therefore be interesting to see future research in cases where local-level actors are less integrated into the network to elucidate the kinds of periphery connectors that build bridges to peripheral local-level actors.

We did not formulate a hypothesis on whether periphery connectors would be more likely to be governmental or non-governmental actors. Yet, an additional finding of our study is the higher likelihood for periphery connector positions to be occupied by governmental actors. Governmental actors might have an interest in reaching out for new information. This is, for example, highlighted by Crona and

Parkers (2012) study on bridging organizations, where public policy makers engaged in enhanced information- and evidence-based water management decisions because of their contacts with other types of actors. Our result showing that governance actors are more likely to occupy the position of periphery connectors should however be regarded as only tentative evidence. This is due to the fact that most of the governmental actors in the three networks under investigation are located at the national or state level, and thus considered higher level organizations. Given the specific nature of our case, we therefore feel more warranted to conclude that, in line with our first hypothesis, the higher level of actors is crucial to making them more likely to be periphery connectors. These positions might just as likely be occupied by nongovernmental, higher level actors in cases where these are more prevalent. This might be especially true for cases including transnational settings, where higher level, nongovernmental actors have been shown to assume important roles in policy processes (Tantivess and Walt 2008).

A closer look at the actors occupying periphery connector positions shows that our measure identifies a meaningful set of actors. The Federal Office for the Environment (FOEN) has a periphery connector position in all regions. For the purpose of illustration, the position of the FOEN in its respective ego network of order two is shown in Figure 9. Albeit the FOEN is not a central actor, it is the only actor that connects two national actors to a number of central state-level agencies in the network. The two national actors that only collaborate with the FOEN are two organizations dedicated to interstate coordination within the federal system. These are the KVU and BPUK, which are the conferences of heads of Swiss state agencies for environmental protection and spatial protection, respectively. Both of these organizations are good examples in terms of actors who are not involved in day-to-day management of water supply but may be of importance for giving access to a broader network of actors, for example, to disseminate good practices learned in other states. Moreover, the FOEN itself collaborates directly with another important periphery connector in all regions, the state-level fishery association (KFVBL). The state-level fishery association integrates the two nature protection organizations present in all regions (Pro Natura [PN_BL] and WWF) into the network. Thus, the viewpoints of nature protection organizations are highly likely to be passed through the fishery association. In highlighting the special role of fishery associations in water policy fields, this result is similar to previous research on policy networks surrounding marine-protected areas in California (Weible and Sabatier 2005).

Central coordinators

The results of our inferential analysis suggest a slightly higher likelihood for central coordinator positions to be occupied by governmental actors but the empirical evi-

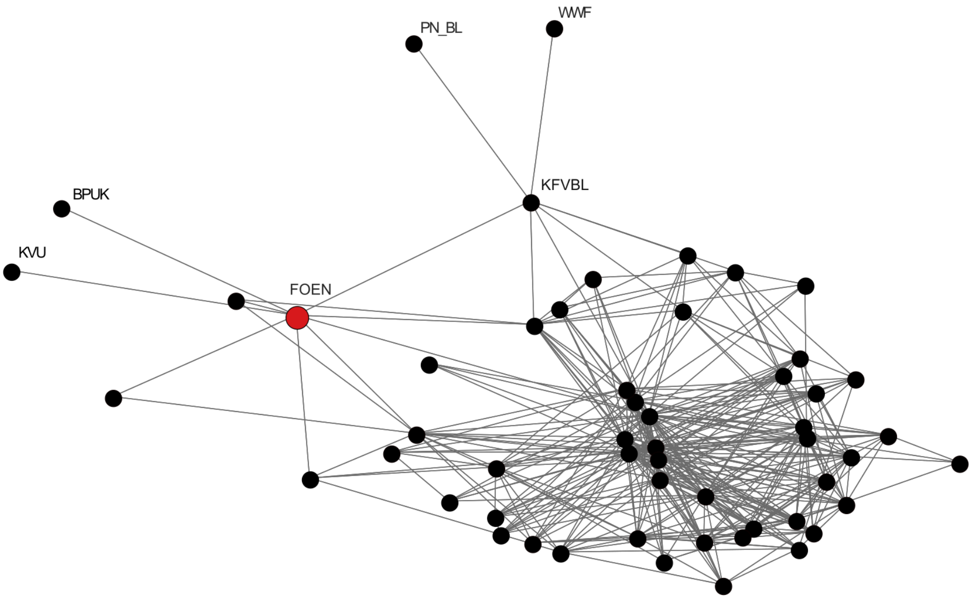

Figure 9: Ego network (order two) of collaboration ties of the Swiss Federal Office for the Environment (FOEN, indicated by red circle) in the water supply governance network of a peri-urban region in the Swiss canton of Basel-Landschaft. The figure illustrates the periphery connector role of the FOEN. KVU and BPUK are the conferences of heads of Swiss state agencies for environmental protection and spatial protection, respectively. The node labeled KFVBL represents the state level fishery association, itself a periphery connector. It integrates two nature protection organizations (PN$_{B}LandWWF)intothenetwork.$

dence should be seen as a tendency rather than a clear pattern. The results therefore provide only weak support for our second hypothesis, as the observed number of central coordinators equals the mean of the distribution obtained through the permutations in the peri-urban and urban regions.

Especially when governmental actors are located at the national level, they do not occupy coordinating positions, whereas state-level governmental actors do so. In singling out governmental actors the study is in line with findings in Ernstson et al. (2010) who found municipal and regional governmental actors to be most active in efforts to induce collaborative governance of urban green areas in Stockholm. The level of involvement of governmental actors also depends on the nature of what is governed. A study of network governance among actors involved in tourism in the Swiss Gotthard region, where the legal requirements for governmental involvement are less far-reaching than for natural resources, they played a lesser (though still pronounced) coordinator role (Luthe, Wyss, and Schuckert 2012).

Another finding of our analysis is that in all regions, private and public actors at the state-level, in contrast to the national, regional, and local levels, tend to occupy central coordinator positions. Results further indicate that the state level is likely to be the decisive level for coordinating collaboration in Swiss water governance. A possible explanation for this finding is that state-level actors directly interact with local-level stakeholders (as opposed to most national-level actors) but do so in various numbers of local settings (as opposed to local- and regional-level actors). This mixture of perspectives, direct local involvement, broader oversight, provides state-level actors with the capacity to play a coordinating role. Although our results do not readily transfer to other, especially nonfederalist settings, it is plausible that the mixture of these two different perspectives is a more general pattern inducing coordinative activity that should also be found elsewhere. A similar finding is reported by Ingolds (2014) study on regional Swiss flood prevention and land use policies: state-level actors played a crucial role in connecting the local and the national level during the top-down implementation of regional projects.

Actors occupying both positions

There are two actors in the urban and three in the rural regions who occupy positions that enable them to adopt periphery connector as well as central coordinator positions. In the rural region, one of them is the state-level utilities agency (AIB). This agency is situated in the periphery of the network, but has ties to many core actors and to other important peripheral actors, such as the FOEN or the state-level fishery association. Beyond this, it exclusively collaborates with two regional engineering and consulting firms.

In the urban region, a look at the only local-level actor occupying both a central coordinator as well as periphery connector position further illustrates both concepts. The actor is a municipal local water technician working for a larger municipality. Taking a closer look at the position and activities of this actor shows that this technician is the only actor who collaborates regularly with the local university in the region because of a project mapping groundwater streams. This exemplifies an important aspect of its periphery connector position, that is, to bring external knowledge into the governance network. The water technician also has an above-average amount of connections to other municipalities and geographically adjacent local actors. In the context of this specific case, the large amount of connections can be explained by the hydrologically important position of the technicians municipality within the region. The municipal territory entails the most important regional groundwater recharge area as well as the site of an accidental fire in a chemical storage facility leading to a significant chemical spill in 1986 that is still being monitored.

Conclusion

In this paper, we have investigated periphery connectors and central coordinators as two specific bridging actor positions that connect actors in governance settings with a high potential for fragmentation. Studying decentralized regional water supply governance structures in Switzerland with high potential for fragmentation, we have shown an effective formal way of operationalizing both positions, based on betweenness centrality computed on ego networks, and a simple node deletion procedure. Further, we have demonstrated that both bridging positions are more likely to be occupied by some actors than others in three important ways.

First, when it comes to overcoming fragmentation, higher level actors provide crucial access to heterogeneity. Higher level actors were more likely to be periphery connectors in our cases, connecting organizations not involved in the day-to-day operations of water supply management to a regional governance network. These actors can provide potential inputs for pluralistic thinking and innovation. Second, governmental actors are more likely than others to be central coordinators. This is in line with previous research on governance and policy networks that has argued that governmental actors remain special in these networks (Fischer and Schläpfer 2017), even taking into account a proposed shift from governance to governance (Rhodes 1996) with a more limited role for governmental actors. Governmental actors are able to draw upon sources of power that are inaccessible to other actors, which influences collaborative processes and should therefore be taken in account in their analysis (Brisbois and Loë 2016). Third, actors are most likely to provide central coordination if they are located at the subnational, state level. We argued that this is due to the mixture of specific oversight functions (for governmental actors) and the combination of local level involvement and a broader perspective that accrues at the state level. Thus, even in contexts where the institutional setting provides barriers for hierarchical coordination, overcoming fragmentation through collaboration remains a task that is mediated by state-level actors.

The aim of our analysis was to show that in a given natural resource governance setting, it pays to look beyond the institutional arrangement to the existing setting of collaboration among actors. Institutional and policy change might be one means to overcome fragmentation, but it could sometimes be more effective to tweak an existing setting by encouraging the activities of, and facilitate interactions between certain individual actors (Borg, Toikka, and Primmer 2015). In this context, we have also identified governmental and higher level actors as promising candidates for such a task.

Our analysis has important limitations that should be addressed in future research. First, our results proved reasonably robust across three cases that differ along a continuum from urban to rural regions. Still, as we observe a degree of variation between regions, this points to the value of analyzing further contextual conditions. Among further conditions that might influence the capacity and willingness of actors to occupy different network positions could be the level of conflict (Weible, Sabatier, and McQueen 2009) or the institutional specificities in the respective project set-up, such as comparing top-down versus bottom-up approaches (Ingold 2014). Furthermore, our research design held the substantive sector (water supply), and state-level as well as national-level institutional factors constant. The specific setting of Switzerland as a country with well-functioning institutions, professional government agencies, and a high level of trust in public agencies needs to be acknowledged (Kriesi and Trechsel 2008, Sciarini et al. 2015). This setting makes it very likely that governmental actors are highly active in governance networks because of legal requirements and their specific capabilities and the results pertaining to the role of governmental actors may thus not transfer readily to settings with weak institutions. However, even in settings with weak institutions, higher level actors could have access to a broader and more heterogeneous actor set than local level stakeholders.

Second, there is a notion of causality inherent to all of our hypotheses that sees actors as individual agents making an informed, purposeful decision to assume a position associated with a certain role based on their varying goals or incentives. This methodologically individualistic logic could however also be reversed, as an actor might not make a purposeful decision to become a coordinator or periphery connector or even perceive itself as one, but could simply end up in a given network position based on the accumulated decisions by other actors that lead it to end up there without making any strategic choice. In reality, a combination of both of these forces, individual decision making and structural opportunity structures, are probably at play. Future analyses should aim at disentangling the direction of causality inherent to all our hypotheses to explore further how a given network structure originates between individual-level agency and structural, contextual factors.

Third, our justification for researching actor roles that help to overcome fragmentation rests on the assumption that overcoming fragmentation contributes to outcomes, notably effective governance through improved coordination and access to new knowledge. This provides the underlying, normative justification for research on the topic. However, we did not directly study outcomes in our research and are thus unable to further scrutinize this assumption. Specifying the causal pathways through which different actors contribute to specific governance outcomes thus remains a crucial field for future research.

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Appendix

Intercept	-1.10^{***}
	(0.25)
Local Administration	-0.07
	(0.36)
Other actors	-1.20
	(0.78)
Politics	1.66^{***}
	(0.40)
Private sector	0.82^{*}
	(0.33)
Science	-0.64
	(0.68)
Service Providers	-0.00
	(0.43)
State and national administration	0.50
	(0.34)
BIC	595.68
Num. obs.	464

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table A1: Logit model of total nonresponse in survey as a function of organizational type. Baseline category: Interest groups

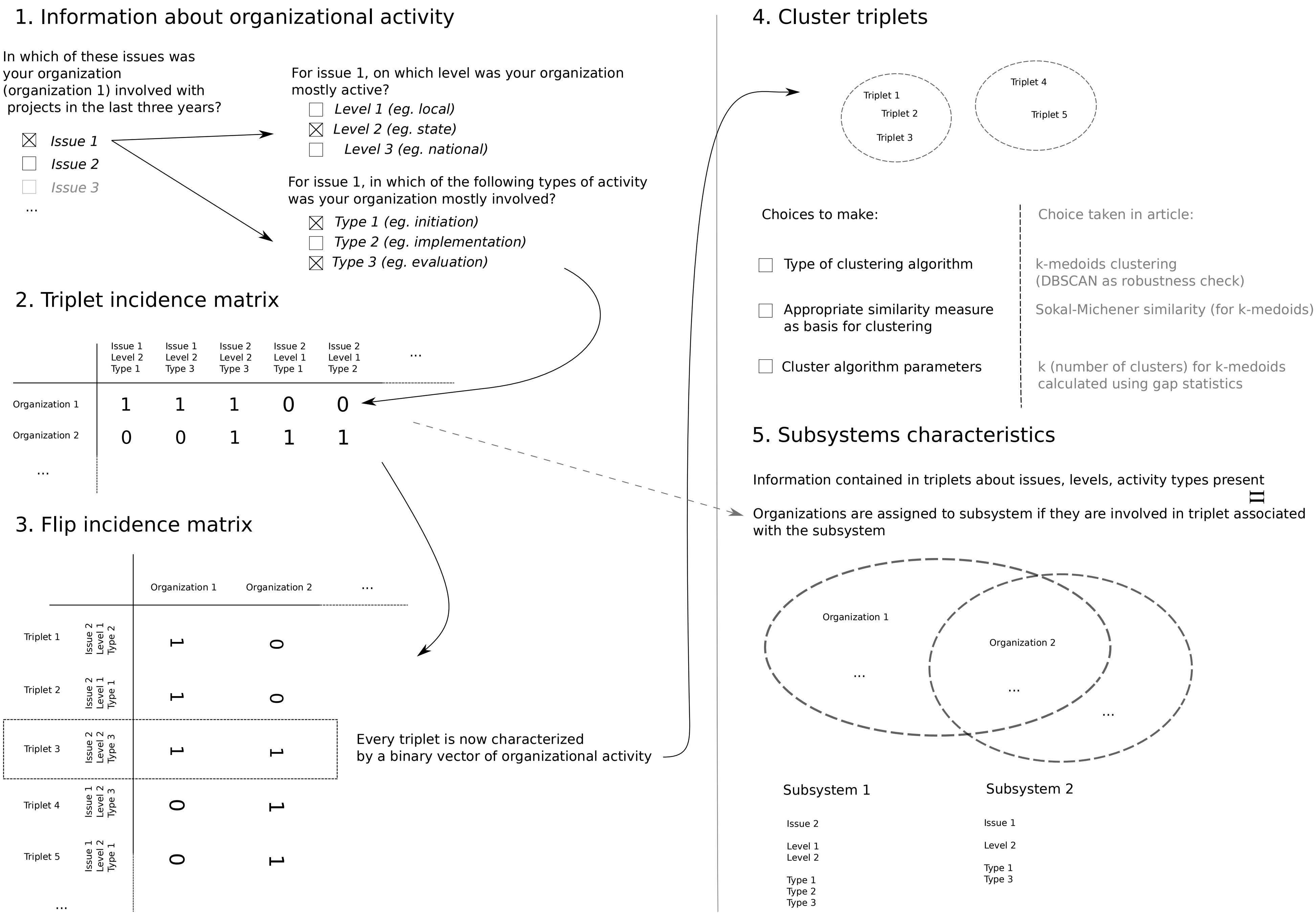


Figure A1: Overview over data gathering and clustering steps for bottom-up subsystem identification based on organizational activity

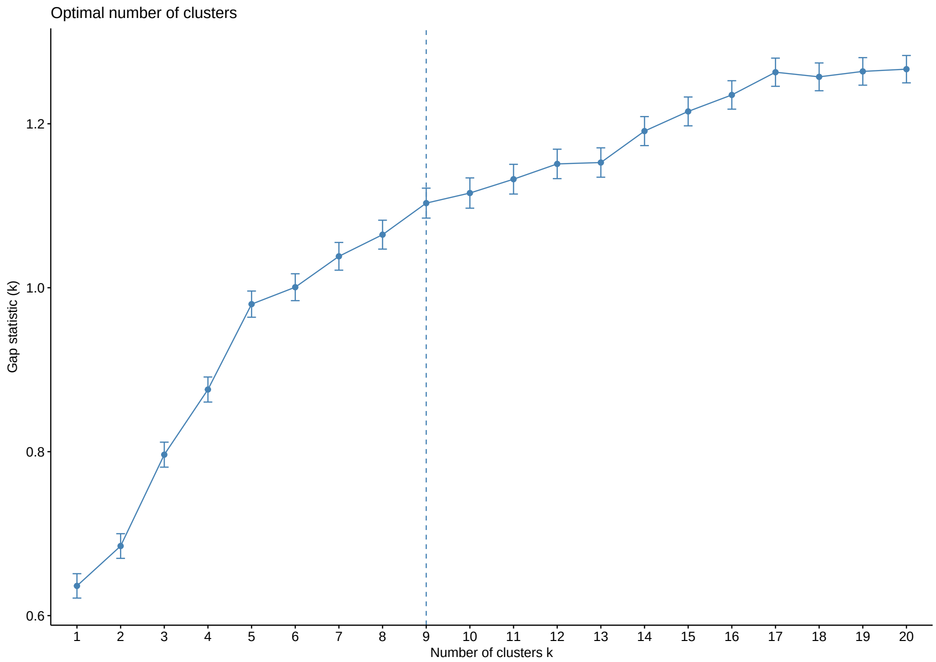


Figure A2: Plot of gap statistic depending on the number of clusters for k-medoids algorithm operating directly on a similarity matrix based on Sokal-Michener (simple matching) similarity. The dashed line indicates the optimal number of clusters based on the criterion proposed in Tibshirani, Walther, and Hastie (2001b).

	Flood control implementation	Local flood planning	Local biodiversity protection	Biodiversity politics	Hydropower planning	Energy politics	Water supply management
Local flood planning	0.6						
Local biodiversity protection	0.32	0.25					
Biodiversity politics	0.23	0.15	0.51				
Hydropower planning	0.3	0.2	0.34	0.29			
Energy politics	0.33	0.26	0.31	0.31	0.55		
Water supply management	0.29	0.32	0.11	0.06	0.16	0.14	
Pollution control	0.35	0.32	0.24	0.21	0.29	0.31	0.43

Figure A3: Overlap between subsystems as percentage of shared organizations

Subsystem	Most prevalent issues	Conflict level
Flood control implementation	Flood protection implementation, Renaturation for flood protection	0.27
Local flood planning	Spatial planning floods	0.28
Local biodiversity protection	Aquatic habitat protection	0.29
Biodiversity politics	Aquatic habitat protection, Biodiversity impacts agriculture	0.36
Hydropower planning	Hydropower impacts, Hydropower construction, Hydropower profitability	0.42
Energy politics	Spatial planning floods, Hydropower profitability, Energy politics, Subterranean resources, Fish biodiversity	0.37
Water supply management	Water supply infrastructure, Water supply planning	0.11
Pollution control	Water supply reorganisation, Water supply planning, Water supply infrastructure, Protection from pollution, Micropollution	0.26

Table A2: Level of conflict of subsystems in Swiss water governance as the ratio of opponents to allies reported by all organizations in the subsystem regarding issues in the respective subsystem

Density-based clustering with noise (DBSCAN)

DBSCAN is substantially different from k-medoids clustering as it groups together points based on their location in space, depending on a minimum number of points set as required per cluster and an epsilon value specifying the minimal distance to reach the points. It has the fundamental advantages of disregarding outliers (not grouping them), and is also much more flexible in detecting clusters of different sizes and shapes. It can also operate directly on a similarity matrix appropriate to a binary data structure, for which in this case Ochiai similarity was chosen, to add another point of deviation from the k-medoids procedure. Ochai similarity results in similar results to the widely used Jaccard similarity but does punish dissimilarity slightly less.

For DBSCAN, parameters for the minimum number of points per cluster and epsilon values, which can be thought of as specifying the breadth of clusters, need to be chosen. The minimum number of points was set to 12, requiring each cluster to contain at least 12 triplets, which is about half of all possible unique triplets that can be associated with an issue. Epsilon was set to 0.4 based on visual inspection and identification of the “knee” in the k-nearest neighbor plot (see figure A4).

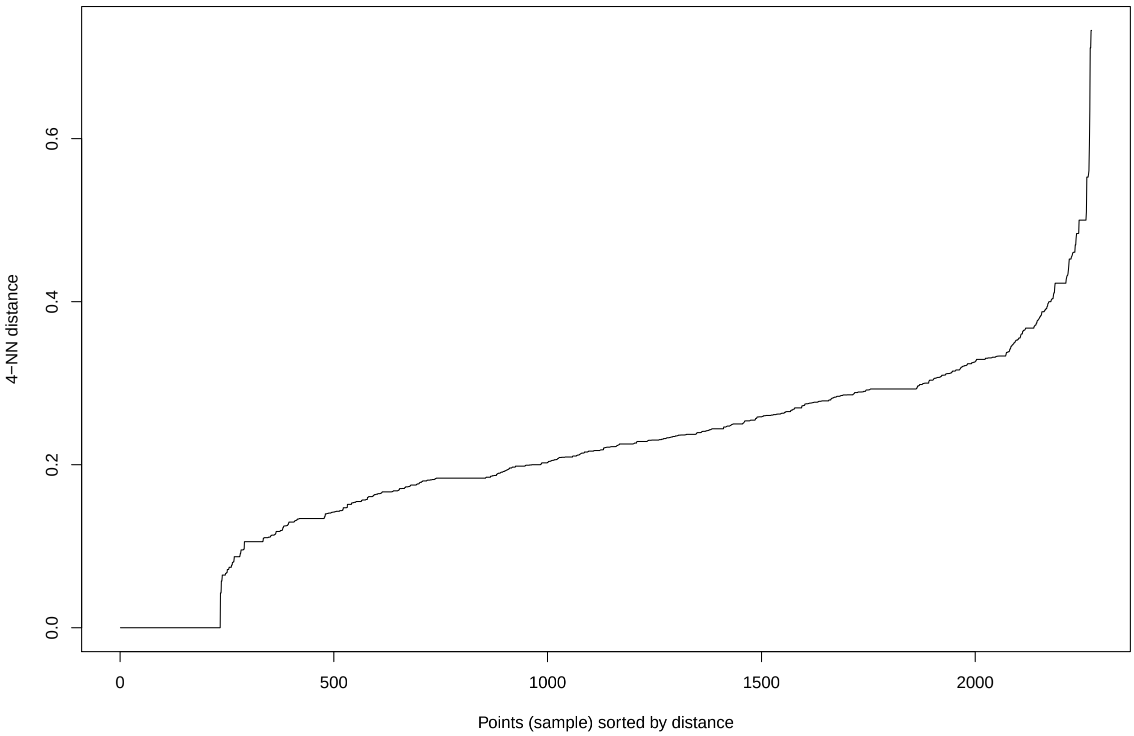
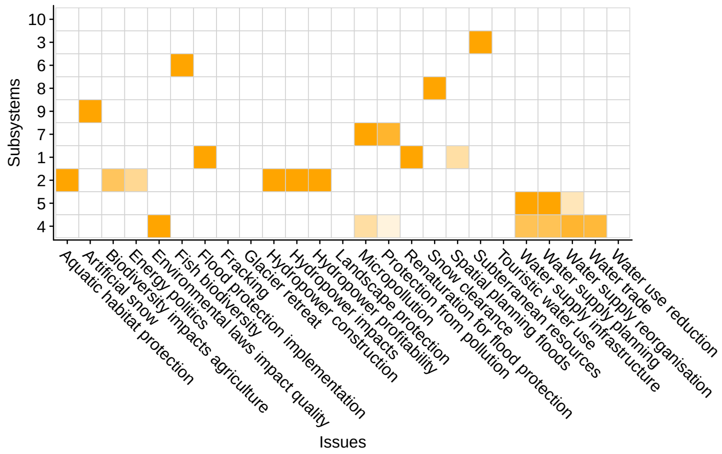
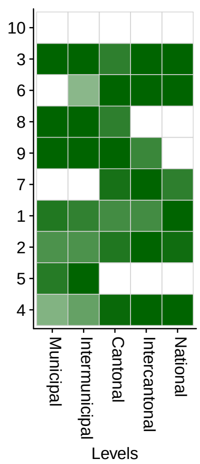


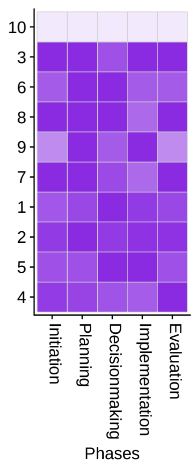
Figure A4: k-nearest neighbors plot based on Ochiai similarity between triplets used in determing epsilon values for the DBSCAN clustering algorithm.



(a) Issue incidence



(b) Level incidence



(c) Phase incidence

Figure A5: Composition of subsystems derived from clustering based on DBSCAN.

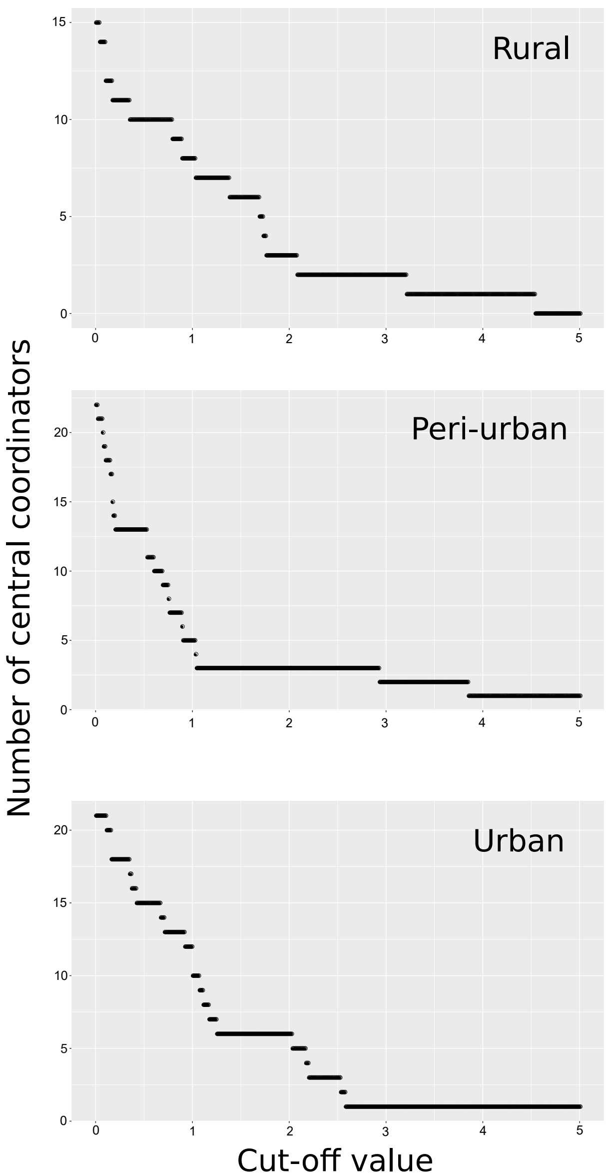


Figure A6: Sensitivity analyses for number of central coordinators depending on variation in cut-off values (standard deviations above mean ego betweenness score) for rural, peri-urban, and urban region

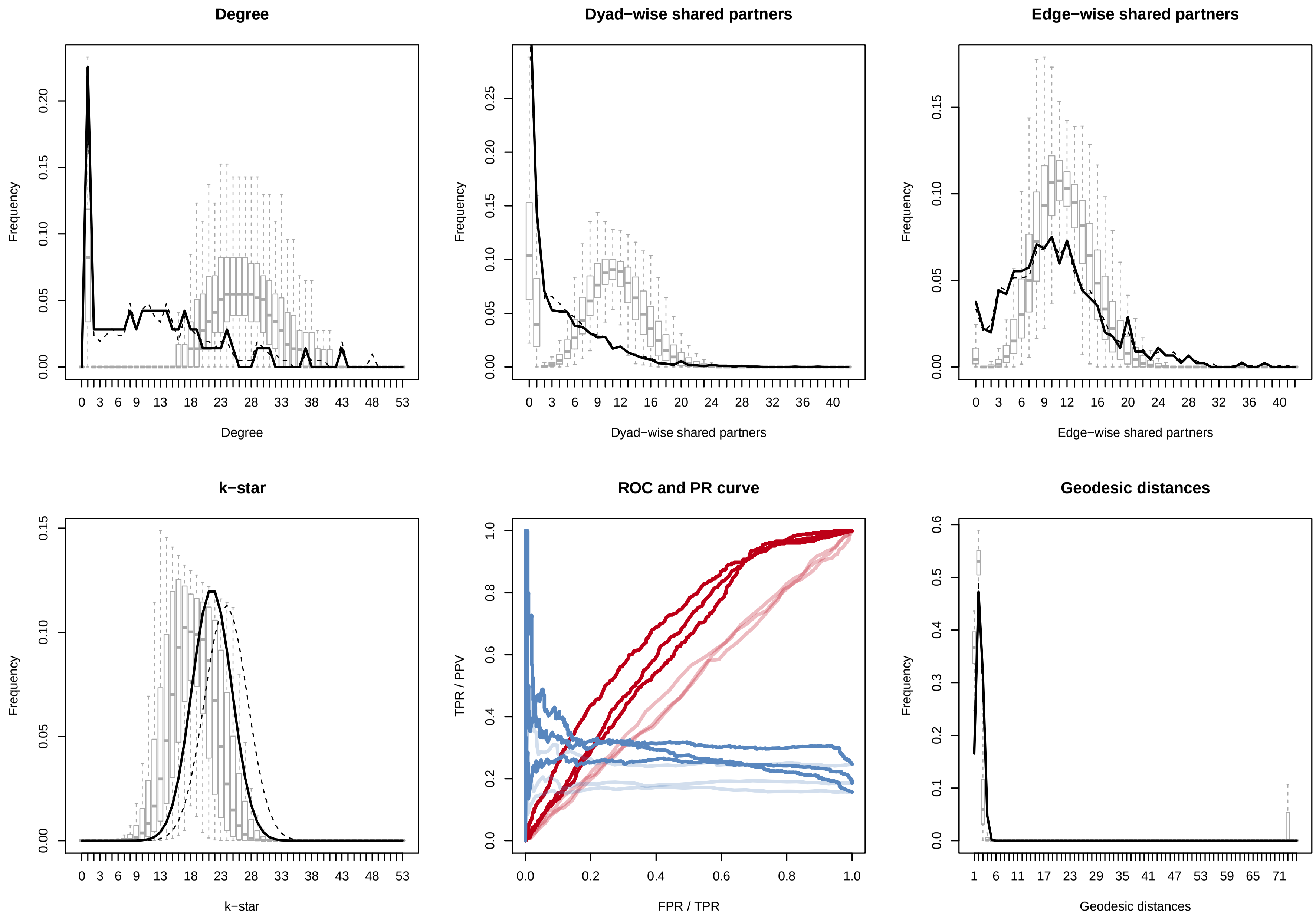


Figure A7: Goodness of fit plots for pooled ERGM based on 1000 simulated networks

	Model 1
Edges	-3.25^{*}
	$[-4.55;\ -2.57]$
Geometrically weighted ($\alpha = 0.5$) edgewise shared partners	1.60^{*}
	$[1.34;\ 2.27]$
Geometrically weighted ($\alpha = 1.2$) degree	-6.87^{*}
	$[-7.85;\ -5.80]$
Geometrically weighted ($\alpha = 0.1$) dyad-wise shared partners	-0.10^{*}
	$[-0.10;\ -0.09]$
isolates	-27.42^{*}
	$[-31.52;\ -28.42]$
State level activity	0.38^{*}
	$[0.10;\ 0.61]$
Regional level activity	0.40^{*}
	$[0.23;\ 0.48]$
Local level activity	0.00
	$[-0.10;\ 0.09]$
Level homophily	0.04
	$[-0.02;\ 0.19]$

* 0 outside the confidence interval

Table A3: Coefficients of pooled exponential random graph model used to generate baseline distributions in permutational analysis. Confidence intervals in square brackets

Selbständigkeitserklärung

Ich erkläre hiermit, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen benutzt habe. Alle Koautorenschaften sowie alle Stelle, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche gekennzeichnet. Mir ist bekannt, dass allenfalls der Senat gemäss Artikel 36 Absatz 1 Buchstabe o des Gesetzes vom 5. September 1996 über die Universität zum Entzug des aufgrund dieser Arbeit verliehenen Titels berechtigt ist.

Zürich, 7. November 2018

Mario Angst