# Perceived threats to common-pool resources – a trigger for actors' engagement in cooperation?

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**Abstract:**

This paper focuses on cooperation among organizations in a common-pool resource (CPR) situation. Cooperation is particularly challenged in settings where resource degradation is produced by a variety of different sectors and parts of the population, and where the problem as well as public responsibilities transcend borders and jurisdictions. Focusing on transboundary water quality management in the Rhine River basin, we ask: *How can cooperation among actors in a CPR problem situation be established? And what drives two actors to cooperate with each other?*

We argue that the degree of threat to a CPR is an important driver for collective action and focus on actors' *exposure to* and *their perception of* a threat to a CPR. Furthermore, we rely on applications of the ecology of games framework, taking the larger institutional context of CPR management into account. This allows us to test whether the participation in regional and international waterbody associations also enhances interaction among actors. Based on survey data and applying advanced network statistics (Exponential Random Graph Models, ERGM) we come to the conclusion that joint participation in a water body association as well as strong problem exposure enhance cooperation among actors. Problem perception is a more delicate factor which hints at having effects on cooperation depending on its intensity and interpretation by actors. Our study thus contributes to research on cooperation in CPR problem settings and further highlights the necessity to include more systematically the effects CPR problems have on actors when analyzing CPR problem settings.

**Key words:** CPR problem; cooperation; problem perception; ecology of games; water quality management; micro-pollutants; SNA; ERGM

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## 1. Introduction

The effective and efficient management of common-pool resources (CPR) constitutes a challenge, particularly in situations of increased resource degradation and over-harvesting (Ostrom 1990; Ostrom 2000a). In such situations, typically a multitude of different resource users causes and is simultaneously affected by environmental degradation. The degree of complexity increases when spatial or temporal cause-effect mismatches exist, e.g. when the source of degradation lies in one jurisdiction or area at a time while effects are deployed in another area at a different time (Ingold et al. forthcoming a). As a consequence, regulatory arrangements and policies should ideally account for cross-sectoral, multi-level, trans-boundary, and long-term characteristics of environmental problems (Guerrero et al. 2015; Peters and Hoornbeek 2005). Coordinated action among a variety of actors and stakeholders representing the public and private sector, different jurisdictions, and decisional levels seems thus key (Driessen et al. 2012; Newig 2012). In this context we ask:

*How can cooperation among actors in a CPR problem situation be established?*
*What drives two actors to cooperate with each other in a CPR problem situation?*

The case we investigate to answer our research questions is the one of actors involved in water quality management in the river Rhine. We focus on cooperation as one particular type of coordinated action among these actors aiming to overcome a (CPR) problem. Like others (Calanni et al. 2015; Monge and Contractor 2003; Ostrom 1998), we define cooperation as a mutual form of interaction that brings benefit to a whole group of involved actors. Applied to a CPR problem situation and to our case, cooperation becomes the way how a variety of public and private actors interact with each other in order to establish regulations and policies that address the CPR problem at stake.

To study cooperation among actors and to answer the research questions, we suggest an innovative approach that has different added values. First, and when asking what drives actors to interact in a CPR problem situation, we suggest an integrative framework as presented by Lubell et al. (Lubell et al. 2012) which takes institutional (macro), structural (meso) and individual (micro) level factors into account. More concretely, we try not to be a priori exclusive, only focusing on institutions or individuals when searching for drivers of cooperation. On the contrary, we investigate what might motivate a single actor to engage in a cooperative relation with another actor, without ignoring the larger institutional and structural context.

Second, and in line with the previous argumentation, we compare observable problem *exposure* to a single actor's problem *perception*. If some actors are exposed more than others to an environmental problem, this might enhance their willingness to engage in collaborative governance arrangements (Ansell and Gash 2008; Berardo and Lubell 2016). Therefore, we argue that the degree of threat is an important driver for collective action. The added value of our research is the reliance on two different forms of threat: relying on natural scientific data and modelling, we assess what can be called "objective" problem exposure; through survey data we grasp an actor's problem perception. How threats are perceived is an important aspect which would be omitted if we took only observable problem exposure into account.

Third, we rely our institutional analysis on the recently revived "Ecology of Games" framework (Long 1958; Lubell 2013). We thereby follow the argument that co-participation in joint venues or forums enhances the chance for actors to meet, to build up trust, to create so-called bonding ties, and finally to engage in cooperation (Berardo and Lubell 2016).

Fourth, the CPR problem we concentrate on is water pollution, conceived as one type of over-appropriation from a CPR (cf. Villamayor-Tomas et al. 2014, 364). More concretely, we look at the spread of so-called micro-pollutants in surface water. The choice of this specific environmental problem is appropriate for several reasons. On the one hand, micro-pollutants are potentially toxic compounds that have a negative effect on humans and the aquatic ecosystem (Brodin et al. 2013; Cunningham, Binks, and Olson 2009). They include pharmaceuticals, biocides and pesticides and stem from a variety of human activities and sources such as agriculture, industry or households; they enter waters thus through point and diffuse sources (Hollender et al. 2009). On the other hand, there is still only little known about their fate in waters, their effects when mixing with other substances and about the principal question of which substances can be classified as micro-pollutants (Schwarzenbach et al. 2006). Micro-pollutants in surface water are thus an environmental problem that comes along with uncertainties about its nature and effects, and causes from different domains at different levels, which further crosses different jurisdictions. Cooperative action across levels and sectors seems thus key to address this type of CPR problem in order to manage its cross-sectoral and trans-boundary characteristics.

To study how and why actors engage in cooperation to solve the problem of micro-pollutants in surface waters, we investigate trans-boundary and international water quality management along the river Rhine within the sub-catchment of the cross-border region of Basel. To model the threat that stems from micro-pollutants in this region, we chose the pharmaceutical Sulfamethoxazole (SMX). We did so for two reasons: first, Basel city and its agglomeration is one of Europe's hotspots when it comes to the production of pharmaceuticals and the installment of multi-nationals in the chemical sector; second, SMX is an antibiotic which occurs frequently in European rivers and has been proven to be persistent also to river bank filtration, a technique applied in drinking water provision (Götz et al. 2010; Herberer et al. 2011). This makes SMX a representative and at the same time a relevant substance to consider. Through a standardized survey among key actors involved in water quality management in our case study region, we gathered data about their cooperation relations as well as about individual actor attributes such as problem perception and venue participation. Applying inferential social network analysis using an Exponential Random Graph Modelling (ERGM) technique allows us to identify the factors accounting for the existence of a tie between two actors in the CPR problem situation. The method further allows us to integrate individual (actor attributes), structural and institutional (endogenous and exogenous network effects) properties at the same time to assess cooperation networks of actors involved in a CPR problem setting.

In the next section, we will introduce the theoretical background from which we derive hypotheses. This is followed by a section on the case study, the procedure of data gathering, the operationalization of the variables and the method applied. The fourth part comprises a descriptive analysis of the dependent and the independent variables and the statistical analysis through the ERGM; while the fifth section discusses the models' results. We finish our paper with some concluding thoughts about the study's added values, the findings and their implication for further research as well as the limits of our study.

## 2. Theory

### 2.1 Common-pool resource theory and the notion of cooperation

Common-pool resource (CPR) problems very often arise from multi-user situations in which the usage of the CPR has become so drastic that the resource is not capable anymore to reproduce its units and maintain its stock (Gerber et al. 2009; Ostrom, Gardner, and Walker 1994, 9ff). Pollution can be seen as one particular type of resource degradation or over-harvest. Through the activity of one polluter the quality of a resource decreases which in turn reduces the quantity of the resource units of good quality available for others. This *qualitative* over-harvest of a resource by one (or more) actor(s) negatively affects other resource uses and users; in some cases it even harms the polluter. This scenario has a direct impact on how to manage resource pollution: those causing and those affected by the pollution are sometimes different resource users, stakeholders or citizens, but can also happen to be the same; all of which is challenging the design of appropriate management principles and policies (Knoepfel 2007). This situation is further complicated when the source of the problem and its effects are detached: when polluters, the potential policy addressees, and those concerned by the pollution belong to different jurisdictions.

One way to bridge such fragmented socio-ecological systems is through collaborative network arrangements: in such, public and private stakeholders come together with public agencies in collective forums to engage in consensus-oriented decision making (Ansell and Gash 2008). Such deliberative, bottom-up ways of collective problem solving are said to improve environmental outcomes (Berkes and Folke 2002; Christensen, Kornov, and Holm Nielsen 2012; Newig 2012). This argumentation is based on the assumption, and some evidence, that participation by affected, concerned and responsible actors promotes the acceptance of decisions which improves policy implementation and the quality of outcomes (Macnaghten and Jacobs 1997). But, even if collaborative forms continued to spread there is not yet consensus about their actual effectiveness or performance (Gerlak, Lubell, and Heikkila 2013; Heikkila et al. 2013).

Still, collaborative ways of problem solving and collective or coordinated action seem to be important conditions to address a CPR problem (Feiock and Scholz 2010; Lubell, Henry, and McCoy 2010; Ostrom 1998). One particular way of coordinated action we are focusing on here is cooperation. Cooperation among two actors is defined as a mutual engagement of these actors in a joint relationship that brings benefits to both of them (Ostrom 1998).

Cooperation can emerge in various ways: some scholars strongly emphasize self-organization of some particular actor groups and focus on the maintenance of collective action (Berardo and Scholz 2010). They lead the creation of cooperation back to users who are particularly dependent upon the resource or especially threatened by resource degradation or over-harvest (Agrawal 2001; Araral 2014).

Lubell et al. (Lubell et al. 2012) present a framework which assesses how network outputs and outcomes come about, and thereby strongly emphasize the importance of not only mere structural factors – such as self-organization and interaction patterns – and micro-level factors – like individual actors resource dependence, problem affectedness or threat; but also highlight the relevance of macro-level elements. More concretely, institutional arrangements can present particular opportunity structures, so-called *venues* such as forums or water body associations (Berardo and Lubell 2016; Fischer and Leifeld 2015; see also Nohrstedt 2010; Sabatier and Weible 2007; Weible and Sabatier 2009; Weible and Sabatier 2005) in which actors can establish and engage in cooperation networks, thereby jointly producing solutions to the particular CPR problem.

## 2.2 Individual and institutional drivers for cooperation

Based on the above mentioned impact of individual and macro-level factors on the establishment of networks and cooperation, we formulate the hypotheses guiding this research. We thereby also follow the claim made by Heikkila and Gerlak (2005) that theory of collective action is one-sided in focusing mainly on the factors making resource management successful and neglecting the ones driving the formation of management and cooperation.

### *2.2.1 Threats caused by environmental problems*

The threat to a resource and its perception by the resource's appropriators are two aspects that do not figure very prominently in theories on collective action in CPR settings. Ostrom emphasized threats implicitly when she identified several resource and user attributes enabling self-organization (Ostrom 2000b). Some scholars went one step further: Heikkila and Gerlak (2005) for instance discovered that the recognition of the resource problem at stake is crucial to make people start working together. So did Gerber et al. (2009), arguing that a great threat to the stability of a resource increases the likelihood of cooperative activities.

In studies on adaptation and resilience, threats are perceived as one major driver for collective action and cooperation among actors (Blythe, Murray, and Flaherty 2014; Schemmel et al.

2016). Primarily literature on climate change adaptation and resource degradation deliberately considers natural threats (e.g. climate change effects) to scrutinize the vulnerability and adaptability of communities exposed to environmental events (Adger et al. 2016; Gersonius et al. 2016). In policy process theories, shocks from outside such as natural disasters (Birkland 2016) and internal changes threatening the position of individuals (Nohrstedt and Weible 2010) constitute important triggers for action as well. Deduced from that, we argue that the degree of an actor's problem exposure or the observable threat of a CPR problem impacts an actor's engagement in cooperation with other actors. As the analytical model we apply (ERGM) runs tests on a variable's effect on the relation between two actors, we already adjust our hypothesis to this dyadic level of analysis, claiming that:

> **Hypothesis 1a:** *A similar exposure of the actors to the CPR problem enhances their cooperation in a CPR problem setting*.

We argue that observable threat and problem exposure is potentially not the sole driver for cooperation. Individuals dependent upon a resource and its use might engage in cooperative action with others only when they perceive resource degradation, over-harvest or pollution as problematic. Following this argumentation, people might furthermore be incentivized to join forces as soon as they feel threatened (Jenkins-Smith, St. Clair, and Woods 1991; Duffy 1997). Our next hypothesis reads thus:

> **Hypothesis 1b:** *A high problem perception enhances actors' cooperation in a CPR problem setting*.

### *2.2.2 Institutional arrangements driving cooperation*

Individuals and actors not only cooperate with each other because they feel threatened or personally incentivized to do so. Besides individual motivations to cooperate with others, some context factors seem to be crucial as well. Actors are given specific opportunities that reduce actors' transaction costs related to engaging in cooperation and network activities (Heaney and McClurg 2009; Henning, Christian H. C. A. 2009). Such opportunities are typically given by venues (Nohrstedt 2010) or forums (Fischer and Leifeld 2015): informal hearings, round tables or information events organized by both, public or private organizations. More formalized venues are consultation procedures organized by state officials or associations' annual meetings (see also Berardo and Lubell 2016; Lubell 2013).

By comparing cooperation among 1800 interstate river catchments, Wolf et al. (Wolf, Yoffe, and Giordano 2003) came to the conclusion that two thirds could be claimed cooperative in nature. Following these authors, supra-national platforms or trans-boundary river body associations and committees facilitated cooperation within the catchment and among the different actors decisively. Based on the findings and thoughts outlined above we formulate our second hypothesis:

> **Hypothesis 2:** *The joint participation in forums, such as water body associations, enhances actors' cooperation in a CPR problem setting.*

## 3. Case, data and methods

To study cooperation in a CPR setting we chose the challenging situation of surface water transcending regional and national borders. In such upstream-/downstream-dynamics, actions of an actor A that affect surface water upstream always have consequences for actor B situated further downstream. We are thus dealing with an asymmetric common-pool resource: the effective management of this joint resource is challenged by the fact that negative externalities are usually only one directional (B most often not being able to affect the use of A). Further complications arise if both actors are not in direct contact with each other (typically B not reaching out to A); if their jurisdiction is not providing any public policies or user rights regulating the externalities; or if both are located in different jurisdictions (see Gerber et al. 2009; Schlager and Heikkila 2009; Villamayor-Tomas et al. 2014). We argue here that direct cooperation between A and B or indirect cooperation mediated by public authorities responsible for the respective jurisdictions and their collaboration with other actors involved in the trans-boundary surface water setting might be important conditions for facilitated CPR problem solving. Sadoff and Grey (2005) list four general benefits that arise from cooperation at international rivers: benefits to the river, like the amelioration of degraded ecosystems; benefits from the river which improve people's well-being as they depend on the resources of and services from the river; benefits from the decrease of tensions between actors; and finally, benefits derived from cooperation between states that go beyond the management of the river. Our case selection, data gathering and case study analysis are designed as outlined below.

### 3.1 The cross-border region of Basel and its affectedness by micro-pollutants

The sub-catchment of the Rhine embracing the area of the Swiss city of Basel and its urban agglomeration is located at the international tri-point where Switzerland, Germany and France meet. This area is known for its pharmaceutical and chemical industries which, together with the urban drainage, are responsible for micro-pollutants in general and pharmaceuticals in particular in the river's surface water. Micro-pollutants are not only found in the area of Basel but in Swiss water bodies in general, many of which belonging to the catchment area of the Rhine (Gälli et al. 2009, 46f.). Therefore, persistent substances entering Swiss water bodies which are connected to the Rhine inevitably appear in the surface water in Basel and further downstream. Rhine surface water also serves as drinking water source for the city's and agglomeration's population.

Swiss politics have developed a strategy to reduce concentration of micro-pollutants and support research on advanced techniques which extract micro-pollutants from the water cycle.[2] In Basel for instance, waste water treatment plants as well as drinking water suppliers started to upgrade their filters in order to retrieve most of the substances.[3,4] Although those techniques are very efficient, some micro-pollutants are still resistant to them or enter streams via diffuse sources, a reason why filtering techniques cannot be the only solution to tackle this complex water quality issue (Metz 2017). Switzerland and Basel as the exit point of one of the most important river streams in Europe are thus challenged to engage in within- and cross-country cooperation in order to solve this CPR problem. Figure 1 illustrates the map of the case study region and its location within Europe.

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[2] Bundesamt für Umwelt, BAFU. (2014). Mikroverunreinigungen. Thema Gewässerschutz. Retrieved from: http://www.bafu.admin.ch/gewaesserschutz/03716/index.html?lang=de; Bundesamt für Umwelt, BAFU. (2011). Mikroverunreinigungen: Reduzierung an der Quelle. Thema Gewässerschutz. Retrieved from: http://www.bafu.admin.ch/gewaesserschutz/03716/11218/11232/index.html?lang=de

[3] ProRheno AG. (no date). Erweiterung der ARA Basel (Projekt EABA). Retrieved from: http://www.prorheno.ch/Umwelt/Erweiterung-der-ARA-Basel--63

[4] Interviews 1 & 2 (for a list of the interviews see Table 5 in the Appendix).

**Figure 1: Maps of the case study region, the city and canton Basel Stadt** (left), **and of Switzerland's location within Europe** (right).[5]


### 3.2 Actor identification, survey, and cooperation network

Relevant actors involved in water quality issues in the Rhine sub-catchment of Basel were identified through an actors' identification approach based on the social-ecological system framework (SESF, cf. McGinnis and Ostrom 2014; Ostrom 2009): in a first step, guided by the SESF elements *resource system, resource unit* and *actor*, direct as well as indirect uses of surface water in the Rhine were identified. This included uses such as irrigation for agriculture, drinking water or hydropower. The pollution of the resource water by micro-pollutants was classified as a type of use as well; so were actor groups affected by the resource's degradation taken into account. In a second step, collective actors representing those use and user groups who are active in the region were identified – such as farmers' associations, trade unions, environmental NGOs, scientific institutes, water work associations, or consumer protection organizations.

Furthermore, we identified actors more closely related to the so-called *governance system* (see McGinnis and Ostrom 2014). We searched for public authorities and administrative entities responsible for water quality policymaking at the regional, sub-national, national, and

[5] For the map of the city of Basel, see https://upload.wikimedia.org/wikipedia/commons/7/77/Karte_Gemeinden_des_Kantons_Basel_Stadt_2007.png; for the map of Switzerland's location within Europe, see https://upload.wikimedia.org/wikipedia/commons/a/ad/Switzerland_in_Europe.svg

international levels. We further included so-called target group actors and other interest groups who might have a stake in the design of policies addressing the issue of micro-pollutants. Finally, and to validate the actors' list, face-to-face interviews[6] with managers, CEOs and heads of offices of organizations which are key to water policy in the Basel region were conducted. As Basel lies at the Swiss border to Germany and France, we identified Swiss, French and German actors involved in the management of micro-pollutants in the Basel region as well as three international actors (which are international water body associations).[7]

The data was collected through a structured questionnaire which was sent to all actors of the finalized list (n=51) via post and E-mail in spring/summer 2016. 36 out of the 51 contacted organizations answered the questionnaire, resulting in a response rate of 70.59%. Out of the four French actors we contacted, only two answered the survey; one of the five contacted German actors did not respond, while two of the other four who did answer the survey did not complete the survey – we could therefore not include them in the analysis. Table 1 summarizes the nationalities and sectors of the actors included in the study.

**Table 1: Actors engaged in water quality management in the Basel region**

| Sector | Swiss | French | German | Inter-national |
|---|---|---|---|---|
| National state actor | 2 | 0 | 0 | 0 |
| Regional state actor | 4 | 0 | 1 | 0 |
| NGO | 3 | 2 | 0 | 0 |
| Water association | 2 | 0 | 0 | 3 |
| Polluter | 7 | 0 | 0 | 0 |
| Science | 5 | 0 | 1 | 0 |
| Service provider | 5 | 0 | 0 | 0 |
| Consumer organization | 1 | 0 | 0 | 0 |
| total | 29 | 2 | 2 | 3 |

[6] In total, six experts on the topic of micro-pollutants in the Rhine catchment area around the city of Basel were interviewed in April and early May of 2016. They had been selected based on their position (CEO or head of department working on the issue of micro-pollutants) within an institution that needed to be a key player in the management of micro-pollutants in the region. The institutions in which experts were interviewed comprise the Cantonal Offices for the Environment in the cantons of Basel Stadt and Basel Landschaft, the Federal Office for the Environment Switzerland (FOEN), two regional drinking water provider and one regional waste water treatment plant operator.

[7] For the list of actors see Table 6 in the Appendix.

The questionnaire comprised questions about actors' problem perception of micro-pollutants in comparison to other relevant environmental and water quality issues. It also assessed actors' membership in water body associations and their cooperation pattern among each other.
The latter question about cooperation patterns was treated and operationalized as our dependent variable. More concretely, cooperation in the management process of micro-pollutants was defined as interaction with others, including

- discussing findings on micro-pollutants;
- the working out of possible courses of actions, like e.g. the joint removing of hazardous waste from the past[8] or the evaluation of adequate filter techniques;
- exchanging opinions on the topic; and
- the joint carrying out of a project related to the management of micro-pollutants.

The answers were transformed into a one-mode matrix, in which 1s indicate that an actor had stated to cooperate with another actor while 0s mean there is no cooperation between two actors. This provided us with the actors' network of cooperation. Note that data was not symmetrized in order to keep the data set as close as possible to the interview partners' perception of how cooperation in the Rhine sub-catchment of Basel works when it comes to establish solutions towards the issue of micro-pollutants. Finally, and in relation to the selected analytical model presented in section 3.4, we are interested in the existence and establishment of a cooperation tie between each pair of actors included in our sample. We thus test for factors that help explain the existence of a tie among two actors in the network of cooperation.

### 3.3 Operationalization of key independent variables

**Problem exposure** (independent variable 1a) was operationalized through the use of mass flow analysis, a technique employed in environmental sciences and engineering (Moser et al. 18 - 20 May 2016; Wittmer et al. 2016).[9] To model the exposure of each actor towards the selected pharmaceutical Sulfamethoxazole (SMX) information on the substance's consumption was gathered through a) spatially distributed population data downscaled to the consumed amount

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[8] Interview 3.
[9] Data used for this paper all stem from the SNF-funded interdisciplinary research project "CR21I1L_146336 CrossWater - Transboundary Micropollution Regulation in Europe: The Definition of Appropriate Management Scales – An Interdisciplinary Approach". The variable "problem exposure" was produced in strong collaboration with our colleagues who are environmental engineers and GIS specialists.

per capita, and b) water quality measurements delivered by wastewater treatment plants. Estimates of the annual loads expected in the river network were calculated by multiplying the substance input data with specific loss rates (Ingold et al. forthcoming b; Moser et al. 18 - 20 May 2016). Finally, we geo-referenced each actor (postal address of head office) in space and created a radius of 15 km around the location's geographic coordinates. We calculated the sum of released SMX load (in mass/time, i.e. kg/yr) to the river network within this area which provided us with each actor's "area of exposure" towards the micro-pollutant SMX.
To see whether two actors who are similarly exposed to the problem also engage in cooperative tie creation, this first independent variable was then transformed in a similarity matrix. For this, we divided the load (i.e. mass of SMX) in the "area of exposure" of actor "i" by the load in the "area of exposure" of actor "j".

$$SI = \frac{L_{b\ radius}(A_i)}{L_{b\ radius}(A_j)} \quad with \quad L_{b\ radius}(A_i) < L_{b\ radius}(A_j)$$

This ratio ranges between 0 and 1 and illustrates in how far two actors are similarly exposed to SMX.

The second independent variable concerns **actors' problem perception** (independent variable 1b), and more specifically the seriousness actors attribute to the issue of micro-pollutants in the surface water of the river Rhine. Different consequences of micro-pollutants' occurrence in river water were presented to the survey participants. The degree to which actors evaluated those consequences as a problem was then evaluated on a scale ranging from 1 (no problem) to 4 (severe problem). The potential consequences deduced from the literature (Bundschuh and Schulz 2011; Bunzel, Kattwinkel, and Liess 2013; Carvalho et al. 2014; Chèvre et al. 2006) that were taken into account are the following: 1) the uncertain interaction effects of micro-pollutants, i.e. the so-called **cocktail effect** that could occur when several different micro-pollutants merge, thereby generating a toxic effect; 2) the **negative effects** micro-pollutants could have **on aquatic organisms**; and 3) a **raised level of hormones** in surface water.

Our last independent variable comprises the **joint participation of two actors in forums** such as water body associations (independent variable 2). Survey participants were asked to indicate their membership or regular participation in different round tables, platforms, committees and water body associations. Their answers allowed us to generate a two-mode matrix of the actors on one side and the different forums they had indicated as participating in on the other. This was then transformed into a one-mode matrix expressing the number of forums two actors in the network are both participating in.

We further **control for different actor type attributes** such as regional- versus national-level actors and different sectors. We distinguish state actors at the national and regional level, NGOs, water associations, polluters (such as industries and waste water treatment plants), service provider (like drinking water provider), scientific institutions and consumer organizations (see also Table 1). We further introduce a control variable for nationality (Swiss dummy) to control for cross-border challenges when establishing cooperative ties.

### 3.4 Exponential Random Graph Models (ERGM)

Through inferential social network analysis, applying exponential random graph models (ERGM), we test which endogenous and exogenous network effects have a significant impact on the existence of a tie between two actors in the analyzed and observed cooperation network.[10] In this regard, the ERGM is able to take network dependencies into consideration when estimating the causes for the existence of a tie in a network. The model is estimated via Markov Chain Monte Carlo Maximum Likelihood Estimation (MCMC MLE) and computed using the `ergm` package for R that comes with the `statnet` suite of packages (Handcock et al. 2008; R Core Team 2013). The model takes the parameters of the observed network one is entering into the model and computes random permutations of this network. In doing so, the model discerns the moment at which an effect occurs not anymore merely randomly, i.e. it is able to distinguish between randomly generated effects and effects proving significance in the observed data.

Our independent variables (co-participation in forums, problem perception and problem

[10] Endogenous network effects are, inter alia, triangles, cycles, density or clustering while exogenous network effects comprise edge covariates like attributes (like actors' age, sex or type) (Leifeld and Schneider 2012: 737; Hunter et al. 2008). The model not only estimates the covariates' effects on network ties while simultaneously controlling for the influence of endogenous network effects on network ties; it also projects parameters which describe the forms of dependence existent in relational data (see Cranmer and Desmarais Bruce A. 2010: 67).

exposure) and control variables (actor types and Swiss nationality) are included in the model as either exogenous node-level covariates (properties of actors involved in a dyad) or dyad-level covariates (a relational property two actors have in common) in order to explain tie formation in networks. *Problem perception* is more specifically tested via two different effects: *activity*, testing whether actors with the specific attribute have the tendency to increase tie creation; and *heterophily*, testing whether two actors not sharing the same attribute have the tendency to share a cooperative tie. The *control variables* are also tested via the *activity* effect as well as via the *node match* effect, checking whether two actors sharing the same attribute also have the tendency to share a cooperative tie with each other.

Furthermore, and to rule out the influence of other factors that might account for the creation of cooperative ties among two actors in our network, we include endogenous network effects (i.e. network dependencies). Inherent in the network itself, they are reflecting the network's own dynamics that might account for the enhancement of cooperation among the network's actors. We include several standardized endogenous network effects into the models: *edge*, which corresponds to the number of edges existent in a network and serves as baseline for all other effects; *mutual*, which controls for reciprocity and thus the tendency of two actors to mutually maintain a cooperative tie; *gwidegree* and *gwodegree*, which control for the geometrically weighted in- and out-degree distribution of actors' ties throughout the randomly generated permutations of the original network; *gwesp* and *gwdsp*, which test for triadic closure, i.e. the creation of triads among two actors who share a tie and a third partner, via geometrically weighted *edgewise shared* partner and geometrically weighted *dyad-wise shared* partner statistics presented by Hunter et al. (2008, 13). These two network effects represent thus transitivity in the network, the connection of two actors through a third one.

## 4. Analysis

Before presenting the results based on the Exponential Random Graph Models, we outline some descriptive statistics about our dependent and independent variables.

### 4.1 Descriptive statistics

The network of cooperation consists of 36 actors with 273 connections among them. The network's density is 21.7%.[11] When looking at the density of connections among the actors of the same type (see Table 2) we observe the following: *polluters* are by far the best connected actor group with a density of 59.5% (n=7); *national state actors* have a strong density of 50% – considering that they are only two this tells us that the cooperation link of one of them towards the other is not reciprocated; *NGOs* (50%), *water associations* (45%) and actors from *science* (43.3%) are all very well connected with their peers; *regional state actors* (30%) and to a lesser degree *service provider* (25%) do have fairly dense connections among each other as well. There is only one actor of the type *consumer organization* in the network, which is therefore not listed in the Table. In general, one can state that cooperation – understood as the connections among actors in the network – in water quality management in the Rhine catchment area around Basel exists and is quite strong with very tight connections among polluters and NGOs respectively.

**Table 2: Network density among the groups of actor types**

| Actor type | Group's network density | n |
|---|---|---|
| National state actor | 50% | 2 |
| Regional state actor | 30% | 5 |
| NGO | 50% | 5 |
| Water association | 45% | 5 |
| Polluter | 59.5% | 7 |
| Science | 43.3% | 6 |
| Service provider | 25% | 5 |

Regarding actors' exposure to the micro-pollutant SMX and their perception of the different effects micro-pollutants can have, we make the following observations (see Table 3).

**Problem exposure** varies strongly across actor types. The actor group exposed by far the most to the substance SMX (on average) is *water associations*.[12] This is to a large extent due to the

[11] Network density describes the share of existing ties within a network compared to the sum of ties that can possibly exist in a network. The descriptive network statistics were calculated with UCINET (Borgatti, Everett, and Freeman 2002).
[12] As there exists no benchmark limit for the load of micro-pollutants which would indicate at which point a certain load of substances can be considered high or low respectively, one needs to discuss the loads exposed in a radius of 15km around the actors in comparison to each other.

fact that they are not only located in Switzerland, but also in German cities further downstream the Rhine catchment area where loads have accumulated.

**Table 3: Average problem *perception* and *exposure* per actor type**

| Actor type | **Average problem perception** (scale from 1 to 4) | | | **Average problem exposure** (kg/yr) |
|---|---|---|---|---|
| | **Neg. effects on aquatic organ.** | **Cocktail effect** | **Raised level of hormones** | |
| National state actor | 3 | 3 | 3 | 21 |
| Regional state actor | 3.4 | 3.2 | 2.8 | 34 |
| NGO | 3.8 | 3.6 | 3.4 | 22,8 |
| Water association | 3.2 | 3.4 | 3 | 51,4 |
| Polluter | 2.9 | 2.6 | 2.4 | 39,3 |
| Science | 3 | 2.5 | 2.8 | 43,2 |
| Service provider | 3 | 3.2 | 2.6 | 27,6 |
| Consumer organization | 4 | 4 | 4 | 19 |
| *Mean* | *3.19* | *3.06* | *2.86* | *35.39* |

The actor group exposed the second most is *science* whose actors are located upstream the catchment area in and around the city Zürich, but also in and around Basel as well as further downstream the river in the German city Karlsruhe. *Polluters* who are all based in and around Basel are exposed to a similarly large load of micro-pollutants throughout the year. *Service provider* are on average less exposed, which at a first glance is surprising as three out of these five actors are located within and near Basel, a region where micro-pollutants and especially a heavily used pharmaceutical like SMX appear in surface water. Looking at the exposure of the single actors it becomes clear that the three located in Basel are heavily exposed (36 - 42 kg/yr) while the other two are not (3 and 19 kg/yr).[13] *NGOs* are on average less exposed than the other actor groups because two of them are located in areas with a low load of micro-pollutants (9 and 10 kg/yr) while the other three, also located on French territory (Strasbourg)

[13] For each actor's problem exposure see Table 6 in the Appendix.

and on Swiss territory in Basel and the neighboring city Liestal, are exposed to a fairly high load of micro-pollutants per year (21 and 37 kg/yr). The *national state actors* are both located in the Swiss capital Bern and therefore further upstream in the Rhine catchment area where the load of substances is still less, while the *regional state actors* are almost all located in the city of Basel and its surroundings where the load of SMX is rather high. Finally, the *consumer organization* is also located in Bern and therefore less exposed than the rest of the actors.

Regarding the mean of the problem perceptions' values in general, **negative effects on aquatic organisms** are perceived as more problematic than micro-pollutants' possible **cocktail effect**. The perception of the effect that **raised levels of hormones** could have is ranked less problematic than the other two possible effects.

Discussing actors' exposure to the micro-pollutant SMX in relation to their perception of the different effects micro-pollutants can have, an interesting picture appears. The two actor groups that perceive micro-pollutants' effects as most problematic – the *consumer organization* (4) and *NGOs* (3.4 - 3.8) – are at the same time the least (19 kg/yr) and one of the less (22.8 kg/yr) affected actor groups. *Polluters*, which are much more exposed to micro-pollutants than *NGOs* are (39.3 kg/yr), perceive this environmental issue on average much less problematic than *NGOs* do (2.4 - 2.9). They are thus comparable to actors from the *scientific* sector which perceive the effects similarly (2.5 - 3) and are equally strong exposed to the substance SMX as *polluters* (43.2 kg/yr). The group of *water associations* is the most exposed one to SMX (51.4 kg/yr) and at the same time one of the most concerned (3 - 3.4), the latter of which is probably due to the fact that their main task is to handle water quality and quantity issues. *State actors* at the *regional* level are stronger exposed to SMX (34. kg/yr) than their counterparts on the *national* level (21 kg/yr). They also have a slightly stronger concern about micro-pollutants' effects (2.8 - 3.4) than *national state actors*. *Service providers* finally range between state actors regarding their exposure to SMX (27.6 kg/yr) and also have quite a wide range of how problematic they perceive substances' effects (2.6 - 3.2).

### 4.2 ERGM results

To test these independent variables' effects on the network's ties, while controlling for actors' attributes and endogenous network effects, we ran ERGM (see Table 4 for results).[14]

**Table 4: ERGM results for the cooperation network in the Rhine sub-catchment in Basel**

| | Model 1 | Model 2 |
|---|---|---|
| IV 2 **Co-Participation in forums** | **0.57 ***** | |
| | (0.11) | |
| IV 1a **Similar Exposure towards SMX** | **0.43*** | **0.50 *** |
| | (0.22) | (0.20) |
| IV 1b **Problem Perception** | | |
| Activity **Cocktail Effect** | 0.15 | **0.33 **** |
| | (0.14) | (0.13) |
| Heterophily **Cocktail Effect** | -0.03 | 0.02 |
| | (0.10) | (0.09) |
| Activity **Negative Effects on Aquatic Organisms** | -0.16 | **-0.17.** |
| | (0.11) | (0.09) |
| Heterophily **Negative Effects on Aquatic Organisms** | -0.14 | **-0.19 *** |
| | (0.09) | (0.08) |
| Activity **Raised levels of Hormones** | -0.09 | -0.19 |
| | (0.15) | (0.13) |
| Heterophily **Raised levels of Hormones** | -0.11 | -0.01 |
| | (0.12) | (0.10) |
| CV Node match **Actor type** | **0.67 ***** | **0.75 ***** |
| | (0.15) | (0.14) |
| CV Node match **Swiss actor** | **0.53 ***** | **0.46 ***** |
| | (0.14) | (0.11) |
| CV **Network Effects** | | |
| edges | -5.03 *** | -5.75 *** |
| | (0.97) | (0.89) |
| mutual | **1.15 ***** | **1.32 ***** |
| | (0.26) | (0.24) |
| gwidegree | 2.03 ** | 1.74 * |
| | (0.75) | (0.74) |
| gwodegree | 2.49 ** | 2.41 ** |
| | (0.85) | (0.83) |
| gwesp.fixed.0.5 | **2.03 ***** | **2.11 ***** |
| | (0.27) | (0.26) |
| gwdsp.fixed.0.5 | -0.07 * | -0.06 * |
| | (0.03) | (0.03) |
| AIC | 962.20 | 1004.62 |
| BIC | 1085.53 | 1122.81 |
| Log Likelihood | -457.10 | -479.31 |

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; Additional control variables were included, but are not reported. Full results as well as the models' goodness-of-fit are reported in Table 7 and Figures 2 and 3 in the Appendix.

[14] The goodness-of-fit (GOF) for both models showed to be satisfying (see Figures 2 and 3 in the Appendix).

In a first model (Model 1) we tested *all* independent variables' effects on the dependent variable; in a second model (Model 2) we excluded the second independent variable **co-participation of two actors in a forum**.

## 5. Results

As apparent in the first model in Table 4, the independent variable **co-participation in forums**, and thus the fact of two actors participating jointly in water body associations or other platforms, has a positive and very strong significant correlation to the existence of a cooperative tie between these two actors ($p < 0.001$). Hypothesis 2 can thus be confirmed for our case study. As this independent variable omits other potential driving factors for the existence of cooperative ties among two actors in the network, we excluded it from the second model.

In both models the coefficients of the **problem exposure** variable (*similar exposure towards SMX*), thus two actors similarly exposed to the micro-pollutant SMX, are significant and positive. This indicates a significant positive correlation between two actors' being similarly exposed to the environmental problem and them sharing a cooperative tie. When excluding independent variable 2 (*co-participation in forums*, Model 2) the significance level stays the same ($p < 0.05$); a sign of this variable's coherence with cooperational ties among actors. These findings thus confirm hypothesis 1a.

Considering the independent variable **problem perception**, not all of actors' perceptions that we tested showed the expected effects; moreover, this independent variable only showed significant effects after we excluded independent variable 2. Significant results in Model 2 are the following: actors perceiving the **cocktail effect** (the potential toxicity arising from the mixture of different substances) as serious threat have a high tendency to engage in tie creation ($p < 0.01$). The contrary is the case for those actors perceiving **negative effects on aquatic organisms** as a serious threat. On a very low significance level ($p < 0.1$) the *activity* term is negative, hinting at the tendency of actors who perceive this consequence of micro-pollutants as problematic to be less likely to establish cooperation ties with other actors in the network. A higher significance and thus a higher meaningfulness shows the *heterophily* term of this independent variable which is significant ($p < 0.05$) and negative. This suggests that actors who *do not* have the same perception of this issue are also *less likely* to share a tie with each other, or put differently, actors who *do have* the same perception of this issue are *more likely* to share a tie with each other. Finally, actors' perception of **raised levels of hormones** in surface water as problematic does not affect their cooperation pattern, as the variable's coefficients are not significant. Hypothesis 1b is thus only partially confirmed. In the case of the perception of micro-pollutants' **cocktail effect**, a *higher problem perception* does seem to enhance actors' cooperation. For the case of micro-pollutants' **negative effects on aquatic organisms**, it is actors who perceive this effect *equally* problematic who tend to share a tie and thus entertain a cooperational relation.

In both models, strong significant effects of reciprocity and transitivity can be observed (*mutual* and *gwesp;* $p < 0.001$), indicating that ties within the network are very likely to be reciprocated and that actors who share a tie with each other also tend to have one or more partners they are connected to in common.
Also, both models show that actors of the same type (node match actor type) have the tendency to engage in cooperation with each other, a fact that became already apparent in the discussion of the descriptive network statistics where a high density among actor types' groups was assessed (cf. Table 2). The models further suggest that Swiss actors have a higher tendency to cooperate with each other than with actors from other countries (node match Swiss actor); a finding which does not seem to be all that surprising when considering that 80.6% of the network's actors are Swiss. Nevertheless, this term being highly significant, it indicates that cross-border cooperation seems to be difficult to establish.

## 6. Discussion

Our results clearly confirm the relationship between our second independent variable and cooperation as outlined in hypothesis 2: co-participation in water body associations and other forums such as river basin committees clearly enhances the chance for two actors to engage in further joint action such as taking a common position on or formulating a joint strategy towards the management or regulation (e.g. policies) of micro-pollutants in the river Rhine. One word of caution needs to be expressed at this stage: although we used conceptually clearly distinguished definitions of water body membership (independent variable) and cooperation relations (dependent variable) in the survey, it might be that survey participants considered the two as different types of the same action, which might explain the correlation between those two factors. In the survey, we clearly defined participation in a water body association or a forum as being an institutional factor (i.e. defined through membership of an institution) whereas engaging in cooperation was defined as a direct relation and thus considered a structural element in water quality management. An interesting finding is that the **problem perception** factors become insignificant as soon as we include the independent variable **co-participation in a forum** in our model (model 1). This, again, highlights this variable's strong relation towards the establishment of cooperational ties in the network.

The degree to which an actor is **exposed to a problem** matters as well, confirming hypothesis 1a: in both models we can observe a significant effect on the existence of a cooperative tie between two actors as soon as these two actors are similarly exposed to the problem of micro-pollutants. This is an interesting result for several reasons.

First of all, being exposed to a pharmaceutical like SMX that resists the technique of river bank filtration used for the recovery of drinking water seems a crucial issue affecting today's societies in general. After consumption several drugs end up as trace compounds in waters, posing a risk to the aquatic ecosystem and humans consuming the water. An antibiotic like SMX has desirable effects to cure specific diseases; effects that one might not want to be exposed to through the consumption of water. Another important insight we gain from this result relates to the area or perimeter we defined as "area of exposure". We decided on a circle of 15km around the actor's location, arguing that this corresponds to a reasonable perimeter in which an actor is active related to drinking water consumption or water use in general. Although the definition of this area was explorative in nature, results seem to confirm its relevance. Finally, we remember that water associations were the most exposed actor type to micro-pollutants and those actors are furthermore considerably integrated in the cooperation network (see for instance Table 2). Problem exposure seems thus to have an impact on the engagement of an actor in cooperation.

**Problem perception** was assessed via three different effects of micro-pollutants we asked survey participants to evaluate: perceived consequences of micro-pollutants in relation to their **cocktail effect**; to their **negative effects on aquatic organisms**; and to effects related to **raised levels of hormones** in surface water. Not all of those factors seem to explain the

engagement of two actors into cooperation. Actors who perceive cocktail effects as very problematic have the tendency to significantly engage in collaborative tie creation. An illustrative example of this effect are NGOs: when taking a look at their individual perception we see that NGOs, which have a high share of connections among each other, are also perceiving this effect as very problematic (two evaluated it with a 3; three evaluated it with a 4). Surprisingly, the contrary is the case for the perception of the negative effects on aquatic organisms. Actors perceiving this effect as problematic are less likely to create ties with other actors in the network (although the significance level of this finding is very low). Strong significant results indicate that actors who perceive this effect equally problematic are more likely to share a cooperation tie. For instance, water associations share a lot of ties among each other and also perceive this aspect of micro-pollutants equally problematic (3); NGOs share a lot of ties with each other as well and, except for one actor (evaluating it with a 3), all perceive this effect as a severe problem (4).
No significant relation can be detected for actors' perception of the effects related to raised levels of hormones in waters. When looking at the mean value of this effect's perception (Table 3) one observes that this effect has been evaluated as the least problematic of all three effects.

Furthermore, to see whether there was a relation between the exposure of an actor towards the environmental problem and this actor's problem perception, we checked for correlation between **problem exposure** and **problem perception.** Even if we only considered actors' mere problem exposure value (cf. Table 3, last column) – and not the dyadic similarity index of two actors – results are straight forward: correlation coefficients of all three problem perception variables and the problem exposure variable range between -0.11 (cocktail effect variable) and -0.17 (negative effects on aquatic organisms variable). The *very* weak negative linear relationship between the negative effects on aquatic organisms variable and the problem exposure variable can almost be neglected; for the other two problem perceptions the correlation coefficients were very close to 0, indicating that they do not have a linear relationship with the problem perception variable.[15]

[15] P-values indicated no significant correlations. The correlation coefficients of the problem exposure variable (load of SMX in a radius of 15km) and the problem perception variables were the following: for "cocktail effect"

Finally, when considering our **control variables** we see that no actor type has a significant impact on cooperative tie creation in the network. However, we can confirm a general actor type homophily effect: actors with the same role in the overall management of micro-pollutants (e.g. political actor, polluter, etc.) have the tendency to establish cooperative ties towards their peers. Such homophily effects are widely observed in management and policy networks (Malang, Brandenberger, and Leifeld forthcoming).

Swiss actors also tend to engage in cooperation with each other much more than actors of other nationalities. Cross-border cooperation seems thus difficult to establish. This has partially been confirmed by one of the interviewed experts who indicated that collaboration of his institution with German authorities is working well while there is much less contact to French counterparts. The expert further mentioned that working groups and committees working on the topic of micro-pollutants are often not connected with each other and in some cases do not even know of each other's existence, therefore creating parallel structures.[16] A positive example of cross-border collaboration was given by three of the interviewed experts: they mentioned a so-called "circle of trust" among the German regional council of Freiburg, authorities in the cantons of Basel Stadt, Basel Landschaft and Aargau, industrial actors and service provider. Within this circle of trust information on concentration of micro-pollutants detected above the authorized limit are communicated in order to find the source of the respective pollution as fast as possible.[17]

Our results suggest that if water body associations allow for international and trans-boundary memberships and participations such cross-country collaboration might be enhanced (see confirmation of hypothesis 2). This seems especially relevant for a persistent and trans-boundary environmental issue like micro-pollutants which does not stop at borders and whose complex multi-level and cross-sectoral polluter-consumer relationships challenge traditional top-down and country-specific resource management and regulation.

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it was -0.1125; for "effects on aquatic organisms" it was -0.1697; for "raised levels of hormones" it was -0.1339. Calculations were done using Pearson's correlation in R.

[16] Interview 3.

[17] Interviews 1, 3 & 4.

## 7. Conclusion

In our study, we posed the question how cooperation among actors in a CPR problem situation establishes. More precisely, we asked which concrete drivers trigger these actors to engage in cooperation with each other. Based on a single case study we assessed the common-pool resource problem of micro-pollutants in the river Rhine catchment, conceptualizing cooperation as a *network* of actors engaged in water quality management in the study region. Applying an Exponential Random Graph Model we tested the influence of the following three factors on the creation of a tie in our network of cooperation: a) *actors' exposure to the micro-pollutant* Sulfamethoxazole, an antibiotic that appears frequently in European water bodies; b) *actors' perception* of the environmental problem *micro-pollutants in surface water*; and c) *actors' joint participation in* water body associations and committees, so-called *forums*.

The findings of our case study analysis suggest that A) two actors' similar exposure to an environmental problem such as micro-pollutants is related to their collaborative relation, the fact of them sharing a tie in the network of cooperation. B) The perception of the environmental problem micro-pollutants plays a role for the existence of a cooperational tie among two actors depending on the *aspects* of the environmental problem that these actors evaluate as problematic, and on the *intensity* or *similarity* with which they perceive this aspect as problematic. Moreover, the perception of the environmental problem shows a significant effect on actors' ties only if we do not control for C) the co-participation of two actors in one or more forums. In our analysis, this factor pointed to such a strong significant relation towards the existence of a tie that it held back the effects of actors' problem perception on cooperation.

Concluding, we can state that our study confirms the assumption of forums' importance for collaborative behavior and cooperational engagement of actors involved in environmental governance. Furthermore, we were able to show that the recognition of the environmental problem itself is relevant for the analysis of cooperation in CPR problem settings. By conceptualizing the environmental problem's influence on cooperation as actors' *exposure to* and actors' *perception of* it, we brought a natural scientific as well as a cognitive perspective into the analysis. Therefore, we claim that research on socio-ecological systems in general and on the management of natural CPR in particular requires a more determined opening towards the ecological system and a more systematic consideration of the relation between actors and resources. After all, further research covering more case studies will be needed to test our findings' general validity and accentuate the effect that the exposure to and the perception of a CPR problem have on actors' cooperation.

## References

Adger, W. N., Tara Quinn, Irene Lorenzoni, and Conor Murphy. 2016. "Sharing the Pain: Perceptions of Fairness Affect Private and Public Response to Hazards." *Annals of the American Association of Geographers* 106 (5): 1079–96.

Agrawal, A. 2001. "Common Property Institutions and Sustainable Governance of Resources." *World Development* 29 (10): 1649–72.

Ansell, Chris, and Alison Gash. 2008. "Collaborative Governance in Theory and Practice." *Journal of Public Administration Research and Theory* 18 (4): 543–71.

Araral, Eduardo. 2014. "Ostrom, Hardin and the commons: A critical appreciation and a revisionist view." *Environmental Science and Policy* 36: 11–23.

Berardo, Ramiro, and Mark Lubell. 2016. "Understanding What Shapes a Polycentric Governance System." *Public Administration Review* 76 (5): 738–51.

Berardo, Ramiro, and John T. Scholz. 2010. "Self-Organizing Policy Networks: Risk, Partner Selection, and Cooperation in Estuaries." *American Journal of Political Science* 54 (3): 632–49.

Berkes, Fikret, and Carl Folke. 2002. "Back to the Future: Ecosystem Dynamics and Local Knowledge." In *Panarchy Understanding Transformations in Human and Natural Systems*, edited by L. H. Gunderson and C. S. Holling, 121–46. Washington, D.C. Island Press.

Birkland, Thomas A. 2016. *An introduction to the policy process: theories, concepts, and models of public policy making.* 4th ed. New York: Routledge.

Blythe, Jessica L., Grant Murray, and Mark Flaherty. 2014. "Strengthening threatened communities through adaptation: insights from coastal Mozambique." *Ecology and Society* 19 (2): 6.

Borgatti, S. P., Martin G. Everett, and L. C. Freeman. 2002. *Ucinet for Windows: Software for Social Network Analysis.* Harvard, MA: Analytic Technologies.

Brodin, T., J. Fick, M. Jonsson, and J. Klaminder. 2013. "Dilute Concentrations of a Psychiatric Drug Alter Behavior of Fish from Natural Populations." *Science* 339 (6121): 814–15.

Bundschuh, M., and R. Schulz. 2011. "Ozonation of secondary treated wastewater reduces ecotoxicity to Gammarus fossarum (Crustacea; Amphipoda): Are loads of (micro)pollutants responsible?" *Water Research* 45: 3999–4007.

Bunzel, K., M. Kattwinkel, and M. Liess. 2013. "Effects of organic pollutants from wastewater treatment plants on aquatic invertebrate communities." *Water Research* 47 (2): 597–606.

Calanni, John C., Saba N. Siddiki, Christopher M. Weible, and William D. Leach. 2015. "Explaining Coordination in Collaborative Partnerships and Clarifying the Scope of Belief Homophily Hypothesis." *Journal of Public Administration Research and Theory* 25 (3): 901–27.

Carvalho, R. N., A. Arukwe, S. Ait-Aissa, A. Bado-Nilles, S. Balzamo, A. Baun, S. Belkin et al. 2014. “Mixtures of chemical pollutants at European legislation safety concentrations: How safe are they?” *Toxicological Sciences* 141 (1): 218–33.

Chèvre, N., C. Loepfe, H. Singer, C. Stamm, K. Fenner, and B. I. Escher. 2006. “Including Mixtures in the Determination of Water Quality Criteria for Herbicides in Surface Water.” *Environmental Science & Technology* 40 (2): 426–35.

Christensen, Per, Lone Kornov, and Eskild Holm Nielsen. 2012. “Between Governance and Government: Danish EIA in Uncharted Waters.” *Journal of Environmental Assessment Policy and Management* 14 (4): 1250021.

Cranmer, Skyler J., and Desmarais Bruce A. 2010. “Inferential Network Analysis with Exponential Random Graph Models.” *Political Analysis* 19 (66-86).

Cunningham, Virginia L., Stephen P. Binks, and Michael J. Olson. 2009. “Human Health Risk Assessment from the Presence of Human Pharmaceuticals in the Aquatic Environment.” *Regulatory toxicology and pharmacology: RTP* 53 (1): 39–45.

Driessen, Peter P. J., Carel Dieperink, Frank van Laerhoven, Hens A. C. Runhaar, and Walter J. V. Vermeulen. 2012. “Towards a Conceptual Framework for the Study of Shifts in Modes of Environmental Governance - Experiences from the Netherlands.” *Environmental Policy and Governance* 22 (3): 143–60.

Duffy, Robert J. 1997. *Nuclear politics in America: A History and Theory of Government Regulation.* Lawrence, Kansas: University Press of Kansas.

Feiock, Richard C., and John T. Scholz. 2010. *Self-Organizing Federalism: Collaborative Mechanisms to Mitigate Institutional Collective Action Dilemmas.* New York: Cambridge University Press.

Fischer, Manuel, and Philip Leifeld. 2015. “Policy forums: Why do they exist and what are they used for?” *Policy Sciences* 48 (3): 363–82.

Gälli, René, Jutta Schmid-Kleikemper, Christoph Ort, and Michael Schärer. 2009. “Mikroverunreinigungen in den Gewässern: Bewertung und Reduktion der Schadstoffbelastung aus der Siedlungsentwässerung.” Umwelt-Wissen 0917. Unpublished manuscript, last modified May 06, 2015. http://www.bafu.admin.ch/publikationen/publikation/01051/index.html?lang=de.

Gerber, Jean-David, Peter Knoepfel, Stéphane Nahrath, and Frédéric Varone. 2009. “Institutional Resource Regimes: Towards sustainability through the combination of property-rights theory and policy analysis.” *Ecological Economics* 68: 798–809.

Gerlak, Andrea K., Mark Lubell, and Tanya Heikkila. 2013. “The Promise and Performance of Collaborative Governance.” In *The Oxford Handbook of US Environmental Policy*, edited by Michael E. Kraft and Sheldon Kamieniecki, 413–34. New York: Oxford University Press.

Gersonius, Berry, Arwin van Buuren, Marit Zethof, and Ellen Kelder. 2016. “Resilient flood risk strategies: institutional preconditions for implementation.” *Ecology and Society* 21 (4): 28.

Götz, C., Christian Stamm, K. Fenner, Heinz Singer, Michael Schärer, and J. Hollender. 2010. "Targeting aquatic microcontaminants for monitoring: exposure categorization and applicationto the Swiss situation." *Environmental Science and Pollution Research* 17 (2): 341–54.

Guerrero, Angela M., Örjan Bodin, McAllister, Ryan R. J., and Kerrie A. Wilson. 2015. "Achieving social-ecological fit through bottom-up collaborative governance: an empirical investigation." *Ecology and Society* 20 (4): 41.

Handcock, Mark S., David R. Hunter, Carter T. Butts, Steven M. Goodreau, and Martina Morris. 2008. "statnet: Software tools for the Representation, Visualization, Analysis and Simulation of Network Data." *Journal of Statistical Software* 24 (1).

Heaney, Michael T., and Scott D. McClurg. 2009. "Social Networks and American Politics: Introduction to the Special Issue." *American Politics Research* 37 (5): 727–41.

Heikkila, Tanya, and Andrea K. Gerlak. 2005. "The Formation of Large-scale Collaborative Resource Management Institutions: Clarifying the Roles of Stakeholders, Science, and Institutions." *Policy Studies Journal* 33 (4): 583–612.

Heikkila, Tanya, Andrea K. Gerlak, Andrew R. Bell, and Susanne Schmeier. 2013. "Adaptation in a transboundary river basin: Linking stressors and adaptive capacity within the Mekong River Commission." *Environmental Science and Policy* 25: 73–82.

Henning, Christian H. C. A. 2009. "Networks of Power in the CAP System of the EU-15 and EU-27." *Journal of Public Policy* 29 (2): 153–77.

Herberer, T., I. M. Verstraeten, M. T. Meyer, A. Mechlinski, and K. Reddersen. 2011. "Occurrence and Fate of Pharmaceuticals during Bank Filtration - Preliminary Results from Investigations in Germany and the United States." *Journal of Contemporary Water Research and Education* 120 (1): 2.

Hollender, J., S. G. Zimmermann, S. Koepke, M. Krauss, C. S. McArdell, C. Ort, H. Singer, U. von Gunten, and H. Siegrist. 2009. "Elimination of organic micropollutants in a municipal wastewater treatment plant upgraded with a full-scale post-ozonation followed by sand filtration." *Environmental Science & Technology* 43 (20): 7862–69.

Hunter, David R., Mark S. Handcock, Carter T. Butts, Steven M. Goodreau, and Martina Morris. 2008. "ergm: A Package to Fit, Simulate and Diagnose Exponential-Family Models for Networks." *Journal of Statistical Software* 24 (3).

Ingold, Karin, Peter P. J. Driessen, Hens A. C. Runhaar, and Alexander Widmer. Forthcoming a. "Connectivity: linking characteristics of environmental problems with the ways in which they are governed."

Ingold, Karin, Andreas Moser, Florence Metz, Laura M. Herzog, Hans-Peter Bader, Ruth Scheidegger, and Christian Stamm. Forthcoming b. "Misfit between physical affectedness and regulatory embeddedness: The case of drinking water supply along the Rhine River."

Jenkins-Smith, Hank, Gilbert St. Clair, and Brian Woods. 1991. "Explaining Change in Policy Subsystems: Analysis of Coalition Stability and Defection over Time." *American Journal of Political Science* 35: 851–72.

Knoepfel, Peter, ed. 2007. *Environmental Policy Analyses: Learning from the Past for the Future - 25 Years of Research.* Berlin, Heidelberg: Springer-Verlag.

Leifeld, Philip, and Volker Schneider. 2012. "Information Exchange in Policy Networks." *American Journal of Political Science* 56 (3): 731–44.

Long, Norton E. 1958. "The Local Community as an Ecology of Games." *The American Journal of Sociology* 64: 251–61.

Lubell, Mark. 2013. "Governing Institutional Complexity: The Ecology of Games Framework." *The Policy Studies Journal* 41 (3): 537–59.

Lubell, Mark, Adam D. Henry, and Mike McCoy. 2010. "Collaborative Institutions in an Ecology of Games." *American Journal of Political Science* 54 (2): 287–300.

Lubell, Mark, John T. Scholz, Ramiro Berardo, and Gary Robins. 2012. "Testing Policy Theory with Statistical Models of Networks." *Policy Studies Journal* 40:351–74.

Malang, Thomas, Laurence Brandenberger, and Philip Leifeld. "Networks and Social Influence in European Legislative Politics." *British Journal of Political Science* Accepted for publication.

Macnaghten, Phil, and Michael Jacobs. 1997. "Public identification with sustainable development: Investigating cultural barriers to participation." *Global Environmental Change* 7 (1): 5–24.

McGinnis, M. D., and Elinor Ostrom. 2014. "Social-ecological system framework: initial changes and continuing challenges." *Ecology and Society* 19 (2): 30.

Metz, Florence. 2017. *From Network Structure to Policy Design in Water Protection: A Comparative Perspective on Micropollutants in the Rhine River Riparian Countries.* Cham: Springer International Publishing.

Monge, Peter R., and Noshir S. Contractor. 2003. *Theories of communication networks.* Oxford, New York: Oxford University Press.

Moser, Andreas, Christian Stamm, Ruth Scheidegger, Hans-Peter Bader, Fabrizio Fenicia, Laura M. Herzog, and Karin Ingold. 2016. "Spatial Relationships Between Sources of Micropollutants and Drinking Water Supply in the Rhine Basin." 7th International Water Resources Management Conference of ICWRS, Bochum, Germany, May 18.

Newig, Jens. 2012. "More effective natural resource management through participatory governance? Taking stock of the conceptual and empirical literature - and moving forward." In *The Challenge of Legitimacy and Effectiveness*, edited by Karl Hogl, Eva Kvarda, Ralf Nordbeck, and Michael Pregernig, 46–68. Cheltenham: Edward Elgar.

Nohrstedt, Daniel. 2010. "Do Advocacy Coalitions Matter? Crisis and Change in Swedish Nuclear Energy Policy." *Journal of Public Administration Research and Theory* 20 (2): 309–33.

Nohrstedt, Daniel, and Christopher M. Weible. 2010. "The Logic of Policy Change After Crisis: Proximity and Subsystem Interaction." *Risks, Hazards, and Crisis in Public Policy* 1 (2): 1–32.

Ostrom, Elinor. 1990. *Governing the commons: The evolution of institutions for collective action.* Cambridge: Cambridge University Press.

———. 1998. “A Behavioral Approach to the Rational Choice Theory of Collective Action: Presidential Address, American Political Science Association.” *The American Political Science Review* 92 (1): 1–22.

———. 2000a. “Collective Action and the Evolution of Social Norms.” *Journal of Economic Perspectives* 14 (3): 137–58.

———. 2000b. “The Danger of Self-Evident Truths.” *Political Science and Politics* 33 (1): 33–44.

———. 2009. “A General Framework for Analyzing Sustainability of Social-Ecological Systems.” *Science* 325 (419-422).

Ostrom, Elinor, R. Gardner, and J. Walker, eds. 1994. *Rules, Games and Common Pool Resources.* Michigan: Michigan University Press.

Peters, B. G., and J. A. Hoornbeek. 2005. “The problem of policy problems.” In *Designing government: From instruments to governance*, edited by F. P. Eliadis, Margaret M. Hill, and Michael Howlett. Montreal, Ithaca [N.Y.]: McGill-Queen's University Press.

R Core Team. 2013. *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org/.

Sabatier, Paul A., and Christopher M. Weible. 2007. “The Advocacy Coalition Framework: Innovations and Clarifications.” In *Theories of the Policy Process*, edited by Paul A. Sabatier. 2nd ed., 189–220. Boulder, CO: Westview Press.

Sadoff, Claudia W., and David Grey. 2005. “Cooperation on International Rivers.” *Water International* 30 (4): 420–27.

Schemmel, Eva, Alan M. Friedlander, Pelika Andrade, Ku'ulei Keakealani, Linda M. Castro, Chad Wiggins, Bart A. Wilcox, Yumi Yasutake, and John N. Kittinger. 2016. “The codevelopment of coastal fisheries monitoring methods to support local management.” *Ecology and Society* 21 (4): 34.

Schlager, Edella, and Tanya Heikkila. 2009. “Resolving Water Conflicts: A Comparative Analysis of Interstate River Compacts.” *The Policy Studies Journal* 37 (3): 367–92.

Schwarzenbach, René P., Beate I. Escher, Kathrin. Fenner, Thomas B. Hofstetter, Anette C. Johnson, Urs v. Gunten, and Bernhard Wehrli. 2006. “The Challenge of Micropollutants in Aquatic Systems.” *Science* 313 (5790): 1072–77.

Villamayor-Tomas, Sergio, Forrest D. Fleischmann, Irene P. Ibarra, Andreas Thiel, and Frank van Laerhoven. 2014. “From Sandoz to Salmon: Conceptualizing resource and institutional dynamics in the Rhine watershed through the SES framework.” *International Journal of the Commons* 8 (2): 361–95.

Weible, Christopher M., and Paul A. Sabatier. 2005. “Comparing Policy Networks: Marine Protected Areas in California.” *The Policy Studies Journal* 33 (2): 181–202.

———. 2009. “Coalitions, Science, and Belief Change: Comparing Adversarial and Collaborative Policy Subsystems.” *Policy Studies Journal* 37 (2): 195–212.

Wittmer, Irene K., Hans-Peter Bader, Ruth Scheidegger, and Christian Stamm. 2016. “REXPO: A catchment model designed to understand and simulate the loss dynamics of plant protection products and biocides from agricultural and urban areas.” *Journal of Hydrology* 533: 486–514.

Wolf, Aaron T., Shira Yoffe, and Mark Giordano. 2003. “International Waters - Identifying Basins at Risk.” *Water Policy* 5: 29–60.

# Appendix

**Table 5: List of interviews**

| Nr. | Organization | Actor type | Position of interviewee | Place | Date |
|---|---|---|---|---|---|
| 1 | Hardwasser plc (WWB) | Drinking water supplier | Deputy managing director | Pratteln, Switzerland | 10/7/2015 |
| 2 | Industrielle Werke Basel (IWB) | Drinking water supplier | Head of the *water quality* department and the laboratory | Telephone interview | 11/17/2015 |
| 3 | Cantonal Office for the Environment and Energy, Basel Stadt (AUE BS) | Cantonal state actor | Head of the *prevention of water pollution* division | Basel, Switzerland | 04/07/2016 |
| 4 | Industrielle Werke Basel (IWB) | Drinking water supplier | Head of the *water quality department* and the laboratory | Basel, Switzerland | 05/03/2016 |

**Table 6: Actors' list**

| Acronym | Actor's name | Actor type | Exposure to SMX: kg/yr | Country |
|---|---|---|---|---|
| ADMLoerr | District administration of the city of Lörrach | Regional state actor | 38 | G |
| AIBBL | Cantonal Office for Industrial Companies, Basel Landschaft | Regional state actor | 39 | CH |
| ALSACENAT | Alsace Nature | NGO | 37 | F |
| APRONA | Association for the protection of the groundwater of the Alsatian plain | NGO | 10 | F |
| AQUAEXP | Union of Laboratories of Swiss Drinking Water Provider | Science | 50 | CH |
| AQUAVIV | Prevention of Water Pollution Northwest Switzerland | NGO | 9 | CH |
| AUEBL | Cantonal Office for Environmental Protection and Energy, Basel Landschaft | Regional state actor | 33 | CH |
| AUEBS | Cantonal Office for the Environment and Energy, Basel Stadt | Regional state actor | 38 | CH |
| AWBR | Association of Waterworks Lake Constance-Rhine | Water association | 2 | Intern. |
| CERCL | Association of the cantonal experts of water biology and chemistry | Science | 51 | CH |
| EAWAG | Swiss Federal Institute of Aquatic Science and Technology | Science | 59 | CH |
| FOEN_W | Federal Office for the Environment, Water Division | National state actor | 21 | CH |
| FSVO | Federal Food Safety and Veterinary Office | National state actor | 21 | CH |
| HKBB | Basel Chamber of Commerce | Polluter | 39 | CH |
| IAWR | International Association of Water Works in the Rhine Basin | Water association | 119 | Intern. |
| ICPR | International Commission for the Protection of the Rhine | Water association | 26 | Intern. |
| IWB | Industrial Works Basel – Drinking water provider in Basel | Service provider | 38 | CH |
| KI | Organization of municipal infrastructure | Service provider | 19 | CH |
| KI.SSV.SGV | Swiss Association of the Municipalities | Regional state actor | 22 | CH |
| LABBL | Cantonal Laboratory Basel Landschaft | Science | 20 | CH |
| LABBS | Cantonal Laboratory Basel City | Science | 39 | CH |
| NOVARTIS | Novartis International - Chemical company | Polluter | 39 | CH |
| PRONA | Pronatura - Environmental Protection Organization | NGO | 21 | CH |

| Acronym | Actor's name | Actor type | Exposure to SMX: kg/yr | Country |
|---|---|---|---|---|
| ROCHE | F. Hoffmann-La Roche plc - Chemical company | Polluter | 40 | CH |
| SBrV | Swiss Association of well craftsmen | Service provider | 3 | CH |
| SFA | Swiss Fishery Association | Consumer organization | 19 | CH |
| SVGW | Swiss Gas and Water Industry Association | Water association | 50 | CH |
| TZWK | German Water Centre, Karlsruhe | Science | 40 | G |
| VSA | Swiss Water Association | Water association | 60 | CH |
| WWB | Hardwasser plc – Drinking water provider in Basel | Service provider | 42 | CH |
| WWF | World Wide Fund for Nature, Switzerland | NGO | 37 | CH |
| WWR | Water Works Reinach and surrounding area | Service provider | 36 | CH |
| WWTPBasel | WWTP Basel, ProRheno plc | Polluter | 38 | CH |
| WWTPBirs | WWTP Birs, Birsfelden | Polluter | 39 | CH |
| WWTPChem Basel | Industrial WWTP, ProRheno plc | Polluter | 38 | CH |
| WWTPRhein | WWTP Rhein, Schweizerhalle | Polluter | 42 | CH |

Abbreviations: CH = Switzerland; F = France; G = Germany; Intern. = International actor; WWTP = Waste Water Treatment Plant

**Table 7: The Exponential Random Graph Models' results**

| | Model 1 | Model 2 |
|---|---|---|
| IV 2 **Co-Participation in forums** | **0.57 ***** | |
| | (0.11) | |
| IV 1a **Similar Exposure towards SMX** | **0.43*** | **0.50 *** |
| | (0.22) | (0.20) |
| IV 1b **Problem Perception** | | |
| Activity **Cocktail Effect** | 0.15 | **0.33 **** |
| | (0.14) | (0.13) |
| Heterophily **Cocktail Effect** | -0.03 | 0.02 |
| | (0.10) | (0.09) |
| Activity **Negative Effects on Aquatic Organisms** | -0.16 | **-0.17.** |
| | (0.11) | (0.09) |
| Heterophily **Negative Effects on Aquatic Organisms** | -0.14 | **-0.19 *** |
| | (0.09) | (0.08) |
| Activity **Raised levels of Hormones** | -0.09 | -0.19 |
| | (0.15) | (0.13) |
| Heterophily **Raised levels of Hormones** | -0.11 | -0.01 |
| | (0.12) | (0.10) |
| CV Node match **Actor type** (benchmark: consumer organization) | **0.67 ***** | **0.75 ***** |
| | (0.15) | (0.14) |
| Activity NGO | -0.15 | -0.02 |
| | (0.47) | (0.44) |
| Activity National state actor | 0.30 | 0.69 |
| | (0.50) | (0.46) |
| Activity Regional state actor | -0.46 | -0.01 |
| | (0.50) | (0.46) |
| Activity Polluter | -0.52 | -0.08 |
| | (0.50) | (0.46) |
| Activity Science | -0.18 | 0.24 |
| | (0.50) | (0.47) |
| Activity Service provider | -0.63 | -0.20 |
| | (0.51) | (0.46) |
| Activity Water association | -0.25 | 0.12 |
| | (0.52) | (0.48) |
| CV Node match **Swiss actor** | **0.53 ***** | **0.46 ***** |
| | (0.14) | (0.11) |
| Activity Swiss Actor | -0.32 | **-0.40*** |
| | (0.22) | (0.19) |
| CV **Network Effects** | | |
| edges | -5.03 *** | -5.75 *** |
| | (0.97) | (0.89) |
| mutual | **1.15 ***** | **1.32 ***** |
| | (0.26) | (0.24) |
| gwidegree | 2.03 ** | 1.74 * |
| | (0.75) | (0.74) |
| gwodegree | 2.49 ** | 2.41 ** |
| | (0.85) | (0.83) |
| gwesp.fixed.0.5 | **2.03 ***** | **2.11 ***** |
| | (0.27) | (0.26) |
| gwdsp.fixed.0.5 | -0.07 * | -0.06 * |
| | (0.03) | (0.03) |
| AIC | 962.20 | 1004.62 |
| BIC | 1085.53 | 1122.81 |
| Log Likelihood | -457.10 | -479.31 |

*** p < 0.001, ** p < 0.01, * p < 0.05

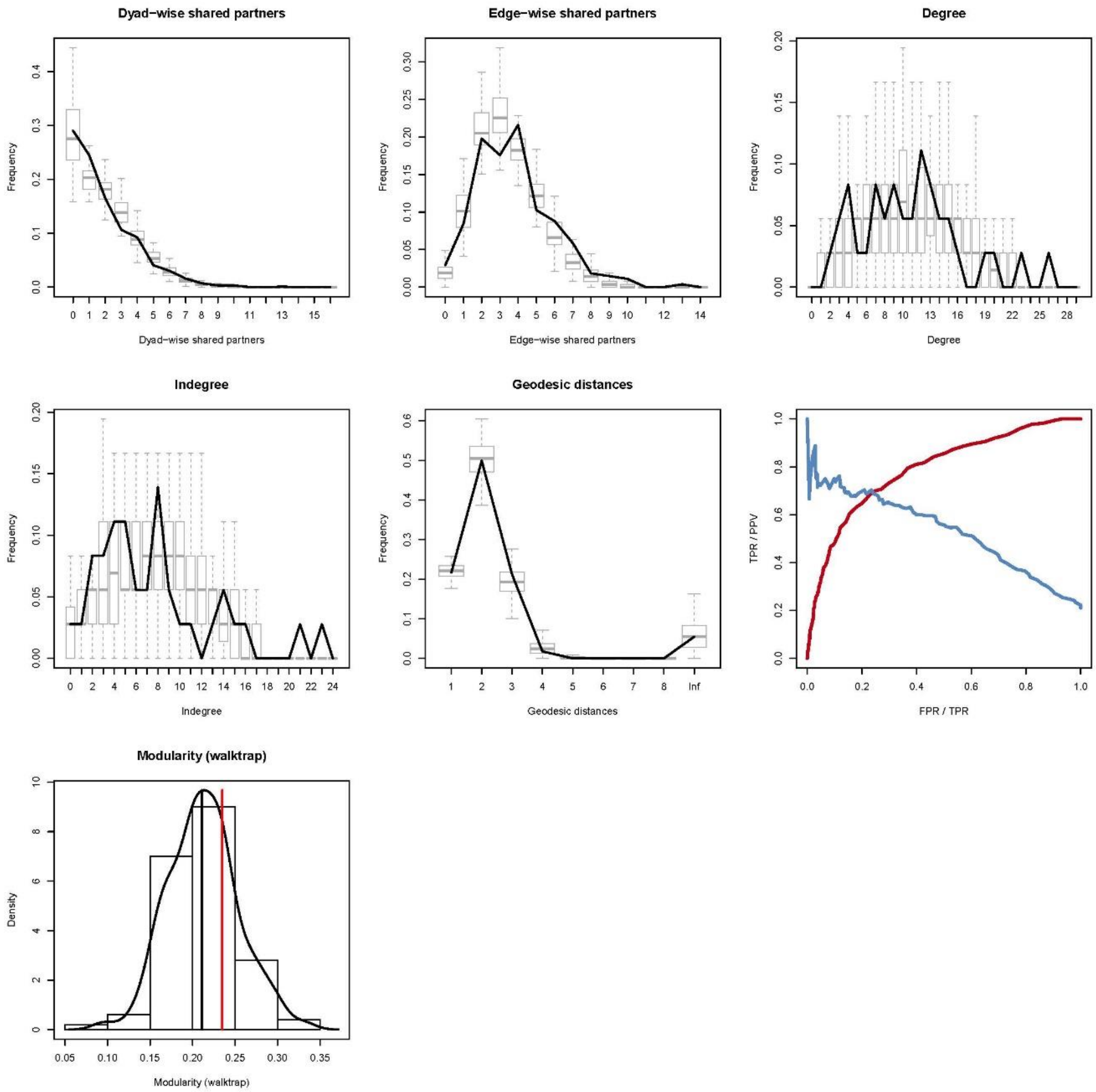


**Figure 2:** Goodness of fit for Model 1; α = 0.5

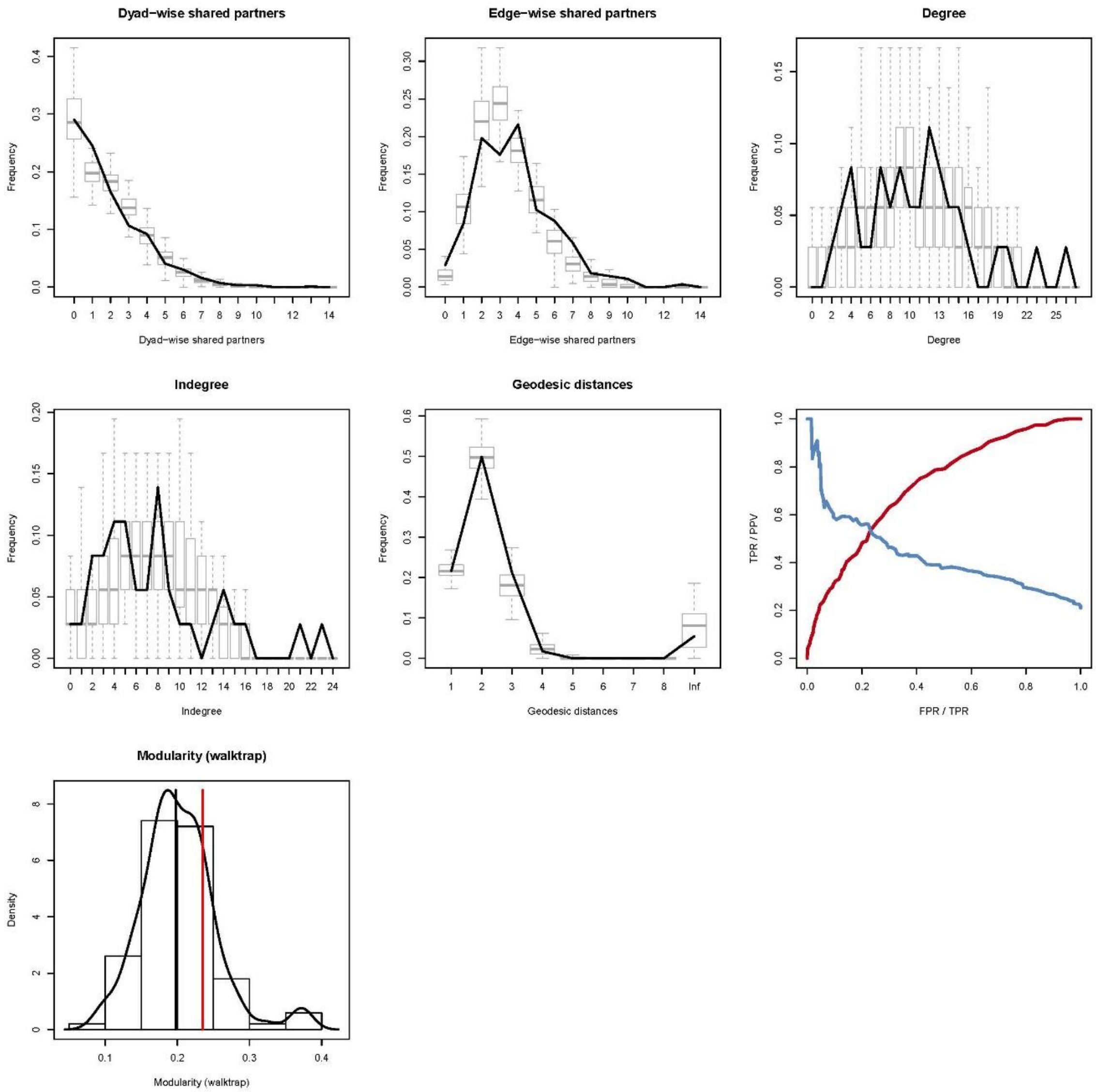


**Figure 3:** Goodness of fit for Model 2; α = 0.5