Conceptualizing large scale common pool resources through the SES framework: resource and institutional dynamics in the Rhine watershed

Sergio Villamayor-Tomas, Forrest Fleischman, Irene Perez Ibarra, Andreas Thiel, Frank van Laerhoven

1. INTRODUCTION

In this paper we develop a case study of water governance in the Rhine River to examine the relevance of Common Pool Resource (CPR) theory for two contexts that have not been extensively tested before: large scale trans-boundary water management, and pollution problems.

Applications of CPR theory to the study of water governance have traditionally focused on identifying the conditions under which individuals are able to cooperate at the local level. In this vein, CPR theory has traditionally understood cooperation as fundamentally mediated by the ability of relatively small and homogeneous communities of users to communicate with relative frequency and design appropriate rules and norms of behavior (Agrawal 2001). Large, trans-boundary systems differ from that ideal scenario in a number of ways. Such systems involve a huge number and diversity of stakeholders, are too large for coordination through frequent interactions, and tend to lack the sorts pre-existing political and social institutions relied on at smaller scales. In this paper we explore to which extent these differences prevent the applicability of CPR theory. Many rivers also face severe pollution problems that require additional exploration (UNEP, ERCE, and UNESCO 2008). In this paper we aim to contribute to that understanding by applying CPR theory to the case of the Rhine river.

A number of studies agree on the success of pollution management in the Rhine (Bernauer and Moser 1996, Dieperink 2000, Froehlich-Schmitt 2003, Huisman et al 2000, van Dijk et al 1995). At the beginning of the 1960s, water quality in the Rhine watershed had reached its poorest state. The lower portions of the river contained high concentrations of pollutants such as lead, mercury, cadmium and zinc, while a number of fish species like salmon had been completely eliminated from the watershed, and the aquatic ecosystem was virtually dead (Nollkaemper 1996). Until that time, international cooperation on the Rhine had been limited to the regulation of shipping and salmon fishing. This changed with the creation of the International Commission for the Protection of the Rhine (ICPR) in the 1960s and a series of pollution management agreements in the 1970s and 1980s. By the mid-1990s, emissions of two thirds of critical chemicals had been reduced by 50%, water quality parameters had improved notably, and the salmon and other fish stocks were on their way to full recovery (ICPR 2012).

Can CPR theory help us to understand the relative success of water pollution management in the Rhine watershed? And, to what extent can CPR theory be applied to pollution problems in similar large, trans-boundary contexts? To answer these questions we characterize the Rhine case across a series of governance, actor and resource variables.

Our case selection is appropriate as a test for CPR theory for several reasons. First, the Rhine is the largest watershed in north-western Europe, covering 170,000 km^2 and a population of about 60 million across eight different countries. Additionally, the historical density of industrial and agricultural activity has been among the highest in the world (Stigliani et al 1993). Second, the long history of conflict between the countries of the Rhine Basin makes it a particularly unlikely case for successful international cooperation. Third, the success of pollution management in the Rhine is only partial. Initial successes emerged only in the late 1970s, after more than a decade of missteps. Moreover, there are still important pollution control gaps, particularly with regard to non-point source emissions (Froehlich-Schmitt 2003). This within-case variation facilitates the identification of factors that contribute to success as well as prevent it. Finally, the case has been studied by a large number of scholars which provides us an opportunity to develop a thorough comparison of the case with CPR theory by drawing on existing studies.

2. CPR THEORY, LARGE SCALE CONTEXTS AND POLLUTION PROBLEMS

The core presumption of CPR theory is that certain environmental problems result from collective action problems, in which actors must overcome incentives geared at short-term individual gains to achieve socially preferred outcomes (Ostrom et al. 1994).

CPR theory distinguishes two types of collective action problems: appropriation and provision problems (Ostrom et al. 1994). Provision problems emerge when the costs of providing a public good (i.e., the productivity of a natural resource) are private while the benefits are shared. A common water management provision problem is underinvestment in infrastructure such as reservoirs or canals. Appropriation problems emerge when benefits from harvesting resource units are private while costs are shared. An example of a water appropriation problem is when farmers overharvest irrigation water. Emitting pollutants can be equated to appropriating resource units, as the benefits of emitting substances are private to polluters while the costs are shared by a broader population[1]. Each is an example of a negative externality.

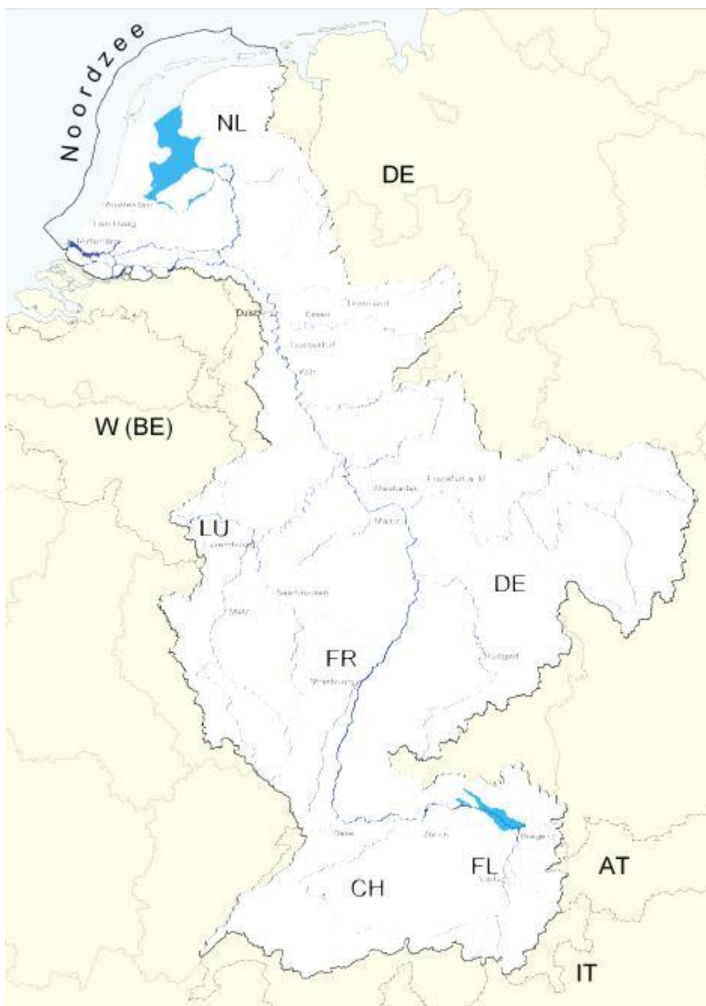
A number of scholars have successfully applied CPR theory to understand water allocation and infrastructure provision in larger river basins (Heikkila and Schlager 2012, Schlager and Heikkila 2011, Blomquist et al 2004, Kerr 2007, Lankford 2010, Yetim 2002). As illustrated by those works, using CPR theory in large scale contexts entails a redefinition of concepts like user group and governance system, as well as the consideration of phenomena other than collective action problems (for example the existence of contentious politics). In many large-scale contexts it appears more useful to understand collective action problems as emerging among nations or other large-scale political entities rather than among individuals.

[1] Pollution problems can also be seen from the perspective of the natural resource being affected by pollution (for example, water, or aquatic species in the Rhine). From this point of view, the management challenge is restoring the productivity of the resource (i.e., improving the quality of water or increasing fish stocks in the Rhine), which is in essence a provision problem.

A number of studies have also applied CPR theory to water pollution problems. Some of those studies aim at identifying the factors that motivate polluters to reduce emissions or invest in water quality (Lundqvist 2001, Emery and Franks 2012). Other studies focus on the collective action problems faced by specific user groups to effectively reduce pollution (Wittgren et al. 2005). In this study we aim at understanding both phenomena simultaneously.

3. CASE BACKGROUND

Since the 19th Century the Rhine (figure 1) has been intensively used for shipping, irrigation, drinking water production, fishing and industrial waste disposal, therewith becoming one of the underpinnings of the economy of Western Europe. The resulting benefits came with a price. By the beginning of the 20th Century the impact of waste disposal and other forms of pollution on drinking water, irrigation and fishing raised a concern about the need to cooperate to control emissions.



Source: Elaborated from (ICPR 2012c)

Figure 1. Map of the Rhine watershed

The history of international cooperation on the Rhine has been extensively documented (Bernauer 2002, Dieperink 2000, Huisman et al 2000, Mostert 2009). A summary of major events across major periods is provided in Table 1. The earliest international cooperation on the Rhine began at the end of the Napoleonic wars, with agreements on trade. Concern over overfishing of salmon led to the creation of the Salmon Commission in 1885. This Commission, however, did not prevent the construction of dams and water works, which had a negative impact on migratory fish species. By 1940 salmon stocks were depleted. The Dutch brought the pollution issue to the Salmon Commission as early as the 1920s (Huisman et al 2000). Despite the Dutch efforts, steps to create a common pollution information system began only in the 1950s. Ultimately, the Berne Convention was signed in 1963 which resulted in the creation of the ICPR.

Table 1. Major events characterizing the governance of the Rhine.

	Date	**Event**
Pollution control focus (capacity building)	1950	- Representatives of the Netherlands bring concern about pollution by Chlorides to the Salmon Commission.
	1963	- Signature of the Berne Convention and development of integrated monitoring system under new ICPR Secretariat.
	1970	- First Rhine Ministers Conference: negotiations to cope collectively with chlorides emissions from French potassium mines
	1970s	- Environmental foundation *Reinwater* and a number of Dutch market gardeners sue French potassium mines
Snapshot 1: Pollution control focus (regulatory approach) 1976-1985	1976	- The European Economic Community (EC) joins the ICPR - European Dangerous Substances Directive (76/464/ EEC) - Convention on the Protection of the Rhine against Pollution by Chlorides & Convention for the Protection of the Rhine against Chemical Pollution (Bohn agreements)
	1979	- Convention on chemicals enters into force - Selection of 83 from 15,000 dangerous substances for further investigation - Emission standards are proposed for mercury
	1980	- Efforts to harmonize existing national reduction programs for grey substances
	1983	- The United Kingdom stops blocking adoption of regulations for specific emission standards; Germany still concerned about competitiveness issues - Emission standards are proposed for cadmium - French parliament approves the Convention on Chlorides after agreement on mechanism to reduce salt emissions

Snapshot 2: Ecosystem management focus (managerial approach to pollution and salmon stock restoration)	1986	- Sandoz disaster - Dutch minister presents McKinsey report
	1987	- Rhine Action Plan (RAP) approved - French potassium mines compensate Dutch market gardeners
	1990	- Additional protocol to the Convention on chlorides is adopted - Rotterdam agreements: between city of Rotterdam and upstream chemical firms in upstream countries, under private law
	1994	- 11th ministerial conference: Ecological Master Plan (salmon chosen as symbol for ecological restoration)
	2000	- New "Berne treaty" - European Water Framework Directive - New "Rhine 2020" Action Plan

Note: "Snapshot" refers to relevant governance periods used in the analysis of this case (see Methods section for further explanation).

Progress following the creation of the ICPR remained slow for the next decade due to conflicts between the Dutch, who bore most of the cost of pollution, and France and Germany, where most of the polluting industries were located. In 1976 a series of deals were reached resulting in the Convention on the Protection of the Rhine against Pollution by Chlorides (Chlorides Convention) and the Convention for the Protection of the Rhine against Chemical Pollution (Chemical Convention). The lengthy procedure to decide which chemicals to regulate slowed down the implementation process of the Chemical Convention. Ratification of the Chlorides Convention took even longer. In the meantime, frustrated Dutch gardeners, environmental groups, and water companies sued the French potassium mines and other polluters, and reached private settlements.

The disastrous chemical spill at Sandoz, Basel (Switzerland) in 1986 was widely considered a turning point in attempts to clean up the Rhine. A special minister's conference was called a few weeks after the disaster, where the Dutch minister proposed an international agreement for improving the health of the ecosystem as a whole. The reintroduction of the salmon in the river and the control of non-point source pollution were two of the new goals of that effort (Bernauer and Moser 1996). This proposal became the basis for a Rhine Action Plan (RAP), which was adopted by ICPR members in 1987. The first edition of the RAP (1987-2000) was relatively successful. A crucial aspect of that success was continuing threats from the Dutch government and private parties to claim compensation for damages from upstream polluters, as well as Dutch flexibility to adopt innovative measures to clean up or facilitate the discharge of pollutants, and to give financial aid to upstream polluters for their polluting activities. Subsequent agreements have built on the successes of the RAP, including additions to the Chlorides Convention, further agreements between downstream and upstream users, and the renegotiation of the Berne treaty and the RAP.

4. METHODS

This study was developed as part of the larger Social-Ecological Systems Metanalysis Database (SESMAD) project which analyses data on a series of physical, actor and governance factors that can be related to sustainable management of natural resources (Cox, this issue). In this paper we assess the relevance of a selection of 17 of those factors identified as particularly relevant in previous works (Agrawal 2001, Poteete et al. 2010). This allowed us to test the relevance of CPR theory as well as to explore the relevance of other factors not emphasized by the theory.

Data were mostly obtained via a content analysis of journal articles. Additionally we used data from primary sources (e.g. the text of agreements, reports produced by public organizations involved in river management and raw data produced by the ICPR), as well as "grey literature" produced by academic and research organizations. New sources were sampled until no significantly new information was obtained with the last source (Glaser and Strauss 1999). Coders worked collaboratively, and controversial information and coding decisions were double-checked with external experts[2].

Information gathered was used as the basis for entering data into the SESMAD database, a relational database hosted at Dartmouth College (Cox, this issue). This database contains information on approximately 200 variables of relevance to the study of social-ecological systems (SES), stored in four main tables and associated linking tables. The structure of the database is based on Ostrom's SES framework (Ostrom 2007, 2009) and modified by Cox (this issue). The first table collects general information on the SES, which is defined as a unit containing at least one resource, at least one governance system, and one or more actor groups that relate to the resource within the context of the governance system. A governance system (GS) is a set of institutional arrangements (such as rules, policies, and governance activities) that are used by one or more actor groups to interact with and govern a resource. An actor group (A) can be comprised of individuals, organizations, or nations that have developed a set of institutional arrangements in order to manage human interactions in a specific environmental system, or who alter resource characteristics through extraction or emission. A resource (R) is an environmental phenomenon that can be subjected to human use and governance. Within the relational database information on relationships between these components are stored in linking tables. The most important linking tables link the governance system to the resource (GSR) and then link this relationship to individual actors (GSRA), allowing the coder to capture relationships between multiple resources, actors, and governance systems. The database also includes a table linking the governance of one resource to another resource (GSR-R). In section 5.1 we show how this framework was operationalized for this case for two separate time periods (i.e.,"snapshots").

Inferences about the causal relevance of variables were drawn in two ways. First, we conducted a series of within-case comparisons across actor groups and resource types and over time (George and Bennett 2005). The degree of presence or absence of actor characteristics like heterogeneity, boundaries or size of groups were compared across the industrial and agricultural actor groups and checked against pollution concentration levels

[2] The lack of a predetermined sample of sources and the fact that there was only one case to be coded made the collaborative coding strategy more appropriate than an independent coding strategy where one individual carries the coding and then reliability is checked against the independent coding of other individuals (Krippendorff 2004).

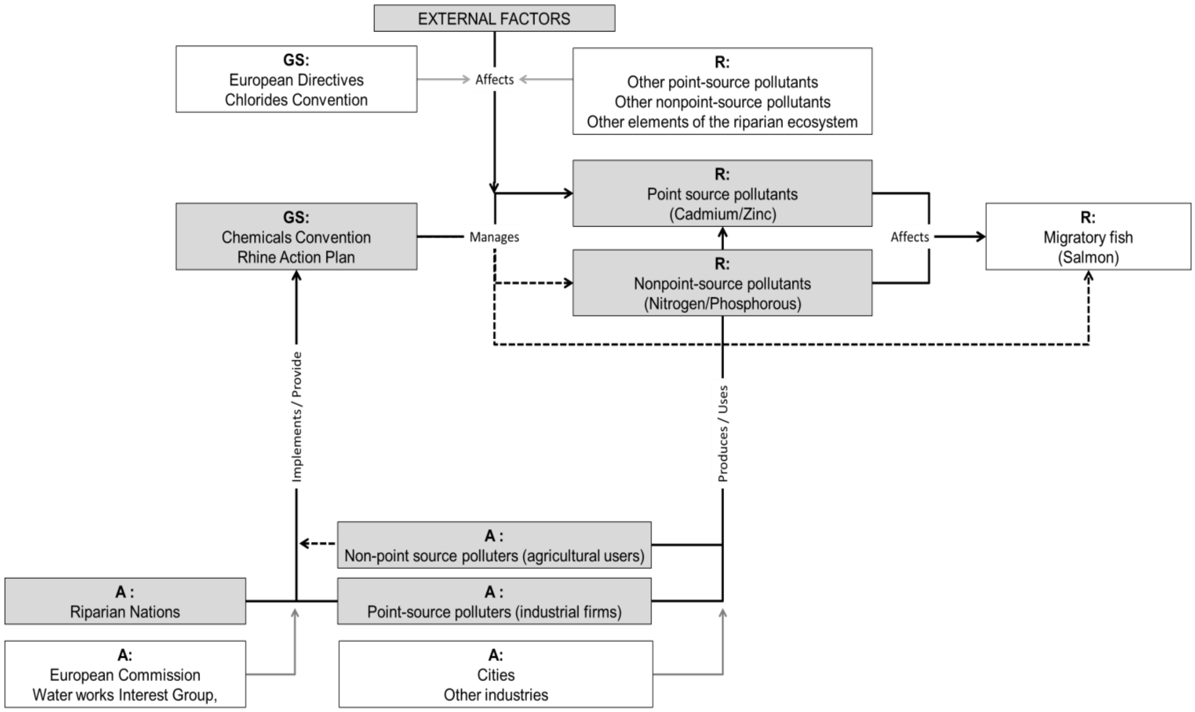
of point and non-point source pollutants, respectively. Similarly, changes in the characteristics of the group of riparian nations as well as governance characteristics across the two periods under analysis were checked against the evolution of pollution concentrations. Through those comparisons we explored whether differences in variables across actor groups/resource types and governance periods made a difference in terms of the pollution abatement outcomes. The development of a chart highlighting relevant variables across those components was instrumental in that process (see section 5.3).

Second, we used process tracing, a within-case inductive technique that lays out, usually in a linear fashion, the course of events that connect cause and effect (George and Bennett 2005, Collier 2011). The emphasis on process enabled us to shed light on why and when some of those variables might be important and whether such importance was contingent on the simultaneous role of other variables.

5. RESULTS

5.1 Structure of the case

Figure 2 shows the structure of the case. First, we distinguish three types of resources: point-source pollutants like Cadmium or Zinc, non-point source pollutants like nitrogen and phosphorous, and natural resources like salmon. Second, we identify one governance system and two relevant governance periods. One period goes from 1976 to 1986 and corresponds to the approval and initial implementation of the Chemicals Convention, and the second goes from 1986 to 2000 and corresponds to the adoption and implementation of the first edition of the RAP. As noted in the Background section, a difference between these two governance periods is the interest of the RAP in managing non-point source pollutants and natural resources in addition to the focus on point source pollution control (see dashed lines in Figure 2). Finally, we identify three clusters of actor groups: the riparian nations, industrial users, and agricultural users.



Note: Grey boxes: main components under analysis. White boxes: secondary components of the analysis. Black continuous arrows: first and second periods of analysis. Dash arrows: only second period of analysis. Grey arrows: secondary relationships.

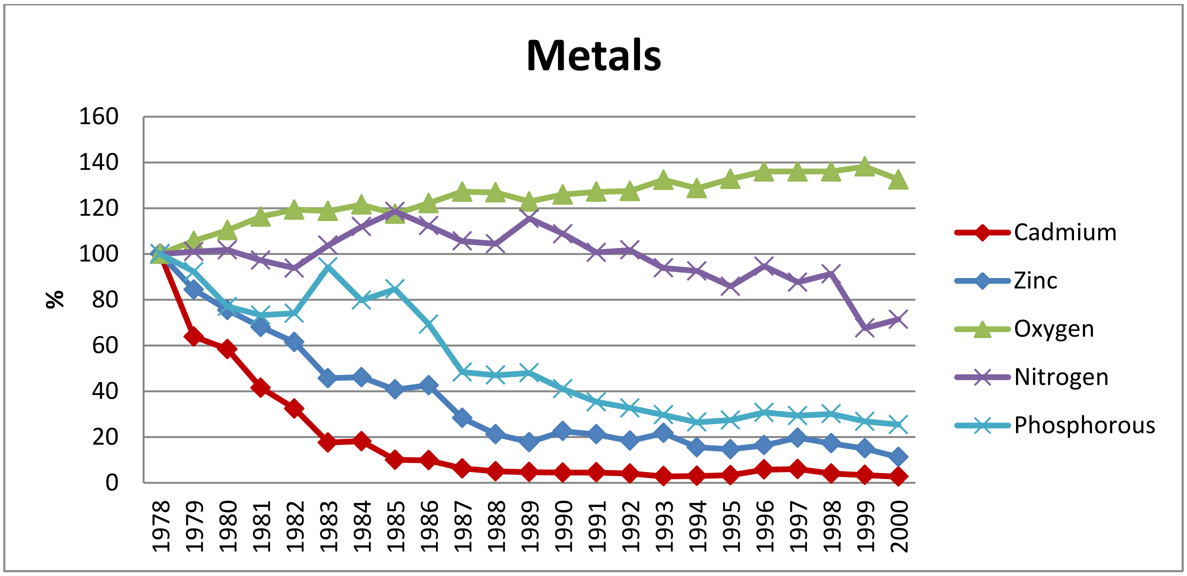
Figure 2. Structure of the Rhine SES.

5.2 Outcomes of the Case

The point of departure of our analysis is a review of concentrations of point and non-point source pollutants and oxygen in the Rhine across the two periods under analysis. Heavy metals like Cadmium and Zinc are used here an indicator of broader patterns in point-source pollution. Although there are diffuse sources of Cadmium and Zinc, most emissions in the 1970s came from point-sources (Stigliani et al 1993). As Figure 3 illustrates, there has been a clear decrease of concentrations since the second half of the 1970s. Despite the improvement and a significant decline in releases, the levels of some heavy metals in suspended matter of the Rhine were still high at the beginning of the 2000s, as a result of long residence times (Froehlich-Schmitt 2003; Martin 2012).

Nitrogen and phosphorous are nutrients that originate mostly from the agricultural sector, and to a lesser extent the urban and industrial sectors (Froelich-Schmitt 2003). These substances are used here as indicators of broader trends of non-point source pollution. The decreasing trend for both substances started by the mid-1980s. As in the case of heavy metals, concentrations at the beginning of the 2000s were still far from acceptable levels (Froehlich-Schmitt 2003) (Figure 3).

Finally, oxygen levels are treated as a proxy for ecosystem health. In this case, the increasing trend is an indicator of the overall success of the governance regime (Figure 3).



Source: elaborated from (ICPR 2012a).

Figure 3. Evolution of selected substances pre- and post-1986 (base year=1978)

Another indicator of the ecological conditions of the Rhine is salmon. Salmon are a good proxy for a number of ecosystem services provided by the Rhine because salmon require clean water, naturally connected river basins, and an abundance and diversity of aquatic invertebrates. Over-fishing, channelization and damming in the late 19th and early 20th centuries reduced salmon stocks tremendously. The subsequent decline in water quality contributed to the extinction of salmon stocks by the 1940s (Nienhuis et al. 2002). The progressive improvement of oxygen levels since at least the 1970s facilitated the implementation of the RAP's goal of restoring salmon stocks from the mid-1980s on. From the 1950s to 1989 six salmon were caught in the entire Rhine watershed, and between 1989 and 1992, the number increased to 18 (van Dijk et al 1995). Salmon stocks continued to improve in subsequent years thanks also to an active policy to restore the natural river bed of the Rhine (Froehlich-Schmitt 2003)

5.3 Influential CPR Variables

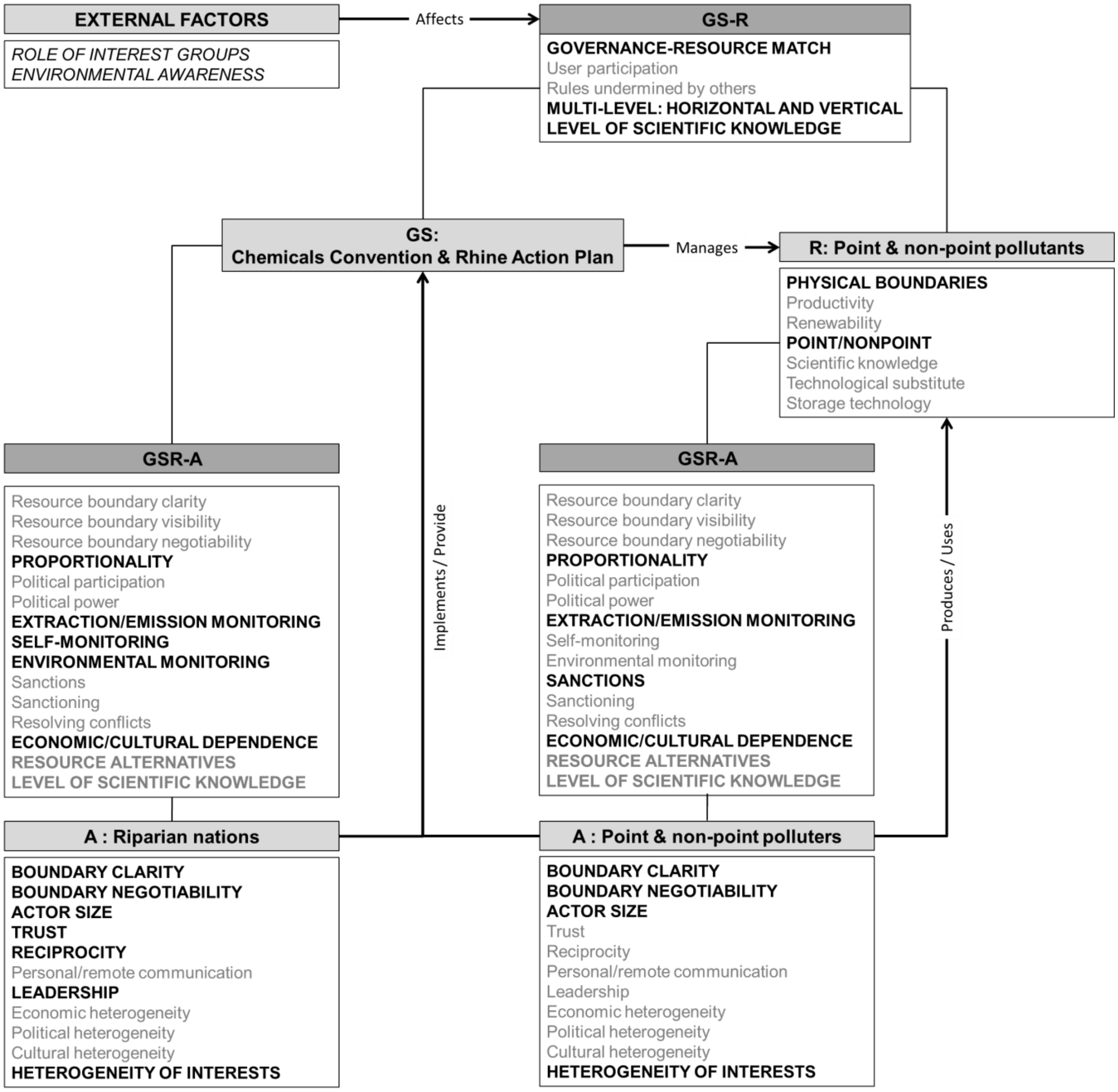
According to our analysis, a number of factors help to understand the performance of the governance system *vis à vis* point and non-point source pollutants over time. Specifically, we find that 13 factors can be associated with the outcomes of the case. Two of the factors are related to the resource system that hosts the pollutants, 6 are characteristics of the actor groups and 5 are properties of the governance system (Table 2). Their hypothesized effect on pollution abatement can be summarized in four overarching processes contributing to cooperation: increasing information availability, lowering transaction costs, guaranteeing rule compliance, and brokering collaboration. We structure the presentation of our results along these lines.

Table 2. Relevant variables in the Rhine case

Theoretical Variable (SESMAD component)	Snapshot 1 (1976-1986)	Snapshot 2 (1986-2000)
Physical variables		
Well defined physical boundaries (R)	Yes. The Rhine's superficial flows are clearly identifiable and well understood. The Rhine's aquifers are also well identified.	
Governance-resource match (GS-R)	No. The ICPR regime encompasses the Rhine's catchment area including indirectly a number of its tributaries.	
Social Variables		
Small group size (A)	Yes for riparian nations (6) and big industrial firms (concentrated into industrial poles)	
	Less the case for farmers	
Clarity of social boundaries (A)	Yes for riparian nations and big industrial firms (organized into sectors and associations). Less the case for farmers (due to larger number of sectors and associations)	
	Less the case for farmers (due to larger number of sectors and associations)	
Heterogeneity (A)	High for riparian nations: self-centered approach to bargaining; upstream vs. downstream.	Low for riparian nations: Common interest in ecosystem restoration supersedes differences
	Moderate/Low. The industrial and farming sectors are not interested in pollution abatement by default. Industry enjoys more homogeneous technology than agricultural sector.	
Proportionality (GSR-A)	No. Riparian nations struggled to allocate abatement costs and benefits	Yes. Integrative bargaining approach among nations that allowed for trade-offs
	Big industrial firms enjoyed favorable market trends	
Social Monitoring (GSR-A)	Only nascent among big industrial firms	Big industrial firms report to national governments and ICPR; not generalized monitoring among farmers
Trust/Reciprocity (A)	Moderate among national governments; promoted by legalistic approach to bargaining	High. Momentum after Sandoz disaster promotes hands-off-based management
Leadership (A)	Yes. Adversarial approach by the Netherlands. Lack of enough authority and accountability to counterparts	Yes. Integrative approach by the Netherlands. Sandoz disaster opens window of opportunity (i.e. authority) to bring change (RAP)
Governance variables		
Environmental Monitoring (GSR-A)	Yes. Progressively consolidated and expanded network of stations for data collection and analysis.	
Nesting/Multilevel (GS-R)	Yes. Only vertical interplay among nations. Only horizontal interplay among big industrial firms	Yes. National governments and big industrial firms' efforts are integrated horizontally and vertically respectively
Sanctions (GSR-A)	Yes. Nor the Chemical Conventions or the RAP foresee sanctions but there is that possibility at national levels and there is ICPR's coercive power to develop stricter regulations	
Non-CPR variables		
Interest groups	Nascent watchdog role of	High impact of those associations'

<table>
<tr><td>(“External Factors”)</td><td>environmental and waterworks associations.</td><td>awareness-raising role powered by Sandoz disaster.</td></tr>
<tr><td>Environmental awareness (“External Factors”)</td><td colspan="2">Increasing salience of ecological and cultural value of the Rhine watershed promoted by broader environmental movement since the 1970s; in turn, riparian nations face increasing political costs of exiting the ICPR.</td></tr>
</table>

Figure 4 emphasizes the relevance of CPR factors (bold capital letters) and non-CPR factors (italicized capital letters). We found four CPR factors that were not relevant (see factors in lower-case letters). All these factors are discussed in the sections that follow.



Note: The boxes in the figure correspond to tables in the SESMAD database. The figure shows key variables analyzed in this case in the context of the database structure. Dark grey boxes are links between main components (see Cox in this issue).

Figure 4. CPR factors, non-CPR factors and other factors associated to the Rhine case.

5.3.1 Increasing information availability

The ability of the ICPR to affect pollution patterns depended to a great extent on its ability to link environmental information to polluter behaviur. We associate this observation with two variables which are emphasized in CPR theory: the existence of strong environmental monitoring systems and the clarity of the underlying biophysical boundaries of the system. According to CPR theory, information fosters transparency and thus cooperation among users (Ostrom et al 1994). Also, environmental monitoring permits the assessment and adjustment of management measures to changing local conditions (Cox et al 2010). In the case of the Rhine, environmental monitoring allowed for the emergence of a close-knit scientific community and an advanced understanding of the dynamics and potential solutions to the pollution problem, which was fundamental to assign pollution abatement responsibilities among polluters (Bernauer and Moser 1996, Raadgever 2005).

The environmental monitoring network in the Rhine is strong in large part because it has a long history and is based on diverse institutions. One of the main accomplishments of the Berne Convention was gathering and publishing information about concentrations of pollutants in the watershed (Bernauer and Moser 1996). In the 1970s, the International Commission for the Hydrology of the Rhine Basin (CHR) was created to strengthen data exchange and standardize measuring methods. The Chlorides and Chemicals conventions signed in the mid-70s led to the consolidation of a network of measuring stations that enabled an assessment of the influence of upstream polluters within the Rhine and its main tributaries on pollution concentrations (Huisman et al 2000). With the RAP, monitoring efforts expanded from the assessment of ambient concentrations to the supervision of emissions by industrial firms. Over the years, the monitoring program increased the frequency of sampling, the number of parameters measured, as well as the speed of diagnosis and information diffusion in case of major spills or other disasters.

The development of the monitoring network was facilitated by the relatively clear boundaries of the resource and their fit with the boundaries of the governance system. Although the Rhine hydrological system includes both surface and underground waters, the latter are confined to well understood regional aquifers (Uehlinger et al. 2009). In addition, a series of ‘corrections’ to the river bed for flood-protection and agricultural production (i.e., dams and river channels) over the 19th and 20th Centuries further delimited the boundaries of the river and its connectivity to the rest of the hydrological system (Wieriks and Schulte-Wülwer-Leidig 2009). Finally, the resource is almost entirely confined within the borders of the ICPR nation states (see figure 1).

5.3.2 Decreasing transaction costs

Even with a successful environmental monitoring network in place, it might be difficult for the diverse set of actors in the Rhine basin to cooperate if the transaction costs involved were too high. Fortunately, a series of actor characteristics contributed to low transaction costs and thus help to explain the performance of the governance system. Some of those characteristics are not uniformly shared by all the riparian nations, or by industry and farmers, nor are they constant over time.

According to CPR theory, clear social boundaries help to internalize positive and negative externalities at low cost, ensuring that those who bear the costs of cooperating are the ones who receive the benefits (Ostrom, Gardner, and Walker 1994). Furthermore, small group size can be associated with reduced costs of coming to agreements and monitoring (Ostrom et al 1994, Poteete et al 2010, Poteete and Ostrom 2004). In pollution cases, clear social boundaries and small group size can facilitate the assignment of pollution abatement responsibilities across different actor groups as well as the emergence and development of cooperation among agents within each group. This seems to have been the case of the group of riparian nations and the industry in the Rhine.

The small number of ICPR members – i.e. 5 nations plus the European Commission (EC) – keep the transaction costs related with coordination low. Moreover, the political costs of exiting the agreements have increased over time with the rise of public environmental awareness (Dieperink 2000). Similarly, the industry in the Rhine is clustered into only 6 industrial poles[3] (ICPR 2012d) and a relatively small number of sectors. Some of those sectors, like the chemical and the metal sectors, are populated by just a handful of big firms[4] (Stigliani et al 1993) that coordinate through federations at the national and European levels (Raadgever 2005). However, in contrast to the riparian nations and industry, the number of farmers is much higher and more spread out (ICPR 2012d). This makes coordination among farmers much more costly than among industry.

A third factor that has been associated with reduced transaction costs, particularly in large scale contexts, is multi-level governance -also referred as nested enterprises (Cox et al 2010, Lam 2006). According to theory, the division of labor across governance levels helps splitting collective action ventures among a large number of actors into smaller enterprises of reduced transaction costs (Cox 2010). Also, "nesting a set of local institutions into a network of medium- to larger-scale institutions helps ensure that larger-scale problems are addressed as well as those that are smaller" (Anderies et al. 2004).
The Rhine's governance system emerged as a multi-level enterprise and has evolved as such. Individual resource users are nested within a small number of nation states that engage in collective decision-making and bargaining. This avoids the need for coordination between a huge number of players, which would have led to prohibitive transaction costs. An example is the environmental monitoring system, which relies on the measuring and reporting efforts of governments and the watchdog role of a number of interest groups at the national level (Bernauer and Moser 1996, Dieperink 2000, Stigliani et al 1993).

A final factor that lowers transaction costs for cooperation is the homogeneity of interests within actor groups. Homogeneity of interests facilitates common understanding, ease the formation of collective agreements and add certainty about behavioral patterns and cooperation (Poteete et al. 2010, Poteete and Ostrom 2004, Varughese and Ostrom 2001). In the Rhine case, this factor helps to understand the cooperative turn of the nation states in the mid-1980s. In the 1970s and early 1980s national governments were concerned about protecting their economies from the costs of pollution (Bernauer and Moser 1996, Verweij 1999). There was clear asymmetry between the Netherlands, which bore the most cost due to its downstream location, and the other nations (Mostert 2009). The situation changed with the Sandoz disaster, which served to raise public awareness of, and thus the political costs of failing to address, the pollution problem. This translated into the RAP and its focus on ecosystem restoration, an activity from which the countries benefit more equally than with pollution control (Verweij 1999, Verweij 2000, Mostert 2009).

[3] This includes the clusters of Basel/Mulhouse/Freiburg, Strasbourg, Rhine-Neckar, Frankfurt-Rhine-Main, Metropolitan region Rhine-Ruhr, and Rotterdam-Europoort.
[4] The chemical sector includes 6 major firms, while in the 1970s, two thermal zinc smelters located on the river were the source of around 50% of all aqueous emissions (Stigliani et al 1993).

5.3.3 Guaranteeing compliance

Compliance with regulations is key to the performance of governance systems. We argue that the effective compliance with formal agreements by the riparian nations from the 1980s on is correlated with an increase in the proportionality of the distribution of costs and benefits as well as in the levels of trust among nations. Compliance in the case of industrial polluters can also be understood by considering proportionality of costs and benefits, as well as rule enforcement by national governments.

According to CPR theory, the likelihood of cooperation increases when agents perceive that costs and benefits associated with their cooperative efforts are fair as compared to the costs and benefits of others (Ostrom 1990). In the same vein, the existence of trust in the reciprocal behavior of others has been shown to enhance cooperation (Ostrom and Walker 2005, Ostrom 1998). In the Rhine case, the heterogeneity of interests among the riparian nations in the 1970s translated into a zero-sum bargaining approach. Additionally, the micro-management approach to pollution abatement prescribed by the Chemicals Convention, prevented the consolidation of trust among the parties (Raadgever 2005). The situation changed with the approval of the RAP. The new Plan contributed to increase the proportionality of costs and benefits among the nations by facilitating side-agreements and compensatory measures. Also, the Plan enhanced trust by eliminating procedural requisites like technical implementation standards at the domestic level (Verweij 1999). A series of side agreements between cities and interest groups from the Netherlands, on the one hand, and upstream polluters in France and Germany, at the other, further contributed to the consolidation of the new approach.

The pollution reduction efforts made by big chemical and metal industries were facilitated by a a period of economic growth and increasing revenues, helping finance investments in new, more efficient technologies (Bernauer and Moser 1996). Further, some authors argue that a number of big chemical firms treated the challenge of developing new water waste treatment technologies as an opportunity to capture a new market niche (Stigliani et al 1993, MPR 2001).

Rule enforcement, i.e., monitoring and sanctioning, has been emphasized in the CPR literature as one of the most important factors stimulating cooperation for its contribution to rule compliance (Coleman and Steed 2009, Gibson et al 2005). The Chemicals Convention did not include any sanctioning mechanism at the international level (Nollkaemper 1996). However, regulations at the national level did and this was effectively used at several times by interest groups to force upstream firms to comply with emission limits and/or to compensate downstream users for pollution externalities (Nollkaemper 1990). Additionally, the extensive political and legal activity carried by national governments within the ICPR in the 1970s was seen by the industrial firms as the prelude to stricter regulations in the Rhine. The interest in anticipating such regulations also motivated firms to reduce emissions (Bernauer and Moser 1996). Later on, the RAP did not add any sanctioning provisions to the governance system; however, it further strengthened monitoring by integrating the industrial sector within the environmental information systems.

5.3.4 Brokering cooperation

A final factor, leadership, can help to understand cooperation in the Rhine. Leaders can reduce the costs of agreement formation, as well as perform more general functions such as trust building, conflict management, knowledge diffusion, and mobilization for change (Ostrom 1992).

In the Rhine case, the Netherlands played a leadership role at different points in time with mixed results (Dieperink 2000, Verweij 1999). The Dutch government was one of the first governments to create regulations to control pollution at the national level as well as to raise the issue of water quality in the Rhine at the international level. The first steps towards the creation of the ICPR were the result of lobbying by the Dutch national and local governments, and Dutch interest groups (Bernauer and Moser 1996, Dieperink 2000). However the Dutch lacked authority to enforce agreements on other countries and their credibility was undermined by an adversarial approach to dealing with upstream polluters. With the Sandoz disaster, a window of opportunity for change opened and this was used by the Dutch minister of transport to bring to the table a more integrative model of governance that gave birth to the RAP. Despite its lack of strong authority or reputation as an impartial party, the Dutch were ultimately able to induce change. (Dieperink 2000, Verweij 1999).

6. DISCUSSION

According to our results, a number of variables from CPR theory help to understand the progress made by the riparian nations with regard to pollution control during the 1970s and 1980s, as well as the pollution abatement efforts carried by a number of industries. Those factors include physical attributes such as the existence of clear hydrological boundaries of the watershed; governance factors such as the articulation of environmental monitoring and decision making at different governance levels; and actor characteristics like small group size and relatively concentrated location of some actor groups (i.e. riparian nations and the industrial sectors) and the leadership role played by the Netherlands. Although the Chemicals Convention was not initially fully implemented, it set the path for pollution abatement efforts by industrial polluters and the consequent reduction in the emissions of a number of point-source pollutants.

The failure of the Chemical Convention to be fully implemented points to the relevance of a number of other CPR factors. These include insufficient trust and the presence of heterogeneities of interests among upstream and downstream nations, as well as the limited proportionality in the allocation of the costs and benefits of implementing the Convention. The collaborative turn of the riparian nations in the mid-1980s correlated with a change in the values of those variables and a new leadership role played by the Dutch government.

Other CPR factors, such as the right of actors to self-organize and participate in collective decisions, the productivity of the resource system, communication among actors or resource dependence were found to be irrelevant or in need of qualification.

First, according to CPR theory, allowing resource users to self-organize contributes to cooperation and the development of institutional regimes that are adapted to different contexts (Ostrom 1990). In the Rhine, both the industrial and agricultural sectors have actively used their right to self-organize into associations for different purposes but only the former showed significant efforts at pollution control.

Second, CPR theory stresses the importance of the collective choice: resource users must be able to participate in decisions that affect: the ability of resource users to participate in decisions that affect their use of the resource at higher levels than their own local self-organization. This factor is also believed to contribute to cooperation (Ostrom 1990) but its relevance for the Rhine case is inconclusive, as neither the industrial or agricultural sectors are directly represented in the decision making processes within the ICPR on a regular basis (ICPR 2012b).

Third, CPR theory posits that resource users are more eager to cooperate and invest in the conservation of a resource if the resource has at least certain level of productivity (Poteete et al 2010). In the Rhine case, however, the riparian nations took collective measures to control pollution only after the 1960s, more than a decade after the biological productivity of the river had reached its poorest state (i.e., zero productivity).

Fourth, CPR theory argues that communication is a prerequisite for cooperation (Ostrom, Gardner, and Walker 1994). While the ICPR was created upon a schedule of regular meetings among the riparian nation's representatives (ICPR 2012) such communication did not prevent the stalemate in the implementation of the Chemical´s Convention in the 1970s.

Fifth, there is the factor of dependence. According to CPR scholarship, unless individuals depend on a resource they will not have incentives to sustain it (Ostrom 1992, Ostrom, Gardner, and Walker 1994). The Rhine case illustrates the importance of economic dependence both to understand cooperation and the lack of it. The pro-collaboration role played by the Dutch government is justified if we consider the exposure of the Netherlands to the decreased water quality of the Rhine, while the resistance of riparian nations like Germany or France to pollution control mechanisms in the 1970s can be understood with regard to the dependence of their economies on polluting activities. Additionally, the case illustrates that cultural salience may play an important role too. The focus on salmon restoration in the mid-1980s cannot be understood with regard to economic incentives, for salmon stocks (and many other fish species) had been extinct since the 1940s. However, salmon held important cultural salience as a result of a growing environmental movement. Such movement had put in relevance the intrinsic value of the Rhine's ecosystem for more than a decade and ultimately constituted the basis for the political crisis triggered by the Sandoz disaster (Mostert 2009).

Two factors not explicitly discussed in CPR theory are relevant for the Rhine case (table A1 in Appendix). Those factors include the role of interest groups and the occurrence of disturbances.

First, environmental groups, waterworks associations and local governments played a watch dog role , from the 1970s onwards, benefiting from the increasing availability of environmental information about pollution in the watershed, and from the coercive power of regulations at the national level (Mostert 2009, Nollkämper 1990). The pressure exerted by those actors over upstream polluters during the 1970s (see timeline for examples) emerged as a reaction to the limited progress that national governments had made since the Berne Convention and contributed to increase the effectiveness of the emerging governance system.

Second, the Sandoz disaster prompted a peak in awareness about the pollution status of the Rhine, and this opened a window of opportunity for reform. As a matter of fact, that was not the first time that a disturbance had triggered a governance change in the watershed. An accident similar to the Sandoz disaster in the 1960s[5] led to the emergence of new interest groups for the protection of the Rhine and negotiations that led to the Berne agreements (Bernauer and Moser 1996, Dieperink 2000). The observation of disturbances is not completely alien to CPR theory. An increasing number of scholars are paying attention to the influence of different types of threats on sustainable management and cooperation (Janssen and Anderies 2007, Schoon and Cox 2011).The Rhine case confirms the relevance of that research agenda.

7. CONCLUSIONS

In this paper, we have aimed to understand the sustainable management of pollution problems in a large, trans-boundary watershed like the Rhine. In that process we have also tested the extent to which the effects of variables identified by CPR theory to explain sustainable management at local levels are applicable to problems other than conventional appropriation or provision problems.

According to our results, CPR theory can help to understand the relative success of the Rhine´s governance system *vis-à-vis* pollution management. Particularly, the theory helps to understand the sustained collaboration among the riparian nations for more than four decades and the gap in performance between point-source and non-point source pollution abatement. That said, the analysis illustrates the need to qualify the role of certain key variables proposed by CPR theory, such as leadership and resource dependence, as well as to consider new variables such as the role of interest groups and the occurrence of disturbances.

The findings of this study are contingent on a series of choices made to reduce the complexity of a large system in order to make it analytically tractable. It is possible that a study that more closely examined the role of municipalities, domestic environmental regulations, or differences across large numbers of point and non-point source pollutants would arrive at somewhat different conclusions than our study, which has aggregated over these complexities. This is an inherent challenge in research on large-scale systems.

Also, applying CPR theory to large-scale and pollution contexts entails the risk of stretching too much the meaning of some concepts. In this study, for example, we have used the term "actor" to refer to nation states (i.e., national governments) as well as organizations (industrial firms) and individuals (i.e., farmers). Similarly, we analysed

[5] In June 1969, an accidental spill of the insecticide Endosulfan by Hoechst Chemicals caused a massive dead of fishes in the Main, one of the most important tributaries of the Rhine.

nested governance by looking at the influence of the European Commission on the ICPR developments as well as at the national efforts in environmental monitoring and sanctioning. Future research might consider construct validity issues in more depth when extrapolating CPR theory to new contexts, particularly if done in comparative perspective.

In our understanding there is a connection between the change in governance in the Rhine during the second half of the 1980s and some explanatory variables proposed by CPR theory. However, the precise nature and extent of the causal mechanism between collective action within and between various stakeholder groups, on the one hand, and pollution abatement, on the other, remains less clear. For example, according to our analysis, the adoption of the RAP in the 1980s did not strongly affect levels of cooperation among farmers; however, the decreasing trend of nitrogen concentrations from the mid-1980s on would suggest that the governance change did have some effect on pollution abatement efforts in the agricultural sector. This caveat to the analysis is illustrative of a broader limitation of CPR theory: factors other than collective action that is proximate to the primary outcome, including coercive regulation, changes in market conditions, or changes in technology, may also play a key role in driving environmental outcomes, and it is difficult to sort out the contributions of these different variables through a single case study. Future research might look into the mediating and/or moderating role of these and other factors to further nuance the role of collective action as a driver of sustainability.

REFERENCES:

Agrawal, Arun. 2001. Common property institutions and sustainable governance of resources. *World Development* 29(10):1649-1672.

Bernauer, Thomas. 2002. Explaining success and failure in international river management. *Aquatic Sciences - Research Across Boundaries* 64(1):1-19

Bernauer, Thomas, and Peter Moser. 1996. Reducing pollution of the river Rhine: The influence of international cooperation. *Journal of Environment & Development* 5(4):389-415.

Blomquist, William, Edella Schlager, and Tanya Heikkila. 2004. *Common waters, diverging streams: Linking institutions and water management in Arizona, California, and Colorado*. Washington: Resources for the Future.

Coleman, Eric A., and Brian C. Steed. 2009. Monitoring and sanctioning in the commons: An application to forestry. *Ecological Economics* 68(7):2106-2113.

Collier, David. 2011. Understanding process tracing. *PS: Political Science & Politics* 44(4):823-830

Cox, Michael. 2010. *Exploring the dynamics of social-ecological systems: The case of the Taos Valley Acequia*, Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington.

Cox, Michael. 2013. Introducing the SESMAD project. *International Journal of the Commons* 7(2).

Cox, Michael , Gwen Arnold, and Sergio Villamayor Tomás. 2010. A review of design principles for community-based natural resource management. *Ecology and Society* 15(4)

Cox, Michael. This issue. Introduction to the Special Issue.

Dieperink, C. 2000. Successes in the international cooperation in the rhine catchment area. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere* 25(3):341-347

ECC. 1991a. Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment.

ECC. 1991b. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

ECC. 1996. Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control.

Emery, Steven B., and Jeremy R. Franks. 2012. The potential for collaborative agri-environment schemes in England: Can a well-designed collaborative approach 28(3):218-231

Froehlich-Schmitt, Barbara. 2003. *Upstream outcome of the Rhine Action Programme*. Koblenz: International Commission for the Protection of the Rhine (ICPR).

George, Alexander L., and Andrew Bennett. 2005. *Case studies and theory development in the social sciences, BCSIA studies in international security*. Cambridge, Mass.: MIT Press.

Gibson, Clark C., John T. Williams, and Elinor Ostrom. 2005. Local enforcement and better forests. *World Development* 33(2):273-284.

Glaser, Barney G., and Anselm L. Strauss. 1999. *The discovery of grounded theory: Strategies for qualitative research.* New Brunswick, N.J.: AldineTransaction.

Heikkila, Tanya, and Edella C. Schlager. 2012. Addressing the issues: The choice of environmental conflict-resolution venues in the United States. *American Journal of Political Science* 56(4):774-786

Huisman, Pieter, Joost de Jong, and Koos Wieriks. 2000. Transboundary cooperation in shared river basins: experiences from the Rhine, Meuse and North Sea. *Water Policy* 2(1–2):83-97

ICPR. 2012a. *Download module* [cited December 2012]. Available from http://maps.wasserblick.net:8080/iksr-zt/dl_auswahl.asp?S=3&JA=2011.

ICPR. 2012b. *International Cooperation* [cited December 2012]. Available from http://www.iksr.org/index.php?id=9&L=3.

ICPR. 2012c. *Maps of the river basin* [cited December 2012]. Available from http://www.iksr.org/index.php?id=335&L=3#c2212.

ICPR. 2012d. *Uses: Agriculture* [cited December 2012]. Available from http://www.iksr.org/index.php?id=10&L=3.

Janssen, Marco, and J. Marty Anderies. 2007. Robustness trade-offs in social-ecological systems. *International Jounal of the Commons* 1(1):43-66

Kerr, John. 2007. Watershed management: Lessons from common property theory. *international Journal of the Commons* 1(1):89-110.

Lam, Wai Fung. 2006. Foundations of a robust social-ecological system: irrigation institutions in Taiwan. *Journal of Institutional Economics* 2(2):203-226.

Lankford, B.H.N. 2010. The cathedral and the bazaar: Monocentric and polycentric river basin management. *Water Alternatives* 3(1):82-101

Lundqvist, Lennart J. 2001. Games real farmers play: knowledge, memory and the fate of collective action to prevent eutrophication of water catchments. *Local Environment* no. 6(4):407-419.

Martin, Charles W. 2012. Recent changes in heavy metal contamination at near-channel positions of the Lahn River, central Germany, *Geomorphology* 139-140:452-459

Mostert, Erik. 2009. International co-operation on Rhine water quality 1945–2008: An example to follow? *Physics and Chemistry of the Earth, Parts A/B/C* 34(3):142-149.

MPR. 2001. Cleaning Up the Rhine. *Max Planck Research* 1.

Nienhuis, P.H., A.D. Buijse, R.S.E.W. Leuven, A.J.M. Smits, R.J.W. de Nooij, and E.M. Samborska. 2002. Ecological rehabilitation of the lowland basin of the river Rhine. *Hydrobiologia* 478(1-3):53-72.

Nollkaemper, André 1990. The Rhine Action Programme: A turning-point in the protection of the North Sea. *Int'l J. Estuarine & Coastal* 5.

Nollkaemper, André. 1996. The River Rhine: from equal apportionment to ecosystem protection. *Review of European Community & International Environmental Law* no. 5(2):152-160

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

Ostrom, Elinor. 1992. The rudiments of a theory of the origins, survival, and performance of common-property institutions. In *Making the commons work: Theory, practice and policy*, edited by Daniel W. Bromley, 293-319. San Francisco, CA: ICS Press.

Ostrom, Elinor. 1998. A behavioral approach to the rational choice theory of collective action: Presidential address, American Political Science Association, 1997. *American Political Science Review* 92(1):1-22.

Ostrom, Elinor, Roy Gardner, and James Walker. 1994. *Rules, games and common pool resources*. Michigan: Michigan University Press.
Ostrom, Elinor, and James Walker, eds. 2005. *Trust and reciprocity: Interdisciplinary lessons for experimental research*. New York: Russell Sage Foundation.
Poteete, Amy R., and Elinor Ostrom. 2004. Heterogeneity, group size and collective action: The role of institutions in forest management. *Development and Change* 35(3):435-461.
Poteete, Amy R., Elinor Ostrom, and Marco Janssen. 2010. *Working together. Collective action, the commons, and multiple methods in practice.* Princeton: Princeton University Press.
Raadgever, G.T. 2005. Transboundary river basin management regimes: The Rhine basin case study. In *New approaches to adaptive water management under uncertainty*. Eds. C. Pahl-Wostl et al. Delft: RBA Center/Delft University of Technology.
Schlager, Edella, and Tanya Heikkila. 2011. Left high and dry? Climate change, common-pool resource theory, and the adaptability of Western water compacts. *Public Administration Review* 71(3):461-470
Schoon, Michael L., and Michael E. Cox. 2011. Understanding disturbances and responses in social-ecological systems. *Society & Natural Resources* 25(2):141-155
Stigliani, William M., Peter R. Jaffe, and Stefan Anderberg. 1993. Heavy metal pollution in the Rhine Basin. *Environmental Science & Technology* 27(5):786-793
Uehlinger, Urs, Karl M. Wantzen, Rob S. E. W. Leuven, and Hartmut Arndt. 2009. The Rhine River Basin. In *Rivers of Europe*. Eds. K. Tockner, C.T. Robinson, and U. Uerlinger, 199-245. London: Academic Press.
UNEP, ERCE, and UNESCO. 2008. *Quality for ecosystems and human health*. Burlington, Ontario: National Water Research Institute
van Dijk, G. M., E. C. L. Marteijn, and A. Schulte-Wülwer-Leidig. 1995. Ecological rehabilitation of the River Rhine: Plans, progress and perspectives. *Regulated Rivers: Research & Management* 11(3-4):377-388
Varughese, George, and Elinor Ostrom. 2001. The contested role of heterogeneity in collective action: Some evidence from community forestry in Nepal. *World Development* 29(5):747-765.
Verweij, Marco. 2000. *Transboundary Environmental Problems and Cultural Theory: the Protection of the Rhine and the Great Lakes.* Houndmills: Palgrave.
Verweij, Marco. 1999. A watershed on the Rhine: Changing approaches to international environmental cooperation. *GeoJournal* 47(3):453-461
Wieriks, Koos, and Anne Schulte-Wülwer-Leidig. 2009. Integrated water management for the Rhine river basin, from pollution prevention to ecosystem improvement. *Natural Resources Forum* 21 2):147-156.
Wittgren, Hans B., Reinhold Castensson, Lena Gipperth, Arne Joelsson, Lars Jonasson, Anna Pettersson, Roger Thunvik, and Gunnar Torstensson. 2005. An actor game on implementation of environmental quality standards for Nitrogen in a Swedish agricultural catchment. *AMBIO: A Journal of the Human Environment* 34(3):237-247
Yetim, Muserref. 2002. Governing International Common Pool Resources: the international watercourses of the Middle East *Water Policy* 4 (4):305-321.