

Governance, polycentricity and the regulation of global nitrogen and phosphorus cycles

Abstract

Global change and governance scholars frequently highlight polycentricity as a feature of resilient governance, but both the theoretical and empirical knowledge about features and outcomes of the concept are lacking. Here we discuss the global governance of nitrogen (N) and phosphorus (P) cycles, two processes in the “planetary boundaries” framework, to investigate the dynamics and structural properties of polycentric governance. The study combine institutional analysis and social network analysis methods to explore governance challenges associated with global N and P cycles. We assess the emergent structural patterns among the principal institutions and actors: all relevant multilateral agreements including European Union directives, combined with a more in-depth analysis of the Global Partnership on Nutrient Management. We show that the current international regimes in place for regulating issues related to global N and P flows, albeit connected through network structures, represent a gap in governance at the global level. In addition, we are able show that the emergence of a self-organized global partnership that focuses on nutrient management provides evident synergies in the context of insufficient governance. We show that the global partnership GPNM can be viewed as a structure of polycentric governance as it involves deliberate attempts for mutual adjustments and self-organized action.

Keywords: nitrogen, phosphorus, global flows, polycentric governance

Research highlights:

- Global mapping of international legal instruments related to N and P issues
- Actor formation in N and P governance architecture
- Illustration of benefits of integrating polycentric theory with network theory

1 Polycentric governance as a strategy for global problems

The international community has been struggling to identify an effective governance model for systemic perturbations of global biophysical systems. ‘Top-down’ natural resource management institutions are often not well suited for local social and ecological realities, nor to complex social-ecological interactions that characterize large-scale environmental systems (Ostrom 2007, Galaz et al. 2008). Polycentric governance, which involves “many centres of decision making that are formally independent of each other” (Ostrom et al. 1961, p.831), is often mentioned as a possible alternative with a number of proposed benefits (e.g. Andonova, 2009, Ostrom, 2010, Galaz et al., 2012a,b). These include the ability to combine local knowledge and support learning through trial-and-error learning processes (Ostrom, 2010). Furthermore, Ostrom (2010) suggests that problems associated with actors not contributing, being tyrannical at the local level, or create discrimination within the system can be addressed as larger units get involved. Toonen (2010) highlights that

polycentric systems tend to enhance innovation, learning, adaptation, trustworthiness, and levels of cooperation of participants.

However, there is incomplete empirical evidence about features and outcomes of polycentric systems (Aligica & Tarko, 2011). It is poorly understood how governance systems shift from one phase of polycentricity to another (Galaz et al., 2012c). We know little empirically about how institutional architecture and actors interact, although this process is suggested as appearing through key individuals and organizations, and their attempts to overcome severe institutional fragmentation and actor complexity (see proposition 2 in Galaz et al., 2012c). Furthermore, it remains unclear how and if partnerships between different actors and interconnected networks enhance the ‘fit’ (how well the attributes of institutions and wider governance systems at multiple levels match the dynamics of biophysical systems through a larger governance context, Galaz et al., 2008) between global environmental governance and social–ecological dynamics at planetary scales (Young, 2002; Galaz et al., 2012a). This poses serious implications to the application of the theory.

In this study, we explore the notion of degrees of polycentric governance (Galaz et al., 2012c) through an investigation of the governance structures associated with global cycles of two key nutrient elements, nitrogen (N) and phosphorus (P). We apply institutional analysis concepts from Galaz et al. (2012c) and the social network analysis (SNA) method of Kim (2013), uncovering institutional and actor connectedness across sectors and scales that potentially outline a governance structure with polycentric governance. We provide insights into which processes are governed, which are not, and at what scale. Our aim is to improve the understanding of if and to what extent polycentric networks can overcome formal institutional gaps.

1.1 Why focus on global nitrogen (N) and phosphorus (P) cycles?

In order to investigate the dynamics and structural properties of polycentric governance we are using the case of N and P governance. These nutrient flows are essential, life-supporting elements, but their biogeochemical cycles have been greatly perturbed by human activities (Fowler et al., 2013; Scholz et al., 2014). When these elements are mobilized in the environment in excessive concentrations, they cause air and water pollution, and problematic ecosystem changes in land and aquatic environments. Global N and P cycles are among the critical Earth-system processes that Rockström et al. (2009) identified as defining “planetary boundaries”,¹ which, if crossed, would increase risks of unacceptable global environmental change.

There is a growing recognition of both a scientific and a governance gap at the global level. De Vries et al. (2013) describes the current governance interest in planetary and regional nitrogen boundaries, and Ebbesson (2014) explores the issue from a legal point of view. While the direct, often local, impacts of increased N and P flows are reasonably well understood (e.g. Sutton et al., 2014; Hicks et al., 2014; Scholz et al., 2014), there is less knowledge about large-scale systemic responses (Rockström et al., 2009; Fowler et al., 2013). This translates to a major societal challenge, since current

¹ More recently, Steffen et al. (2015) have proposed a more generic “planetary boundary” to encompass human influence on biogeochemical flows, and revised the quantitative N and P boundaries in the framework in light of critiques and recent research (de Vries et al. 2013, Carpenter and Bennett 2011).

governance and management paradigms often do not take complex interacting planetary risks into account, or lack a mandate to act upon them (Walker et al. 2009).

Another challenge arises from the spatial variability of N and P impacts. N and P biogeochemical cycles are globally systemic processes – and so are some of their anthropogenic effects. However, the main causes of N and P flows (agriculture, combustion, industrial processes) are day-to-day actions taken by actors at multiple levels of social organization.

Considering the multilevel nature of the problem, and the limited international attention on the topic, we expect the governance structures to be weak and unconnected. Progress in global nutrient governance has been very limited to date, and there are substantial barriers to change (Sutton et al. 2013). A critical problem associated with nutrient use – eutrophication – is essentially a local to regional issue (Sutton et al, 2013; de Vries, 2013), hence the largest scale of governance is at the regional scale.

1.2 The governance of global nitrogen and phosphorus cycles as analytical case

The lack of strong international governance in place at the international level makes N and P flows interesting to study theoretically. It provides a clear example of where the application of theories about polycentric governance should be fruitful and provides new insights into their emergence, function and effectiveness. A focus on polycentric governance entails a focus on not only formal institutions, but also clusters of norms, principles, regimes and multiple social entities, as well as cross-level interactions. We investigated institutional structures and actor collaborations for the governance of N and P cycles. Specifically, we elaborate the following questions that are of both theoretical and practical interest:

- *To what degree is there a network structure amongst formal institutions at the international level and what is its nature? To what extent is there a gap in formal governance?*
- *Do particular actors facilitate this network structure or has actor engagement appeared through self-organisation?*

The first question is elaborated under the term *governance architecture* of N and P, which is here viewed as ‘the overarching system of formal institutions that are valid or active in relation to the politics of direct and indirect anthropogenic disturbance of the N and P cycles’ (based on definition outlined by Biermann et al., 2009a, p.15, 2009b). The second question complements the analysis of formal institutions with a focus on actors and their collaboration patterns at the international level. In particular, we have studied the emergence of a fairly recent international initiative, the Global Partnership for Nutrient Management (GPNM) (<http://nutrientchallenge.org/>) and its workings during the time period of September 2014-June 2015. This is a constellation of relevant actors that may have an influence on governance outcomes and the Partnership was formed in response to the global context in which the analysed governance regimes take place.

1.3 Governance architecture and polycentricity

Institutional analysis has focused substantially on effectiveness, relationship and interactions (e.g. Biermann, 2008; Young, 2011, Oberthür and Stokke, 2011). The overall *architecture* at the macro-level however has remained largely outside the focus of many previous studies (Biermann, 2007). The study by Kim (2013) is a key

exception, so we have applied a similar approach in this study while investigating both institutional structures and actor collaborations – very different, “formally independent” social entities (sensu Ostrom et al. 1961, p. 831).

In addition, most studies of polycentric governance have focused on case studies, usually specific common pool resources (e.g. Kloosterman and Lambregts, 2001; Wade, 1994). Identifying processes such as information sharing, coordination of efforts, knowledge production activities, and investments in monitoring systems is currently a vital limitation of theory.

The combined approach of exploring the notion of degrees of polycentric governance (Galaz et al., 2012c) through an investigation of the governance structures associated with global cycles of two key nutrient elements, nitrogen (N) and phosphorus (P), using a SNA methodology of Kim (2013) do therefore address some key knowledge gaps with regards to polycentric governance. In addition, we build an understanding of pragmatic nature: “Global solutions” negotiated at a global level have to be backed up by a variety of efforts at national, regional, and local levels to function effectively (Ostrom, 2010). This means to map out governance functionality, and investigate emergent properties. It challenges the view of anarchy at the international level, and it also means to use a corresponding perspective on fragmented architecture, focusing on responses of governance arrangements that are categorized as emerging and/or self-organizing.

1.3.1 Institutional network as part of polycentric governance?

Relationships among social entities can be analysed using social network analysis (SNA) (Wassermann & Faust, 1994), a theoretical approach that uncovers the underlying system architecture to aspects of the political, economic, or social structural environment. Most studies using SNA have studied actors (e.g. Bodin and Crona, 2009; Prell et al., 2009), however, we have viewed different regional and international agreements as social entities. The reason is that although in one sense they are static texts, at the same time they are closely linked to actors like their respective Conferences of Parties, secretariats and other treaty bodies, states, and international organizations (see Churchill and Ulfstein, 2000; Ulfstein, 2012, Kim and Mackey, 2013).

Moreover, SNA has recently emerged as a toolkit in the analysis of complex systems (Amaral and Ottino, 2004; Newman, 2011). A network approach enables an estimation of the structure of a system. Without the use of a method such as SNA it is near impossible to analyse institutional complexity of a global system such as the governance regimes in place for N and P management. Another key benefit with this approach is the power of visualizing these institutional elements through a network. This ensures us to view the actual size of the system, and to some extent its complexity.

2 Nitrogen and phosphorus flows – a global concern

In order to map out the *governance architecture* of N and P flows, we are using the flows and the chemical forms and physical states of the N and P cycles. Hence, if we want to analyse the whole governance architecture, it requires an understanding of all the different aspects of the flows that are being altered and what actor activities that are causing this perturbation. This understanding then outlines the basis for our

selection of the legal instruments active directly and indirectly in governing N and P. In order to create this understanding we include how the N and P cycles operate across multiple “components” of the Earth system (the oceans, biosphere, atmosphere, and lithosphere) (see Figure X).

2.1 Anthropogenic disturbances of the N and P cycle

N compounds exist in many chemical forms and physical states. Figure 1 **Error! Reference source not found.** summarises the N cycle and Figure 2 shows the main flows between the major Earth system components. Although many fluxes are subject to large uncertainties (Fowler et al., 2013), many components of the global N budget have been quantified over the last 30 years, providing an important evidence basis for policy responses at different levels.

The main human alteration of N fluxes (shown in red arrows in **Error! Reference source not found.**) is the conversion of non-reactive atmospheric N to reactive forms, and their application to the land surface (Galloway et al., 2013). Humans create reactive N in three main ways. The major route is the industrial fixation of elemental nitrogen (N_2) to ammonia (NH_3) for use as fertiliser and as an industrial feedstock. Other sources are the cultivation of legumes, and the combustion of fossil fuels forming nitrogen oxides (NO_x) and organic N-containing compounds.

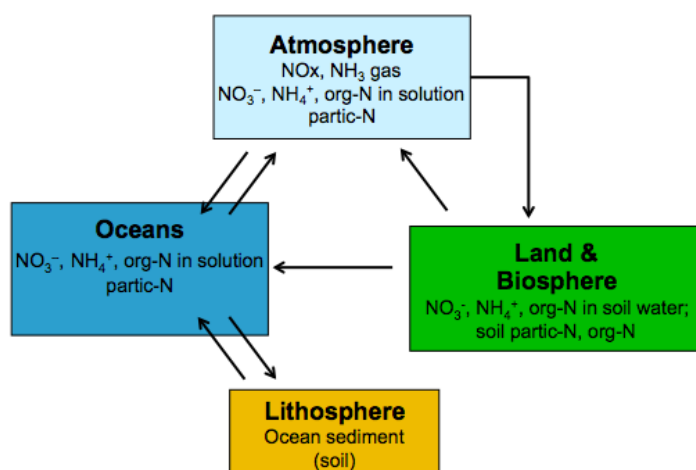


Figure 1. The global nitrogen cycle. A schematic outline showing the multiple chemical forms and physical states of N and the main flows between the different “components” of the Earth system.

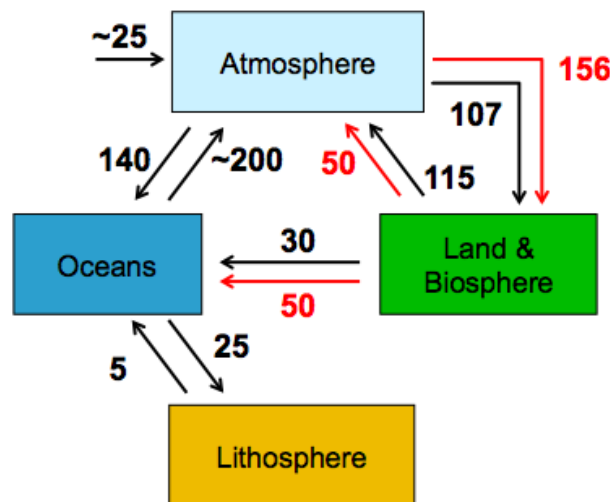


Figure 2. Global nitrogen budget. The figure shows current best estimates of the N flow between systems. Red arrows show main human-caused flows. Units are Tg N yr⁻¹ = million tonne N yr⁻¹. Flows are based on data from Ward (2012).

The P cycle is visualised in Figure 3. The human perturbation of the P cycle is the mining of finite phosphate rock deposits, their conversion to fertilisers or detergents, and their application to terrestrial-based systems (Steffen et al., 2004). The major response is (i) enhanced growth of terrestrial biota due to the use of fertilisers, (ii) leakage of applied P into rivers and eventually to the coastal zone and surface waters, and (iii) enhanced growth of marine biota (Steffen et al., 2004).

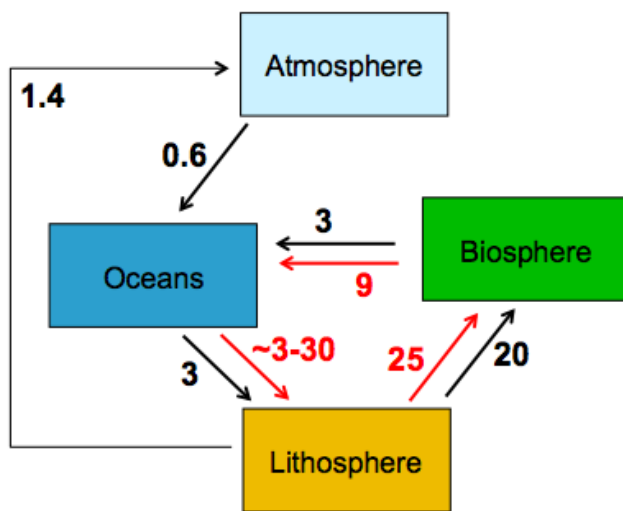


Figure 3 Global P flows through systems. Units are Tg P yr⁻¹ = million tonne P yr⁻¹. Flows are based on data from Sutton et al. (2013) and Filippelli (2002).

3 Integrating polycentric theory with network theory

We structured our study in two steps: (a) an analysis of institutional structures, using social network analysis techniques in combination with expert interviews; and (b) an in-depth study of actor collaborations in the GPNM, based on a review of documents

and expert interviews. This approach allows formal institutional processes in polycentric systems to be explored from both a structural and a process oriented entry point.

3.1 Network Analysis

The dataset of source information about N and P governance that was used for the SNA contains ninety-nine international agreements (see *Supplementary Materials*). These agreements were identified through systematic searches for keywords (Table X) in the International Environmental Agreements Database (Mitchell, 2016) and the ECOLEX database (FAO/UNEP/IUCN, 2014). The agreements were selected on the basis of their effects on drivers of Earth system change (the arrows in Figures 1-3), potentially pushing the N and P cycles beyond their proposed planetary boundaries. Interviews data obtained from nine subjects (see section 3.2) expanded and validated the dataset. Effort was made to include all relevant agreements related to N and P issues, using an iterative selection strategy to ensure that the database is as complete and representative as possible. Part of that process was to target legal instruments that had both a direct and indirect effect on N and P use as discussed in section 2. The use of a broad notion of the *governance architecture* of N and P is useful as this paper analyse if polycentric networks can contribute in overcome formal institutional gaps. This notion means to also incorporate legal instruments into the analysis that are targeting related activities but not the specific use of N and P. For example, the different instruments targeting water use, is closely linked to N and P use, and the environmental degradation that eutrophication is causing. Hence, these ‘connecting regimes’ are legal instruments that are classified as having indirect influence on N and P flows due to unspecific criteria. We classified them as being either (a) a large agreement affecting regional agreement, (b) trade agreement affecting levels of regulation and production, or as (c) agreement dealing with business or industry related to specific criteria outlined in table A. The reason they are “connecting” is especially viewed in Figure 4 below where it is clear that these legal instruments are instrumental in holding the network together. Hence, the network would have been much more fragmented if we had not included these instruments. Hence, these legal instruments also represent an interesting link to the actors involved in the global governance of N and P. Viewing these instruments as the glue of the network, it becomes interesting to investigate actor activity that is shaping global N and P governance through self-organization and their direct and indirect links to these agreements. This creates an understanding that there are more actors involved, at different levels of organisations, than what one would have first expected.

Table A. Criteria for the selection of agreements included in database. The table describes which search terms were used for each legal document to be able to identify legal substance related to key terms. Specific criteria were set up using the key processes as entry points from Figure 1, 2 and 3.

Key Term	Search terms	Specific criteria
Nitrogen	Agriculture Nutrient Nitrogen Pollution Emission Combustion Eutrophication Fertilizer	(Reactive nitrogen (Nr)) Nitrogen oxides (NO _x) Ammonia (NH ₃) Nitrous oxide (N ₂ O) Nitrate (NO ₃ ⁻)
Phosphorus	Agriculture Nutrient	P in sewage sludge P in waste water

	Phosphorus Phosphate Eutrophication Sewage Waste water Sewage treatment plant Detergent Fertilizer	Detergents Fertilizers
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The reason for us to analyse the institutional structures through social network analysis is due to the phenomena that MEAs (and other legal instruments) often cite a number of other agreements that their parties consider relevant (Kim, 2013). The inter-treaty citations could create an extension of the legal effect of cited texts to the texts that cite them (Kiss and Shelton, 2007). We created a network using citations as proxies for relationships (links) between agreements (nodes). Each agreement was manually scanned and searched for citations to other international agreements. The network was analysed using a SNA software called UCINET and visualized (figures 4, 6-9) with its NetDraw tool (Borgatti et al., 2002). A basic analysis of network topological properties was performed:

- ***Degree centrality*** is a means to measure the importance of an agreement (the most connected ones), calculating the number of inward citations and outward citations. This premise is developed from prior studies of law that have been using degree centrality (and citations as links) as a way to measure the continuing relevance or importance of a given case or judge (see Landes and Posner, 1976; Kosma, 1998; Hansford and Spriggs, 2006).
- ***Betweenness centrality*** measures interactions between two agreements and how they might depend on other agreements in the network, especially the agreements that lie on the paths between the two (description of actor interaction, see Wasserman and Faust, 1994). We use betweenness centrality to help in identifying important agreements and cross-scalar interactions between EU directives and international regional and international agreements.

It has to be carefully noted that there are some limitations with regard to what citation networks can show. A citation network has directed links, which show one-way flow of information or influence from node A to node B. A citation does not say anything about (or presume the existence of) the potential flow of information/influence in the opposite direction from node B to node A. However, we have assumed citations as bidirectional links. We note that citations in the treaty context do often mean information often flows in both directions. For example, while the Convention on Biological Diversity (CBD) cites UNCLOS, UNCLOS does also interact with CBD in practice (Wolfrum and Matz, 2000).

3.2 Case study – the Global Partnership on Nutrient Management

We use the GPNM as a case study as to analyse whether any particular actors facilitate the agreement network structure of formal regional and global agreements. The GPNM is a global partnership of governments, scientists, policy makers, and non-governmental, private sector and international organisations. It was established in 2009 to address the multiple linked challenges of promoting effective nutrient management, minimising negative impacts on the environment and human health, and maximising the contribution to global sustainable development and poverty reduction. It operates through strategic advocacy and cooperation at the global level, prompting

discussion on the complexity of the nutrient challenge and the opportunities for cost effective policy and investment interventions by countries (*pers. comm.*, de Vries and Cornell).

Semi-structured interviews were conducted with nine subjects who have been or are actively involved in the GPNM. The interview questions were designed to capture milestones for the partnership, its missions and goals, the GPNM goals over time, its functioning in comparison to current governance regimes, challenges, and opportunities associated with the partnership.

4 Global governance of N and P

4.1 The citation network of global N and P governance

Figure 4 is a network map showing all identified international agreements that are in place, regulating activities that influence the anthropogenic effects of N and P flows, both directly and indirectly. In the figure, node colour indicates issue area or objective, and node shape denotes agreement type.

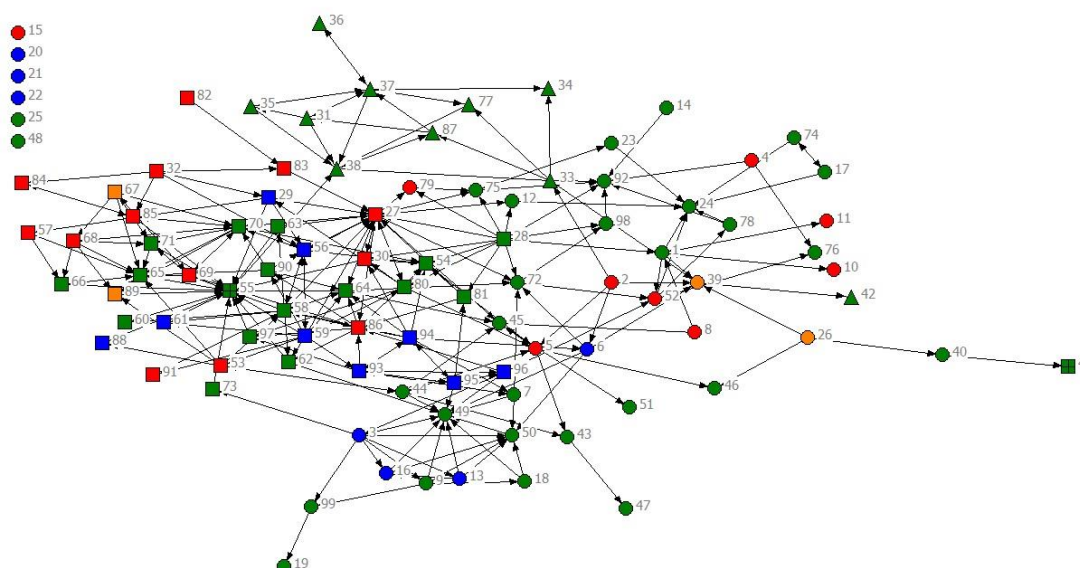


Figure 4. Visualisation of the agreement connectivity network. Blue = N, orange = P, red = N&P, and green = other relevant factor. Circle = MEA, square = EU-level directive/regulation, triangle = trade, and box = other relevant regional or international agreement. Nodes in the upper left corner are unconnected nodes (agreements without citation links). Numbers denote the agreement (listed in Supplementary Information)

Most legal instruments indirectly influence N and P flows, but are actually targeted at other relevant factors (green nodes account for 57% of the total), hence the ‘connecting regimes’. Also, individual element flows (blue and orange nodes) are less recognised in agreements than more general nutrient issues involving both N and P (red nodes).

In the figure, the circles are MEAs. However, very few of these circles represent an MEA with global coverage. On the contrary, the analysis identified some regional agreements with clear N and/or P focus such as the *1979 Geneva Convention on Long-Range Transboundary Air Pollution* (node nr 49). *United Nations Convention on the Law of the Sea* (UNCLOS) (green node nr 92) and some additional regional

seas conventions all apply to marine pollution through N and P (Ebbesson, 2014). Furthermore, the *1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone*, often referred to as the *Gothenburg Protocol* (node nr 3) also applies to nitrogen emission through the atmosphere. If this protocol is complied with, it should result in a reduced introduction of nitrogen in near sea areas since sets out, inter alia, national emission caps for nitrogen oxides and ammonia (Ebbesson, 2014). The analysis show that there is a network structure at the international level, however, its nature is a loose interconnected network where a only a few legal instruments with direct influence of N and P usage has been identified. In this context it is interesting to include what actor engagement that has structured in response. As discussed by interviewee I9b in section 5, there are fragments of governance so far with some global conventions dealing with certain aspects of nutrient management the main the value of GPNM could be developed in this context where a further integrated approach could be applied. GPNM have through its network members from many different sectors and different interests including research, policy, producers, and other actors from the private sectors coming together. This is representing configuration of the national level, and is executed in a multi-level implementation through the wide range of actors and through its local demonstration areas (see interviewee I2b).

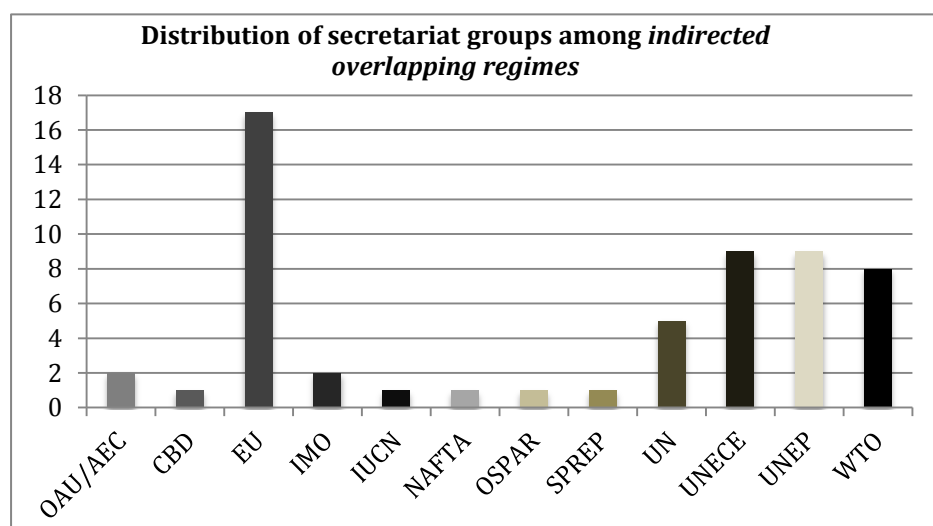


Figure 5. Distribution of secretariat groups to uncover the different regimes part of the hub “connecting regimes” (green nodes in figure 4). See Appendix III and the set of criteria that was used to categorise the agreements, as well as and Appendix IV for the selection of agreements.

In the context of this identified large ‘connecting regimes’ that connect the otherwise fragmented structure of N and P governance, it is interesting to see what organisations that are covering *indirect* activities important for the governance of N and P. Figure 5 illustrate the distribution of secretariat groups in the hub ‘connecting regimes’, which are legal instruments regulating the issues around N and P *indirectly* (green colour code in Figure 4 of the agreement connectivity network). In figure 5 the clear diversity of regimes that are having an impact on N and P flows are shown. This certainly tells us about the gap in governance in terms of agreements regulating the identified issues *directly*. This also draws attention to the chosen approach of mapping out the overall governance architecture, which enabled to find that the WTO agreement system, the EU (-level) Directives system, and the system of MEAs are clearly connected in a network. This is hence is maze of three systems outlining a *regime complex* that in the end governing the different human activities steering and

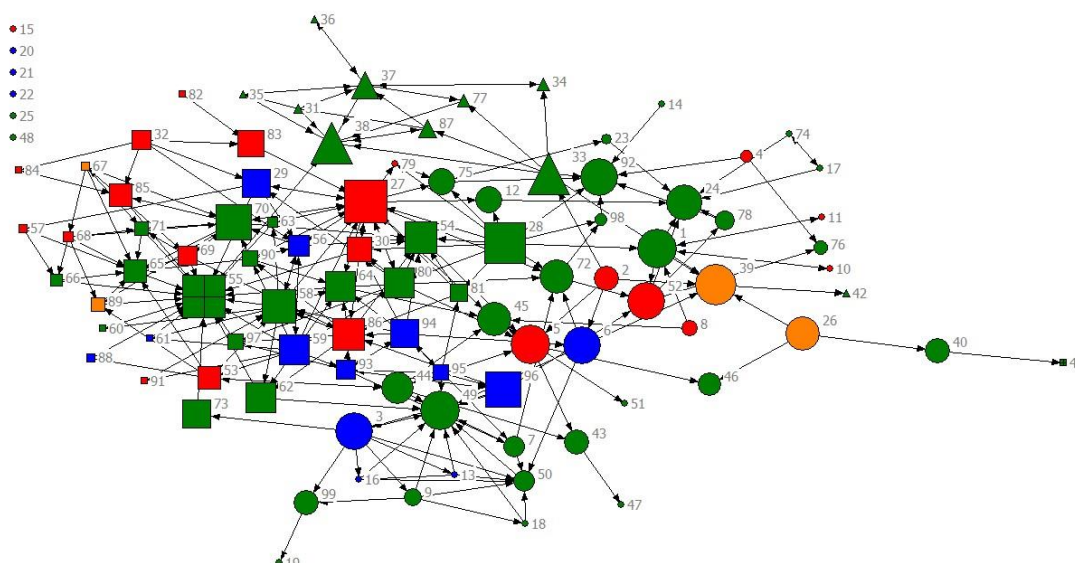


Figure 8. Visualisation of the agreement connectivity network using *betweenness centrality*. The size of the nodes indicates the *betweenness centrality* (the larger node the higher *betweenness centrality*). The largest red node (nr 27) in the middle represents the *EU Water Framework Directive*, and the green largest node (nr 28) represent the *Marine Strategy Framework Directive*.

The examples on cross-sectoral and cross-scalar linkages using *degree centrality* measures and *betweenness centrality* in relation to the two-level visualisation image (Figure 9) is suggested to outlay patterns that represent emerging polycentric governance. What is clear is that the EU-level regime outline a dominant hub within the global network, and that the *EU Water Framework Directive* (node nr 27) and *Marine Strategy Framework Directive* (node nr 28), *UN Convention on the Law of the Sea* (node nr 92), and *Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants* (node nr 96) could be seen as acting ‘legal gateways’ to international law. Even more interesting is possible role of the *1979 Geneva Convention on Long-Range Transboundary Air Pollution* (node nr 49), since it is an agreement that is citing and being cited by other international agreements, across these identified hubs.

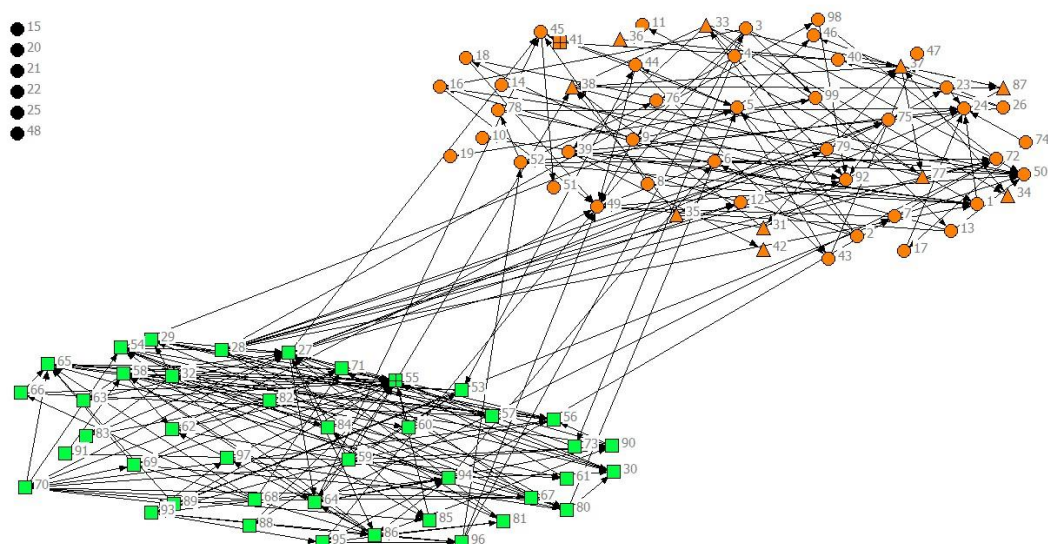


Figure 8. Cross-scale citation connectivity network. The cluster of nodes to the left represent EU (-level) Directives and the cluster of nodes to the right represent different regional and international agreements. Certain nodes such as number 27, 28, 49, 92 and 96 are suggested to act as ‘legal gateways’ since they are connected across the legal levels of European environmental law and international environmental law.

4.4 The Global Partnership on Nutrient Management – emerging polycentricity

4.4.1 Functioning of the GPNM in relation to current governance regimes

Interviewees confirmed that the GPNM has self-organised into a supporting governance structure to the loose network structure of formal institutions. The cross-scalar dimension of how they have been coordinating themselves can especially be viewed through their work on structuring platforms of information sharing and knowledge production activities through local demonstration areas where integrated view on nutrient management have been used and that have been linked to inter-governmental process. Their aim has been to create a platform where multiple actors come together and work towards a better governance of N and P flows. However, the views of the exact function of the GPNM differ:

“They [actors involved in GPNM] could start the process on an inter-governmental agreement on nutrients. And that’s a long way, but I think that’s the role of GPNM, not only being regionally active and with demonstration areas and science development, but working towards an integrated, inter-governmental process – science based.” (I2b)

“I think there is no global governance structure for addressing nutrients (...) other than GPNM (...). So in that sense it’s the first step. If you look at nitrous oxides – that’s a greenhouse gas, so that’s part of the UNFCCC agenda so to say. And I think also the CBD, the Convention on Biological Diversity, addresses one of the effects of nutrient use, namely the effect on biodiversity. So there’re fragments so far, as there are global conventions dealing with certain aspects of nutrient management but there’s no integrated approach and I think that’s the main the value of GPNM (...). (I9b)

4.4.2 GPNM – a partnership with cross-scalar and cross-sectoral collaboration

The GPNM is a partnership initiative with some clear successes in terms of how partners organised themselves, including working across sectors, to create a global

multi-level collaboration structure. It could be viewed as structuring polycentric governance as it involves deliberate attempts for mutual adjustments and self-organized action (see Galaz et al., 2012). In addition, this multi-stakeholder formation is suggested to have real benefits especially since the entry of the private sector.

“The partnership is a multi-sectoral partnership. It is, I guess, it intended to reflect what is the configuration of the national level. So we have different stakeholders representing different interests. We have interests in policy design, interest in research, interests from producer organisations, interests from fertilizer supply organisations, companies. So by having a governance structure with the GPNM that allows for interference between different stakeholder groups allows for a transfer of knowledge at the local level.” (I4b)

“So the International Fertilizer Association for example, has come on-board as part of a public-private partnership (...). Which in my opinion has strengthened the whole effort. I think the real benefit of the partnership at this moment is that this problem [N and P issue] can't be solved without the cooperation with the private sector.” (I6b)

5 Linkages between agreement connectivity network results and actor testimonies

As visualised in Figure 8, there are certain agreements that link the cluster of nodes that represent EU (-level) Directives and the cluster of nodes to that represent different regional and international agreements. These are suggested to act as ‘legal gateways’ since they are connected across the legal levels of European environmental law and international environmental law. These “citation links” are not evidence of legal diffusion processes themselves since it is not evident what norms or ideas that are diffused. However, as seen in section 5.2, there are no regimes in place at the global level though the above-mentioned ‘legal gateways’ can play more important roles than what can be drawn from the abstract representation of the agreement connectivity network. The *EU Water Framework Directive* (WFD) (node nr 27) may well have this function mainly for water governance but also for nutrient governance as seen in Figure 4, 6-9 due to a couple of reasons:

The WFD is acting as an interesting node in the network. The WFD is referring to the *Convention on the Protection of the Marine Environment of the Baltic Sea Area*, (node nr 12), the *Convention for the Protection of the Marine Environment of the North-East Atlantic*, (node nr 72), and the *Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-Based Sources to the Convention for the Protection of the Mediterranean Sea Against Pollution* (node nr 79). The Directive is referring to these agreements as important, but the most significant citation link is seen to the *United Nations Convention on the protection and use of transboundary water courses and international lakes*:

“This Directive is to contribute to the implementation of Community obligations under international conventions on water protection and management, notably the United Nations Convention on the protection and use of transboundary water courses and international lakes, approved by Council Decision 95/308/EC(1) and any succeeding agreements on its application.”

The above citation shows that the link between node nr 27 and nr 45 is an important link in reality, not only abstract representations in the agreement connectivity

network. Furthermore, Engel et al. (2009) suggest; the WFD (and the UNECE *Convention on Transboundary Waters and International Lakes*) can play role model functions in terms of providing a framework concept where one of the main benefits are the design that enable adaptive elements in water legislation. They continue with the suggestion that certain elements such as the efforts to establish synergies between international, regional, and local level of water management and protection can lead to certain [improved] conclusions regarding approach to be adopted and strategic priorities realised. Again, this is relevant for water governance, but nutrient management that have an effect on water and marine environment means that the case of nutrient governance will also be affected by these inter-linkages that is viewed as key for cross-scalar connectivity but more importantly cross-sectoral importance of the WFD. The suggestion by Engel et al. (2009) is in line with testimonies by interviewee I8b:

“One of the most advanced regional frameworks would be the EU Water framework directive, which is not really about nutrients. But it is looking at the bottom view impact of nutrients, which is also widely quoted.”

An example of a combined top-down and horizontally linked citation in the case of WFD, is the fact that the Marine Strategy Framework Directive cite the WFD, while at the same time harnessing main principle from the United Nations Convention on Law of the Sea, which represent a citation link with actual importance. This is done through the following text:

“The obligations of the Community and its Member States under those agreements should therefore be taken fully into account in this Directive. In addition to the provisions applicable to the marine waters of the Parties, the Unclos includes general obligations to ensure that activities under the jurisdiction or control of a Party do not cause damage beyond its marine waters, and to avoid that damage or hazards are transferred from one area to another or that one type of pollution is transformed into another.”

Having a mere focus on nutrient governance it is evident from the agreement connectivity network that among these ‘legal gateways’, there are a few other agreements that outline importance as they have indirect effects on governance structures (see Table B). Some of these agreements are the *Nitrates Directive* (node nr 29), *CBD* (node nr 98), and *UNFCCC* (node nr 99). The *Nitrates Directive* cite WFD (node nr 27), *The Directive on the quality of water intended for human consumption* (node nr 56) and the *EU regulation on relating to fertilizers* (node nr 57). The *Nitrates Directive* is furthermore cited by the *Commission Regulation laying down detailed rules for the implementation of Council Regulation on organic production and labelling of organic products with regard to organic production, labelling and control* (node nr 32) and *EU (-level) Directive concerning the management of bathing water quality* (node nr 80). *CBD* is citing *Convention for the Protection of the Marine Environment of the North-East Atlantic* and the *Marine Strategy Framework Directive*. *UNFCCC* is citing the *Vienna Convention for the Protection of the Ozone Layer* (node nr 19) and is being cited by the *LRTAP protocols to Abate Acidification, Eutrophication and Ground-Level Ozone* (node nr3) and *on further Reduction of Sulphur Emissions* (node nr 9). These international agreements are hence citing some

of the identified ‘legal gateways’ in the agreement connectivity network namely the *WFD*, the *Marine Strategy Framework Directive*, and the *LRTAP* through its protocols. This is in line with testimonies in section 5.2 (19b).

Table B. Gateway agreements – ‘legal gateways’ for cross-scalar and cross-sectoral agreement connectivity in the global governance of N and P.

Agreement that cite	Agreement being cited
Water Framework Directive (node nr 27)	<i>Convention on the Protection of the Marine Environment of the Baltic Sea Area</i> , (node nr 12)
	<i>Convention for the Protection of the Marine Environment of the North-East Atlantic</i> , (node nr 72)
	<i>Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-Based Sources to the Convention for the Protection of the Mediterranean Sea Against Pollution</i> (node nr 79)
	<i>United Nations Convention on the protection and use of transboundary water courses and international lakes</i>
Marine Strategy Framework Directive (node nr 28)	Water Framework Directive (node nr 27)
Nitrates Directive (node nr 29)	Water Framework Directive (node nr 27)
	<i>Directive on the quality of water intended for human consumption</i> (node nr 56)
	<i>EU regulation on relating to fertilizers</i> (node nr 57)
<i>Commission Regulation laying down detailed rules for the implementation of Council Regulation on organic production and labelling of organic products with regard to organic production, labelling and control</i> (node nr 32)	Nitrates Directive (node nr 29)
<i>Directive concerning the management of bathing water quality</i> (node nr 80)	Nitrates Directive (node nr 29)
CBD (node nr 98)	<i>Convention for the Protection of the Marine Environment of the North-East Atlantic</i>
	<i>Marine Strategy Framework Directive</i>
UNFCCC (node nr 99)	<i>Vienna Convention for the Protection of the Ozone Layer</i> (node nr 19)
LRTAP protocol to <i>Abate Acidification, Eutrophication and Ground-Level Ozone</i> (node nr3)	UNFCCC (node nr 99)

LRTAP protocol <i>on further Reduction of Sulphur Emissions</i> (node nr 9)	UNFCCC (node nr 99)
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When interpreting the functioning of those ‘legal gateways’, we suggest that this could represent diffusion processes in the emergence of law between European legislation and international law. Twining (2005) define diffusion of law as “the processes by which legal orders and traditions are influenced by other legal orders and traditions”. Visualisation through networks is here suggested to be useful to detect diffusion processes that could be tested in future research.

6 Interpreting the governance architecture for N and P

Polycentricity at a global level includes an analysis of cross-scalar and cross-sectoral entities. When analysing whether polycentric governance emerges among relevant institutions and actors, it is relevant to discuss what the overall current governance structure is not doing in terms of governance. This means to uncover whether there is a “gap in governance”, and possible responses to this gap. The emergence of the global partnership initiative GPNM becomes important here. The partnership was established due to a recognized need for special attention to land-based sources of N and P to the seas and oceans, especially run-off and leaching to estuaries, which was a response to an acknowledged “gap in governance” at the global level.

The focus on mapping the connected regimes has also enable us to include social entities that indirectly affect governance of N and P, for example, certain agreements on trade. This is indeed important in terms of governance and interacting planetary boundaries, such as in the present case with N where we have multiple anthropogenic disturbances, e.g. combustion, emission of N and interactions with P in eutrophication processes (see the N cascade in Galloway et al., 2003; Sutton et al., 2011). This is not only affecting different types of fresh water- and marine systems, but also climate change and biodiversity (see figure S10 on the interaction between the biosphere integrity planetary boundary and other planetary boundaries in the supplementary material for Steffen et al., 2015).

As discussed in section 4, the "connecting regimes" (the majority of nodes in Figure 4, 6-8) plays a significant role in connecting the network. A study with a more narrow focus would likely find the gap in governance to be not only larger, but also not consisting of the same interrelations and possible flaws. The approach of studying the overall governance architecture has hence resulted in a network that symbolizes a regime complex for N and P that illustrated the real benefit of using a broader notion of governance and the usefulness in combining polycentric theory with network analysis.

6.1 GPNM as self-organised governance structure

The GPNM partnership is a self-organised governance structure part of formal institutional network structure that form the governance of N and P cycles at the global level. The partnership has been formed as a “polycentric response” to a gap in governance, since it involves deliberate attempts for mutual adjustments and self-organized action when for example coordinating international knowledge production and international study areas. The GPNM is not only a platform intended for pure

information sharing, but rather a partnership that have the potential to facilitate a stronger form of polycentricity involving tangible joint projects and experiments, which also include people on the ground participating on improving nutrient management. However, the GPNM will probably not facilitate the emergence of polycentric governance including strong formal ties between key actors, and global joint projects. The reasons are: (1) the current objective of the GPNM and (2) the lack of feasibility due to the current state of the global intergovernmental settings. This is a conclusion that can be interpreted from the inconsistent interviewee testimonials in section 4. However, this previous trend could of course be changed, the potential, due to the acknowledged success of the partnership, is still there for a stronger polycentric governance structure in the future.

The case of global governance of N and P is interesting since it represents a tension between emergence and design; it can be argued that a governance system that has emerged into a more networked, polycentric governance has better capacity to deal more flexible with the context that it has emerged from. However, in an emerged [polycentric] system actors that are already weak tend to be weaker, which can affect legitimacy. This is especially true for regime complexes where it is said that only powerful actors can have an influence (see Orsini et al, 2013). However, trying to “design” institutions that match not only the individual planetary boundaries, but also their interactions, is practically impossible (Galaz et al. 2012a, Galaz et al., 2012c).

6.2 N and P boundaries and polycentric governance

The case of global N and P governance and the identified polycentric structure need to finally be set in the context of the multilevel nature of the problems and the identified planetary boundaries for N and P use. A more generic approach towards the concept of all identified “planetary boundaries” can help support an international environmental governance structure that is more integrated and synergistic. Galaz et al. (2012b) argue the following:

“Planetary boundaries are not fixed 'supply limits', but are set within a safety margin around complex thresholds that are intertwined at regional and global scales. Ecosystem changes caused by nitrogen pollution, for example, are driven by global trade and cannot be uncoupled from climate change and alterations in land use. Also, investment in new phosphorus technologies can address the problems of both pollution and stock control.”

What Galaz et al. (2012b) pinpoint is that the multiple scales in which those complex thresholds exist are acknowledged, and that there is no contradiction in taking the global level into consideration while at the same time looking into regional levels. The reasoning is made on the basis that the N and P cycles are global (see for example Steffen et al., 2004; Sutton et al., 2014). However, there is a clear need for governance to look different on different places, which is illustrated by the fact that large regions in Northern Africa are being under-fertilized, meanwhile the most urgent areas in which the N and P boundaries are transgressed are mainly located in the global North (see figure S5A and S5B in the supplementary material for Steffen et al., 2015) where also most knowledge production is taking place. Economic development in the global South will require more knowledge about institutional solutions, useful policy tools, and new practises to be shared as to avoid harming the ecosystems the way current N and P practises do. It also has to be acknowledged that

countries encounter different problems due to regional and local circumstances. For example, increased food production or re-structuring of the P flows into recycling systems when building new treatment plants. This is also a clear argument for the long-term benefits of having a global partnership in place that could facilitate those processes.

The N and P agreement connectivity networks in Figures 4, 6-9 are useful visualisations of the connectedness between the different governance regimes. However, these visualisations were only enabled through using the broader notion of the *governance architecture* of N and P that show the complexity and necessity to take a holistic, integrated approach to nutrient governance. The multilevel nature of the N cycle require governance approaches that not only address effects in the N cascade, but also impact interactions between ‘biosphere integrity’ planetary boundary, as well as other planetary boundaries. Therefore, a self-organized polycentric structure that do take into account the multilevel nature – as well as the need for the need of cross-sectoral collaboration has potential for establishing synergetic structure in which more holistic, integrated approach can be established.

Finally, it is important to discuss governance challenges for N and P in relation to the lack of knowledge about the dynamics of these processes at the global scale. Many fluxes are still subject to large uncertainties and require extensive measurements to constrain the current range of values (Fowler et al., 2013). Conclusions regarding the identified governance network structure and the future need for better governance has to be drawn upon this uncertainty and acknowledged in the structure so that unpredictable change is somehow being tackled.

7 Conclusion

This study has shown that the global governance of N and P consist of a network structure amongst formal institutions that is emerging at the international level. A focus on the overall governance architecture enables an approach to include legal instruments with direct and indirect effect of N and P usage. This approach enable the finding of some particular agreement that act as ‘legal gateways’ that connect the network across scales, possibly representing legal diffusion processes. These gateway agreements are seen as important for connecting the governance structure across scales and across sectors. This network structure is complemented by the workings of a formation of a set of actors that have established a partnership called the GPNM that engage in cross-sectoral and cross-scalar collaboration. This emerging “polycentric response” to the gap in N and P governance plays a visible and important role for the governance of global N and P cycles as it involves deliberate attempts for mutual adjustments and self-organized action, for example in its coordination of international knowledge production and capacity extension. However, the exact understanding of emerging polycentric governance will require a longer timeframe of analysis to uncover fully.

With this study, we have exercised the applicability of polycentric theory despite it to date limited empirical benefits. We have shown that the case of the poorly governed global N and P boundaries is a case in which the self-organized formation of GPNM has a clear potential to not only bridge between different actors but also the network structure of formal institutions. The study emphasizes and highlights the usefulness of actor-institutional analysis because it enables an understanding of how institutions are

being developed. Finally, this study is an attempt to illustrate that there are interesting benefits from integrating polycentric theory with network theory.

8. References

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Supplementary Materials for**Governance, polycentricity and the global nitrogen and phosphorus cycle****List of agreements**

1	Convention on the Protection of the Black Sea against Pollution	http://www.blacksea-commission.org/convention.asp
2	Protocol on Pollutant Release and Transfer Registers to the Convention on Access to Information, Public-Participation in Decision-Making and Access to Justice in Environmental Matters	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-13-a&chapter=27&lang=en
3	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-Level Ozone	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-1-h&chapter=27&lang=en
4	Protocol concerning Pollution from Land-Based sources and activities to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/cartagena-convention/lbs-protocol/lbs-protocol/lbs-protocol-english/view
5	Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters	http://www.unece.org/env/pp/treatytext.html
6	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants	http://www.unece.org/env/lrtap/pops_h1.html
7	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Heavy Metals	http://www.unece.org/env/lrtap/hm_h1.html
8	Convention on Cooperation for the Protection and Sustainable Use of the Danube River	https://www.icpdr.org/main/icpdr/danube-river-protection-convention
9	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on further Reduction of Sulphur Emissions	http://www.unece.org/env/lrtap/fsulf_h1.html
10	Protocol on the Protection of the Black Sea Marine Environment against Pollution by Dumping	http://www2.unitar.org/cwm/publications/cb1/synergy/pdf/cat3/UNEP_regional_seas/convention_bucharest_protos/protocol_dumping.pdf
11	Protocol on the Protection of the Black Sea	http://www.blacksea-commission.org/convention-protocols.asp

	Marine Environment against Pollution from Land-Based Sources	
12	Convention on the Protection of the Marine Environment of the Baltic Sea Area	http://helcom.fi
13	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes	http://www.unece.org/env/lrtap/vola_h1.html
14	Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources	http://www2.unitar.org/cwm/publications/cbl/synergy/pdf/cat3/UNEP_regional_seas/convention_kuwait/Protocols/protocol_prot_marine_env_against.pdf
15	Regulation No.83: Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-83&chapter=11&lang=en
16	Protocol to the Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-1-c&chapter=27&lang=en
17	Protocol for the Prevention of Pollution of the South Pacific Region by Dumping	https://www.sprep.org/legal/the-convention
18	Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at Least 30 per Cent	http://www.unece.org/env/lrtap/sulf_h1.html
19	Vienna Convention for the Protection of the Ozone Layer	https://treaties.un.org/doc/Treaties/1988/09/19880922_03-14_AM/Ch_XXVII_02p.pdf
20	Regulation No.49: Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous pollutants from positive-ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles	http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/R049r5e.pdf
21	Regulation No.47: Uniform Provisions concerning the Approval of Mopeds equipped with a Positive-Ignition Engine with regard to the Emission of Gaseous Pollutants by the Engine	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-47&chapter=11&lang=en
22	Regulation No.40: Uniform Provisions	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-

	concerning the Approval of Motor Cycles Equipped with a Positive-Ignition Engine with regard to the Emission of Gaseous Pollutants by the Engine	40&chapter=11&lang=en
23	Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft	http://www.unepmap.org/index.php?module=content2&catid=001001001
24	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	http://www.imo.org/About/Conventions/ListOfConventions/Pages/Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter.aspx
25	Regulation No. 15: Uniform Provisions concerning the Approval of Vehicles Equipped with a Positive-Ignition Engine or with a Compression-Ignition engine with regard to the Emission of Gaseous Pollutants by the Engine - Method of Measuring the Fuel Consumption of Vehicles	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-15&chapter=11&lang=en
26	Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa	http://www.unep.org/delc/BamakoConvention/BamakoBackgroundDocuments/tabid/106424/Default.aspx
27	Protocol to the 1979 Convention on long-range transboundary air pollution concerning the control of emissions of nitrogen oxides or their transboundary fluxes	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-1-c&chapter=27&lang=en
28	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (In short: EU Water Framework Directive)	http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32000L0060
29	DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (In short: Marine Strategy Framework Directive)	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0056
30	Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (IN short: Nitrates Directive (1991))	http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:31991L0676

31	Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31991L0271
32	URUGUAY ROUND AGREEMENT Agreement on Agriculture	https://www.wto.org/english/docs_e/legal_e/14-ag_01_e.htm
33	Commission Regulation (EC) No 889/2008 of September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2008.250.01.0001.01.ENG
34	North American Free Trade Agreement (NAFTA)	https://www.nafta-sec-alena.org/Home/Legal-Texts/North-American-Free-Trade-Agreement
35	World Trade Organization Agreement on Government Procurement (WTO-AGP)	https://www.wto.org/english/tratop_e/gproc_e/gp_gpa_e.htm
36	Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement)	https://www.wto.org/english/tratop_e/sps_e/sps_agr_e.htm
37	Agreement on Trade-Related Aspects of Intellectual Property Rights	https://www.wto.org/english/tratop_e/trips_e/t_agm0_e.htm
38	Marrakesh Agreement establishing the World Trade Organisation	https://www.wto.org/english/docs_e/legal_e/legal_e.htm
39	General Agreement on Tariffs and Trade	https://www.wto.org/english/docs_e/gattdocs_e.htm
40	1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx
41	African Convention on the Conservation of Nature and Natural Resources	http://www.au.int/en/content/african-convention-conservation-nature-and-natural-resources-revised-version
42	Treaty Establishing the African Economic Community	http://www.wipo.int/wipolex/en/profile.jsp?code=AEC
43	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx
44	Convention on Environmental Impact Assessment in a Transboundary Context (in short Espoo Convention)	http://www.unece.org/env/eia/eia.html
45	Convention on the Transboundary Effects of Industrial Accidents	http://www.unece.org/env/teia/about.html
46	Convention on the Protection and use of	http://www.unece.org/env/water/text/text.html

	Transboundary Water courses and International Lakes (UNECE Water Convention)	
47	The World Charter for Nature 37/7	http://www.un-documents.net/a37r7.htm
48	Ramsar Convention	http://archive.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-31-38_4000_0
49	Convention on the Law of the Non-Navigational Uses of International Watercourses	https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-12&chapter=27&lang=en
50	1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone	http://www.unece.org/env/lrtap/multi_h1.html
51	The 1994 Oslo Protocol on Further Reduction of Sulphur Emissions	http://www.unece.org/env/lrtap/fsulf_h1.html
52	1979 Convention on Long-Range Transboundary Air Pollution	http://www.unece.org/env/lrtap/lrtap_h1.html
53	Protocol on Long-Term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe	http://www.unece.org/env/lrtap/emep_h1.html
54	Boundary Waters Treaty of 1909	http://www.ijc.org/en/BWT
55	Charter on Groundwater Management	http://www.internationalwaterlaw.org/documents/regionaldocs/groundwater_charter.html
56	International Convention for the Prevention of Pollution from Ships (MARPOL)	http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/HistoryofMARPOL/Pages/default.aspx
57	Protocol of 1978 relating to the Convention for the prevention of pollution from ships	http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/HistoryofMARPOL/Pages/default.aspx
58	COUNCIL DIRECTIVE 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31996L0082
59	DIRECTIVE 2003/4/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32003L0004
60	Treaty Establishing the European Economic Community	http://europa.eu/eu-law/decision-making/treaties/index_en.htm
61	COUNCIL DIRECTIVE 98/83/EC of 3	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31998L0083

	November 1998 on the quality of water intended for human consumption	
62	Regulation 2003/2003 of the European Parliament and of the Council of 13 October 2003 relating to fertilizers	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32003R2003
63	COUNCIL DIRECTIVE 91/692/EEC of 23 December 1991 standardizing and rationalizing reports on the implementation of certain Directives relating to the environment	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0692
64	COUNCIL DIRECTIVE 90/656/EEC of 4 December 1990 on the transitional measures applicable in Germany with regard to certain Community provisions relating to the protection of the environment	http://eur-lex.europa.eu/legal-content/LV/TXT/?ELX_SESSIONID=vHCJ44gfPfc1mZzr1pPIpNsX4TRCKSyWG2QtlVMOLTLWhHPyVcKB!-2075031620?uri=CELEX:31990L0656
65	Council Directive of 15 July 1980 on air quality limit values and guide values for sulphur dioxide and suspended particulates (80/779/EEC)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31980L0779
66	Council Directive of 7 March 1985 on air quality standards for nitrogen oxide (85/203/EEC)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31985L0203
67	COUNCIL DIRECTIVE of 28 June 1984 on the combating of air pollution from industrial plants (84/360/EEC)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31984L0360
68	COUNCIL DIRECTIVE of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (86/278/EEC)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31986L0278
69	COUNCIL DIRECTIVE of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (76/464/EEC)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31976L0464
70	Council Directive of 27 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (67/548/EEC)	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31967L0548
71	Commission Directive 93/112/EC of 10 December 1993 amending Commission Directive 91/155/EEC defining and laying down detailed arrangements for the system of specific information relating to	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32001L0058

	dangerous preparations in implementation of Article 10 of Council Directive 88/379/EE	
72	Commission Directive 91/155/EEC of 5 March 1991 defining and laying down the detailed arrangements for the system of specific information relating to dangerous preparations in implementation of Article 10 of Directive 88/379/EEC	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0155
73	Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32004R0648
74	DIRECTIVE 1999/45/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 31 May 1999 concerning the approximation of the laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labelling of dangerous preparations	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31999L0045
75	Council Directive 76/769/EEC of 27 July 1976 on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31976L0769
76	Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31998L0008
77	Council Directive of 27 July 1976 on the approximation of laws of the Member States relating to cosmetic products	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:121191
78	Convention for the Protection of the Marine Environment of the North-East Atlantic	
79	Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31970L0156
80	Convention for the Protection of the Natural Resources and Environment of the South Pacific Region	https://www.sprep.org/legal/the-convention
81	Convention for the Protection of the Marine Environment and the Coastal Region of the	http://www.unepmap.org/index.php?module=content2&catid=001001004

	Mediterranean	
82	Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/cartagena-convention/text-of-the-cartagena-convention
83	Agreement on Implementation of Article VI of the general agreement on Tariffs and Trade 1994	https://www.wto.org/english/res_e/booksp_e/analytic_index_e/anti_dumping_e.htm
84	Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships	http://www.imo.org/en/KnowledgeCentre/ReferencesAndArchives/HistoryofMARPOL/Pages/default.aspx
85	1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter	http://www.imo.org/en/OurWork/Environment/PollutionPrevention/Pages/1996-Protocol-to-the-Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter,-1972.aspx
86	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities	http://www.unep.ch/regionalseas/main/med/mlbsprot.html
87	Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006L0007
88	Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32007L0002
89	Commission Regulation (EC) No 1235/2008 of 8 December 2008 laying down detailed rules for implementation of Council Regulation (EC) No 834/2007 as regards the arrangements for imports of organic products from third countries	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32008R1235
90	Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007R0834
91	Council Directive 96/25/EC of April 1996 on the circulation of feed materials, amending Directives 70/524/EEC, 74/63/EEC, 82/471/EEC and 93/74/EEC and repealing Directive 77/101/EEC	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31996L0025
92	Council Directive of 30 June 1982	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31982L0471

	concerning certain products used in animal nutrition (82/471/EEC)	
93	Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31996L0061
94	Protocol of Provisional Application of the General Agreement	https://www.wto.org/english/res_e/booksp_e/gatt_ai_e/prov_appl_gen_agree_e.pdf
95	Council Directive of 15 July 1980 on the approximation of the laws of the Member States relating to straight ammonium nitrate fertilizers of high nitrogen content (80/876/EEC)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31980L0876
96	Council Directive of 26 June 1978 on the approximation of the laws of the Member States relating to the classification, packaging and labelling of dangerous preparations (pesticides) (78/631/EEC)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31978L0631
97	Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council	http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=068466&database=faolex&search_type=link&table=result&lang=eng&format_name=@ERALL
98	Directive 2006/44/EC of the European Parliament and of the Council of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to protect fish life	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0044
99	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm

List of interviewees for pre-study

I1a	Representative	Swedish Ministry of the Environment
I2a	Assistant professor, Dr	University, Canada
I3a	PhD Student	University, Denmark
I4a	PhD Student	University, Denmark
I5a	Director, Dr	University, Austria
I6a	Senior Research Fellow, Dr	Research Institute, Sweden /Research Institute, Germany
I7a	Senior Research Fellow, Dr	Research Institute, Sweden
I8a	Professor, Dr	University, The Netherlands
I9a	Associate professor, Dr	University, Japan

List of interviewees for Case Study (GPNM)

I1b	Professor, Dr	Institute strategic policy University, The Netherlands
I2b	CEO/Professor, Dr	Independent research institute University, The Netherlands
I3b	Anonymous A	
I4b	Programme Officer	UNEP
I5b	Environmental Affairs Officer	UNECE
I6b	Anonymous B	
I7b	Project manager, Dr /Coordinator	Research Organization, UK/Task Force on Reactive Nitrogen
I8b	Environmental Affairs Officer	Convention of Biological Convention
I9b	Representative	Ministry of Infrastructure and Environment, The Netherlands