Forest Policy and Economics 90 (2018) 90–96

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

From wicked problem to governable entity? The effects of forestry on mercury in aquatic ecosystems

Rolf Lidskog[a,*], Kevin Bishop[b], Karin Eklöf[b], Eva Ring[c], Staffan Åkerblom[b], Camilla Sandström[d]

[a] Environmental Sociology Section, Örebro University, Örebro SE-70182, Sweden
[b] Department of Aquatic Sciences and Assessment, The Swedish University of Agricultural Sciences, Box 7050, Uppsala SE-75007, Sweden
[c] The Forestry Research Institute of Sweden (Skogforsk), Uppsala Science Park, Uppsala SE-75183, Sweden
[d] Department of Political Science, Umeå University, Umeå SE-90182, Sweden

ABSTRACT

In all Swedish lakes, the concentration of mercury (Hg) in fish exceeds the European Union threshold limit. While the ultimate source of Hg is primarily airborne emissions from fossil energy, forestry plays a small but important role because some forestry operations help mobilize and transform Hg, increasing Hg loads in downstream aquatic ecosystems. Simultaneously, climate change is placing additional demands on forests to provide biomass as a substitute for fossil fuel. Thus, decision-makers are facing a complex situation, a "wicked problem," when it comes to how to handle the problem of forestry's effects on Hg in aquatic ecosystems while at the same time securing other ecosystem services. In order to explore forestry's degree of responsibility as well as possible solutions to this problem in Sweden, a transdisciplinary method has been used consisting of a structured dialogue with actors from relevant governmental agencies, forest companies, and forest associations. The analysis shows that while the issue can be addressed constructively, the complex character of the problem requires consideration of not only management practices for forestry but also current regulatory goals and environmental objectives. The Hg problem represents a class of difficult issues for forestry where stand- or property-based production has an impact on a greater spatial scale. This means that regulating the more direct impacts of forestry needs to be weighed against the implications this regulation may have on the overall issue of ecosystem services.

1. Introduction

Inputs of mercury (Hg) from anthropogenic emissions to the environment have led to enhanced loads of Hg in terrestrial and aquatic ecosystems, contributing to fish Hg concentrations well above the European Union standards for good chemical status in Fennoscandia (Åkerblom et al., 2014). There is mounting evidence that forestry operations can increase the concentrations and loads of Hg to surface waters by mobilizing Hg from the soil (Eklöf et al., 2014). There are also calls to increase forest harvesting as a means of mitigating climate change, but long-term strategies for decreasing emissions of carbon dioxide (through intensified forestry) may also lead to increased transport of Hg from forest soils to aquatic ecosystems as a result of forestry operations. Forestry does not, however, contribute to an increase in Hg levels in forest soils, and it is not clear how much forestry's impact on downstream Hg can be mitigated by altering forestry practices. Even if forestry operations could be managed in such a way as to make no contribution to Hg mobilization, this alone will not solve the general problem of high Hg levels in aquatic biota (Eklöf et al., 2016).

Thus, while the fact that forestry operations exacerbate Hg problems in aquatic ecosystems in the forest landscape is a problem that needs to be handled, at the same time the task of allocating responsibility as well as developing relevant and viable management strategies is extremely complicated. It appears to be a "wicked" problem – one that is incomprehensible and resistant to solution (Rittel and Webber, 1973). The goals for forestry and Hg in fish are at odds with each other, the problem is characterized by uncertain knowledge, and there is no suitable regulatory framework for resolving the situation. We thus have a highly problematic governance situation, and the question arises of how to address this seemingly unresolvable problem. Is there a way to work toward a solution, if not a definitive one then at least a provisional one? And how much responsibility should the forest sector accept for a problem in which it plays a role, but is not the sole or ultimate cause?

It seems virtually impossible at present for any negative

* Corresponding author.
E-mail addresses: rolf.lidskog@oru.se (R. Lidskog), kevin.bishop@slu.se (K. Bishop), Karin.Eklof@slu.se (K. Eklöf), eva.ring@skogforsk.se (E. Ring), staffan.akerblom@slu.se (S. Åkerblom), camilla.sandstrom@umu.se (C. Sandström).

https://doi.org/10.1016/j.forpol.2018.02.001
Received 16 May 2017; Received in revised form 2 November 2017; Accepted 1 February 2018

environmental condition to be successfully transformed into a political problem without scientific support in the form of data and analysis (Lidskog, 2014). But receiving scientific support is not sufficient; awareness of the problem also needs to be spread more widely in society, or at least to policy-makers. It is through organizations' claim-making activities that particular problems climb on political agendas and opportunities for concerted action are created (Hannigan, 2014). Furthermore, environmental problems are responded to by changing policies and regulatory frameworks, as well as organizational and individual behaviors. This is mainly accomplished by means of legislation, economic incentives, and norm distribution (Hood et al., 2001). Also, many environmental problems involve non-environmental aspects, not least economic and social issues. This leads to disagreement and contestation about hierarchies and priorities, and to trade-offs between different goals. Environmental problems are thus co-constructed by processes in nature and society, making both natural science and social science important to understanding the particular character of an environmental problem and finding options for action (Lidskog, 2014; Nordin and Sandström, 2016).

This is clearly visible in the case of the topic of this paper: forestry and Hg in aquatic ecosystems. Natural science is needed to refine our understanding of the links between Hg output from soils to Hg bioaccumulation in aquatic ecosystems and of why there is such great variation in the effects of forestry operations on Hg output. But social science is also needed to investigate the social processes that have made it into a political problem, as well as to explore the societal factors conditioning its handling. For a problem like this, involving multiple stakeholders located at different regulatory levels and holding different interests, there is no simple and straightforward way to find viable and legitimate options for action.

In light of the seemingly wicked nature of the problem, the aim of this paper is to explore the potential to apply a risk governance perspective to the issue of forestry's effects on aquatic Hg as a way to make this issue governable. We ask to what extent it is possible to develop partial and provisional courses of action that can be accepted by involved stakeholders. It is not within the scope of the paper to discuss in detail options for dealing with the problem of Hg export from Sweden's managed forest landscape, but we do elaborate on potential directions for future work. Due to the scarcity of written material from stakeholders on this issue, a workshop with stakeholders, based on a structured dialogue, was chosen as the primary method to gather empirical material about possible ways forward.

The paper consists of five sections, including this introduction. In the next section, the environmental problem and the regulatory context are presented. The third section presents the study itself – the theoretical approach and the empirical material used. The fourth section investigates how the stakeholders understand and address the problem of bioaccumulation of Hg in aquatic ecosystems. In compiling their views, we stress three central dimensions of risk governance: risk assessments, scaling activities, and responsibility allocation. The fifth section discusses the results, stressing the need to modify the current regulatory system in Sweden as well as discussing whether certain environmental objectives adopted at the EU or national level should be revised. The section concludes by asking what can be learned from this case and considering its relevance for other issues.

2. The problem complex

2.1. Hg in Swedish lakes

Long-range atmospheric transport of Hg has caused contamination in aquatic ecosystems far from the emission sources and contributes to the high levels observed even in remote areas. Mercury policies that address environmental and human health risks have developed over 50 years, including international regulatory instruments to reduce emissions of mercury to the atmosphere (Selin and Selin, 2006). Efforts to decrease Hg concentrations in the atmosphere and deposition to forests will eventually lead to decreased Hg loads to aquatic ecosystems (Meili et al., 2003). Until then the dominant exposure route of Hg to humans will remain via consumption of fish, or in some areas rice (Mergler et al., 2007; Rothenberg et al., 2014). But the link between Hg deposition and Hg accumulated in food-webs is complex, making it unclear to what extent and in what timeframe reduced Hg deposition will have an effect on Hg concentrations in biota.

In early 2000, the role of forestry in this problem was recognized in Fennoscandia (Bishop et al., 2009). Research provided tentative but very alarming results on mercury in fish as a result of conventional harvest operations. Simultaneously stump harvesting came up as a way to intensify forestry and thereby contribute to national climate goals. The environmental organizations involved in the certification of forestry pointed to the lack of data on water quality effects (e.g. mercury mobilization from soils) as a reason for postponing a decision on stump harvesting. As a result public agencies financed research on this issue. Parallel to this, the introduction of the European Union's Water Framework Directive (EP, 2000), as a basis for managing Sweden's waters and aquatic ecosystems, helped make water issues a more central concern for forestry.

The management of high Hg concentrations in Swedish aquatic ecosystems is complex, and involves many aspects at different regulatory levels. According to the Water Framework Directive (WFD), water management is conducted in six-year management cycles (the first cycle ended in 2009, the following cycle in 2015, and the current cycle will end in 2021), where different workflows (monitoring, classification of water bodies, and establishment of management plans) recur at regular intervals. The aim of this work plan is to improve water quality and reach good ecological and chemical status in water bodies. This management tool is complemented by the National Environmental Quality Objective (NEQO) “A Non-Toxic Environment,” which states that within a generation “concentrations of non-naturally occurring substances will be close to zero and their impacts on human health and on ecosystems will be negligible. Concentrations of naturally occurring substances will be close to background levels” (http://www.miljomal.se/Environmental-Objectives-Portal). However, in all (> 99%) of Sweden's 100,000 lakes, Hg levels in fish exceed the EU limits for good chemical status (0.02 mg Hg/kg wet weight, Directive 2008/105/EC) and are thus classified as not having good chemical status, and also exceed the targets set within the NEQOs. The ultimate origin of much of this Hg is anthropogenic emission of Hg to the atmosphere associated with industrialization over the past century. Some of this Hg is converted by methylating bacteria to MeHg in soils and sediments. This MeHg can enter the aquatic food chain, accumulate in living organisms, and biomagnify higher up the food chain. Forest harvest operations can increase the loading of MeHg to aquatic ecosystems in several ways, such as through elevated groundwater levels, changed catchment flow pathways, and rutting (Shanley and Bishop, 2012).

The most recent survey of studies on forestry's impact shows a broad range of responses in the loading of Hg to surface waters and to downstream aquatic ecosystems, from none to several hundred percent increases that persist for many years (Eklöf et al., 2016). This variation in response has several potential causes, including the way that forest operations were carried out, but also spatial variation in the sensitivity of ecosystems to forest management. The large variation in the Hg concentration response necessitates caution when drawing general conclusions for specific sites. Nonetheless an earlier estimate (Bishop et al., 2009) that somewhere between 10 and 20% of the Hg in Swedish freshwater fish results from forest harvest operations still appears reasonable and was arrived at independently by a new analysis (Kronberg et al., 2016).

Since Hg levels in fish exceed the EU criteria for acceptable Hg levels (0.02 mg/kg) in almost all Swedish lakes, and exceed even the much less restrictive human consumption limits recommended by the WHO (0.5 mg/kg) in more than half of Swedish lakes (Åkerblom et al.,

2014), even the complete removal of forestry's effects would not reduce Hg levels to close to or below the EQS set by the EU and WHO. When it comes to measures that could mitigate forestry impacts when conducting harvest operations, the recommendations are in general agreement with those for good harvest practices for addressing other concerns. These measures include riparian buffer zones, bridges for crossing watercourses, and avoidance of rutting. There is currently no quantification of how much these measures will reduce the effect of forestry. The uncertainty in the problem complex is further complicated by the fact that human factors besides forestry influence the Hg concentrations in freshwater fish. One example is the role of atmospheric deposition of anthropogenic sulfate that can promote the bioavailability of Hg (Åkerblom et al., 2013). Since forestry contributes to many ecosystem services, forest managers have to balance different goals and navigate between different interests, where reducing forestry's contribution to Hg accumulation in aquatic ecosystems is only one priority among many.

2.2. The Swedish forestry model

Sweden is a heavily forested country with a large, export-oriented forest sector. The current forestry regime, often designated as the Swedish Forestry Model, has two main components (both based on the Forestry Act of 1993). The first is that the goal of preserving the environment should be given the same importance as the goal of high wood production. The second is that the governing principle of forest management is based on the concept of "freedom with responsibility." This means that the principles for forest use are laid out in a set of rules, while the Government mainly limits its action to providing information, advice, and recommendations (Beland Lindahl et al., 2017; Löfmarck et al., 2017).

With its concept of freedom with responsibility, however, the model puts the Forest Agency – the national authority in charge of implementing the forest policy – in a difficult position. The Agency is responsible for seeing to it that forest owners take suitable precautions to protect the natural environment when conducting forestry operations, and one of these goals is not to degrade water quality. To accomplish this the Forest Agency has set a number of guidelines (some mandatory and some recommendations). Some of these are relevant for preventing increased mobilization of Hg, and MeHg in particular, to surface waters to surface waters (Eklöf et al., 2016). However, even if these guidelines are relevant, they are far from enough, due to the great amount of Hg that is already stored in superficial forest soils (Alriksson, 2001). Apart from issuing guidelines, the Forest Agency also influences forestry practice through knowledge distribution, dialogue and advisory activities (the latter often together with forest owners at the local level). Acting under the principle of freedom with responsibility requires the agency to cooperate with representatives from the forestry and environmental sectors in working toward the goal of making forestry both economically and ecologically sustainable. An example of this is the establishing of arenas where different stakeholders can meet, cooperate, and negotiate around different issues (Sundström, 2005). One such arena concerns stakeholders' dialogue on establishing "target images" (*målbilder*) to provide guidance on how environmental considerations should be taken into account in forestry (Andersson et al., 2013, 2016). One such "target image" calls for off-road forestry transportation to be conducted in ways that avoid harmful impacts, with Hg bioaccumulation mentioned as one impact among others (Andersson et al., 2016). This could help to achieve one of the sixteen NEQOs ("A non-toxic environment").

The approach to managing Hg concentrations in fish reflects a general shift away from the focus on local point sources that characterized environmental policy in the 1970s and toward a focus on long-range atmospheric transport of Hg (as the main sources of Hg emissions are found outside Sweden). If a lake does not live up to the standards of good chemical status, the EU WFD requires the authorities to implement effective measures to enable good status to be achieved. However, the problem of Hg in the Swedish forest landscape is extremely difficult to manage, both because of the numerous pathways and processes that contribute to establishing Hg loads to aquatic ecosystems and because of the specific character of the Swedish forest sector with its distributed responsibility. Mercury management is further complicated by the Forest Agency being only one of several authorities responsible for controlling Hg levels in the environment. The Swedish Environmental Protection Agency is the main responsible authority, but at least five other public agencies at the national and regional levels are responsible for aspects of this issue.[1] When it comes to water quality, the standards are set by Sweden's five water districts in accordance with the WFD, the NEQOs, and the Forest Agency's mandatory and recommended guidelines for protecting water quality in general. Some of these guidelines and recommendations are suitable for reducing mobilization of Hg to surface waters, for example promoting the use of ground protection when driving logging machinery across wet areas, and leaving buffer zones near streams, wetlands and lakes, in which practices such as forest harvest, stump harvest and/or site preparation are restricted.

3. The study

3.1. Approach: risk governance

All problem solving is based on a particular understanding that makes it possible to imagine a problem, diagnose it, and propose a relevant solution (Hajer and Wagenaar, 2003; Hannigan, 2014; Palmer, 2012). Thus, an inability to reach a general understanding of a problem – to define it and spread the definition to a wider circle of stakeholders and decision makers – constitutes a central obstacle to problem solving in the public domain. If no general definition is agreed upon, then there is rarely any opportunity to formulate a joint plan for concerted action. Problems characterized by these inherent challenges are usually called "wicked problems" (Rittel and Webber, 1973). Whereas "tame problems" enjoy relative consensus about both their definition and solution, and there are existing public authorities designed to solve them, this is not the case for "wicked problems." The latter kind of problem has no definitive formulation and solution; that is, there is no single best approach to tackling the problem. This kind of problem is complex, spanning different sectors, regulatory frameworks, and policy targets. It is new in the sense that there is limited experience about how to handle and solve this kind of an issue. It is uncertain, with a deficit of knowledge both about the problem's character and also, in a more strategic sense, about to what extent and in what ways actors will respond. Lastly, the problem is value-laden; involved stakeholders have different goals for their activities and therefore differ in their normative evaluation of the severity of the problem.

The concept of 'wicked problems' was originally developed in opposition to what at the time was the dominant view of planning: the rational-technical approach. This approach presupposed the existence of relevant and certain knowledge, as well as of objectives that are both distinct and do not go against other established objectives. However, in real life planners and decision-makers face much more complex and multifarious situations. Even when it is possible in principle for science to make a restricted and clear definition of a particular problem this is not sufficient, because the problem is perceived differently by different stakeholders, and also because the problem occurs in different contexts and situations that generate new sets of challenges. Thus, wicked problems cannot be solved by simple, rational-technical approaches, although this does not mean that they are impossible to tackle (Head and

[1] The Swedish Agency for Marine and Water Management, the Swedish Forest Agency, the Swedish Chemicals Agency and, on the regional level, the Swedish Water District Authorities and the County Administrative Board.

Alford, 2015; Roberts, 2000).

Traditionally, three different strategies are suggested to handle a wicked problem: authoritative, competitive, or collaborative (Roberts, 2000). In line with Head and Alford (2015) we believe that even if it is difficult to find consensual solutions to wicked problems, it is nevertheless possible to develop partial and provisional courses of action that can be accepted by involved stakeholders. However, whereas Head and Alford stress the need for more holistic ways to think about and address problems, as well as for new models of leadership that better appreciate the distributed nature of information, interests, and power, we will stress other relevant aspects to consider in addressing a wicked problem.

In response to a situation characterized by increasingly complex environmental issues, the notion of "risk governance" was developed. This refers to a body of ideas about how to deal with uncertain, complex, and ambiguous risks in more responsible and efficient ways (van Asselt and Renn, 2011; Lofstedt et al., 2011). Fundamental ideas of risk governance are openness, transparency, participation, and reflexivity. Due to the complexity of many problems, it is important that involved experts are open to questioning the situation, that issues of uncertainty are not concealed, and that regulators are receptive to the input and participation of stakeholders. Research has also shown that in order to make this governance productive – in the sense of leading to regulatory arrangements – it is important to reduce the complexity of the issue at stake and to create a spatial identity and allocate responsibility for it (Lidskog et al., 2011). These findings have been important for the design of the workshop dialogue and have also been used to structure and present our results section (Section 4).

3.2. Method: structured dialogue

In February 2016, a national full-day workshop was convened: *Forestry and mercury in fish in Swedish lakes. How to reach the environmental objective of 'a non-toxic environment'*. The background of the workshop was that Hg concentrations in fish exceed the European Union's threshold limit in almost all Swedish lakes, and there was a need to clarify the part that forestry should play in addressing this problem. The workshop, organized by the national research program *Future Forests*, centered on two questions: Is current environmental policy adapted to this kind of difficult problem? What responsibility does the forest sector have for the problem, and what can it do to deal with it?

In selecting workshop participants, we chose only to include those organizations that are responsible for the task: government agencies and forest owners. This means that environmental organizations were not invited to the workshop, despite the fact that they may be important drivers of change (as media also can be). The reason is that this study focuses solely on the organizations that are responsible for developing rules and changing practices to handle the Hg issue. Participants were representatives from governmental agencies (5), and forest owners, the latter comprising either forest companies (1) or forest owners' associations (2). (In total there were eight participants representing seven organizations. See Appendix A for a detailed description.) The rationale for inviting these organizations was that forestry's influence on Hg in fish was an issue that involved all these organizations. It was therefore expected that they would have opinions on how to understand and regulate the problem, as well on what decisions their own organizations should make and what they should do (in terms of both action and inaction).

Based on the fundamental ideas of risk governance – openness, transparency, participation and reflexivity – the workshop was designed to follow a specific structure for systematically collecting data (Mårald et al., 2015). In preparation for the workshop the participants were asked to collect information about their organization's views on Hg-related issues. The workshop began with all participants presenting the collected information. First they presented their organizations' view of the problem and, in a second round, how they handled it and would like to handle it. This gave us an initial overview of the stakeholders' understandings, views and priorities in relation to the problem. In the next step, brief research presentations were made, where relevant findings from the natural as well as social sciences were presented and discussed. The third step consisted of structured discussion guided by a risk governance approach. In the fourth and concluding step, a general discussion was held, which aimed (i) to identify aspects where there was a shared understanding among the stakeholders or where there was fundamental disagreement; (ii) to collect general proposals for recommendations and guidelines; and (iii) to discuss issues of responsibility for handling the problem.

The workshop was led by the research team, and apart from short research presentations on the state of the art (from a scientific as well as a regulatory point of view), we limited ourselves to acting as facilitators and moderators of the discussion. This was in order to leave as much space as possible for the discussion. This design – a structured discussion of problem/handling/research – enabled the workshop to function as a data-collecting exploration of how the participants conceptualized and evaluated the problem, as well as a discussion of viable ways to move forward, all without neglecting the complex, contested character of the problem.

4. Results: from final solution to provisional handling

The workshop revealed that the participating stakeholders held a fundamental problem definition in common. They all agreed that the high Hg concentration in freshwater biota is an important problem that needs to be dealt with. They also agreed that the current regulations, with their threshold limits for good chemical status, are very problematic because the limits cannot be achieved through actions by either the Swedish forest sector or Sweden more generally. There is a need for international emission abatement agreements at both European and global levels, although even these will have little prospect of making Swedish freshwater fish safe for consumption by humans or wildlife within a generation. It is important to note that the stakeholders did not use this as an excuse to avoid responsibility for the issue; they all agreed that the forest sector has to develop measures to reduce mobilization of Hg. An often-mentioned example of proactive and voluntary measures was the sector-wide policy for how to prevent off-road traffic from causing damage during forestry operations, which was the result of a dialogue process (Berg et al., 2010).

Already in the initial discussion it became obvious that two dominant frames influenced views on potential ways forward. One frame restricts the discussion of responsibility to the forestry sector. This casts the problem in an unsolvable form, because forestry only has the power to influence a part of the problem, namely the mobilization of Hg in forest soils and the conditions for the transformation of Hg to more bioavailable forms. If the frame only concerns processes in the forest, and forestry operations are put in focus, then no solution is available, even in a long-term perspective. Another frame focuses on the processes causing Hg deposition and Hg bioaccumulation, which makes a broader category of actors part of the solution, including forestry. It may thereby be possible to take action in the right direction, and a risk governance approach is a method to start a deliberative process on how to make the issue governable. When brought to the attention of the participants, the risk governance approach was deemed preferable to regulatory or competitive governance approaches.

From a governance perspective, the task is to render the issue of Hg in environments manageable. Research has shown that if no general definition is agreed upon, then there is rarely any opportunity to formulate a joint plan for concerted action (Lidskog et al., 2011; Palmer, 2012). In this case, however, the workshop shows that there seems to be agreement about the problem as such, and also agreement about why it is so hard to handle. Thus, there seems to be an opportunity to take a few steps forward.

As mentioned above, from the perspective of a risk governance approach, three processes are particularly relevant to rendering complex issues governable: handling an issue and reducing its complexity, tying the issue to geographical administrative jurisdiction, and assigning responsibility and capabilities to particular actors. Based on the data collected in the structured dialogue (stakeholders' perspectives on and assessment of the issue), we will elaborate on how a risk governance approach can contribute to making the Hg issue governable.

4.1. Risk: reducing complexity

The aim of risk regulation is to manage risk by establishing boundaries for what is acceptable and developing systems for risk control (Hood et al., 2001). Uncertainties need to be managed, which mainly is done through scientific activities, such as measuring and monitoring. These practices transform uncertainties into calculable risks. Several of the stakeholders stressed that there was a lack of knowledge about both the situation and what measures might be appropriate to undertake. “We don't dare to create new routines when the effects are unclear,” as one of them put it. As with many other environmental problems, scientific support in the form of effect studies is crucial for mobilizing action and changing practices (Bijker et al., 2009; Lidskog, 2014).

Even if more science is needed, it will probably not be enough to handle the uncertainties associated with the Hg issue. This is because there are large uncertainties in calculating forestry effects with regard to Hg bioaccumulation and the extent to which findings from one catchment are valid for another catchment (Eklöf et al., 2016). The influence of an intervention may differ dramatically depending on where a forestry operation is located relative to the stream network, as well as on soil structure, soil chemistry, topography, weather, and wetness. Conditions such as temperature, deposition, and potential ground frost during the harvest have also been suggested as influencing the degree of disturbance (Eklöf et al., 2014). Thus, while science is crucial, it will probably not be able to provide certainty about what to do in specific cases, at least not in the short term.

There are other ways to handle uncertainties than using scientific methods. One common way is to acknowledge uncertainties, thereby making them transparent for stakeholders and opening up a space for discussion of what risks and costs should be seen as acceptable. Uncertainty is thereby handled by delimiting the scope of the regulatory object, placing certain aspects in the center while disregarding others. In this case there is a need to take decisions with explicit reference to both scientific knowledge and fundamental principles and values (Gieryn, 1999). By drawing boundaries for what is acceptable and developing systems for controlling risk, even issues to which great uncertainty is attached can be made manageable. Thus, more scientific knowledge is needed, but also more dialogue and deliberation by the organizations involved in the regulation.

4.2. Scale: tying environmental issues to administrative jurisdiction

Although environmental issues are increasingly understood as transboundary risks, to be governable they must be tied to administrative-geographical jurisdictions. By ascribing specific spatial characteristics to a problem, actors implicitly advocate a certain way of handling the problem, as well as who should be included in the regulatory process. Thus opportunities for, as well as restrictions on, action are created by determining appropriate temporal and spatial boundaries for the issue at stake; on what scale should it be regulated? Should specific milestones be established? In the workshop, the stakeholders unanimously stressed that a restricted spatial and sectorial focus on Swedish forestry is sub-optimal. The Hg export from Swedish forestry should be placed in a broader spatial and temporal perspective; otherwise many of the factors contributing to the problem of Hg in fish will not be addressed and regulated.

In the discussion, the stakeholders also voiced the need for national policy integration, giving two main reasons. First, a number of governmental agencies (see footnote 1) are currently responsible for Hg issues, but their responsibility is fragmented across scales and levels. Thus there is too little coordination of activities to integrate the areas of responsibility into a more holistic approach. Secondly, there is a tension between the collective aspects of the WFD, which primarily focuses on catchment areas, and the need to consider how land ownership (public, private, and corporate) defines the responsibilities of individual actors.

The way forward for the jurisdictional issue is not to tie management to a particular scale and administrative body, but rather to stress the multi-scalar and multi-sectoral character of the Hg issue, which implies that actions and responsibilities need to be differentiated. In this way the incentives, motivations, and opportunities for action may increase for the Swedish forest sector, though with the understanding that it is not the only sector that has to address this issue.

4.3. Responsibility: developing capacities

To make an issue governable, it is not sufficient to reduce its complexity and construct a spatial identity for it. It is also necessary to identify which actors are to be seen as competent to handle the issue and decide which ones should be responsible for it. This is often implicitly done. Reducing the complexity and shaping the spatial identity of an issue often has substantial implications for what tasks, mandates and responsibilities are assigned to various actors. This results in certain organizations being seen as central to the regulatory work and others as less relevant. When it comes to the Hg issue, because science cannot easily provide certain and robust knowledge, and the issue can be ascribed a multi-scalar identity, it is crucial to allocate responsibility. Thus, while the problem of Hg in the forest landscape is a challenge that needs to be handled, it is also an extremely complex task that involves not only developing relevant and viable countermeasures but also allocating responsibility.

In the workshop, the stakeholders shared the view that the Swedish forest sector should bear some but not all of the responsibility for solving the problem. They all agreed that even if the Hg was originally delivered by airborne emissions (as well as natural sources), forestry nevertheless should be responsible for reducing the increased terrestrial export of Hg to aquatic environments caused by forestry operations. Also, the discussion in the workshop stressed that, on a fundamental level, it is a question of tradeoffs. Forestry makes many positive contributions (readily visible from an ecosystem services perspective), and efforts to reduce Hg mobilization must always be weighed against negative impacts resulting from these efforts.

As with many other environmental problems, there is a need for contributing actors to take responsibility and develop plans for action. The challenge is to determine the level of responsibility that forestry should take for minimizing its contribution to the bioaccumulation of Hg in the aquatic environment. Forestry cannot avoid responsibility altogether, but should share it with other actors. The stakeholders stressed the importance of not blaming forestry for a problem largely caused by others. Instead the importance of revealing opportunities for constructive action was stressed. Even if these actions will not be sufficient to solve the entire problem, they demonstrate that the forest sector is ready to take partial responsibility and try to handle the problem.

5. Discussion and concluding remarks

Before we discuss the potential to apply a risk governance perspective to the empirical issue of forestry's influence on aquatic Hg as a way to make the issue governable, we will reflect on the specific method that we used to collect data. We will continue by discussing the possible need to revise the current regulatory system in Sweden and the EU, and conclude by elaborating on the wider relevance of this

particular case.

5.1. Method: structured dialogue process

A transdisciplinary method has been used, consisting of a structured dialogue with actors from relevant governmental agencies, forest companies, and forest associations. This has its strength and weakness, but as a first step toward finding shared views of a problem and possible ways forward it is a relevant and reasonable method (Mårald et al., 2015). Important to note, however, is that the structured dialogue was centered on a very restricted (though complex) issue, namely forestry's role in bioaccumulation of Hg in aquatic ecosystems. It is also important to note that the aim was not to modify or widen the involved stakeholders' different views, but to explore how they conceptualize and evaluate the problem, and to discuss ways forward for handling this issue, all without neglecting its complex contested character.

It became obvious during the workshop that when analyzing environmental regulations, actors' understandings of an issue cannot be disregarded. It is their interpretation and evaluation of an issue – including values as well as knowledge – that motivates their actions, especially if the regulatory regime to a large extent is based on soft instruments rather than strict legislation. This makes a participatory dialogue process even more fruitful when approaching complex issues, as in this particular case. This is also supported in the literature, where studies have shown that collaborative processes can be used to identify, discuss, and contextualize uncertainties, conflicting goals, and divergent values, as well as to give direction to the handling of the problem (Mårald et al., 2015; Norton, 2005). However, since the participants in the workshop had the role of experts on water quality within their respective organizations, it is not certain that the views expressed by the participants are identical to those of the organizations they represent (Boström and Uggla, 2016). “There is a tension between those of us who are working with the water issue and those who are not,” a participant mentioned in passing. The reason for this is that specialists are better informed and do not have to balance a broad array of tasks. “The issue is not at the center of attention for the organization, but is a piece of the great puzzle of water management,” as one participant put it. This may also explain why there was no strong disagreement among the participants; they all had knowledge about how to minimize forestry's contribution to Hg exports from forest soils to aquatic ecosystems, and felt a sense of responsibility to do so. Obviously, inviting other stakeholders – such as environmental organizations – would probably have resulted in a wider collection of standpoints and also disagreements. However, the aim of the workshop was only to approach those organization that are responsible for regulating the issue or changing their practices (public agencies and forest owners) in order to explore viable ways to handle the issue.

5.2. From established objectives to provisional solutions?

Restricted rational-technical and hierarchical approaches to regulation and decision-making, where the priority is to find measures to reach specific targets and goals, have many times proven to be a dead end when facing complex problems. One reason for this is the lack of certain and robust knowledge, together with a lack of clear and viable objectives whose implementation does not get in the way of other established objectives. This means that particular actors have to take too large a share of the responsibility for problems caused by a wider category of actors. For situations where no universal and consensual solution is possible, risk governance has been developed to search for acceptable provisional solutions, where the aim is to take a step in the right direction rather than to find a universal solution or reach a predefined goal. By reducing complexity, shaping spatial identity and allocating responsibility, a risk governance approach tries to make things happen, to get stakeholders involved in regulatory processes aiming for change.

However, as was stressed by the stakeholders in this study, the legally established goal of good chemical status – which essentially all of Sweden's water bodies fail to meet with respect to Hg concentrations – may be counter-productive. Regardless of how far forestry will go in reducing effects of forest management on Hg bioaccumulation, those efforts will not lead to goal-attainment. Therefore it is necessary for the European Union to decide how to harmonize the implementation of the WFD regarding Hg in aquatic ecosystems. A particular problem is that the WFD does not include forestry and forestry-related issues (Futter et al., 2011). Another problem is that only a few countries so far, including Sweden, are reporting Hg in aquatic biota. The EU must decide whether to require all countries to report on Hg in the biota; this might show a widespread failure to reach good chemical status and in turn may lead to modification of the objective of good chemical status, or at least pave the way for a more intermediate target and broader responsibilities. This also relates to Sweden's environmental quality objective ‘a Non-Toxic Environment,’ which is far from being successfully implemented, because it is impossible to reach in practice.

5.3. Relevance for other/wider issues?

The wickedness of the Hg issue reveals a substantial gap between policy objectives, defined in EU terms as “good chemical status” or in the Swedish context as a “non-toxic environment,” and the ability of traditional sectoral governance modes (including management by objectives) to achieve these policy objectives. In that sense, this case is not unique. More generally, the Hg problem represents a class of difficult issues for forestry (as well as for agriculture) where landscape-based production has impacts on a greater spatial scale. This means that regulating the more direct impacts of forestry needs to be weighed against the implications this regulation may have for the overall issue of ecosystem services. The situation is similar for climate-related policies as well as for many other general environmental issues that are characterized by being difficult or impossible to solve due to incomplete, contradictory, and changing requirements that are often difficult to reconcile.

To be able to close the gap between policy and governance/management, it is therefore necessary to apply alternative approaches capable of producing provisional and agreed-upon solutions in anticipation of better ones, especially as this is often better than business as usual. This study has suggested that risk governance, with its more reflexive and dynamic approach to both governance processes and their outcomes, may provide decision-makers and stakeholders with such an alternative. By gradually developing a knowledge base which will spill over into how we define the regulatory object – thereby reducing complexity, identifying a spatial identity, and allocating responsibility – we may successively achieve better outcomes. However, the development of a risk governance approach has to be accompanied by more efficient mechanisms for policy integration and adaptive management, and the application of more holistic geographical planning perspectives, for instance using landscape or ecosystem approaches.

Acknowledgements

This paper was written as part of the Swedish interdisciplinary program Future Forests, which is financed by MISTRA (The Foundation for Strategic Environmental Research), the Forestry Research Institute of Sweden (Skogforsk), the Swedish University of Agricultural Sciences (SLU), and Umeå University.

Appendix A

Participants in the workshop represented the following organizations:

LRF Forestry (LRF Skogsägarna) is made up of about 112,000 family forest owners cooperating in four regional associations structured

as producers' cooperatives, owned and managed by the members of each association. The central organization is LRF Forestry, The Federation of Swedish Family Forest Owners.

SCA Forest (SCA skog) is Europe's largest private forest owner with 2.6 million hectares of forest. The company is part of the SCA Forest Products business unit, which produces paper for newspapers, magazines, and catalogs, as well as pulp, sawn timber, packaging, and renewable energy. Timber from the company's own forests accounts for 50% of the business unit's total wood consumption. Wood from other Swedish forests represent 32%. SCA Forest also offers services that cover the entire range of forest owners' needs – from the making of forest management plans to planting, forest management, thinning, and final felling.

Södra is the largest forest-owner association in Sweden and is an international forest industry group. Its operations are based on responsible forestry and on industries where they convert the raw material into sawn timber, paper and green energy.

The Swedish Forest Agency (Skogsstyrelsen) is the national authority in charge of forest-related issues. Its main function is to promote the kind of management of Sweden's forests that will enable the objectives of forest policy to be attained.

The County Administrative Boards (Länsstyrelse) are the representatives of the National Government at the regional level. The boards are responsible for ensuring that decisions from Parliament and the Government are implemented at the county level. The board has a broad area of responsibility, including environmental issues. The task of the boards is to coordinate these and other areas of public responsibility to achieve efficient solutions for a sustainable development.

The Swedish Agency for Marine and Water Management (Havs- och vattenmyndigheten) is a government agency that works for healthy seas, lakes, and streams for the benefit and enjoyment of all. It is responsible for managing the use and preventing overuse of Sweden's marine and freshwater environments. It takes into consideration the needs of the ecosystem and of people, both now and in the future.

The Swedish Environmental Protection Agency (Naturvårdsverket) is the overarching public agency responsible for environmental issues in Sweden. It carries out assignments on behalf of the Swedish Government relating to the environment in Sweden, the EU, and internationally. The Agency's remit is threefold: compiling knowledge and documentation (to develop the agency's own environmental efforts and those of others); developing environmental policy (by providing the Government with a sound basis for decisions and by giving an impetus to EU and international efforts); and implementing environmental policy (by acting in such a way as to ensure compliance with the Swedish Environmental Code and achievement of the national environmental objectives).

References

Åkerblom, S., Bishop, K., Björn, E., Lambertsson, L., Eriksson, T., Nilsson, M.B., 2013. Significant interaction effects from sulfate deposition and climate on sulfur concentrations constitute major controls on methylmercury production in peatlands. Geochim. Cosmochim. Acta 102, 1–11.

Åkerblom, S., Bignert, A., Meili, M., Sonesten, L., Sundbom, M., 2014. Half a century of changing mercury levels in Swedish freshwater fish. Ambio 43, 91–103.

Alriksson, A., 2001. Regional variability of Cd, Hg, Pb and C concentrations in different horizons of Swedish forest soils. Water Air Soil Pollut. 1, 325–341.

Andersson, E., Andersson, M., Birkne, Y., Claesson, S., Forsberg, O., Lundh, G., 2013. Målbilder för god miljöhänsyn. In: En delleverans från Dialog om miljöhänsyn. Skogsstyrelsen, Jönköping (Report 5).

Andersson, E., Andersson, M., Blomquist, S., Forsberg, O., Lundh, G., 2016. Nya och reviderade målbilder för god miljöhänsyn: Skogssektorns gemensamma målbilder för god miljöhänsyn vid skogsbruksåtgärder. Skogsstyrelsen, Jönköping (Report 12).

Beland Lindahl, K., Sténs, A., Sandström, C., Johansson, J., Lidskog, R., Ranius, T., Roberge, J.-M., 2017. The Swedish forestry model: more of everything? For. Policy Econ. 77, 44–55.

Berg, R., Bergkvist, I., Lindén, M., Lomander, A., Ring, E., Simonsson, P., 2010. Förslag till en gemensam policy angående körskador på skogsmark för svenskt skogsbruk (Work report 731). Skogforsk, Uppsala.

Bijker, W.E., Bal, R., Hendriks, R., 2009. The Paradox of Scientific Authority. The Role of Scientific Advice in Democracies. MIT Press, Cambridge, MA.

Bishop, K., Allan, C., Bringmark, L., Garcia, E., Hellsten, S., Högbom, L., Johansson, K., Meili, M., Munthe, J., Nilsson, M., Porvari, P., Skyllberg, U., Sorensen, R., Zetterberg, T., Åkerblom, S., 2009. Bioaccumulation of Hg in boreal freshwaters – an assessment of contribution by forestry based on available data and current recommendations for good silvicultural practice. Ambio 38, 373–380.

Boström, M., Uggla, Y., 2016. A sociology of environmental representation. Environ. Sociol. 2, 355–364.

Eklöf, K., Schelker, J., Sørensen, R., Meili, M., Laudon, H., von Brömssen, C., Bishop, K., 2014. Impact of forestry on total and methyl-mercury in surface waters: distinguishing effects of logging and site preparation. Environ. Sci. Technol. 48, 4690–4698.

Eklöf, K., Lidskog, R., Bishop, K., 2016. Managing Swedish forestry's impact on mercury in fish: defining the impact and mitigation measures. Ambio 45, 163–174.

EP, 2000. Directive of the European Parliament and of the Council 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy (Official Journal L 327, 22/12/2000). European Parliament (EP), Strasbourg.

Futter, M.N., Keskitalo, E.C.H., Ellison, D., Pettersson, M., Strom, A., Andersson, E., Nordin, J., Löfgren, S., Bishop, K., Laudon, H., 2011. Forests, forestry and the water framework directive in Sweden: a trans-disciplinary commentary. Forests 2, 261–282.

Gieryn, T.F., 1999. Cultural Boundaries of Science: Credibility on the Line. University of Chicago Press, Chicago.

Hajer, M., Wagenaar, H., 2003. *Deliberative Policy Analysis: Understanding Governance in the Network Society*. Cambridge University Press, Cambridge.

Hannigan, J.A., 2014. Environmental sociology. In: A Social Constructivist Perspective, 3rd ed. Routledge, London.

Head, B.W., Alford, J., 2015. Wicked problems implications for public policy and management. Adm. Soc. 47, 711–739.

Hood, C., Rothstein, H., Baldwin, R., 2001. The Government of Risk. Oxford University Press, London.

Kronberg, R.M., Drott, A., Jiskra, M., Wiederhold, J.G., Björn, E., Skyllberg, U., 2016. Forest harvest contribution to boreal freshwater methyl mercury load. Glob. Biogeochem. Cycles 30, 825–843.

Lidskog, R., 2014. Representing and regulating nature: boundary organisations, portable representations, and the science–policy interface. Environ. Polit. 23, 670–687.

Lidskog, R., Uggla, Y., Soneryd, L., 2011. Making transboundary risks governable: reducing complexity, constructing identities and ascribing capabilities. Ambio 40, 111–120.

Löfmarck, E., Uggla, Y., Lidskog, R., 2017. Freedom with what? Interpretations of 'responsibility' in Swedish forestry practice. For. Policy Econ. 75, 34–50.

Lofstedt, R., Bouder, F., Wardman, J., Chakraborty, S., 2011. The changing nature of communication and regulation of risk in Europe. J. Risk Res. 14, 409–429.

Mårald, E., Sandström, C., Rist, L., Rosvall, O., Samuelsson, L., Idenfors, A., 2015. Exploring the use of a dialogue process to tackle a complex and controversial issue in forest management. Scand. J. For. Res. 30, 749–756.

Meili, M., Bishop, K., Bringmark, L., Johansson, K., Munthe, J., Sverdrup, H., De Vries, W., 2003. Critical levels of atmospheric pollution: criteria and concepts for operational modelling of mercury in forest and lake ecosystems. Sci. Total Environ. 304, 83–106.

Mergler, D., Anderson, H.A., Chan, L.H.M., Mahaffey, K.R., Murray, M., Sakamoto, M., Stern, A.H., 2007. Methylmercury exposure and health effects in humans: a worldwide concern. Ambio 36, 3–11.

Nordin, A., Sandström, C., 2016. Interdisciplinary science for future governance and management of forests. Ambio 45 (Suppl. 2), 69–73.

Norton, B.G., 2005. Sustainability: A Philosophy of Adaptive Ecosystem Management. The University of Chicago Press, Chicago.

Palmer, J., 2012. Risk governance in an age of wicked problems: lessons from the European approach to indirect land-use change. J. Risk Res. 15, 495–513.

Rittel, H.W., Webber, M.M., 1973. Dilemmas in a general theory of planning. Policy. Sci. 4, 155–169.

Roberts, N.C., 2000. Wicked problems and network approaches to resolution. Int. Pub. Manag. Rev. 1, 1–19.

Rothenberg, S.E., Windham-Myers, L., Creswell, J.E., 2014. Rice methylmercury exposure and mitigation: a comprehensive review. Environ. Res. 133, 407–423.

Selin, N.E., Selin, H., 2006. Global politics of mercury pollution: the need for multi-scale governance. Rev. Eur. Community Int. Environ. Law. 15, 258–269.

Shanley, J., Bishop, K., 2012. Hg cycling in terrestrial watersheds. In: Bank, M.S. (Ed.), Mercury in the Environment: Pattern and Process. Univ. of California Press, Berkeley, pp. 119–141.

Sundström, G., 2005. Målstyrningen drar åt skogen – Om government och governance i svensk skogspolitik. Score, Stockholm (Report 2005:6).

Van Asselt, M.B.A., Renn, O., 2011. Risk governance. J. Risk Res. 14, 431–449.