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

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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

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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.,