

Interactive comment on “Impact of forest harvesting on water quality and fluorescence characteristics of dissolved organic matter in Eastern Canadian Boreal Shield lakes” by P. Glaz et al.

Anonymous Referee #1

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General comments

This manuscript reports on the immediate impact (less than 2 years) of forest harvesting on particular lake water parameters in the Canadian boreal region. Elevated concentrations of total phosphorus were detected up to two years after perturbation and elevated DOC concentrations one year after perturbation. No other measured parameters were found to differ between before and after forest harvesting. The paper is generally well written and the authors give adequate credit to relevant research relating to the impact of forest harvesting in the boreal forest on lentic and lotic habitats.

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However, I have major concerns with the novelty of the research, study design and statistical methods used, as well as the conclusions drawn from such a temporally-limited study. Some of these concerns (i.e. study design) cannot be rectified. Forest harvesting in the boreal zone is a major activity, and any changes to its management can have extensive social, environmental, and economic ramifications. It is essential that any research about the direct impact of boreal forest harvesting is done so with enough statistical rigor, and the study design is robust enough, to withstand thorough criticism. Based primarily on the study design I do not think this research meets these requirements. Assessing the impact of a perturbation on the natural environment is best completed using a before-after control-impact (BACI) design (see Underwood 1991 for an early reference) – this is something the authors fail to acknowledge and for which, however, the study design and statistical analysis largely resemble. BACI designs, and subsequent improvements (such as MBACI and staircase designs), are designed to accurately detect responses to perturbations by separating natural variability from that due to the perturbation of interest. In these BACI-related studies one of the most important pieces of information is a good characterization of natural variability in the response variables before the perturbation occurs. This information establishes if the response variables vary synchronously through time in all study sites – if they do not, then you cannot isolate any effects due to a perturbation from that due to natural, site-specific variability. The characterization of this variability should include both seasonal and inter-annual variability in order to account for all major sources of natural variation – however, seasonal and inter-annual variability are not characterized in this study. As Figure 2 shows, natural variation in some of the response parameters each year is just as large as the apparent response to harvesting. Not only does the lack of this pre-perturbation information place a large question mark over the current results (because impacts detected may not be due to forest harvesting but rather to natural site-specific variability), it may also hinder their ability to detect any impacts from forest harvesting that are occurring. Essentially, it is very difficult (in a statistical sense) to attribute any changes in lake water parameters to forest harvesting using the current

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study design. Furthermore, this study relies heavily on the notion that sampling on just one date (in July) in each year accurately characterizes the parameters of interest in each lake. The boreal ecosystem is highly patchy and seasonal, and these lakes are not identical (which is evident in Table 1). Furthermore, many of the key response parameters (i.e. DOC) can change rapidly (minutes to hours) in response to natural events, such as precipitation events. Consequently, it is likely that even subtle differences in the response of each site to external events may heavily bias some of the key response effects, and thus mask or falsely indicate a response to forest harvesting. Sampling multiple times per year at each lake would have at least captured some of the influence that seasonal and natural events (i.e. snow melt and storms) have upon the response parameters. Although the monitoring of forest management activities on freshwater ecosystems is very important, we (researchers and forest managers) already know that there will likely be a short-term impact – this has been documented in many forest types. The most critical piece of information is if this short-term impact will have long-term consequences for aquatic structure and function (i.e. resilience). The authors do acknowledge this in the Introduction. Even so, the novelty of this research is lost due to its very short-term nature and the inadequacy of the study design to properly separate changes in the response variables due to forest harvesting from that due to natural variability.

Specific comments

How many streams drained into each lake? If so, these streams must also drain the harvested forest areas. Do you have an idea of the relative contribution of stream, overland and sub-surface flow for maintaining lake-water levels? i.e. where does the lake water come from and how does it get there? If there are streams draining into the lake, do these streams drain any upstream lakes? It is very difficult to determine this from Figure 1. This information is very important for understanding the flow paths and transport time from the harvested area to the lake, which may help explain subtleties in the lake water parameters and the response of these parameters to harvesting.

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Carbon and nutrients can be transformed (i.e. immobilized, mineralized, evaded as CO₂) before being input into lakes in, for example, riparian 'hotspots' (see Ledesma et al. 2015 - Global Change Biology for a recent boreal reference) or within the stream channel. There is thus the potential for substantial changes in many of the lake water parameters measured before they enter each lake.

Are any lake-water parameters correlated, both within lakes and pooling all lakes (other than the one correlation reported between the absorption coefficient and DOC)? It is very common for many of the variables measured to be correlated. P, for example, is commonly associated with DOC because it is adsorbed very easily to soil or sediment particles (that are DOC rich). DOC and P also happen to be the only parameters of interest that you have reported as responding to forest harvesting.

Discussion – this is too long for the quantity of results presented. I am concerned with the disparity in what is discussed and what the study investigated. This research measured lake water parameters before and after forest harvesting, but they did not quantify the export, transport, or processing of variables before they entered each lake. Despite this, much of the Discussion is concerned with the processes that control the input of nutrients and carbon due to terrestrial disturbance and its transformation during / whilst being transported to the lake. It would be beneficial if the Discussion was more focused on directly relevant mechanisms and was less speculative.

Furthermore, there are many instances where conclusions are drawn that are not supported by the results or even the study design. For example, on Page 9321 (Line 22-25) the authors suggest that the input of logging slash due to harvesting was responsible for increasing DOC concentrations; however, this manuscript does not measure logging slash and cannot attribute changes in lake DOC concentrations to it.

Page 9309 (Line 15-17). It is stated here that lakes were significantly different one year after harvesting, based on the multivariate statistics. But I cannot find any evidence in the Results, Tables, or Figures that show evidence for this significance difference.

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Furthermore, on Page 9318 (Line 22) it states that 'PERMANOVA analysis revealed no significant interaction between treatment and year for the water characteristics and DOM variables.'. Perhaps this is a typing error in the Abstract?

Page 9309 (Line 18-19). In the last sentence of the Abstract please specify that the 'return to its original condition' is just in terms of the fluorescence and water quality parameters that you assessed.

Page 9316 (Line 16-18). Why was this interaction of primary interest? Please provide an explanation and references for your statistical choices.

Page 9316 (Line 20 - 21). Why were the same variables analysed twice in slightly different designs? Both analyses appear to be investigating differences between treatment and year, and thus the impact of harvesting upon them. It is best to just have one statistical analysis for each hypothesis/question.

Page 9319 (Line 6). Because you cannot rule out natural, site-specific variability in many of your response parameters, there are also numerous, natural processes which can cause elevated TP and also DOC. Please also include discussion of these possible natural factors.

Page 9320 (Line 4-7). DOC can also be lost via heterotrophic respiration (i.e. CO₂ evasion).

Technical comments

Page 9310 (Line 7). 'important' depends on what you value. I would suggest changing to 'extensive'.

Page 9310 (Line 23). Fellman et al. (2010) is a review article about DOM fluorescence and is not suitable to quote for this text. Please find more suitable references supporting the statement.

Page 9320 (Line 15). Please change 'sunny season' to something more technical such

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as 'summer' or 'summer and spring'. Also, please expand this sentence. Photodegradation only directly causes CO₂ production from inorganic carbon in the absence of water. Furthermore, Winter et al. (2007) did not measure CO₂, so remove this reference, or rephrase the sentence to only talk about the photodegradation of organic matter.

Page 9321 (Line 23). Please change 'because the fast degradation' to 'because of the fast degradation'.

Page 9321 (Line 25). Please change 'for few years' to 'for a few years'. Also, do you have a reference to support this statement? Because CPOM and woody debris can actually increase in streams in the first few years after harvesting.

Page 9322 (Line 2). Remove 'somewhat'.

Page 9322 (Line 7). Please remove 'amazing'.

Page 9322 (Line 19). Please insert 'the' prior to 'fluorescence'.

Page 9322 (Line 25). Change 'showing' to 'indicating'.

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