FULL PROPOSAL

WATER JOINT PROGRAMMING INITIATIVE

WATER CHALLENGES FOR A CHANGING WORLD

ERA-NET COFUND WATERWORKS 2015

“SOurce STream (headwater) PROtection from forest practices: what are the costs and benefits, and how best to do it?”

“SOSTPRO”

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1. EXCELLENCE

Introduction

Small streams are closely linked to the forest landscape surrounding them, and are vulnerable to alteration due to forest harvest (Naiman & Décamps 1997, Gomi et al. 2002, Richardson & Danehy 2007). The surrounding forest provides shade, bank stability, moderated rates of water flows, inputs of organic matter, and nutrient uptake. In most of the world small streams typically receive the least protection from forestry within the stream network, from narrow buffers to none. Removal of the surrounding forest through harvesting results in increased summer temperatures (e.g., Gomi et al. 2006), alteration to hydrology, loss of bank stability, increased turbidity and sediment transport, higher nutrient fluxes, and alterations to biodiversity. Protecting small streams may incur a potentially large cost and impediment to the forest industry, but it is difficult to estimate the costs to water quality and quantity, and habitat that comes with the *status quo*. This is of special concern because small streams are numerous across the landscape and impacts may be carried downstream along river networks, causing cumulative negative effects. We propose to quantify the cumulative impacts of harvesting around small streams and its impacts downstream for a representative set of forest landscape types. This will allow an appraisal of the values of riparian buffers of different widths and configurations for the benefit of preserving good ecological conditions and delivering ecosystem goods and services of source streams and their downstream receiving waters.

Rules and practices have been imposed on the forest industry for riparian protection for streams, especially source (headwater) areas, and vary among jurisdictions (e.g. Richardson et al. 2012). For instance, in Washington state (USA), small, fishless streams require 15 m wide reserves on each side for at least 50% of the stream length, with particular emphasis on confluences, and headwall seeps and springs. Similar rules are being imposed on Oregon state forestry practices following field trials. In British Columbia, Canada, no treed buffers are required on streams without fish, or <1.5 m wide, while other jurisdictions impose fixed-width reserves along headwater streams. In Sweden, the protection of small headwaters (1-2 m width) is suggested as 5-30 m of unharvested buffers, with the narrowest allowable limit being mostly used in reality. However, smaller streams (< 1 m width) are often left with little or no buffers (no trees, but often a machine-free zone) in Sweden, Canada and elsewhere. This minimal protection has largely been motivated by the commercial value of timber without due consideration for the local, incremental and cumulative effects of such changes to catchments that other users depend upon (e.g., Sweeney et al. 2004, Sweeney & Newbold 2014). The temporal variation in hydrological connectivity and the high spatial distribution of small streams make them difficult to map which also imposes problems with their protection. Nevertheless, achieving good ecological conditions (through ecological and biochemical protection) of all waters (Water Framework Directive) has to begin with the source areas, including those in forestry landscapes.

It is increasingly apparent that lack of protection from source streams to downstream has resulted in degradation of stream and river networks, reduced their productivity, and incurred enormous expenses to restore (rarely successfully) downstream areas (e.g., Dudgeon et al. 2006, Palmer et al. 2014, Nilsson et al. 2015). The dependence of downstream reaches on upstream source areas has been demonstrated (e.g. Wipfli et al. 2007) because headwaters supply water, nutrients and organic matter to downstream, hydrologically connected systems. Headwaters also support unique and high biodiversity ecosystems providing critical habitats to many species (e.g., Meyer et al. 2007, Richardson & Danehy 2007, Cantonati et al. 2012), and are among the most vulnerable of freshwater ecosystems (e.g. Dudgeon et al. 2006, Sweeney & Newbold 2014).

Small streams are sensitive to their local, reach-scale surroundings and disturbance to the forest nearby. This sensitivity comes from responding dramatically to changes in light caused by canopy removal (i.e., forest harvest). This in turn results in rapid heating (and in winter, cooling) of the small volume of water, with impacts on biogeochemical rates and biological diversity. Changes in local hydrology resulting from increased peak flows following harvesting (reduced evapotranspiration, compacted soils, drainage from roads, etc.) can result in higher rates of erosion and sediment transport, changes in geomorphology, and transport of higher nutrient loads (review in Richardson and Danehy 2007). Removing surrounding vegetation alters stream food webs by increasing primary production and reducing inputs of organic matter (e.g. Kiffney and Richardson 2010), and even as vegetation regrows, the type of vegetation remains different from the original composition, which affects stream food webs (e.g. Sweeney and Newbold 2014). Finally, a small catchment area means small streams are vulnerable to low flows during dry periods and temporary drought, which is exacerbated by nearby harvesting. All these impacts to small streams are transmitted through the stream network to downstream, and once sediment, nutrients and pollutants enter the water, they are not easily removed, impairing water quality and habitats in downstream reaches.

State-of-the-art and relation to the work programme

Complete removal of forest cover around streams impairs stream integrity and impacts are well known (e.g. Sweeney et al. 2004, Sweeney and Newbold 2014) and therefore, riparian buffers of some sort are usually applied (e.g. Richardson et al. 2012, Kuglerová et al. 2014). However, retention of treed riparian buffers is often allocated to larger streams and rivers, while small streams are often afforded little to no riparian buffers. Nevertheless, small streams dominate landscapes and thus the cumulative consequences of their poor protection should be detectable downstream. Thus, larger streams may be impaired, despite receiving local, reach-scale protection. Many studies demonstrate the direct ecological, hydrological and physiochemical effects of forest management around small streams, but little is known about the monetary value of different buffer configurations (Tiwari et al. 2016). Even fewer studies have addressed the cumulative consequences of headwater impairment for sustaining good ecological status in downstream waters. Sufficiently wide and well-designed riparian buffers reduce the impacts of forestry, but do not prevent some changes, such as increase in runoff. The appropriate allocation of streamside protection depends on knowing the local and cumulative impacts of different protection designs, the magnitude and duration of impacts, and the values of reserved trees. Such decision science procedures have to include the biophysical, social and economic dimensions (e.g. Mantyka-Pringle et al. 2016).

Our project addresses parts of all Challenges. We will address Challenge 1 by evaluating forestry landscape management in the context of resilience, especially to extremes of weather (e.g., peak and low flows, high temperatures). Most current measures are designed for average conditions and not extremes, and do not build in safety factors as we do in most other activities affecting human safety (topic 1.b). It meets Challenge 2 by quantifying how much different forestry practices around water protect against nutrient and sediment loading, increased thermal pollution, biodiversity impacts, and loss of ecosystem resilience (in line with goals of Horizon 2020 and Water Framework Directive). Finally, we will address challenge 3 (3.b) by considering trade-offs between opportunity costs of industry (and social benefits from jobs and taxes) versus other social values, including clean water, fish safe for eating, flood hazard protection, and others (e.g., waterways used for leisure – paddling, swimming, fishing etc.).

Objectives and overview of the proposal

Our proposal has three primary objectives, i.e. work packages.

1. We will develop catchment-scale models to evaluate the contributions of different forestry practices around headwater (source) streams to local and downstream ecosystem integrity and to compromises of ecosystem services. These process-based models will integrate what we know about the magnitudes and durations of impacts from forest harvesting on a number of response measures, and consider the additive and interactive effects among the driving variables. The response measures will be the impact on local and downstream systems and effect sizes of deviations from reference ecological status. These response measures will include aspects of catchment-scale discharge responses (peak flows, number of large flows, hydrological drought conditions, etc.), temperature regimes, water quality, and biological attributes (including fish, benthic invertebrates, primary productivity, ecosystem metabolism, and organic loading). We can model scenarios including no buffers along any streams

(headwaters or downstream), vary the number and network position of streams with buffers of different sizes, different allocations of buffers to headwaters versus larger streams etc. The models will include comparisons of changes in supplies of timber and water resources, using scenarios based on different landscape designs, particularly on the allocation of riparian forest protection around different features of catchments (e.g. headwaters versus larger streams, buffer widths, continuity of buffers, etc.). Using these models, we can consider what range of protection might lead to better outcomes for addressing climate-change impacts on both source areas and further downstream. For instance, we have very good physical models for predicting thermal energy balances in streams (e.g., Moore et al. 2005), we can use these relations to explore temperature dynamics in response to the alterations of stream cover and hydrology in streams.

2. We will augment existing data with new data by replicating field studies across the three regions (Canada, Finland and Sweden). These observational studies will include two levels. First, each of the two field years there will be a reconnaissance of field sites using a rapid assessment procedure, allowing for visits to a large number of sites. Second, later in the summer a selection of about 30 sites per region per summer will be visited for more comprehensive biological, physical and chemical sampling, including streams considered in reference condition. The field observations can also serve as a testing data set for the outcomes of the models from objective 1.

We aim to design two experiments which will investigate the ecological, chemical and biological conditions of different streams with different levels and ages of interventions. These experiments will be controlled flow-through stream mesocosm studies and will provide additional information about the mechanisms by which reach-scale disturbance from forestry activities affects headwaters.

3. We will develop a white paper on riparian area management to meet multiple objectives. This paper will include guidance on how to design riparian area protection at multiple scales (reach and catchment scales), incorporating ideas of the Emulation of Natural Disturbance (e.g. Kreutzweiser et al. 2012), hydrologically sensitive areas (e.g., Kuglerová et al. 2014), partial or selective harvest, and how to incorporate principles of resilience into such designs. We will also incorporate ecosystem services as incentives to sustaining proper functioning condition of stream networks (Richardson is part of a Canadian Network for Aquatic Ecosystem Services – www.cnaes.ca). Within the white paper we will elaborate a detailed design for a future, distributed experiment to test the effectiveness of reassigning allocations of riparian protection for stream networks.

Research methodology and approach

The objectives stated in the previous actions will be achieved through the following approaches:

1. Models – A model will permit us to put together a spatially explicit, network model that will incorporate hydrology, sediment transport, nutrient flux, temperature, and organic matter inputs (including wood). There are many potential model platforms, including *EcoPath*, which we will select from among. The model will permit us to input a range of scenarios of potential changes to headwater (source) streams, and the propagation of effects downstream from forestry, climate change, and management policy choices. As a basis underlying the models, we can incorporate well-described, process-based variables, such as light and thermal regimes, sediment transport, nutrient inputs, and other processes. These physical and chemical processes are well behaved and average conditions, as well as stochastic events based on deviation from the average conditions, can be used. Biological and sediment transport responses can be coupled to these key driving variables. Using such models, we can explore different protection scenarios, mostly in the form of riparian buffer strips, as commonly applied in forestry operations. In these models, buffer strip width and structure or other designs (e.g. tree age, species composition, canopy levels etc.) can be used as a variable. This suite of models will be parameterised using data from the wealth of studies that have empirically examined the effects of different forestry practices on small to mid-sized streams. For instance, recent meta-analyses have found hundreds of studies in international publications and many more studies are likely available (e.g., Marczak et al. 2010, Richardson & Béraud 2014). We will augment the existing data bases with a further search of the literature, contacts with colleagues and with new data from Objective 2.

Our collection and collating of data from a range of streams from around the world for the parameterisation of the models, will allow us to use those data to perform various analyses and meta-analyses. These analyses will take advantage of the broad environmental gradients (covariates) in terms of stream size and gradient, chemistry, climate, catchment areas, etc., to consider how regional context influences local changes to streams (e.g., Richardson & Béraud 2014). This will extend our ability to include regional differences in extrapolation of model results and recommendations for practices to enhance the prospects for good ecological status in streams (WFD).

2. Empirical work – Field work will augment the data available. Sampling will take place in summers of year 1 and 2, allowing for subsequent laboratory processing of samples, analysis and writing in the third year. The field work will be based on sampling in all three countries using a 2-stage approach. The first level in the early summer will use a rapid assessment approach. The second level will be a more in-depth sampling of a subset of sites selected from the rapid assessment, including streams considered in *reference condition* for their type (e.g. Pardo et al. 2014). This allows us to use the first level of sampling to select sites on the basis of criteria to be refined.

In the rapid assessment sampling, we will consult with our forestry and government colleagues to find sites in both active forestry and less active forest areas. Each stream visited will be evaluated following a rapid assessment protocol, which will include classification of the surrounding (e.g. buffer or not, width, status etc.), obvious local impairments (e.g. sediment loads, scouring, drought indications, machine tracks), and important ecosystem features (e.g., large wood volumes and piece numbers, flow conditions, etc.). Performing rapid evaluation will allow us to visit a large number of sites but still provide meaningful information. Up to 4 (or more) sites a day can be sampled with this approach. Such sampling will occur in a select region of each country, but it is not possible to represent all forest landscape types.

In the second level of detailed sampling, we will select at least 30 sites per country per summer for more intensive sampling, yielding a sample size of at least 180 sites over two years. These sites will be selected from the rapid assessment sites based on representation of a range of stream sizes, degree of forest harvesting activities, stream gradients, and perhaps other criteria to be determined. At each site we will measure temperature (summer maximum, accumulated degree days), nutrients (P, N, K, DOC), turbidity, and discharge. At each site we will also use measures of ecosystem structure and function, including benthic invertebrates and fish (although fish diversity is very limited in these regions), leaf litter decomposition, ecosystem metabolism, and primary production. Some of these measures will depend on leaving temperature data loggers, leaf packs and tiles for biofilm growth, all of which will be retrieved at the end of the summer and returned to the respective laboratories for analysis.

These data will be analysed in a generalised linear mixed model framework with region and year as random factors. Many of the predictor variables are continuous in nature, and thus these covariates will include stream size and gradient, equivalent clearcut area (ECA) upstream, time since harvesting, and treed-buffer widths (assuming areas with no harvesting have a large buffer). We will look for evidence of patterns with such underlying environmental gradients (e.g. catchment area, buffer width, gradient), as suggested in Richardson and Béraud (2014). This data set will be used to explore some of these patterns. These data will also be used as a way to test model predictions from objective 1 and contribute to development of ideas for objective 3.

A before-after, control-impact (BACI) comparison within sites is not possible during a 3-year grant period, so replicating within a "treatment" (space-for-time substitution) is the best way to generate useful empirical data. In addition, selecting sites with different "time since harvest" will serve as an ideal data set for chronosequence study, using this variable as a covariate in analyses. These regional data sets will provide a gradient of underlying environmental variables representing the natural range of variation in forested landscapes which we can use to understand landscape- and regional-scale responses of streams to forestry (e.g., see Richardson & Béraud 2014).

We will use mesocosm experiments to study mechanisms as indicated from the field studies that might lead to community and ecosystem level responses to changes in abiotic and biotic conditions related to different levels of riparian forest removal. In the mesocosms, we can manipulate light levels (representing various buffer strip widths), temperature (representing radiative changes after forest removal), different litter subsidy (representing changes in near-stream vegetation) and disturbance (e.g., sediment loadings and erosion). Similar variables as described above (i.e., decomposition, water chemistry, biotic communities, metabolism etc.) will be measured and their responses to manipulated effects will be quantified. We have very good infrastructure in Canada (Malcolm Knapp Research Forest) and Finland (Kainuu Fisheries Research Station, Paltamo) to accomplish that. We will take a multiple stressors approach to determine the mechanisms by which in-stream processes are affected by forestry practices (e.g. Elbrecht et al. 2016, Mustonen et al. *in press*). There will be one experiment in each of the two facilities (Canada and Finland), followed by laboratory processing of samples to determine results, with options for additional experiments if time allows.

3. White paper and experimental design - We will write a white paper along with stakeholders considering innovations in streamside management and future options to go beyond typical thin, fixed-width buffers (Richardson et al. 2012, Kuglerová et al. 2014). It is important to take a landscape view of streamside management, as impacts upstream affect downstream in all cases. Some components of the landscape are more vulnerable to forest harvesting, such as hydrological sensitive zones, confluences, and steep catchments, and may need different management options. For example, in hydrologically sensitive areas with shallow groundwater table, management will also have to include recommendations for machine operations and not only focus on buffer widths. Above all it is important to link riparian management options to the scientific foundations that have been developed in the past couple of decades, rather than administratively simply, fixed-width buffers for the protection of freshwater systems for all users. Large-scale experiments involving whole catchments and industrial-scale forestry are needed to properly evaluate the effectiveness of riparian management practices and variations on those practices, as well as to test our model outcomes. Many of us have suggested for years that more protection is needed on small streams, and perhaps less on larger streams (as a trade-off) to ensure inputs of nutrients and sediments, as well as warmer water, are not transported downstream from source areas. A large investment and careful designs will be needed to implement a large, long-term and distributed set of experiments to test alternative protection measures. We will develop a detailed draft of that proposed experiment and budget options to take to various supporting agencies.

The data sets obtained in objective 1 and 2 will help to develop the white paper and set future avenues for research. For example, only after proper evaluation of local practices (i.e., data collected by the rapid assessment across numerous sites) we can start elaborating on measurements which are detrimental for knowing the stream conditions. Many freshwater processes are linked to abiotic features of streams and thus repetitive measurements of biotic responses might not be necessary, if we successfully identify these linkages across harvested and reference catchments. An evaluation protocol, including these vital measurements, which could be applied to streams across jurisdiction will be one outcome of this work. Further, combined with the models from objective 1, the evaluation protocol can be “plugged in” a model to decide the likelihood of downstream impairment and the protection level needed.

It will be necessary to collaborate on the white paper with agencies and industry in order to deliver mutual beneficial documents. Across the three countries, we have initiated necessary contacts and our work seems to be met with enthusiasm. Governmental and forestry organization are obliged to incorporate water protection in the landscape management plans in order to meet various goals (e.g. Horizon 2020, WFD) and thus, research addressing the issues of forest harvest, one of the largest industries in Scandinavia and Canada, is greatly appreciated.

Work Plan

The three PIs will work together to lead this project. Each will interact regularly (Skype calls) to discuss plans and progress. The PIs, post-docs, and partners will work together to develop the white paper with input from government and industry partners. Each PI will be responsible for supervising specific aspects of the work package, including local data collection.

The Post-doctoral fellow to be based at UBC will be largely responsible for the modelling work, but will also contribute during the first two summers to the field-based collection of additional data as described in Objective 2. The PhD student based at UBC will be co-supervised by Richardson and a colleague, Dr. Tara Martin, who is expert in resource economics and conservation decision science (e.g. Martin et al. 2012). Dr. Martin will help direct the student through the decision science aspects of economic scenarios of trade-offs between values, as well as the spatial and temporal aspects of where harvesting occurs and how quickly riparian-stream systems recover. The student will primarily be engaged in Objectives 2 and 3, contributing to the trade-offs analyses and participating in experimental mesocosm work, along with field collections.

The work in Sweden will be led by L. Kuglerová as a Research Associate. She will collaborate with Prof. Hjalmar Laudon, who is the head of the Department of Forest ecology and Management (SLU) and who will be involved as external partner. L. Kuglerová will be responsible for the field data collections for objective 2 during the two seasons and will have 1 summer assistants for helping out with the field work. She will also be involved in the modelling and meta-analyses (objective 1) and will have regular contact with the Richardson's postdoctoral fellow. She will also participate on the white paper and will be in regular contact with the local external collaborators.

The post-doctoral fellow to be based at U of Oulu, Dept. of Ecology and Genetics, will focus mainly on objective 2, being responsible together with Prof. Muotka for conducting the field work for the survey-based approaches (two summers) as well as the mesocosm experiment during the second summer of the project. They will collaborate with an external partner, Prof. Björn Klöve (a hydrologist), head of the Environmental Engineering Laboratory at UOulu. Both Prof. Muotka and the post doc will also contribute to objectives 1 and 3. For field assistants, we will recruit several undergraduate students who will prepare their thesis works in this project (not funded from this call).

This project will include a Research Associate, two post-doctoral fellows and at least one PhD student, as noted above, to carry out the modelling and empirical work. Supplies (sample processing, field work, water analysis) and equipment (including computers, field equipment) will be a small overall cost and much of the needed infrastructure is already available (e.g. mesocosms [use costs apply to the Finland systems], microscopes, balances, etc.). Travel includes field work as well as international travel to meet with the team, and with agency and industry personnel at annual workshops and meetings. Funds for publication and extension are also included.

Originality and innovative aspects of the research (ambition)

No-one has addressed the trade-offs between protection of source areas in terms of the industry's and society's opportunity costs, the values of the ecosystem services provided or the mitigation of uncertainty associated with climate change and other environmental changes. Yet, such research is crucial to managing our waterways towards high resilience and resistance in the changing world. Such work is very challenging because involved partners and collaborators must span various research areas (ecology, hydrology, social sciences) as well as numerous stakeholders, industry and governmental organizations. Our team is unique in this aspect because we cover large areas of expertise and have established important contacts.

Further, there are very few studies looking at the cumulative effects of headwater impairments, although this research area has been growing in past years. Most of the efforts are however performed in urban or agricultural landscapes while forested catchments are usually considered as "reference" systems. Yet, forestry can represent a threat to ecosystems similarly as urbanization or agriculture. In order to design the best freshwater protection and/or restoration measures we need to address forestry effects on streams at local and catchment scales.

Our proposed work will benefit from work in parallel in forested catchments across three regions of the world to enhance generality of the outcomes. This will provide an opportunity to unify the knowledge about forestry effects on streams and test the transferability of our models. Such research efforts are very rare, yet highly desirable.

Clarity and quality of transfer of knowledge for the development of the consortium partners in light of the proposal objectives

Learning about the forest systems in Canada, Sweden and Finland together will benefit all the PIs. The knowledge will be gained by using different modelling approaches, spatial analyses and novel statistical techniques. The proposed work will be a large learning experience for all involved parties because the project goes beyond an ecological study. This study will apply the research findings to real management decisions and we also aim to cover socio-political and economical aspects and this is indeed an area where ecologists need to get comfortable. Further, we will train a next generation of researchers (PhDs and postdocs) which will participate in and learn from a multidisciplinary working group and will thus be equipped with unique skills for further work.

The consortium members will complement each other’s expertise and provide an opportunity to broadly consider the many dimensions of protecting freshwater ecosystems and enabling novel approaches to streamside forest management. Each member of the collaboration has a wealth of experience to bring to the shared research vision of this project. Richardson has co-ordinated projects of similar scope, involving multiple co-PIs and many graduate students, post-doctoral fellows and technicians, which have had outcomes that have influenced forest practices. These collaborations include people with a range of expertise and the opportunities for novel and transdisciplinary research are great. Collaborators are, or have been, in several other research consortia. For instance, T. Muotka has been a principal investigator in several projects funded by the Academy of Finland, Finnish Ministry of Environment and Ministry of Agriculture and Forestry (1996-2016). He has also been involved as a team leader or management committee member in several EU projects and networks (FP7 GENESIS; COST Action 626 "European Aquatic Modeling Network”). L. Kuglerová’s previous work on riparian buffer strategies focused on variable widths determined by hydrological conditions within the riparian areas and she has delivered the research findings to various Swedish organizations. Including our academic and agency partners in the research will bring additional and diverse expertise to the learning experience, including decision science, economics, forest practices, water supply management, and others.

Quality of the consortium partners and collaborative arrangements. Capacity of the consortium to reinforce a position of leadership in the proposed research field

The team is led by three co-PIs with strong international reputations. The team co-ordinator is John Richardson (University of British Columbia, Canada), with partners Timo Muotka (University of Oulu, Finland), and Lenka Kuglerová (Swedish Agricultural University, Umeå, Sweden). We represent three of the top forestry countries in the northern hemisphere. As a team we have complementary expertise in ecology, hydrology, geographic information systems and forestry. We will also develop partnerships with agency and industry personnel, and colleagues with economic and social science expertise.

Richardson has over 30 years of experience doing research related to forest-stream interactions, and as will be evident from the CV, he has published over 190 scientific articles, 148 of which are in international, high-quality, peer-reviewed journals. He has been involved in many government panels, species recovery teams, scientific advisory panels, chairs the South Coast Conservation Program, journal editorial roles, and has made many other contributions towards the sustainable management and conservation of freshwater and forest resources.

T. Muotka has 25-yr experience of research in stream community ecology and biodiversity. His recent research has focused on multiple-stressor interactions (climate change vs. land use impacts) and restoration ecology. He has led research on issues related to biodiversity conservation at the stream-forest interface, and published 120 articles in recognized international peer-reviewed journals. He has served several government panels and working groups (stream restoration, invasion biology, national assessment of threatened habitat types) in Finland as a member or a scientific advisor.

L. Kuglerová has been part of a large multidisciplinary projects during her PhD education and postdoctoral experiences. In Sweden, she was involved in the Krycklan catchment study and was the leading member of research on vegetation and groundwater interactions. She was also involved in a European Union-funded Life project (http://vindelriverlife.se), investigating the effects of river restoration. Her postdoctoral research is a collaborative project between universities and local authorities in Canada investigating spatially explicit, cumulative effects in stream networks from land uses. Despite her early career stage, she has numerous experiences with research on streams and riparian areas, buffer management and is skilled with analytical techniques, and she has a good publication record.

2. IMPACT

Impact of the proposal

This work will provide science-based knowledge in support of European and Canadian policies. We will refine the problem and provide quantitative outcomes to enhance decision-support processes for policy makers. We will also address differences and similarities between major forested regions to provide general as well as place-specific guidelines. We will provide a rational, integrative and rigorous platform to study scenarios of how to balance public goods and services (ecosystem services) with industry uses, including values of high quality water, wood production, ecosystem and biodiversity conservation, and protection of human health and safety. Together we represent several of the landscapes with the most intensive forestry operations in the north temperate regions.

We will create a steering committee of key partners from government agencies and the forest industry to focus our work to serve directly the needs of these partners. We will also bring together stakeholders from governments and industry to participate in round tables to refine objectives and share detailed understanding around the table. Given our previous research, we have already established these contacts. This will communicate results to partners and beyond, but we also ensure further extension of the results and interpretations to broader groups through workshops. We expect the research to help reduce uncertainty about forest management practices to secure the protection of good ecological status of source streams and the larger streams they flow into. This will provide an international perspective on a problem that has mostly been dealt with at state levels, without understanding how region-specific effects modify management needs. This is especially valuable considering how extreme events associated with climate change might compromise the health and status of European and Canadian freshwaters.

The connections between science and policy established during this project will likely extend beyond the time period of the grant. We will create a future research agenda and propose a design for a future experiment testing the effectiveness of reassigning allocations of riparian protection for stream networks in objective 3. Thus, our work will have long-term influence because of the connections established, our findings and future study designs.

Our proposed research fits well with the European Union Water Framework Directive. According to WFD, all waters should have achieved a good ecological status by 2015 and protecting source areas, as proposed by us, might be an important strategy together with restoration and mitigation efforts of already impacted areas. WFD remains a key set of targets for ecological protection and chemical protection of surface and ground waters. This project matches with the Horizon 2020 goals of coupling research with innovation by exploring new ways of balancing forestry and protection of freshwater resources. Climate proofing of our streams (Thomas et al. 2015, 2016, Martin & Watson 2016) might be promoted by providing better protection of source areas to avoid the initial warming of streams, and mobilisation of sediments, nutrients and contaminants (e.g., aims of Horizon 2020). This work also fits well with Sweden's Future Forest program. Future Forest provides collaboration possibilities with forest industry representatives, forest owners and policy makers and it is well acknowledged and appreciated program by both researchers and government/industry.

Expected outputs

We will hold annual meetings with government, industry and other stakeholders to present and extend our results. The outcomes of these meetings will be outlines for the white paper, meeting minutes and reports. We will train at least 2 post-doctoral fellows, 1 PhD students, and 5 undergraduate students. The work will produce a model platform for testing scenarios regarding different allocations of riparian protection with respect to outcomes. Throughout the project we will produce current summaries of results through social media outlets. We will also actively participate scientific conferences to present our findings and to open possibilities for further collaborations. Each of the partner organization will include aspects of this work into course curricula. The project will yield several peer-review articles in various research fields (ecology, management, social and policy fields, ecosystem science, etc.; i.e. mesocosms experiments, the observations and measurements in field (the field sampling) and rapid assessments, process-based modelling, and meta-analysis, resulting in at least 7-8 publications. Finally, the project will produce a white paper for policy development around riparian area protection.

Opportunities for the PhD student(s), Post-doctoral Fellows and Research Associate to travel to work with each other is always possible, and will be encouraged to provide exchanges between groups. These mobility options will allow the trainees to work and collaborate directly in other countries and be exposed to other ideas.

Exploitation and communication activities (measures to maximise impact)

We will use several means of communicating our results including: website, white paper, conference presentations, boardroom presentations to industry, blogs, research "shorts" (one-page, colourful articles), a Facebook page, a Twitter account, etc. A key means of sharing information will be our annual workshops, including both scientific and practitioner participants. We will also report annually to our government and industry partners. Finally, we will publish articles in international, peer-reviewed journals (open access where feasible) to ensure the highest level of credibility of the work, providing broad, international access to the work. Each of the project team members has a very successful record of publishing in high-impact journals and having influence on policy development.

The collected data sets in the three regions and through experiments will be available through our publications as supplementary material. A database will also be established where all members and collaborators can contribute data on streams, following the bioassessment protocol. Likewise, data files from meta-analyses will be archived as supplementary files at the journals where the work is published. At the end of the project data summaries and data files will be stored in a publically accessible and controlled data archive.

Market knowledge and economic advantages/return of investment

Healthy river systems have the ability to provide us many ecosystem services, such as clean water, fish, biodiversity and leisure. These services are becoming increasingly threatened due to intensification of land use and changing climate. Many watersheds across the globe are nowadays affected by numerous anthropogenic influences which leads to water scarcity, pollution, extreme events and generally less predictable water availability. Clearly, new strategies for protection of our water ways are needed in order to stand up to the challenge of global change.

Protecting our water ways is one of the main priorities nowadays and thus, the market for knowledge of "how best to do it" is large. In forest dominated landscapes where forestry operations go more than hundred years back in time, adaptive management must be applied. We will contribute the necessary knowledge for the adaptive management strategies. At the same time, the increased protection of riparian forests across large number of small streams might come with seemingly unbearable cost. Thus economical losses must be compensated by ecological and social gains and it will be presented to land managers in such a way.

Our work can bring economic benefits to the end product users because protecting source areas might lead to lower costs of restoration (often in the hundreds of thousands or millions of euros per km of stream). Restoration of riverine ecosystems is a large business, often with low success rates (e.g. Palmer 2014, Nilsson et al. 2015). This is partly because locally applied restoration actions (usually in and along larger streams) do not prevent sites from being affected by upstream impaired sites. As our research indicates, cumulative effects have the potential to carry degraded conditions along the entire river network and prevention of such effects should start at the source areas. Similarly, the benefits of healthy river systems in terms of biological diversity, healthy fish and clean water will likely balance the potential economic losses from timber harvest. Trade-offs of ecosystem services, other social values, and direct economic benefits will be compared using comparisons of different scenarios.

3. IMPLEMENTATION

Overall coherence and effectiveness of the work plan

WP Number	WP Title	Duration (months)	Starting Month	End Month
WP1	Modelling	36	Apr. 2017	March 2020
WP1 Description	Catchment-scale models to evaluate the contributions of different forestry practices around headwater (source) streams to local and downstream ecosystem integrity and to compromises of ecosystem services.			
WP2	Empirical data collection and analyses	36	Apr. 2017	March 2020
WP2 Description	Data collection across streams in the three countries with various buffer management applied. Mesocosm experiments. Rapid bioassessment and other field data.			
WP3	White paper	18	Oct. 2018	March 2020
WP3 Description	White paper will be written along with stakeholders considering innovations in streamside management and future options to go beyond typical thin, fixed-width buffers. It will also set up an avenue for future research agenda.			

Deliverables –

1. Model (WP 1) – A process-based model for riparian buffers scenario

    1.1 A manuscript focused on meta-analyses of published and other data obtained on stream responses to different buffer managment scenarios
    1.2 A manuscript describing the process-based model outcomes, i.e., local and downstream (cumulative) responses to different buffer management scenarios

2. Empirical work (WP 2)

2.1. Manuscript describing our findings from rapid bioassessment surveys across numerous streams at harvested and unharvested sites, and overall summarizing the current forestry practices around source streams.

2.2 – Manuscripts describing the results of mesocosms experiments, i.e., manipulation of abiotic factors which likely change with riparian forest harvest (e.g. light, temperature, flow) and measurements of biotic responses (e.g. decomposition, metabolism, primary production).

2.3 – Manuscripts describing the results of work on studied streams with different buffer conditions and position in the river network (headwaters vs. downstream reaches).

2.4 Presentations at conferences and user workshops (annually).

3. Completed white paper (WP 3)

Milestones

1.1.1 Data gathered for meta-analyses, i.e., publications with quantification of responses to riparian forest management (WP 1)

1.1.2 manuscript on meta-analysis and summary of model rates submitted

1.2.1 Gather data and rate estimates (from publications and colleagues) for model (WP 1) – data which will serve as a basis for process-based model creation and data for model parametrization.

1.2.2 test runs with model platform accomplished.
1.2.3 manuscript on process-based model outcomes submitted.

2.1 (WP 2)

2.1.1.1 Data for bioassessment protocol collected;

2.1.1.2 Protocol for evaluating stream responses to harvest based on the rapid bioassessment drafted;

2.1.2.1 Mesocosm experiments accomplished;

2.1.2.2 Data from mesocosm experiments analysed;

2.1.2.3 Manuscript(s) submitted for publication

2.1.3.1 Data collected from streams in forestry landscapes (season 1 and season 2) and laboratory sorting, identification and enumeration accomplished;

2.1.3.2 Data analysis based on seasons 1 and 2;

2.1.3.3 Manuscript(s) submitted for publication.

2.2. Participation in international conference (e.g., AGU, EGU, IUFRO meetings).

3.1 Annual meeting with stakeholders to outline the key points for white paper (WP 3)

Appropriateness of the management structure and procedures, including quality management

The team members have extensive experience of successfully working in teams of collaborators on projects of similar scope. For instance, Richardson and Muotka have successfully led several teams of researchers on projects. They have also been involved in many workshops and meetings with practitioners and government policy makers using science to guide policy development. This project includes a relatively small team.

Each team member will be responsible for the local work (e.g. field work, communication with stakeholders, hiring assistants etc.). Progress of the work will be communicated regularly between the three PIs and decisions about experimental designs, field work and analyses will be made together under the lead of coordinator. The hired postdoctoral fellows and PhD students will be decided on by each team member at their institutions in consultation with other team members. We will have monthly team conference calls and other regular communications, and annual Stakeholder meetings. This organization will enable us to frequently communicate and to make local decisions individually as appropriate because of the credibility of the PIs.

Each team member has their own budget administered through their institution, and normal financial management and accounting standards will be used as appropriate to the granting agencies and university.

Risk management

All scientific and management conflicts will be dealt by the coordinator and the partners and discussed and decided in simple votes. We do not foresee problems related with stakeholders losing interest in the project, and we prevented this by involving stakeholders that have a long and excellent working relationship with the coordinator and partners, and have expressed their interest in the project and willingness to participate.

There may be delays in attracting and hiring the best candidates for the post-doctoral and PhD positions. This could delay progress, and may require slight extensions to the planned time frame. We have had good success getting highly qualified personnel for projects in the past with only occasional delays. There would be impacts on students and post-docs of any delays in progress in the overall program. This would be dealt with as a consortium.

Potential and commitment of the consortium to realise the project

The consortium includes high quality researchers and leaders who will be committed to this project. They have demonstrated their ability to successfully realise and finish large projects and manage demanding work. The successful outcome of this call is thus foreseen. The institutions with which the PIs are affiliated have a good record of supporting collaborative projects and are highly committed to research on forestry issues providing a secure and committed work environment.

Added-value of the partnership to Water JPI

The Consortium members are all experienced researchers working on applied scientific questions regarding the interactions of forestry and streams (and riparian areas) to find solutions to balance values of our freshwater and riparian ecosystems with the direct economic benefits of timber harvesting. Each of the members of the team have published in this field and have had impacts on the policies around streamside management in their countries and internationally.

The northern European countries of Finland and Sweden, Canada and the USA have well-established forestry industries, and also have produced a majority of global forest research for the protection of water. Innovations over the past 40 years from forestry countries such as Canada, Finland, and Sweden have been adopted around the world. Despite enormous progress in protection of freshwater resources, there is still much to be learned and implemented as the intensification of land use and demands for water increase. However, best management practices also need regional refinements. This new partnership will take advantage of three of the leading forestry-intensive countries and the expertise there. There are some connections between each of the co-PIs, but we have not worked as a team before. The research collaborators all have international records of accomplishment and impact on environmental stewardship practices.

The team and our partners in government and industry will seek innovations as all partner countries are interested in developing practices that are effective and efficient at balancing multiple social values, including resources, employment and environmental protection. This project will provide excellent training opportunities for next-generation scholars as students in the team will be able to work with a team of well-respected scientists, interact with government and industrial partners, and influence land-use practices to protect water resources.

GANTT CHART

Month/ Description	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	M	A
Work Package 1 - modelling																																				
Deliverable 1.1																																				
Milestone 1.1.1																																				
Milestone 1.1.2																																				
Deliverable 1.2																																				
Milestone 1.2.1																																				
Milestone 1.2.2																																				
Milestone 1.2.3																																				
Work Package 2 – field work																																				
Deliverable 2.1.1																																				
Milestone 2.1.1.1																																				
Milestone 2.1.1.2																																				
Deliverable 2.1.2																																				
Milestone 2.1.2.1																																				
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Milestone 2.1.3.1																																				
Milestone 2.1.3.2																																				
Milestone 2.1.3.3																																				
Deliverable 2.2																																				
Milestone 2.2																																				
Work Package 3 – white paper	**1**																																			
Deliverable 3.1																																				
Milestone 3.1																																				
Progress Monitoring																																				
Mobility Schemes	**2**																																			
Conferences and partner workshops																																				
Risk Management																																				
Others																																				

1. The White Paper will be outlined early on as a draft for discussion, but real work on that workplan will begin in the second half of the overall program.

2. We have not defined specific mobility schemes for the Research Associate, Post-doctoral Fellows or PhD student(s), as these will be determined as work proceeds and according to opportunities for exchanges to participate in different deliverables. It will be valuable to the participants and the stakeholders to include such exchanges.

3. Final column indicates that some items, such as revision to manuscripts for final acceptance, will occur after official end of grant period.

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4. FINANCIAL DETAILS: BUDGET TABLE AND JUSTIFICATION OF BUDGET ITEMS

Partner order according to budget table	Budget (in euros)	Budget Items	Justification
Partner 1 – the University of British Columbia (JSR)	3795	EQUIPMENT	Sampling nets, water quality sonde
	175122	STAFF	Post-doctoral fellow (salary and benefits) – this person will lead the process-based modelling work, as well as contribute to some of the field work and white paper development; PhD student stipend – student will work on field sampling, mesocosm experiment and laboratory work; summer field assistant, part-time laboratory assistant (2 d/month)
	11316	SUB-CONTRACTING	External lab analysis for water quality, benthic samples
	31050	MISSIONS	Travel for meetings with partners and stakeholders; conference travel; field work in two regions of western Canada
	4657.5	CONSUMABLES	Jars, forceps, preservatives, filters, glassware
	9263	OTHER COSTS	Computers and software for new post-doc and student; €3588 for page charges
		OWN CONTRIBUTION	In kind – equipment, offices, laboratory and other tools, etc. NSERC provides indirect costs of research (overheads) to universities separately.
	€234997	TOTAL COSTS	
Partner 2 University of Oulu, Finland (TM)	6000	EQUIPMENT	temperature and water level data loggers
	169800	STAFF	post doc student, 3 years
	20000	SUB-CONTRACTING	external services (water chemistry analyses; identification of invertebrate samples)
	25000	MISSIONS	field surveys; participation to domestic seminars and workshops; participation in international scientific conferences (once a year, post doc)
	5000	CONSUMABLES	waders, sample jars, ethanol for sample preservation
	140000	OTHER COSTS	university overheads

	107940	**OWN CONTRIBUTION**	University of Oulu (30% of total costs)
	€467740	**TOTAL COSTS**	
Partner 3 Swedish Agricultural University (LK)	5000	**EQUIPMENT**	temperature and water level data loggers, laboratory supplies, field computer supplies, sondes
	202360	**STAFF**	3 years of salary for L. Kuglerová (90%), 3 field seasons summer assistant (1).
		SUB-CONTRACTING	
	19190	**MISSIONS**	Regular travels to the field sites, scientific conferences (once a year) and consortium meetings (once a year)
	5000	**CONSUMABLES**	waders, sample jars, ethanol for sample preservation
	85050	**OTHER COSTS**	University overhead and localities
	19766	**OWN CONTRIBUTION**	10% salary for L. Kuglerova (3 years) from Department of Forest Ecology and Management, SLU
	336366€	**TOTAL COSTS**	

The majority of funding in this request is for the four non-permanent positions, i.e. a research associate, two post-doctoral fellows, and at least one PhD student, along with short-term field and laboratory assistants. Travel for field studies, meetings with the team and partners, and conference attendance is the other primary set of costs.

5. DESCRIPTION OF THE PARTICIPATING RESEARCHERS, LETTERS OF COMMITMENT FROM COLLABORATORS and STAKEHOLDERS, LETTERS OF COMMITMENT OF OWN FUNDING CONTRIBUTIONS

Below we list all collaborators, including other investigators not requesting funds, and our agency and industry partners. Each has provided a letter indicating their commitment to the project as proposed.

Name of Collaborator or Stakeholder	Name of Partner to which the Collaborator/Stakeholder is associated to
Hjalmar LAUDON	Swedish Agricultural University, Krycklan Watershed
Sari SAUNDERS	British Columbia Ministry of Forests, Lands and Natural Resource Operations
Elisabet ANDERSSON	Swedish Forest agency
Anna CABRAJIC	SCA Skog AB (a forestry company in Sweden)

Per OLSSON	The Swedish Agency for Marine and Water Management
Helena DEHLIN	Svesaskog (a forestry company in Sweden)
Isabel PARDO	Department of Ecology and Animal Biology, University of Vigo, Spain
Tara MARTIN	CSIRO, Australia and UBC, Canada
Joakim KRUSE	Bothnian Sea Water District Authority
Pauliina LOUHI	Metsahallitus Parks and Wildlife Finland
Anssi NISKANEN	Metsäkeskus, Finnish Forest Centre
Jari OKSANEN	University of Oulu
Joe CHURCHER	Ontario Ministry of Natural Resources and Forestry
Timothy RYAN	Forest Practices Board, British Columbia

6. CAPACITY OF THE CONSORTIUM ORGANISATIONS

Partner		General Description
Partner 1 – the University of British Columbia	**Role and main responsibilities in the project**	Co-ordinator of program. Supervisor of a post-doctoral fellow and at least 1 PhD student on this project. Modelling, field work, and leading of white paper production.
	Key research facilities, infrastructure, equipment	Annual budget of over $1661 million (Canadian), approx. 55,000 students. Laboratories for stream studies, equipment, vehicles, field station. In top 40 universities of the world.
	Relevant publications and/or research/innovation products	$430 million/y in research funding, with >10,000 active research projects. Over 4300 publications in international journals per year.
Partner 2 - University of Oulu	**Role and main responsibilities in the project**	A postdoctoral fellow will be employed and supervised at University of Oulu. U. of Oulu will provide office space and facilities, laboratories, and other logistical support
	Key research facilities, infrastructure, equipment	Experimental facilities at Kainuu Fisheries Research Station, Paltamo, NE Finland www.kfrs.fi provide access to a set of artificial flumes for experimental manipulations of stressors.
	Relevant publications and/or research/innovation products	**Oksanen, J**., et al. 2013. Community Ecology Package 'vegan'. http://www.r-project.org. (a widely used statistical package with more than 5000 citations in ISI). **Eskelinen, A.** & Harrison, S. 2015. Resource co-limitation governs plant community responses to altered precipitation. Proc. National Academy of Sciences 112: 13009 – 13014. **Huusko, K.,** et al. 2015. Short-term impacts of energy wood harvesting on ectomycorrhizal fungal communities of Norway spruce saplings. ISME J. 9: 581-591.
Partner 3 – Swedish Agricultural University	**Role and main responsibilities in the project**	SLU will employ Kuglerová as a Research Associate providing, office space, laboratories, experimental facilities, access to research catchments, etc.
	Key research facilities, infrastructure, equipment	Svartberget Field Research Infrastructure (**Krycklan catchment study -** http://www.slu.se/en/krycklan), Bajlsö experimental study
	Relevant publications and/or research/innovation products	**Laudon, H**., et al. 2013. The Krycklan Catchment Study—A flagship infrastructure for hydrology, biogeochemistry, and climate research in the boreal landscape. *Water Resources Research, 49* **Laudon, H.,** et al. 2011. Consequences of more intensive forestry for the sustainable management of forest soils and waters. *Forests, 2* **Gamfeldt, L.,** et al. (2013). Higher levels of multiple ecosystem services are found in forests with more tree species. *Nature Communications 4*