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ENGAGEMENT PAPER

Taking Fire Science and Practice to the Next Level: Report from the PAGES Global Paleofire Working Group Workshop 2017 in Montreal, Canada – *Paleofire Knowledge for Current and Future Ecosystem Management*

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This report summarizes the outcome of the PAGES Global Paleofire Working Group workshop 2017 that took place in Montreal, Canada – Paleofire knowledge for current and future ecosystem management. The workshop aimed to (1) discuss the importance of past fire or paleofire research, focused on long-term influence of fire on the environments worldwide, in nature conservation, (2) find ways to integrate scientific achievements of paleofire research into ecosystem management practices, and (3) start the dialogue with ecosystem managers, practitioners and policymakers (EMPPs). With this report, the members of the Global Paleofire Working Group would like to open a discussion about how igniting new collaborations with EMPPs and make paleofire data useful for fire risk management. We recognized four main challenges in communication and cooperation between scientists and EMPPs: little awareness of EMPPs about paleofire research, differences in professional language used in an operational context by scientists and EMPPs, scientific data availability, and costs of paleoecological expertise. Moreover, we indicate the way to improve the communication between scientists and EMPPs by proposing a scheme of cooperation between both groups. We want to encourage researchers working in various fields of paleoecology to open up for the cooperation with EMPPs in the future, especially helping to create ecosystem management plans, because paleoecological data carry important information about the evolution of ecosystems that is vital in the context of global change.

Keywords: fire; paleoecology; sustainable management; policy; practitioners; environmental managers

Introduction

Fire is becoming a threat along with progressing climatic and land-cover changes, and is projected to increase in many parts of the world (EEA Report, 2012; Flannigan et al., 2013; IPCC, 2014). Moreover, scientists anticipate longer fire seasons in the future (Dello, 2017). However, those projections vary between different regions and ecosystems as the legacy of human activities on fire regimes is disrupting the information about natural ecosystem pathways (Vannière et al., 2016a). Along with biodiversity and ecosystem services losses, increased carbon emissions and other environmental impacts (Flannigan et al., 2013; PAGES, 2010), fires cause socio-economical losses and threats which directly affect populations, for example death of people, health problems, evacuations, higher insurance costs (Bowman et al., 2017). Landscape managers from across the world are currently being challenged to reintegrate disturbance processes into management and conservation plans, and are lacking information about past fire regimes (frequency, area burned, severity or intensity) and consequences of fires in different ecosystems (Gillson and Marchant, 2014). Historical information about fire regime changes can be acquired using different sources: from charcoal accumulated in sediments (lakes, peatlands, soil) to fire scarred trees (Conedera et al., 2009). Integration of past fire disturbance information into management plans and decision support tool can only be done through cooperation between scientists, ecosystems managers, practitioners and policymakers (EMPPs).

The interest of the Global Paleofire Working Group phase 2 (GPWG$_2$; *http://pastglobalchanges.org/ini/wg/gpwg2/*

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intro; Vannière et al. (2016b)) is to understand fire dynamics connected with humans, vegetation and climate over a long-time scale (decadal to millennial scale). Integration of specialists working on paleofire from various ecosystems across the world is essential, therefore, in the last few years, $GPWG_2$ organized a series of workshops to broaden the knowledge about fire regime changes, their causes and consequences (Daniau and Brücher, 2016; Feurdean and Vannière, 2017; Robertson et al., 2016; Vannière et al., 2014). The latest $GPWG_2$ workshop took place in 10–14 October 2017 at the Station Biologique des Laurentides, and was organized by Olivier Blarquez (Université de Montréal) and Pierre Grondin (Ministère des Forêts, de la Faune et des Parcs, Government of Quebec, Canada). The workshop gathered 24 scientists working on paleofires from boreal, temperate, Mediterranean and tropical ecosystems. The reason for the workshop was to explore the lessons from fire history records to support ecosystem management, and to identify current connections between scientists and ecosystem stakeholders. The main aim was to find new ways for paleofire experts to communicate with EMPPs by identifying a common vocabulary and developing a framework for the transfer of knowledge from paleofire research to management.

Workshop activities and discussion topics

The workshop started with a warm welcome by organizers and presentation of the objectives of the workshop and was followed by a presentation session. The keynote lecture presented by Sylvie Gauthier (Canadian Forest Service) focused on boreal forest and ecosystem management, showing Canadian examples of integration of paleofire research into forest management. Then followed a series of talks intended to demonstrate how paleofire research already contributes to management planning in Québec and how communication between scientists and ecosystem stakeholders can effectively lead to integrated research. Those talks demonstrated that (1) policies need to take into account ecosystem history (Boucher et al., 2017) that can be (2) supplemented with long-term fire disturbance analyses and historical fire regime data (Hennebelle et al., 2018) and (3) integrated within a common ecological framework regularly used by ecosystem stakeholders (Grondin et al., 2014). This sequence requires communication and co-development of research questions between academics and EMPPs in order to acquire and then transfer scientific knowledge into operational management, and was taken as an example for subsequent discussion during the workshop.

Before the workshop, participants were asked to contact EMPPs from their regions and to submit to them a short questionnaire provided by organizers (**Table 1**). The aims of the questionnaire were to (1) gather the information about the awareness of EMPPs about the paleofire research, and (2) recognize ecosystem stakeholders needs (for example useful data type/format) for their decision support tools and management plans. Altogether, 15 respondents from four continents working in three different biomes and with broad professional background (i.e. from governmental organizations, forestry units or conservation agencies) answered the questionnaires (**Table 2**). Full answers to the questionnaires are provided as Supplementary Material (Supp. File 1). We discussed the output of the questionnaires in subgroups and later analysed problems in communication and cooperation between EMPPs and scientists. We identified four challenges that were underlined in all questionnaires from all analysed regions.

1. The first challenge is little awareness among EMPPs about what paleoecology as a research field is, what methods are used in paleofire science, and how long-term data can be helpful when preparing management and conservation plans. In general, there is a lack of paleoecological education at schools, and there is a need to integrate paleoecology and paleofire studies into study programs in forestry, biology and ecology at the academic level. Moreover, paleosciences should be popularized among society to underline fire risks and the importance of research on this topic. The respondents

Table 1: Workshop questionnaire distributed by organizers and answered by EMPPs.

- Do you communicate often with Academics (university-based researchers) and from which scientific discipline?
- Do you use scientific evidence (studies and/or data) for defining management policies or targets in your area? If yes, which kind of data do you use?
- Do you order scientific studies on your ecosystem of interest? What kind of studies?
- What are the main challenges when integrating scientific knowledge into effective management plans for you? (For example: relevant spatial or temporal scale, human resources and understanding? Accessibility of science papers and data)
- Have you used that knowledge for a better understanding of the ecosystem under your responsibility? And for defining management targets?
- Do you believe that long-term knowledge of the fire regime in your area could be useful for defining ecosystem management strategies?
- What kind of data about fire regime knowledge should be supplemented with? (vegetation history, climate data, human demography, land use, etc.)
- Which kind of data presentation will be best useful to you? Database with raw data, graphics, scientific articles, maps, transformed and calibrated data (which units?), etc.
- What level of engagement would be useful between academic fire researchers and your policy analysts and management plan development teams?
- Would you be interested in promoting paleoecological and paleofire studies, in your geographical area of interest? Would you be reassured to work/deal with an international group of paleofire specialists?

Table 2: Respondents to the questionnaire.

Continent	Questionnaires answered	Biome of interest	Questionnaires answered	Institution	Questionnaires answered
Africa	1	Boreal forest	6	Conservation agency	3
Asia	2	Temperate region	5	Forestry unit	6
Europe	9	Tropical biomes	4	Foundation/NGO	2
North America	3			Governmental organisation	2
				Natural park	1
				Peatland restoration agency	1

often mentioned they use scientific expertise from time to time, but not based on long-term paleoecological studies. For example, a representative of a non-government agency from Russia underlined that "Every year NGO communicate with 20–30 experts: biologists, botanists, bryologists, pedologists, zoologists, sociologists, forest ecologist. There is a need in economists (to calculate the risks)." A stakeholder from Poland said: "Yes, I do communicate with Academics especially from hydrobiology and ecology discipline.", whereas a forester from Canada mentioned that "There is little direct communication with academic researchers. However, scientific studies are used at strategic moments in our forestry planning (e.g. in the development of forest certification). […] It is not really our responsibility, the forest companies, to integrate scientific knowledge into forest management."

2. The second challenge underlined by EMPPs is that the professional language used in an operational context is different than the one used by researchers; also, some expressions used by EMPPs carry different meaning for scientists. The respondent from Poland mentioned that "some discoveries and research results, because of their complexity, are difficult to use in an easy practical way in an ecological managing", a respondent from Sweden said that "forestry is very conservative when it comes to adapting new knowledge". Therefore, there is a need to establish a common language that could be used by EMPPs and researchers to smoothen the communication and mutual understanding. Hence, the $GPWG_2$ decided to prepare a glossary with >30 definitions of expressions used commonly in paleofire research, where underlying concepts are associated with metrics that can differ between paleofire research and operational management. For example: 'fire frequency' in forestry is usually considered as an estimate of the probability distribution of survival or mortality from fire in a population of non-overlapping landscape units (Johnson and Gutsell, 1994), compared with paleofire research where frequency represents the number of fire events (in the sense of charcoal peaks: Clark (1990), Higuera et al. (2010)) detected by unit of time, usually by millennia, at a single point in space (a lake or a peat bog for example). Other metrics such as 'fire severity' commonly used by managers reflect burn depth or the mortality (Keeley, 2009), and are more difficult to relate to paleofire metrics of severity which reflect the sedimentary charcoal signal. There, charcoal signal related to biomass burning could be divided by the fire frequency in order to assess the charcoal production by individual fire events that should be related to fire area (Ali et al., 2012) or fire severity (Kelly et al., 2013). These types of metric are only an index of the probable real past fire severity/area and cannot be directly related to EMPP fire severity metrics, but nonetheless can be summarized more broadly as reflecting the degree of alteration to the soil. Thus, a good understanding of the definitions and the metrics used in both management and paleofire research is capital for future communications.
3. Another issue is data availability. Most of the data produced by scientists is not available for EMPPs, for example there is a restricted access to scientific papers. Moreover, data that are already available are often not sufficient for EMPPs. EMPPs that responded to the questionnaire underlined that the main challenge when integrating scientific knowledge into management is the "[low] availability of the information and lack of clear methodology of research" (respondent from Poland). The type of data that would be the most useful for EMPPs are graphics, maps, high-resolution data, raw data and simplification of research findings as "scientific articles are difficult to understand for us" (respondent from Canada). As the communication between scientists and ecosystem stakeholders is limited, scientists simply do not know what kinds of data are important for EMPPs. For example, raw charcoal data which is freely available within the Global Charcoal Database (*www.paleofire.org*) is not necessarily useful for EMPPs

since raw data does not carry information that are readily applicable for management, conservation or restoration. Data that are of interest of EMPPs concern scientific interpretations and reconstructions of fire regime parameters in the past (ex. fire frequency, cycle, range of variability, etc.), and those are buried within scientific papers under a layer of scientific methods and jargon not always accessible out of the academic world. Improved communication between EMPPs and scientists should help to solve those problems, but the paleofire community also has to develop calibration studies (Hawthorne et al., 2017) to transform raw charcoal data into fire metrics understandable outside of this community, which can be used as decision making tools for ecosystem stakeholders.

4. The last important issue raised by EMPPs is budget limitations. Specialists' expertise is often costly and most of the public organizations are not able to finance a broad scientific expertise. As an example, a respondent from Canada said: "I think the biggest challenge to integrating scientific knowledge into effective management is the cost of implementing any program that we're not already doing"; a respondent from the wood industry from Indonesia underlined that "The main challenge is how to make a project low price and maximize profit and also make use of existing labor efficiently". This problem is hard to overcome just by communication. However, in this case discussions between scientists and EMPPs could result in scientists conducting research projects focused more on the practical use of the data. Scientists could also choose study areas common with those that are under the interest of EMPPs and need scientific expertise, for example sites located in protected areas or in their buffer zone.

After the analysis of questionnaires, attendees discussed the influence of fire on different ecosystems: boreal, temperate, Mediterranean, tropical (savanna, rainforest). As the influence of fire is very different in each of the ecosystems and there are different projections for the future (e.g. more fires projected in boreal forest, but fewer fires in savanna) (Abbott et al., 2016; EEA Report, 2012; Flannigan et al., 2013), paleofire research question needs to be developed to answer management challenges at the landscape or regional scale. Also within those regions human impact needs to be integrated in those scenarios, for example at the Wildland Urban Interface human activities and livelihoods need to be integrated within fire management plans. In the Mediterranean, because of the very high population density, we can easily question is there yet a "safe space" for wildfire? (Moritz et al., 2014). Here paleofire researchers showed how human fire-practices since few millennia associated to land use triggered fire history and had a significant impact on land cover dynamics (Vannière et al., 2016a). Even if future conditions may have no analogues in the past, human-driven fire legacy has to be precisely described at the regional or local scale to be included in forest management plans.

Outcome of the workshop and a proposition of a cooperation path between fire scientists, ecosystem managers, practitioners and policymakers

Better management practices and conservation plans can be prepared only when scientific knowledge meets the interests and needs of ecosystem stakeholders willing to cooperate with paleoecologists. Our interviews with EMPPs and the analysis of questionnaires exposed certain problems in communication and coordination. Therefore, we propose a scheme of possible cooperation path between fire scientists and EMPPs (**Figure 1**). First of all, identification of a common language and areas for the future cooperation is necessary in order to establish a dialogue and transfer of knowledge from both scientists to EMPPs and vice versa. This would trigger discussions and enable fire scientists to understand the needs and expectations of EMPPs. Knowing those needs, scientists could provide reliable scientific paleofire data (including raw charcoal data, statistical analyses and fire-vegetation-human-climate relationships at spatial resolutions of EMPPs work), interpretation of past fire regime changes and then pertinent proxies and decision tools for practical use. Having this information gathered from fire scientists, EMPPs should be able to prepare better fire policies, management strategies and conservation or restoration plans.

The $GPWG_2$ community is planning to develop such a program with paleofire calibration investment, database openness to all, but also enriched with interpreted paleofire products understandable by the great majority of EMPPs, and co-construction of projects that would integrate both scientific knowledge and management challenges often faced by EMPPs. Such research projects could serve as scientific investigations focused on answering key paleo- and ecological questions including work packages focused on practical use of the produced data sets in management or environmental planning. Moreover, the direct output of the workshop – the paleofire glossary – will be also published soon as a separate paper. The problematic expressions identified and discussed by paleofire researchers during the workshop will be further discussed and analysed together with EMPPs. We believe that the glossary will be a helpful tool in paleofire management worldwide, and will be translated into other languages for the use in the local scale.

The work of the $GPWG_2$ continued through the organization of regional workshops covering ecosystems possessing different fire regimes and fire history (e.g. in Nairobi in July 2018, in London in September 2018). These workshops will help us to meet our goals of exploring specific ecosystems, local administration procedures and conservation strategies. The workshops will also give us an opportunity to promote the main product of the $GPWG_2$ – the Global Charcoal Database (GCD; *www.paleofire.org*), a public freely accessible online database of sedimentary records of fire from all around the world. GCD is open to all scientists, EMPPs and the public and we would like to encourage paleofire researchers to upload their data to this database, which will make their work more visible within the fire community. Together, this will consolidate the individual efforts into regional and global syntheses of fire activity and recognition of broad-scale patterns of fire activity in centennial-to-multi-millennial time scales.

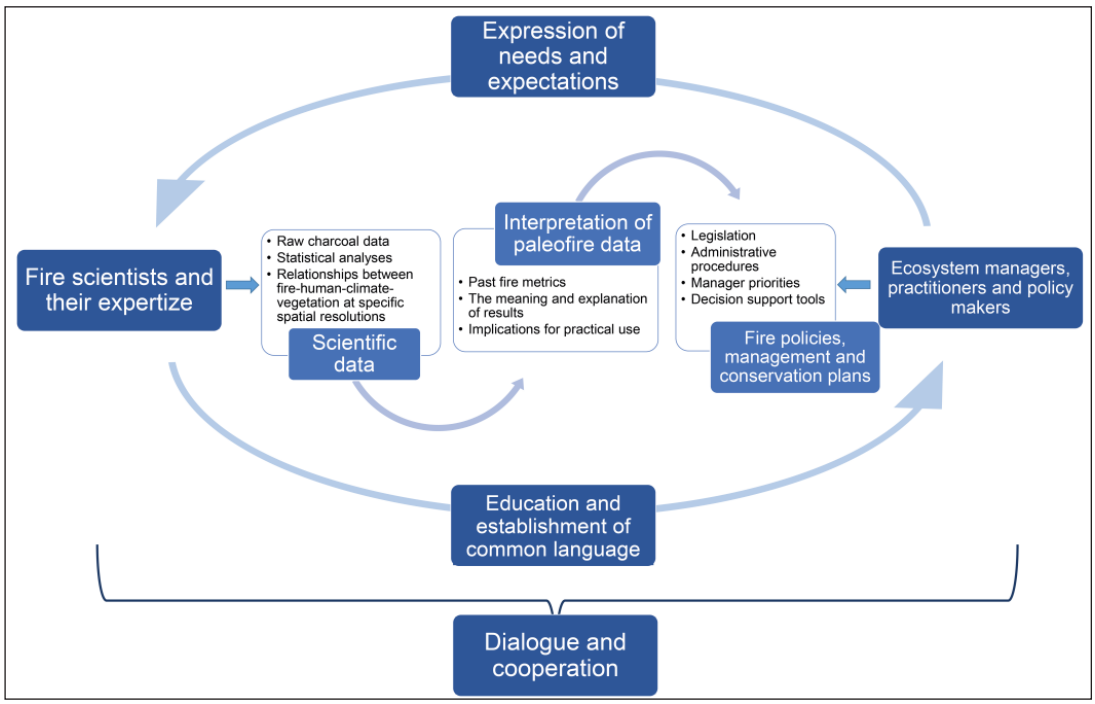

Figure 1: Cooperation path integrating fire scientists, ecosystems managers, practitioners and policymakers to build the capacity for fire risk assessment, ecosystem services estimates and delivery of valuable mitigation trade-offs.

Paleofire and paleoecological research offer a unique time perspective allowing to assess long term ecosystem trajectories, which represents an underestimated potential of information for ecosystem management and conservation. Even though the integration of paleoecological data into management faces some difficulties (Barnosky et al., 2017; Birks, 2012; Vegas-Vilarrúbia et al., 2011), there already exist examples of successful application of paleoecology into site-based conservation decisions, mainly for defining reference conditions and management strategies in wetland restoration (Blundell and Holden, 2015; Chambers et al., 2013; McCarroll et al., 2017; Riedinger-Whitmore, 2016) or in shrubland and grassland ecosystems (Forbes et al., 2018) or in forest ecosystems (Hennebelle et al., 2018). However, this potential is not explored enough, for example, a respondent from Sweden underlined that "[long term knowledge of fire regime could be useful] in some areas at least, especially since it is getting warmer and the fire-weather is likely to get worse and fire regime is likely to change". We call for increased openness and engagement of the paleofire scientific community and ecosystem stakeholders and their needs in order to introduce co-planning and co-development of sustainable management and nature conservation plans. Moreover, scientists ought to invest their time and efforts into education and promotion of paleofire and paleoecological studies, and underline the importance of this research fields to face the environmental challenges that ecosystem managers, practitioners and policymakers will meet in the near future. The issue of fire risks and consequences of fire disturbance in the future warmer world should be included in study programs not only in higher education (for example forestry or geography studies) but also during basic education in preliminary and secondary schools (for example during geography classes). Publicizing the disastrous effects of fires in media and informing the society on fire risks and ways to prevent fires will also rise public awareness on this topic. Informing the society is highly important because "most of the fires that we observe (>90%) is of anthropogenic origin (ignition, burning of rubbish in the forest)", as underlined by a forester from Poland. Greater public engagement and awareness about the role of scientific studies in nature conservation and management could trigger public pressure on the government and funding agencies for helping to gaining funds for scientific studies focused on restoration, conservation, or mitigation of our environments.

Additional File

The additional file for this article can be found as follows:

- **Supplementary File 1.** Questionnaires (created by workshop organizers) on the basis of which the conclusions of the workshops were drown. DOI: https://doi.org/10.5334/oq.44.s1

Ethics and Consent

Informed consent was obtained from all questionnaire respondents for their responses being publicly disseminate during the workshop and in this paper without nominative identification. Additional informed consent was obtained from all individuals for whom identifying information is included in this article including the country of origin and the type of institution. Opinions expressed by questionnaire respondents remain their own view and do not necessarily represent the views of the manuscript authors.

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Competing Interests

The authors have no competing interests to declare.

Author Contribution

OB organized the $GPWG_2$ workshop in Montreal, to which this report is referring. BV leads the $GPWG_2$ activities and project. KM wrote the paper and prepared figure and tables together with BV and OB.

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