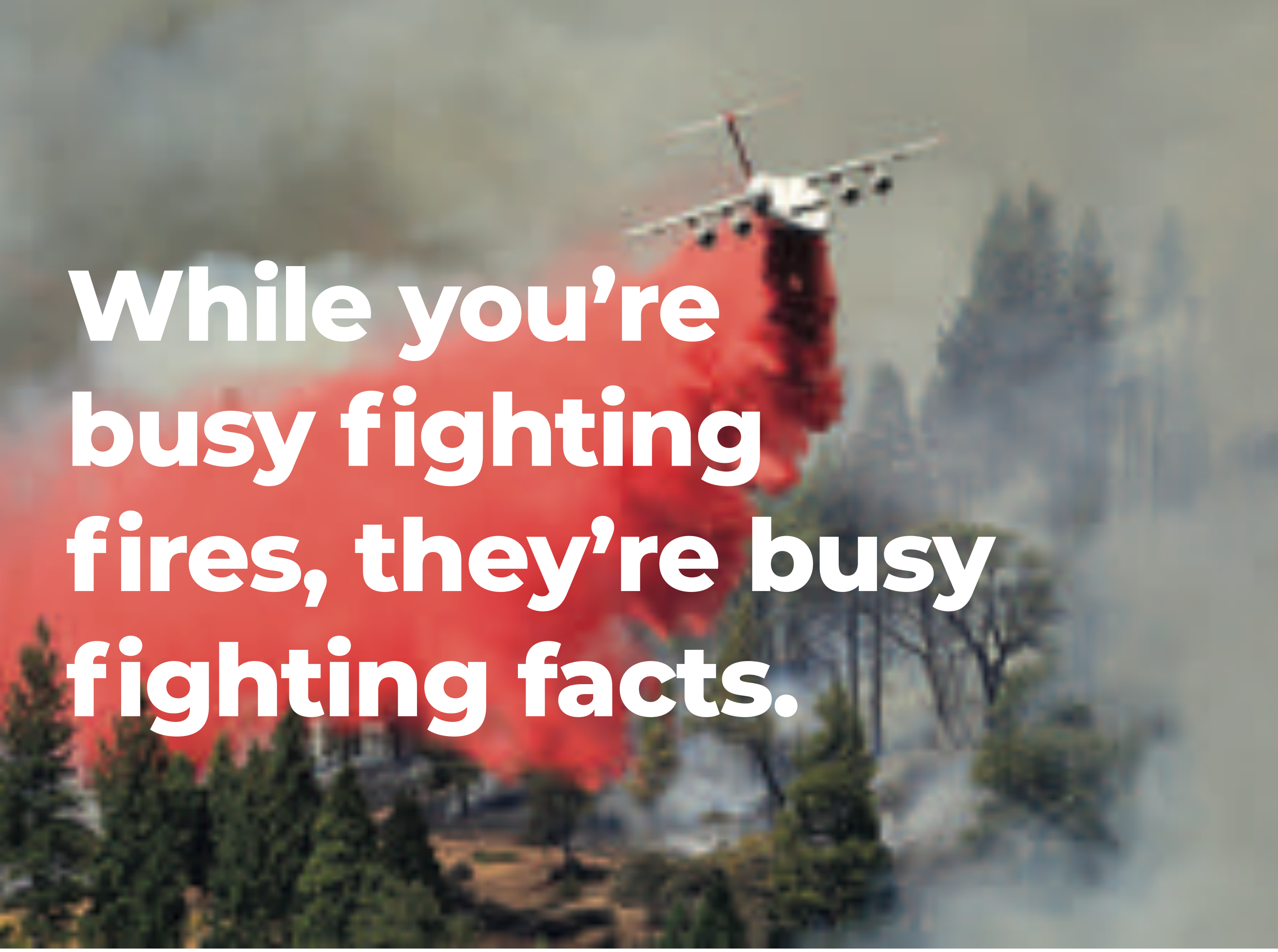
QUARTER 1, 2022
UNITING THE GLOBAL WILDLAND FIRE COMMUNITY

WILDFIRE®

An offical publication of the INTERNATIONAL ASSOCIATION *of* WILDLAND FIRE

SIXTH-GENERATION FIRES
PATAGONIA REGION DEVELOPMENT LEADS TO DEVASTATION

CANADA TACKLES WORKPLACE CULTURE P. 18 | **TREE MAP** P. 22



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NEWS AND OPINION

FIRELINE **5**
THE GAMUT OF FIREFIGHTER SAFETY
BY LAURA KING

PRESIDENT'S DESK **6**
THE HEART OF OUR COMMUNITY
BY JOAQUIN RAMIREZ CISNERO

IAWF NEWS **9**
CONFERENCES, EVENTS AND UPDATES

THOUGHTS ON LEADERSHIP **44**
A LEGACY OF LEADERSHIP
BY LAURA KING AND MICHAEL DEGROSKY

FEATURES

IJWF ARTICLES THAT MAKE YOU THINK **16**
A SELECTION OF IJWF OPEN-ACCESS
PIECES AVAILABLE FOR REVIEW

SIXTH-GENERATION FIRES **18**
PATAGONIA REGION DEVELOPMENT
LEADS TO DEVASTATION
BY MERCEDES BASHFISCHER, MARC CASTELLNOU AND NICOLAS DE AGOSTINI

TREE MAP **22**
A DATASET OF FOREST STRUCTURE FOR USE IN LAND
AND FIRE MANAGEMENT
BY KARIN RILEY, WITH MARK FINNEY AND ISAAC GRENFELL

INDUSTRY STANDARD **24**
UNDERSTANDING THE SCIENCE OF
CHEMICAL RETARDANTS
BY EDWARD GOLDBERG

EXTREME EVENTS **28**
THE LINK BETWEEN WILDFIRES AND CLIMATE CHANGE
BY RICK MCRAE

THE FUTURE OF FORECASTING FIRE DANGER ... **34**
DEVELOPING THE AUSTRALIAN FIRE BEHAVIOUR INDEX
BY JEN HOLLIS AND STUART MATTHEWS

CANADA TACKLES WORKPLACE CULTURE **40**
LGBTQ PERSONNEL REPORT HIGHER
LEVELS OF DISSATISFACTION
BY LAURIE VANDESCHOOT AND NINA VAUGHAN

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Dauntless Air is an aerial firefighting company that exists to protect people, land and property. We fly to win the war against wildfires.

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THE GAMUT OF FIREFIGHTER SAFETY

As a Canadian, I'm impressed that the Canadian Interagency Forest Fire Centre (CIFFC) had the wherewithal to survey firefighters about equity, diversity, and inclusion.

It's humbling for an employer to learn that a workplace is less than ideal. And it's even more humbling – and disturbing – to learn that there's an element of "intentional incivility, harassment and discrimination being experienced and witnessed" among deployed firefighters.

Full disclosure: I am employed by CIFFC as a part-time contractor in a communications role; I have no connection to the survey, the consultants who conducted it, or the firefighters who responded.

CIFFC will address the survey results with a four-phase plan: focus groups and an audit of policies; a respectful-workplace culture assessment report; the development of a national strategy focused on EDI; and the identification of policies and practices to support the psychological health and safety of deployed members.

"We know that not everyone is experiencing deployments in the same way," CIFFC executive director Kim Connors says in our story on page18.

"Let me be unequivocal: CIFFC and its member agencies find no place for harassment, bullying, or other forms of disrespectful workplace behaviors by deployed personnel or contractors."

Firefighter safety, which includes PPE and strategy/tactics, and also bullying and harassment, is a key pillar of the IAWF strategic direction that was developed back in 1997 by the board and president Michael DeGrosky.

I had the privilege of interviewing DeGrosky in mid-January (page 44); firefighter safety, he said, was the biggest and most important issue during his time on the board, and which, of course, led to the safety summit, now an IAWF staple that draws presenters and participants from around the globe.

This year, the 17th International Wildland Fire Safety Summit will be held in conjunction with the 9th International Conference on Forest Fire Research (ICFFR) in November. ICFFR conference chair Domingos Viegas outlines conference details on page 9.

Notably, the CIFFC survey revealed that while respondents felt positive about their deployment experiences, some areas require attention related to workplace culture and behaviors.

Almost 30 per cent of the 530 respondents disagreed that they had been properly briefed by the receiving agency on how to report workplace concerns while on deployment, 10 per cent did not feel they could discuss workplace issues with their direct supervisors, and nine per cent did not feel that humor was used appropriately in the workplace.

Fascinatingly, the consultants said, the results indicate that deployed members love their jobs, and like being deployed through CIFFC, but they are willing to put up with high levels of disrespectful workplace behaviours to do so – which shouldn't be the case.

Completely unrelated to the CIFFC survey, I asked DeGrosky during our conversation what he thinks is the most important issue the IAWF needs to tackle.

"I think, I think the current focus interest on diversity, equity and inclusion within the wildland fire service is the one of the big topics of our time," he said, noting that fire-adapted communities and community adaptation to fire are equally significant.

An IAWF/*Wildfire* magazine survey in the fall of 2020 asked readers to identify topics they wanted to see included in future issues. There were 111 responses to that question; 40 people ticked diversity and inclusion – it ranked third lowest on a list of 20 topics, the top five of which were research and science (pages 16, 22 and 24), fire behavior, prescribed fire, fire effects and fire ecology, weather and climate (page 28, 40), and international activities and issues (page 34).

Our objective is to provide subject matter, stories, and opinion pieces that are relevant to all readers, from researchers and scientists to fire managers, fire-behavior analysts, fuels specialists, pilots, firefighters and officers, mapping experts, health and safety personnel, consultants, and retired folks whose expertise is invaluable.

As always, let us know if we've succeeded; email me at **laura@iawfonline.org.**

Laura King
Managing editor
Wildfire

THE HEART OF OUR COMMUNITY

JOAQUIN RAMIREZ CISNERO
IAWF PRESIDENT

In my first message as IAWF president, I ask you to stop for a moment with me and gather the memories that come to mind when you look at your wildfire career. Whether you've enjoyed a lengthy career or are just starting out, I think that collectively, these memories form an incredible collection of the best of what we can do for each other. The IAWF is a vibrant community. When I reflect on the fantastic opportunities that I have experienced during my career in this challenging field, the dedication of my colleagues comes to mind. Share your adventure with us and let's grow our association to reflect the diversity in our community. There are many disciplines and individuals who fuel our community. You can feel how big their hearts are. Consider the following examples.

JOSE LUIS DUCE

PRESCRIBED FIRE TRAINING SPECIALIST AND CALIFORNIA BURN BOSS, WITH THE WATERSHED TRAINING AND RESEARCH CENTER

Our wildland firefighters face nature unleashed in extreme conditions every year across the globe. During longer and harder fire seasons, they put themselves on the line to preserve and protect fellow citizens and our most beloved landscapes. They recognize how to use "good fire," learning from a time and a culture that had a more balanced relationship with the fire than we have had recently. To have achieved this, an outstanding level of commitment, sacrifice, camaraderie, and generosity is what we find when we share time with them.

KELLY MARTIN

FORMER CHIEF OF FIRE AND AVIATION, YOSEMITE NATIONAL PARK, NATIONAL PARK SERVICE, PACIFIC WEST REGION

Our wildfire incident managers deal with the complexity of short-term response, mastering the art of emergency management and leading ICS to become the standard for other organizations. At the same time, they deal with the long-term planning of creating safer communities and more resilient landscapes through fuels management and community engagement, usually with very few resources. They do all this, facing the opposition of sometimes short-sighted groups that cannot fully appreciate the complexity of the big-picture challenge.

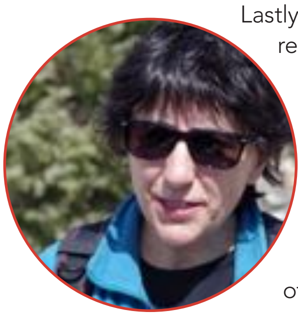
MATT JOLLY
RESEARCHER AT RMRS MISSOULA FIRE LAB

Our fellow scientists face the immense challenges of understanding the different scales of the interaction of fire on our planet, from the micro-scale processes to the uncharted territories of the interactions at a global scale. They analyze the past to predict the long-term future with resources so scarce that if we invent a ratio of complexity of a problem versus the budget invested to get significant advances, the numbers would be huge compared to any other discipline. Add to that the immense challenges in social sciences, where so much understanding is needed to balance our relationship with our favorite phenomena: knowing that there are no lone solutions that work everywhere, anytime.

JAVIER BAENA
FOUNDER & CEO AT VALLFIREST TECNOLOGÍAS FORESTALES

The innovators in our community are improving the conditions of tomorrow's job environment. They create solutions, from aerial resources to sensors and software, from better pumps and hand tools to lighter and stronger personal protective equipment. Within the technologist community, you will find nonstop innovation and a willingness to partner and improve together.

LUZ VALBUENA
PROFESSOR OF FIRE ECOLOGY, MASTER FUEGO, UNIVERSIDAD DE LEON, SPAIN



Lastly, our fellow academics, research students and members of the professional training community share with passion their love to know more and to aim higher; they pose the hard questions to the ones who think they have seen it all, and keep us all eager students of wildland fire every day.

The challenges we face are of a planetary scale. We as an association need to support actions everywhere, from places in which we need to reintroduce fire, to places that need recognition and better conditions for our colleagues. We have to achieve this development goal together and raise that effort to a global collaborative aspiration.

I have the privilege to start 2022 surrounded by the best examples of our vibrant wildfire community, represented in the IAWF board of directors, having received the torch from our immediate past president, Toddi Steelman. Steelman skillfully led us during one of the most demanding times that our community has experienced. We have learned the value of creating safe environments, caring for each other, and using all the means we have to keep communication alive during tough times. Our community now collaborates, shares, and learns from all points on the planet, as we experienced during our most recent conferences.

This May in Pasadena, and June in Melbourne, we will address this global challenge together at IAWF's first Fire & Climate conference. This event will provide an incredible opportunity to get back together in a hybrid environment for those who wish to gather in person and others who wish to attend remotely. It will enrich us as professionals to deliver the best science and knowledge to a public that is receiving partial messages and sometimes the wrong ones from others.

We are a unique association with a plural, global, and highly informed voice. Together and with our partners, the Association for Fire Ecology and the Pau Costa Foundation, we will send a powerful message. This outreach of our voice is already illustrated in IAWF's most recent Climate Change & Wildfire position paper; other position papers – the next focusing on prescribed burns - will add to this chorus. IAWF needs your voice, your experience, and your vision to make this association as diverse and global as we can. The heart of our community makes a difference every day. Let's beat together.

ABOUT THE AUTHOR

Joaquin Ramirez Cisneros is a wildland fire technologist who has been working for the last 25 years to bridge the gap between scientists and end users. In 2013, Ramirez moved to San Diego from Spain, and now works with agencies worldwide trying to convert the best science into actionable tools. Ramirez is the creator of several of the most advanced fire behavior software model implementations and decision support systems, including the Wildfire Analyst and fiResponse software tools. Since 2011, Ramirez has co-ordinated the first European M.S. in Forest Fires (www.masterfuegoforestal.es) with Prof. Rodriguez Francisco y Silva (UCO) and Prof. Domingo Molina (UdL). Ramirez is a founder and active member of the Pau Costa Foundation. He earned his PhD in remote sensing and GIS at the University of Leon in 2003, an M.S. in forestry from the University of Lleida, and his B.S. in forest engineering from the Polytechnical University of Madrid, Spain.

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ICFFR TO HOST 2022 SAFETY SUMMIT

When the 9th International Conference on Forest Fire Research (ICFFR) begins in November, 32 years will have passed since the first conference took place in Coimbra, Portugal, in 1990. Back then, 87 participants from 12 countries presented 63 oral communications, mainly related to fire behavior and modelling.

Gathering every four years, the ICFFR has built a reputation for providing a hospitable atmosphere while striving to be one of the top scientific forums in the field. In 2018, we hosted almost 250 participants, and speakers presented more than 200 oral communications and 45 posters in the four days of the event.

From Nov. 11-18, the Forest Fire Research Centre of ADAI, at the University of Coimbra (ADAI-CEIF), will once again organize the ICFFR in Coimbra.

This edition of the conference is proving to be a challenge to organize, during a time in which the world is dealing with the COVID-19 pandemic. We are preparing the conference to be an in-person event. We are, of course, considering options, in the case that the health situation in Portugal or worldwide imposes restrictions.

In the 2022 IX ICFFR we are proud to once again be associated with the International Association of Wildland Fire (IAWF) and host the 17th International Wildland Fire Safety Summit, after hosting the 14th Conference on Fire and Meteorology and the Wildland Fire Safety Summit in Luso in 2002, together with the IV ICFFR.

The conference has had many truly memorable moments in the past, from the keynotes to the visits to ADAI-CEIF's Forest Fire Research Laboratory. We recall many prominent researchers who participated in previous editions of the conference, several of them delivering invited lectures, including Richard Rothermel, Stephen Pyne, Michael Weber, Philip Thomas, Louis Trabaud, Malcolm Gill, Michael Fosberg, Ricardo Velez, Jack Cohen, Patricia Andrews, Robert Martin, Brian Stocks, Richard Thornton, Albert Simard, Martin Alexander, Wendy Anderson, Anatoly Grishin, Philip Chenney, Mark Finney, Bret Butler, Susan Conard, Emilio Chuvieco and Mike Flannigan. Flannigan has been the chair of the scientific committee since 2006 and contributed strongly to the high quality of the evaluation process of the paper submissions.

As has been the custom, preceding the conference, two short courses will be offered.

On Nov. 11, the 6th Short Course on Fire Safety will be aimed mostly at operational personnel but is also of interest to researchers and students. The course is focused on presenting the advances on methods, protective equipment, and technology to improve fire safety both to operational personnel and to civilians. This 6th edition will be co-ordinated by Jason Sharples, from the School of Science at the University of New South Wales, Canberra, Australia. He succeeds Bret Butler, from the USDA, who has organized the last three editions. This short course is usually bi-lingual, with simultaneous translation in English and Portuguese.

On Nov. 12-13, the 9th Short Course on Fire Behavior will take place, mainly aimed at researchers and students, given the more scientific focus. The objective of the course is to share the more recent and advanced studies on fire behavior modelling, based on the work presented by the top scientist who are invited. As in the last editions, Albert Simeoni, from the Worcester Polytechnic Institute will be the co-ordinator. We hold a special place in our memories of the first edition of this short course, as it was co-ordinated by Richard Rothermel in 1990.

Speaking of Rothermel, next year will be the fiftieth anniversary of his original and outstanding publication, Mathematical Model on Fire Behavior Modeling, that is still considered the heart of many fire behavior to promote a special session dedicated to this milestone in fire science.

One of the highlights of the conference is usually the visit to our Fire Research Laboratory. The lab has several combustion tables and tunnels, mostly of our own design and construction, that facilitate the study of many different aspects of fire behavior; it is the largest laboratory in Europe fully dedicated to research in this field.

At the end of the conference the traditional field trip will take the participants to discover the natural beauty of Portugal, while we explore specific regions that have experienced wildfires and their impact.

For more information on this conference please visit www.adai.pt/icffr

- BY DOMINGOS VIEGAS

IAWF WELCOMES NEW BOARD MEMBERS

AMY CARDINAL CHRISTIANSON
Fire research scientist
Canadian Forest Service, Natural Resources Canada
Alberta, Canada

Dr. Amy Cardinal Christianson is a Métis woman from Treaty 8 territory, living in Treaty 6 (central Alberta). She is a fire research scientist with the Canadian Forest Service, Natural Resources Canada. Her research explores Indigenous fire stewardship, Indigenous wildland firefighters, wildfire evacuations, and Indigenous research methodology. Amy co-hosts the Good Fire podcast, which looks at Indigenous fire use around the world. She recently co-authored the book First Nations Wildfire Evacuations: A Guide for Communities and External Agencies with Tara K. McGee and Blazing the Trail: Celebrating Indigenous Fire Stewardship with Indigenous colleagues.

SARAH HARRIS
Manager
Research and Development at Country Fire Authority
Victoria, Australia

Dr Sarah Harris is the manager, research and development at Country Fire Authority (CFA). Within this role, Sarah undertakes and drives best-practice research and development that enhances corporate knowledge, community partnerships and operational capability in relation to wildfire risk. Sarah has almost 20 years of research experience including completing her PhD at Monash University funded by NOAA Climate and Global Change Program, and as a Caltech postdoctoral research scholar based at NASA's Jet Propulsion Laboratory. Sarah's research focuses on the variability and change in fire weather, climate-wildfire links and prediction of seasonal wildfire activity, understanding fire behaviour and using remotely sensed data in wildfire applications. Sarah is an active participant in several Australasian Fire and Emergency Services Authority Council (AFAC) groups, including deputy chair of the climate change group and deputy chair, predictive services-research working group, and is a contributing author for IPCC 6AR Working Group II – Australasian chapter. Sarah supports incident management throughout the fire season as a fire behaviour analyst.

TREVOR HOWARD
Retired, Department of Biodiversity, Conservation and Attractions
Western Australia

Commencing in forestry in 1975, Trevor has extensive experience in land, fire and emergency management across several states including the Northern Territory, New South Wales, Queensland and Western Australia. His career has included forest and rangeland fires, operational, incident management and strategic command roles, engaging with remote Aboriginal communities, and working at regional, state and national levels. Trevor is a former member of the National Council of the Australian Institute of Agricultural Science and Technology, as well as the North Australia Fire Managers Group which brings together land management agencies and emergency services from several jurisdictions. He has also chaired the fire aviation subcommittee of the Interagency Bushfire Operations Committee in Western Australia. With expertise in prescribed burning and the management of risk, Trevor has provided leadership in shaping national best practices, conducting post-incident reviews, managing assurance programs, sharing lessons learned and guiding continual improvement. Trevor retired from the Department of Biodiversity, Conservation and Attractions in 2020 and continues to work in fire management through the private sector. Trevor has qualifications in public safety, anthropology, agriculture and rangeland management, a strong interest in the sustainable use and management of natural resources, and a passion for the human dimensions of wildland fire.

XINYAN HUANG
Assistant professor
Department of Building Environment and Energy Engineering
Hong Kong Polytechnic University

Dr Xinyan Huang is an assistant professor at The Hong Kong Polytechnic University and the deputy director of the Research Centre for Fire Safety Engineering. He received his PhD from Imperial College London, MSc from the University of California at San Diego, and BEng from Southeast University, China. Before moving to Hong Kong, Huang was a postdoc and lecturer at the University of California at Berkeley and collaborated with NASA on spacecraft fire safety. Huang's research interests include fire dynamics and modelling, smouldering wildfires, and smart fire fighting with artificial intelligence, and he has co-authored more than 100 journal papers. Huang is an associate editor of the International Journal of Wildland Fire and Fire Technology, an editorial member of Fire Safety Journal, a chartered engineer, a committee member for Hong Kong Fire Safety Code, and a fire expert for the high court. He is a winner of Bernard Lewis Fellowship and Sugden Best Paper Award from Combustion Institute, IAFSS Proulx Early Career Award, Ricardo Award from Institute of Physics, Fire Engineering Grand Award from The Hong Kong Institution of Engineers, "5 under 35" and Bono Award from Society of Fire Protection Engineers.

ADAM LEAVESLEY

Manager – prescribed burning and research utilisation
Parks and Conservation Service
Australian Capital Territory (ACT), Canberra, Australia

Adam is a fire ecologist-turned-bushfire practitioner with experience across Australia from Tasmania to the Top End, and expertise in prescribed burning and research utilisation. A key function of Adam's role is bringing new research and technology into operational use with a focus on adapting the ACT Parks fire management program to meet the extremes of climate changed fire regimes. Adam has contributed to the utilisation component of a number of successful research partnerships, bringing to the ACT a local version of FIREMON burn severity mapping, a post-fire hydrological risk tool, high-resolution LiDAR-derived fuel maps, and three high resolution methods for estimating landscape flammability. Adam has a keen interest in cultural burning and served as lead end-user of the Bushfire and Natural Hazards CRC research project aimed at supporting the expansion and enhancement of agency partnerships with traditional custodians in southern Australia. Adam is a member of the National Council for Emergency Services (AFAC) research committee and Australian representative to the Global Wildfire Information System supported by the European Union. He served as the lead editor of the book: Prescribed Burning in Australasia: The Science, Practice and Politics of Burning the Bush, which was published by AFAC in 2020.

NÚRIA PRAT-GUITART

Pau Costa Foundation
R&D&I projects
Spain

Núria earned her PhD in environmental sciences from the University College Dublin, Ireland (2016), and her master's in biology from the University of Santiago de Compostela (2010-2011), and graduated in geography from the University of Barcelona (2006-2010). In 2016, Núria joined the Pau Costa Foundation executive team; she leas the research area, promoting, and participating in several initiatives to innovatively connect fire management and science. Núria is the co-ordinator of the AFAN project, dedicated to connecting wildfire experts across Europe, and is an executive board member of PyroLife, a PhD training network on wildfire science operating across 10 European universities. Additionally, Núria has participated in several research and innovation projects funded by the European Commission. Her main interests are fire ecology, fire dynamics and the effects of fire on ecosystems.

IAWF RECEIVES PASSIONATE RESPONSES TO CLIMATE POSITION PAPER

COMMENTS

The IAWF asked members for feedback on its position paper on climate change, which comprised the cover story in the Q4-2021 issue of Wildfire. Here are the responses.

Q: On a scale of 1-5, how much do you agree with the IAWF climate change position statement?
A: Average 4.5

Q: How likely are you to use the position paper as a reference guide for your own work or education?
A: Average 4

- To help address some of the issues raised in this position paper the IAWF should create another membership level for "community" members, so that local communities can become more engaged in the issues and learning within the global fire community. These could be for non-practitioner/ non-research people with a greater interest in wildland fire.
- There are some pieces where the tense shifts from "this is happening" to "this may/will happen"; maybe this is due to research evidence but keeping the "this is happening and will keep happening" framing throughout would strengthen some spots I think there needs to be more prominent mention of the fact that natural disasters, including fire, already disproportionately impact disadvantaged communities and people, particularly those who are POC, lower-income, rent houses, etc. There should be a call-to-action piece that specifically calls out the need to address this in how we respond to wildfires, implement prescribed fires, build resilient communities, etc.
- I would like to see the volunteer fire service's role in wildland fire prevention and suppression addressed. It would be nice to know the true cost savings the volunteer firefighter is to this country. How many wildland fires do VFDs put out, and on who's land? How many hours do they spend doing fire prevention work? How much money do they spend on wildfire? How often are they doing IA on federal lands?
- Unless I missed it, I think we should address the root causes that will exacerbate the wildfire problem, such as the movement of insect and disease throughout the forests of the world that cause the decline of forest health, which provides a ready fuel source. The spread of non-native species which alter the eco systems, which in turn causes an imbalance in the forest health, as well as displaces the native flora and fauna.
- How the fire community can and should join with broader, larger efforts to advocate for the large-scale actions needed to genuinely address our climate crisis.
- Workshopping around reimagining the fire workforce and communicating this with policy and decision makers.

G'DAY FROM AUSTRALIA,

I have read email asking for feedback on the position statement on climate change and saw the feedback page. Rather than just ticking a box, I felt the need to provide detailed feedback. In summary the position paper is desperately needed. It misses the mark in a number of areas. Basically, the impact of climate change on wildland fire is a lot more serious than you are stating. A lot. Here are my detailed comments. I hope they are useful. More background is available if needed.

CHEERS,

Rick McRae
BUSHFIRE RESEARCH GROUP | SCHOOL OF SCIENCE | UNSW CANBERRA | UNIVERSITY OF NEW SOUTH WALES

II. HUMAN-INDUCED CLIMATE CHANGE AND THE RISK

This section misses the mark. It is not just warming – there are other major processes underway. The ability of the oceans to absorb heat is changing, causing major anomalies in SSTAs. These in turn affect the moisture content of weather systems affecting nearby continental areas and have been clear precursors to all major wildfire events of recent years.

Even the smoke discussion misses the big picture for eastern Australia. Climate change-driven changes in weather systems and their interactions with terrain have created mechanisms to expose communities to smoke types not normal encountered on the surface. Canberra had the worst air quality in the world in early 2020, so I've breathed this.

III. CLIMATE, WEATHER AND FIRE

It is not just a matter of fire seasons getting longer – it is more complex than that. Using MODIS hotspot data, McRae (2019) showed that in different part of eastern Australia seasons are getting earlier and later in a complex pattern, but are evolving into a more uniform overall spatial pattern. This creates resource sharing problems.

In a real sense it is no longer just a problem of fire seasons. Black Summer sensu lato started in the Tasmanian central plateau in February 2019 and in the eastern Victorian high country in March 2019. The same extraordinary activity pattern continued after a "winter break", resuming in August in Queensland. This is unprecedented.

It is easy to say that Black Summer was due to global warming. However true that may be, it provides no useful insights. Black Summer started with a persistent pattern of cool sea surface temperature anomalies west of Australia. This ensured dry air moving in with the synoptic circulation. Differential heating between the land and sea in the south-east drove the formation complex, branched trough-lines and delayed cold front passage. This was the context within which record heat acted to form dangerous fire conditions.

It must be stated loud and clear that Black Summer was completely unprecedented. Peterson, et al. (2021) makes this clear. There is no ability to put probabilities of reccurrence on this. What is clear is that we must pay heed to messages from British Columbia where the heat dome led to massive fire escalation and an unprecedented pyrogenic lightning event. There is a small jump from a complex branched trough to a heat dome. To have had a set of violent pyro-convective plumes rotating in an anti-clockwise fashion in a meso-scale synoptic system should make all fire services nervous.

IV. FIRE REGIMES, ECOSYSTEM CHANGE AND FUEL MANAGEMENT

In south-east Australia we are seeing forest stands stressed by climate change – repeated impacts of Blow-Up Fire Events (BUFEs), extreme drought, hailstorms, and susceptibility to insect or fungal attack. Forest fire danger forecasts use a Drought Factor derived from a Drought Index. Two are

in widespread use: Keetch-Byram Drought Index and Soil Dryness Index. Both require a contextual input: average annual rainfall for the former and canopy type for the latter. Both inputs are now reflecting climate change – declines in AAR and change in stand type to a more arid type. The net result for both is that, for example, a 15 millimetre rainfall event will have greater impact on Drought Factor (fine fuel availability) for longer. Through this mechanism, climate change can reduce forest fire danger. Neither dynamic is currently embedded in the official fire weather forecasting infrastructure.

The discussion of the role of prescribed burning (PB) is flawed. In the lead-up to Black Summer our forests were subjected to extreme drought. BoM NDVI anomaly maps put vast tracts at between 3 and 5 sigma from the mean. The entire structure of forest and woodland stands decayed "to duff." Shrub layers disappeared; grass layers did the same. Canopies died back. The impact on stand flammable biomass was vastly greater than even the best conceivable PB program, and over the entire landscape. And then we had the worst fires ever recorded. This shows that there is a non-linear relationship between fuel reduction and risk as contextual severity increases. As normal fire risk increases, the impact of PB kicks in and goes up. After a threshold is passed, that total risk escalates drastically while the impact of PB decays to minor levels. In SE Australia during Black Summer, the effects of PB were limited to a reduction of intensity from one year old burning only. We cannot make a claim to be able to mitigate the impacts of any future replay of Black Summer through fuel management.

Another impact of the previous point is that any carefully planned indigenous landscape management is at jeopardy if another Black Summer event occurs. Entire ecosystems that do not experience fire were trashed by Black Summer. Carefully crafted fire regimes were reset.

Again arising from the previous point, we cannot discuss global wildfire problems from an Anglo/Franco-centric perspective. A massive La Nina in place now as the austral Summer commences indicates a potential for the next BS event to be near the southern edge of Amazonia. How do we – IAWF – help prevent (or, more realistically, mitigate) a looming global catastrophe?

V. WILDFIRE MANAGEMENT

Weather: While weather parameters will change due to climate change, we need to focus on the context. Is the profile dryness changing? Is the convective cap changing? As things warm. Is the LCL going up or down? Many of the questions asked decades ago by pioneers like Don Haines remain to be fully answered.

Support systems: The biggest challenge globally is that the international sharing of key resources, whether it be FBANs, incident management specialists, or Large Air Tankers we are near the limits of sustainability.

VI. CALLS TO ACTION

The Vision: IAWF seeks to safely and effectively extinguish wildfires, when necessary; to use prescribed and wildland fire when possible to meet protection and land and resource management objectives; to manage natural resources through progressive fuel reduction to increase landscape resilience; and to create fire adapted communities that can accept shared responsibility for addressing how to co-exist with smoke and wildland fire.

In my view this is a seriously flawed statement. Let me explain.

Climate change is pushing us into a context where wildfire suppression is no longer the means to mitigate threats to our communities and our environment. I was in the IMT for the first major climate change impact on an Australian city – the 2003 Canberra wildfires. The enquiries after these fires listened carefully to experts, many of whom had a conflict of interest arising from the income streams from Governments and the forestry sector to carry out PB. Despite the implementation of the usual raft of systems upgrades. had rains been delayed a week, a full replay of 2003 was expected in early February 2020.

While there may be discussions around probability of repeat analyses from climate change scientists, the context for both 2003 and 2020 is clear. I maintain the Australian pyroCb register. From 1978 to 2001 Australia had experienced between 2 and 4 pyroCbs in total. After 2003 there was consternation that we had reached 16 in total. It now stands at 114, with a doubling during Black Summer alone. That is the context.

Whether it is in SE Australia, California or the Mediterranean we are seeing more and more news footage of towns razed by wildfires. Risk reduction will have to evolve. If a BUFE occurs, the IAP should have the incident objective as "Save lives." The best way to achieve this is to forecast BUFEs. Work is rapidly progressing on this, but with a serious handicap.

Ninety-plus per cent of fires are steady state fires – if you know the weather, terrain and fuel, then you can (mostly) make an unambiguous prediction of fire behaviour. These fires cause a limited amount of damage because firefighters have career-long training and experience with them, excellent resources and systems. Dynamic fires are coupled with the atmosphere and have feedback mechanisms in play allowing rapid escalation. In Australia these are less than five per cent of fires and cause over 95 per cent of the damage. In Canberra, in 80 years of steady-state fire activity we lost no houses, but in one day of dynamic fire activity we lost 512.

And yet dynamic fires get less than five pre cent of the attention at the industry level. I expect the same is true in the United States, as it was in Canada when I was there as an FBAN in 2017. In fact much of the potentially relevant research confounds the two types of fire, producing meaningless results.

ACTION 1. INCREASE PRESCRIBED BURNING

Increase PB! What more can I say? McRae and Sharples (2015) showed that prior PB had limited effectiveness again BUFEs.

The vast majority of MODIS hotspots recorded in Australia are in the tropical savannah belt. The numbers dwarf those of other parts on the continent. There is little commonality between tropical and temperate fire management, and it should not be oversold.

Further, in recent years the world has seen the first ever confirmed tropical pyroCbs (in Bolivia), indicating a potentially serious escalation of tropical fire risks to communities not accustomed to dynamic fire behaviour.

ACTION 2. SHARED RESPONSIBILITY

While this is true, it needs to be carefully targeted. I have been heavily involved in three of the worst extreme wildfire outbreaks, 2003 in Canberra, 2017 in British Columbia and 2019 in SE Australia. These have things in common: the community feels helpless because things evolve so quickly that their plans cannot keep up; and a significant involvement by the military and other external agencies due to swamping of fire service's capabilities. At time when climate change is having its fullest impact, the tagline is actually "shared helplessness."

ACTION 3: REIMAGINE AND INVEST IN THE WILDLAND FIRE MANAGEMENT WORKFORCE AND SYSTEMS

As I said earlier there are two types of fire, and steady-state fires are well managed by career firefighters. This should never be belittled or reduced. It is not obsolete. What we MUST do is add a career overlay for dynamic fires. We must not imagine that extra burning-out is a useful tool for dynamic fires. During Black Summer, fire crews doing burn-out operations under the auspices of the IAP created some of the most intense fire activity ever observed. We need to be able to switch between offensive and defensive IAPs. In defensive mode no-one should be allowed to use a drip-torch. We do not yet know if "overwhelming force" has a role during dynamic fire behaviour.

Analysis of Black Summer shows spatiotemporal patterns that could be used to set appropriate IAP types in place. It shows the inevitability of dynamic fires in rugged landscape doing what they wish and ignoring what we throw at them. Large Air Tankers then serve only to save individual structures – hardly cost effective when the entire landscape is threatened.

ACTION 5. CREATE OPPORTUNITIES FOR CONTINUOUS IMPROVEMENT AND ADAPTIVE MANAGEMENT MUCH OF WHAT IS WRITTEN FOR THIS ACTION IS NOT JUSTIFIED.

The rate of change is speeding up. Record fire outbreaks, globally, have been logged in 2001,2009, 2017 then 2019. 2021 came close. How do we get the science done in time to drive useful lessons-learned? How do we share them globally? How do we coordinate the science? In Australia, the United States, Canada or Europe, papers are strongly biased to citing papers from the same region. We use different key modelling platforms. Sharples (2019) extended the Australian concept that fire danger is really wind speed divided by fuel moisture content to include Canadian fuels.

A decade ago, we published a paper (Sharples, et al., 2010) that showed that foehn winds affect fire danger in Australia. Four years ago, two damaging, foehn-driven BUFEs showed what can result. Black Summer produced over 40 more foehn-driven BUFEs. If ever there was a clear case for international exchange of skills, lessons and science this is it.

IJWF ARTICLES THAT MAKE YOU THINK

A SELECTION OF JOURNAL OPEN-ACCESS PIECES AVAILABLE TO VIEW

DEAD AND DOWN WOODY DEBRIS FUEL LOADS IN CANADIAN FORESTS

BY CHELENE C. HANES , XIANLI WANG AND WILLIAM J. DE GROOT

In Canada, fire behaviour is modelled based on a fuel classification system of 16 fuel types. Average fuel loads are used to represent a wide range of variability within each fuel type, which can lead to inaccurate predictions of fire behaviour. Dead and down woody debris (DWD) is a major component of surface fuels affecting surface fuel consumption, potential crown fire initiation, and resulting crown fuel consumption and overall head fire intensity. This study compiled a national database of DWD fuel loads and analysed it for predictive driving variables. This study provides tools to improve our understanding of the spatial distribution of DWD across Canada, which will enhance our ability to represent its contribution within fire behaviour and fire effects models.

www.publish.csiro.au/WF/WF21023

'ANY PREDICTION IS BETTER THAN NONE?' A STUDY OF THE PERCEPTIONS OF FIRE BEHAVIOUR ANALYSIS USERS IN AUSTRALIA

TIMOTHY NEALE, MATTEO VERGANI, CHLOE BEGG, MUSA KILINC, MIKE WOUTERS AND SARAH HARRIS

Internationally, fire and land management agencies are increasingly using forms of predictive services to inform wildfire planning and operational response. This trend is particularly pronounced in Australia where, over the past two decades, there has been an alignment between increases in investments in fire behaviour analysis tools, the training and development of fire behaviour analysts (FBANs), and official inquiries recommending the expanded use of these tools and analysts. However, while there is a relative lack of scholarship on the utilisation of predictive services, existing research suggests that institutional investment and availability are poor indicators of use in contexts with established social dynamics of trust and authority. To better understand the utilisation of predictive services in Australia, we undertook a survey of key predictive services users (e.g. incident controllers, planning officers) in order to test several hypotheses developed from existing studies and ethnographic fieldwork. Our results provide directions for further research and indicate that, rather than simply invest in tools and systems, there is a need for fire management agencies to foster personal connection between predictive services practitioners, their tools and their users.

www.publish.csiro.au/WF/WF21100

VARIABILITY IN WILDLAND FUEL PATCHES FOLLOWING HIGH-SEVERITY FIRE AND POST-FIRE TREATMENTS IN THE NORTHERN SIERRA NEVADA

IAN B. MOORE, BRANDON M. COLLINS, DANIEL E. FOSTER, RYAN E. TOMPKINS, JENS T. STEVENS AND SCOTT L. STEPHENS

Surface fuel loads are highly variable in many wildland settings, which can have many important ecological effects, especially during a wildland fire. This variability is not well described by a single metric (e.g. mean load), so quantifying traits such as variability, continuity and spatial arrangement will help more precisely describe surface fuels. This study measured surface fuel variability in the northern Sierra Nevada of California following a high-severity fire that converted a mixed-conifer forest to shrub-dominant vegetation, both before and after a subsequent shrub removal treatment conducted as site preparation for reforestation. Data were collected on vegetation composition, spatial arrangement and biomass load of the common surface fuel components (1–1000-h woody fuel, litter, duff and shrubs). Mean shrub patch length decreased significantly from 9.25 to 1.0m and mean dead and down surface fuel load decreased significantly from 131.4 to

73.4 Mg ha–1. Additionally, probability of encountering a continuous high fuel load segment decreased after treatment. This work demonstrates a method of quantifying important spatial characteristics of surface fuel that could be used in the next generation of fire behaviour models and provides metrics that land managers may consider when designing post-fire reforestation treatments.

www.publish.csiro.au/WF/WF20131

HOW TO MEASURE THE ECONOMIC HEALTH COST OF WILDFIRES – A SYSTEMATIC REVIEW OF THE LITERATURE FOR NORTHERN AMERICA

RUTH DITTRICH AND STUART MCCALLUM

Wildland firefighters in the United States are exposed to a variety of hazards while performing their jobs. Although vehicle accidents and aircraft mishaps claim the most lives, situations where firefighters are caught in a life-threatening, fire behaviour-related event (i.e. an entrapment) constitute a considerable danger because each instance can affect many individuals. In an attempt to advance our understanding of the causes of firefighter entrapments, a review of the pertinent literature and a synthesis of existing data were undertaken. Examination of the historical literature indicated that entrapment potential peaks when fire behaviour rapidly deviates from an assumed trajectory, becomes extreme and compromises the use of escape routes, safety zones or both. Additionally, despite the numerous safety guidelines that have been developed as a result of analysing past entrapments, we found issues with the way factual information from these incidents is reported, recorded and stored that make quantitative investigations difficult. To address this, a fire entrapment database was assembled that revealed when details about the location and time of entrapments are included in analyses, it becomes possible to ascertain trends in space and time and assess the relative influence of various environmental variables on the likelihood of an entrapment. Several research needs were also identified, which highlight the necessity for improvements in both fundamental knowledge and the tools used to disseminate that knowledge.

https://www.publish.csiro.au/WF/WF19091

SIXTH-GENERATION FIRES

PATAGONIA REGION DEVELOPMENT LEADS TO DEVASTATION

BY MERCEDES BACHFISCHER, MARC CASTELLNOU AND NICOLÁS DE AGOSTINI

The Andean Patagonian Region mountains experienced some of the most devastating wildfires in Argentina's recent history during the summer of 2021. Extreme fires, although not new for the region (Chile 2017, Argentina 2018, Bolivia 2019), are clear indicators of change for the worse. Until now, fires were on the dry pampa or hilly forested areas, not in the alpine ecosystems of the Andes. Climate trends and these fires point to a near future with bigger firestorms. This extreme is also confirmed by recent events in the Chilean region. An analysis of the incidents and lessons learned show the wildland urban interface putting increasing pressure on the area, and therefore stress for responders. Attention must be paid to the metres-deep organic soil layer, which is becoming a clear driver of long-lasting fires. A PyroCb event, which was unexpected due to strong wind and highly stable atmosphere over the area, is also a matter of concern. TRANSLATED BY THE PAU COSTA FOUNDATION.

In less than two months in the summer of 2021, the two largest wildfire complexes in Argentina in recent years occurred in the 42nd Parallel Andean Region, a micro-region in Northwest Argentina that includes six main towns and their rural areas.

One of these fires turned out to be a wildland urban interface (WUI) fire, with hundreds of homes destroyed, and fatalities, giving it the dubious distinction of being among such tragic fires as Santa Rosa (U.S., 2017), Kineta (Greece, 2018) and Pedrógão Grande (Portugal, 2017).

The events of 2021 can be classified as sixth-generation fires, with characteristics similar to Las Máquinas and Agua Fría (Chile, 2017 and 2020), El Tajamar (Argentina 2018), Roboré and Otuquis National Park (Bolivia 2019 and 2020). Sixth-generation fires are said to be a consequence of the interaction of climactic and atmospheric conditions; rather than depending on external factors, such as wind, to spread, these fires find their own paths and are unpredictable. Another definition of a sixth-generation fire is an area of more than 5,000 hectares burned, along with aggressiveness, in conjunction with bad weather.

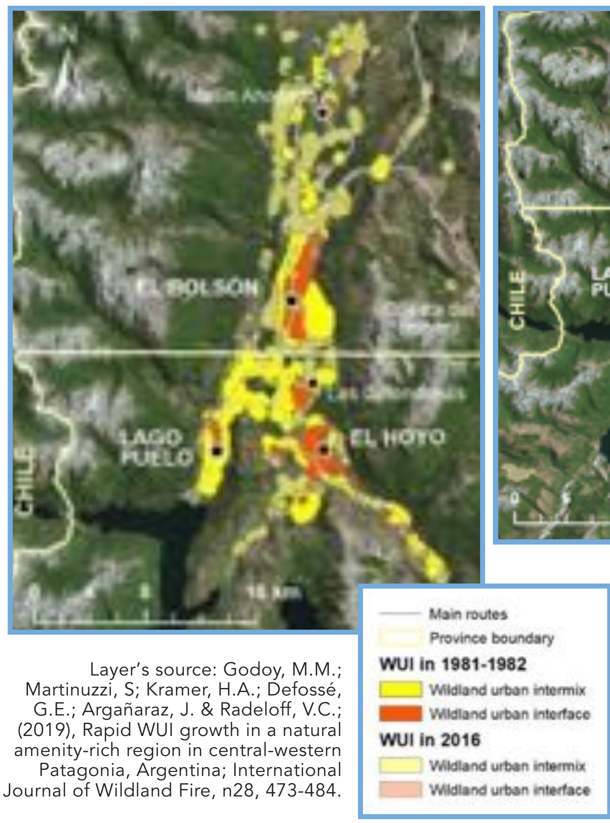
The 42nd Parallel Andean Region is characterized by its glacial valleys surrounded by high peaks, permanent snow, and lakes. The climate is temperate, although on warmer days the temperature can rise to 30 C (86 F). Winds are predominantly from the west-northwest. Summer is dry, and the most contrasting climatic variation in this area is rainfall, which decreases dramatically from west to east, due to the mountains that function as natural barriers to the humid winds from the Pacific. This directly influences the geographic distribution of different types of vegetation, and it is translated into the existence of diverse environments just a few kilometers apart: the Andean Patagonian Forest followed by a transition area, the "ecotone," and finally, further east, the steppe, a large area of flat grassland. Although native species predominate (most of the area is covered by mixed forests dominated by Chilean cedar-Southern Beech (Austrocedrus–Nothofagu), in some spots, there are exotic species such as ponderosa pine, Rocky Mountain lodgepole pine, and Douglas fir).

In this region, the primary employer is government administration, followed by tourism and leisure activities. The region boasts intensive agriculture, with the production of berries and hops. Since the 1990s, timber and extensive livestock production have declined.

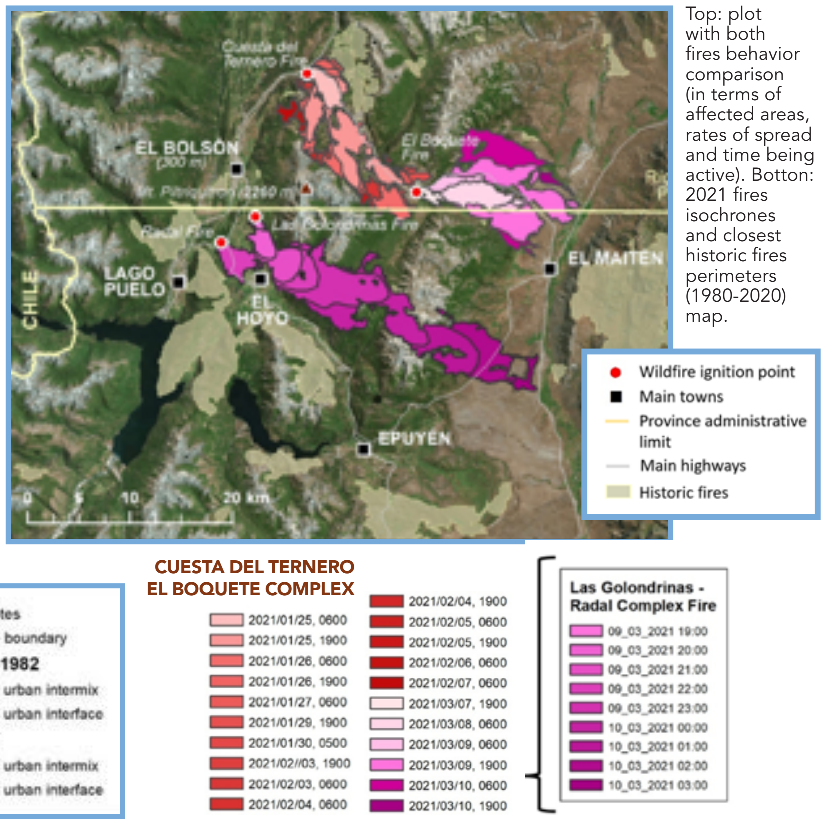
Due to the beauty of the landscape, the region has experienced land subdivision; property is valued more as a real-estate resource than a productive one. Wealthy families from the main cities in Argentina have moved in, with the vision of living in a place that is presumably safer and allows them to be in contact with nature, but they do not take up the traditional uses of the rural land. Therefore, expansion of the city has accelerated, incorporating new social patterns, and configuring new wildland urban interface areas of increasing complexity.

The pressure of a greater population over the landscape results in more roads, most of them narrow and winding, and sometimes with steep slopes; the houses are mainly made of

Argentinian firefighter working at the Cuesta del Ternero – El Boquete Complex Fire at Mallín Cumé, on March 9, 2021. PHOTO BY PABLO ALCORTA.



Layer's source: Godoy, M.M.; Martinuzzi, S; Kramer, H.A.; Defossé, G.E.; Argañaraz, J. & Radeloff, V.C.; (2019), Rapid WUI growth in a natural amenity-rich region in central-western Patagonia, Argentina; International Journal of Wildland Fire, n28, 473-484.



Top: plot with both fires behavior comparison (in terms of affected areas, rates of spread and time being active). Botton: 2021 fires isochrones and closest historic fires perimeters (1980-2020) map.

wood, and are built in the forest without respect for the risks of fires; new overhead power lines end up being in contact with the tree branches, frequently causing fires, especially on windy days; and given the increase in wildfire ignitions , there is an insufficient water supply.

In addition, people are vulnerable because they come from cities and have never experienced a wildfire; thus, their perception of the risk of living in the WUI is skewed by their deeper interest of being part of the idyllic landscape, surrounded by greenery and wildlife.

HISTORICAL AND 2021 FIRES

Of course, there were wildfires before; in some cases, fires affected almost as much area was burned by each of the 2021 events. But during the 2021 fire season, two characteristics were different from previous events: groundfire persistence (Cuesta del Ternero – El Boquete complex)); and the elevated rate of spread (Las Golondrinas – Radal complex).

CUESTA DEL TERNERO – EL BOQUETE COMPLEX

On Jan. 24, the Cuesta del Ternero fire was human caused, and within 24 hours, the fire perimeter had burned beyond the limit of Río Negro province. Because the wildfire had spread such a long distance another jurisdiction became involved in the fire suppression effort. The development of a PyroCu (pyrocumulous cloud caused by a wildfire) was observed that evening, after which the fire made its big run. During the next couple of days, there was minimal fire growth, but it was a dangerous situation for firefighters working in deep ravines on steep zones with complex topography.

On Feb. 6 and 7, part of the fire, near the tail, was reactivated due to the strong winds from the east-northeast. Homes in an Indigenous community were at risk from the fire, and if the appropriate maneuvers had not been carried out, the western slope of the Piltriquitron mountain and various surrounding neighborhoods could have been strongly affected.

On Feb. 23, the fire was deemed controlled and soon after, extinguished. However, on March 7, a new wildfire ignited (El Boquete) and it was presumed that it may have been a reactivation of the Cuesta del Ternero fire, because of the strong winds that day (more than 90 km/h). On March 9, the Cuesta del Ternero fire demonstrated a remarkably high rate of spread, and the wildfire again crossed Río Negro province limits, towards the jurisdiction of Chubut, threatening the town of El Maitén. This fire was extinguished May 28, affecting a total area of 15,710 ha (38,820 acres).

LAS GOLONDRINAS – EL RADAL COMPLEX

On March 9 at 1600 hours, the Las Golondrinas fire started. One hour later, the El Radal Fire began just four kilometers away. At 1800 hours, this new fire was absorbed by the first one, causing extreme fire behaviour. During the next five hours, this complex fire did its biggest run – 23 kilometers – and after that, without growing noticeably, kept burning very slowly. Las Golondrinas – El Radal was deemed controlled on April 4, with a total affected area of 12,580 ha (31085 acres).

LESSONS LEARNED

1. Weather conditions and fire environment

The risk caused by pre-fire conditions in the areas of the two 2021 fires significantly contrasted with the fire weather index. The availability of fine fuels that burn easily (Fine Fuel Moisture Code values exceeding 90, which are associated with ease of ignition), the significant participation of coarse fuels in the combustion process (Buildup Index and Drought Code values), and drought conditions in the region indicated vidence of continuing fire in deep soil layers.

These characteristics allow us to understand how, in a closed and unmanaged forest with high fuel load and continuity, and where the depth of the mulch was close to one meter, the fire remained dormant for three weeks, penetrating the dry organic layer and being reactivated when the meteorological conditions allowed it – mainly high temperatures and drought conditions, but with the addition of strong winds with gusts of 90 km/h.

On the other hand, the high availability of the fine fuel explains the quick rate of spread and the generation of multiple hotspots. Similar to the El Tajamar fire (La Pampa, Argentina) in 2028, Las Golondrinas fire developed a PyroCb (pyrocumulonimbus) at night, associated with the arrival of humidity from the west, facilitating the buoyancy of the column that, until then, was flattened by the wind, and from that point, reached the moment of maximum pyroconvectivity and extreme behavior.

2. Weeks versus hours

An interesting comparison is that although the surfaces affected were relatively similar, the duration of these fires was completely different. In that sense, while Cuesta del Ternero remained active for a month and a half, Las Golondrinas – El Radal, characterized as a firestorm due to its speed and intensity (greater than 60.000 kw/m), advanced in a few hours from its beginning, 33 kilometers (at a rate of spread of 6 km/h and with averages of 10 km/h, at the critical moment), and in that short period of time, developed a PyroCu that transitioned to PyroCb.

The occurrence of these fires, along with those in Australia (2020) or California (2021), shows us the diversity of environments where these fires can be expected. Until now, these fires were associated with plains areas of grasslands and open vegetation, such as La Pampa or the Chiquitano chaco, but dense forests and steeper slopes came also into play. Additionally, the high spread rate of these wildfires implies increased risks for everybody, not only the firefighters working on the fields under possible entrapments, but also the population that is aligned with the direction of spread of the fire. In both cases, it's key to be aware of the situation and know the escape routes.

3. Wildfire impacts: rural areas and WUI

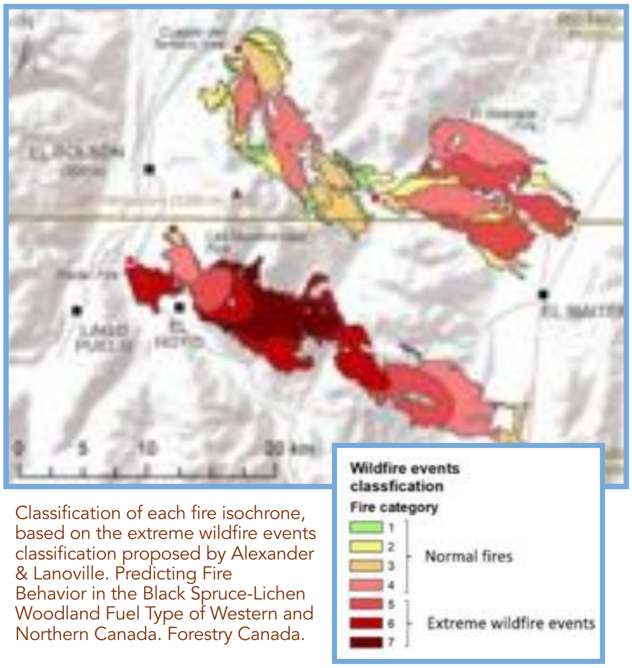
As mentioned, the region has experienced a significant increase in its population in recent years, not concentrated in main urban or suburban housing developments, but scattered throughout the entire territory. This sprawl makes a large portion of residents highly vulnerable to wildfires.

The two fires also presented their differences. Cuesta del Ternero – El Boquete complex affected forest masses and rural areas, with the consequent loss of forest plantations, land suitable for grazing, cattle, sheds, and two houses. In contrast, Las Golondrinas-Radal complex fire generated an extreme impact on the wildland urban interface areas of Las Golondrinas, Cerro Radal and El Hoyo neighborhoods, destroying the existing infrastructure while the fire was spreading across the terrain – fences, powerlines, sheds, and 511 houses, in addition to dozens of injuries and three civilian fatalities (one of them trapped by the fire).

REFLECTIONS AND CHALLENGES

Society is facing, on a global scale, fires that are far more intense than people or firefighters are used to. Remarkably high rates of spread, the development of convective columns that result in a PyroCu and sometimes a PyroCb, and the massive destruction of the environment are all indicative of sixth-generation category fires.

As had been witnessed in California (2020), Bolivia (2019), Chile (2017) and in 2021 in Europe (Greece, Italy, France, Belgium, Spain), climate change has played a main role in creating the perfect conditions for these big fires to occur. In the Cuesta del Ternero – El Boquete complex fire, the long dry period, the high temperatures, and the strong winds influenced not only the availability of fuels above the ground but also the deeper organic layer, helping the development of ground fires and explaining why the fire remained latent for more than three weeks, and the subsequent reactivation and spread over 8,000 hectares.



Classification of each fire isochrone, based on the extreme wildfire events classification proposed by Alexander & Lanoville. Predicting Fire Behavior in the Black Spruce-Lichen Woodland Fuel Type of Western and Northern Canada. Forestry Canada.

These sixth-generation fires are capable of surpassing the attack speed and operational capacity of traditional fire suppression organizations and practices; they require many resources over long durations and demonstrate higher rates of spread and unpredictable fire behavior, resulting in greater risk for the people working on the field, potential fatalities due to lack of situational awareness, and therefore, entrapments.

This important change in the environmental conditions and consequently, fire behavior, exposes the need to change the way people relate to the environment, the way fire management agencies try to accomplish their missions, and the way we forecast dangerous fire behaviors and conditions for the people fighting fire in the field, and the society in general.

The poor perception of risk by a significant portion of the population living in WUI areas and consequently, the existence of extremely high-risk zones, is why it is key for wildfire management agencies to make residents aware of the dangers and risks. This can be done through ongoing environmental education programs and awareness campaigns but must be accompanied by the participation of different social actors and all levels of government, which must implement consistent local policies, legislate and enforce those policies, and pursue the development of a resilient landscape, economy, and society.

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TREE MAP

A DATASET OF FOREST STRUCTURE FOR USE IN LAND AND FIRE MANAGEMENT

BY KARIN RILEY, WITH MARK FINNEY AND ISAAC GRENFELL

I'm the lead researcher on a project called TreeMap. When I give presentations about TreeMap, I often ask participants, "If you had a map showing the size and species of every tree in the continental United States, what would you do with it?"

Here are some of the answers I've heard:

- calculate number of live and dead trees in each state and National Forest
- select areas for fuel treatment and estimate the thinning volume and revenues
- apply thinning prescriptions and see how they would change fire behavior and likelihood
- see the effect of prescribed fire and fuel treatment on stream runoff.

You can explore tradeoffs between timber harvest and fuel management. You can make a map of snag density and height for use during active fire incidents, so that firefighting personnel could avoid traveling and building lines through high-risk areas. One fire captain who used TreeMap in the summer of 2021 wrote, "the Snag Hazard map proved a valuable tool when interfacing with IMT Safety and Operations. A picture is definitely worth a thousand words."

If you happen to be someone who enjoys computational fluid dynamics modeling, you might use TreeMap to help satiate your curiosity about how flames might or might not travel from tree to tree. By making some assumptions about crown structure and tree locations, you can generate 3D renderings of forests and aerial fuel materials.

With carbon markets gaining importance, you can estimate how much carbon a forest stores.

The TreeMap dataset is being used for all these purposes.

The reason TreeMap came into existence isn't what you might expect. In research, you might think that the end point of the journey is in sight when we embark, but that isn't always the case, and that wasn't the case here.

About a decade ago, I was working with a small group of researchers at the U.S. Forest Service's Missoula Fire Sciences Lab looking for a way to calculate risk to forest carbon from wildfire. We had just completed fire simulations for the United States that gave us a detailed map of the likelihood of wildfire, and even the likelihood of burning at various flame lengths. But to use this tool to assess potential wildfire effects on forest carbon storage, we also needed a map showing tree-level detail of the forests. We could then use that map to estimate the amount of carbon stored in the trees, as well as how much carbon would be emitted by fires of various flame lengths. We expected a tree-level model of the forests of the United States would already exist, but after a thorough search we did not unearth one.

As fire scientists and not vegetation mappers, we were hesitant to create a map. Many other groups had already embarked on this daunting task. We were told that this task was too difficult, and we would fail. However, we had some different ideas about methods that might work, so we decided to approach the problem from a new angle.

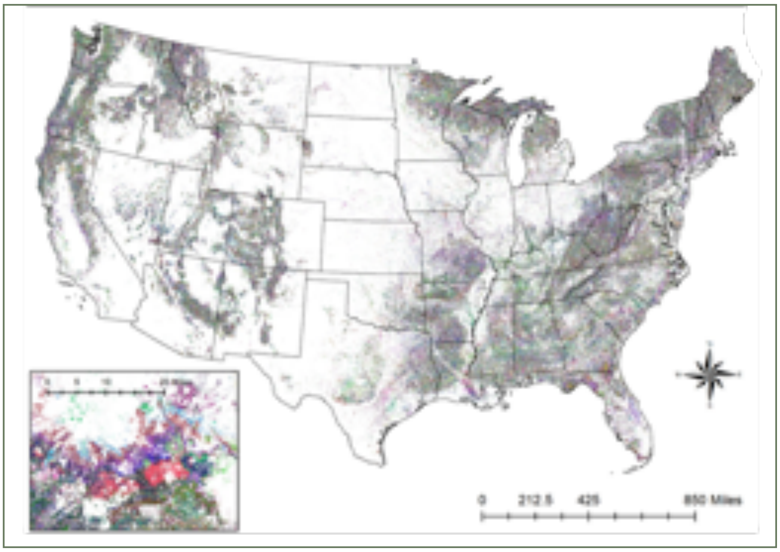
Fortunately, we did not have to start entirely from scratch as there are some areas on the landscape where the type of detailed tree-level information we needed (tree diameter, height, and species) was already recorded, notably at the locations of plots where the US Forest Service's Forest Inventory Analysis (FIA) staff carefully measure every tree and sapling. During this process, staff also record the cause of death for trees that have perished, and recent disturbance history. However, only one of these plots is measured for every 6,000 acres of forest, meaning that for vast expanses of forest, very little is known.

To fill in those gaps, we looked to the LANDFIRE project which has mapped topography, bioclimate, vegetation (forest cover, height, and vegetation type), and recent disturbance on a grid for the entire United States, at 30x30m resolution.

Armed with those two datasets, we applied a machine-learning algorithm called random forests to match forest plots to pixels. The algorithm seemed to have an apt name for a forest-mapping project, but we soon learned that its name comes from the way it builds hundreds of decision trees to find interrelationships among the input variables (in our case, plot location, topography, bioclimatic variables like

"We were told that this task was too difficult, and we would fail. However, we had some different ideas about methods that might work, so we decided to approach the problem from a new angle.

precipitation and temperature, vegetation cover, height, and type, as well as recent disturbance). Our computers churned for months, finding the best-matching plot for each of approximately 2.8 billion forested pixels in the United States. We then honed the method for several years, adding in recent disturbances including fire, insects, and disease. In 2018, we released the first product from this effort, a tree-level model of the forests of the western United States circa 2009. Subsequently we released two additional versions: one for the continental United States for c2014; and most recently a c2016 version for the continental United States.



Continental-scale map of TreeMap 2016. Each unique color corresponds to a unique Forest Inventory and Analysis (FIA) forest plot. The inset window shows a portion of the TreeMap for the Mogollon Rim in Arizona; color bands highlight biophysical gradients that drive plot assignments.

These datasets can be downloaded from the US Department of Agriculture Research Data Archive. You'll get a rather large raster dataset, and in the most recent version, an attribute table that has summarized information for each pixel on number of live and dead trees, forest type, biomass, volume, carbon and more. That means you can generate maps of those attributes at the click of a button. Additionally, you can click any pixel and generate a list of the trees.

Will TreeMap expand to other countries and continents? The methodology could be used anywhere there is a country-wide system of forest plots and maps of vegetation, topography, bioclimate, and disturbance.

With the major technical hurdles out of the way, we continue to refine the dataset. We are currently refining the species distributions and adding in better mapping of insect- and disease-affected areas. The use of random forests imputation technique has shown remarkable utility and we intend to continue improving and refining the TreeMap products to serve the needs of the Forest Service and other land management clients.

As we recently read in a meme (which is of course where one should look for wisdom), "Difficult things take a long time, impossible things a little longer."


Firefighters on the Blue Mountain 22 Rx fire near Missoula, Montana. The TreeMap is used on active fire incidents to help firefighters gauge snag hazard. PHOTO BY KARIN RILEY

LINKS TO DATASETS:

Western United States (c2009):
https://doi.org/10.2737/RDS-2018-0003

Continental United States (c2014):
https://www.fs.usda.gov/rds/archive/catalog/RDS-2019-0026

Continental United States (c2016):
https://www.fs.usda.gov/rds/archive/Catalog/RDS-2021-0074

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Karin Riley is a research ecologist with the US Forest Service. Her current research focuses on better understanding the relationship between climate and wildfire, and how this relationship might shift with climate change.

Mark Finney is a research forester with the US Forest Service. His research involves wildland fire behavior, modeling of fire risk, and landscape fuel treatment effects.

Isaac Grenfell is a statistician with the US Forest SErvice and has been working for or with it for 18 years. He is from Missoula, Montana,and earned his master's degree at the University of Montana in mathematics. His work has touched on the landscape effects of wildfire as well as the probabilistic nature of the physical description of fire behavior.

UNDERSTANDING THE SCIENCE OF CHEMICAL RETARDANTS

BY EDWARD GOLDBERG

INDUSTRY

Wildfire season is getting longer, and fires are growing in intensity. This is apparent to people in the Western United States, Australia, Canada, Europe, and other parts of the world where wildfire activity has increased in recent years. As this is the new reality, it is more important than ever that firefighters and fire management agencies are equipped with the tools they need to effectively manage these fires. These tools must be safe, effective, and reliable.

LONG-TERM FIRE RETARDANT

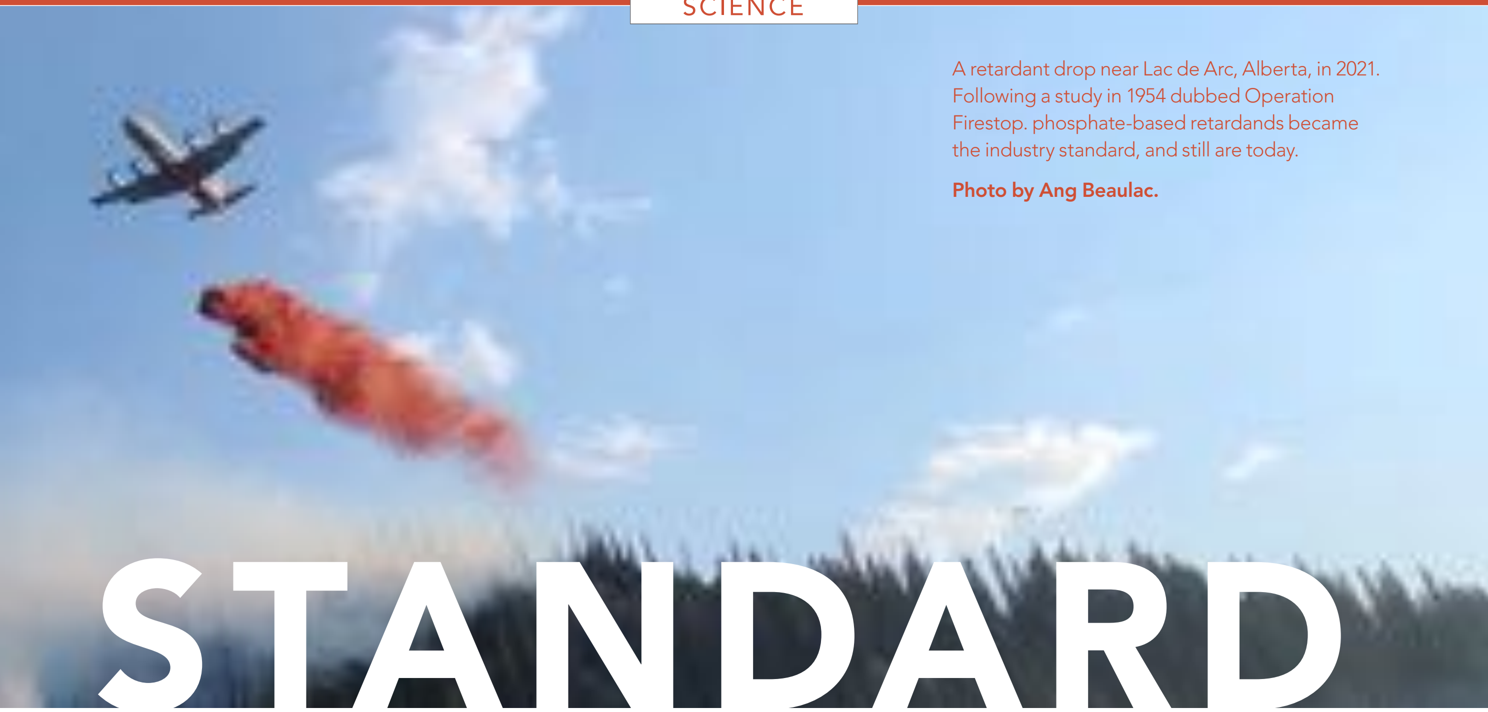
Aerial fire fighting was first attempted in the 1920s. Containers of water were literally dropped from planes on active wildfires, but this practice presented dangers to firefighters on the ground. Despite these challenges, fire-management organizations saw promise in aerial firefighting and started more sophisticated attempts in the early 1940s. These efforts were rudimentary compared to today, as very small planes were used, with water serving as the extinguishing agent. It wasn't long before people realized that dropping water from the air to fight fires was incredibly inefficient, as the speed of the plane, combined wind velocity, and the heat from the flames would prevent most of the water from reaching the ground. Chemicals were quickly added to water to thicken it and to improve its stability and effectiveness in dousing fires.

By the 1950s, agencies started using air tankers with installed tanks to drop long-term fire retardants. Long-term retardants chemically render fuel non-flammable – a chemical reaction that does not rely on water for effectiveness. Though water is incorporated with long-term retardants, it functions merely as a tool to get the retardant to the ground. Once the retardant is on the ground, the water evaporates, leaving the retardant to function. Long-term retardant is typically used to create a fire break but is also effective for direct attack; it will remain effective for weeks or months – until a heavy rain washes it away – and it has become the dominant technology in aerial wildfire fighting.

Early forms of long-term fire retardant were developed using hydrating clays, such as bentonite and borate, and then gum-thickened waters, which are very similar to the gels that are used today. Borate was used in retardants for only a couple of years because it was found to be toxic to soil. Other chemicals were tried as potential replacements, including sodium silicate, magnesium chloride, ammonium sulfate, ammonium phosphate, and others.

This wide use of chemicals piqued the interest of researchers who wanted to understand the effectiveness of these chemicals in stopping fires. One of the first major studies to investigate this took place in 1954 and was dubbed Operation Firestop, which was a collaboration among the United States Forest Service (USFS), CalFire, Los Angeles County, the City of Los Angeles, the U.S. Department of Defense and other organizations. The major focus of the research was to study new technologies. Among the methods tested were aerial water bombing and sprays from both airplanes and helicopters, aerial backfiring from predetermined control lines, the use of fog and smoke barriers to slow fire spread, the use of backfires to turn or slow down running fire fronts, and fire-retardant chemicals and sprays.

One phase of Operation Firestop tested the effect of fire-retardant chemicals on the ignition time of wood, on the fire intensity of burning wood, and the retardant's ability to suppress flaming wood. The study covered several chemicals that had been in use over the previous decades in firefighting products. The findings from Operation Firestop were clear, and they have shaped the future of the retardant industry. Ammonium phosphate was among the most effective chemicals in reducing fire intensity, while boric acid, magnesium chloride, and polyvinyl acetate were among the worst. Following this groundbreaking study, phosphate-based retardants became the industry standard (and still are), while boric acid, magnesium chloride, and polyvinyl acetate were discarded and are no longer considered viable options as active ingredients for long-term retardants.



A retardant drop near Lac de Arc, Alberta, in 2021. Following a study in 1954 dubbed Operation Firestop. phosphate-based retardands became the industry standard, and still are today.

Photo by Ang Beaulac.

STANDARD

Later, in 1970, University of Montana scientist Aylmer Blakely conducted his own research and presented a paper entitled A Laboratory Method for Evaluating Forest Fire Retardant Chemicals. He built on what was found in Operation Firestop and looked at additional chemicals and effectiveness parameters. Blakely used a method called the superiority factor method, a composite of various factors combined to determine the overall effectiveness of different chemicals.

THESE PARAMETERS INCLUDED:

- The rate of weight loss
- The remaining residue after burning
- Amount of heat radiation emitted.

Using the Blakely superiority factor, it was determined that any long-term fire retardant that measured greater than 0.3 on the scale was most effective; those that rated between 0.2 and 0.3 were moderately effective; and chemicals that scored between 0.1 and 0.2 were slightly effective. Blakely concluded (again) that ammonium phosphates topped the list of effective retardant chemicals (diammonium phosphates finished at the top, monoammonium phosphates ranked second). Potassium chloride was the least effective (finishing 14 out of 14 chemicals tested) and magnesium chloride finished ninth, failing to register any score above 0.3 in the tested superiority factors.

CONTINUOUS INNOVATION

It takes more than just the active ingredient to formulate a usable long-term fire retardant. To be effective, retardants must:

- Be safe for people, animals, fish, and the environment
- Cause minimal corrosion to protect aircraft and other equipment
- Have higher recovery rates – meaning a high percentage of the solution hits its target
- Be stable
- Be able to be stored for extended periods
- Be visible when dropped and remain visible for pilots when it is on the ground, to form a continuous fire line.

Innovations have been made to ammonium phosphate-based retardants over the last 60 years to improve these retardant characteristics. Better thickeners were developed to improve drop characteristics, more sophisticated corrosion inhibitors were added, enhanced flow conditioners made mixing easier and more efficient, and new colorants enhanced visibility and its environmental profile.

In 1975, the first fugitive color retardants started being used. Iron oxide was initially used to provide red color to the solution, but when applied it permanently stained surfaces that it contacted, including homes and other structures. This important innovation with fugitive color provided fire-management agencies the ability to effectively fight fires in aesthetically sensitive areas such as national parks and in wildland-urban interface areas, where iron oxide-colored retardants were less desirable or unacceptable. Fugitive-colored retardants also reduced the risk of staining airport runways, taxiways, and other exposed areas, as the color goes away after exposure to weather and other conditions.

In 1985, a synergistic blend of ammonium sulfate and ammonium phosphates was created to significantly reduce the cost of retardant while providing similar performance.

Advanced gum-thickened retardants were also developed, offering a range of viscosities. Previously, the only options for the fire manager were very low-viscosity (un-thickened-water-like) or high-viscosity retardants. This innovation allows the agencies using the retardant to optimize its characteristics based on the delivery system, topographical, fuel, and specific fire situation.

Today, phosphate-based retardants continue to be recognized by the scientific community as the most effective wildland fire retardants; they offer significantly higher recovery rates than water or retardants based on other chemical solutions. The water generated by fuel decomposition in the presence of the retardant adds to the efficacy of fire suppression, and it is better at preventing re-ignitions because it renders fuel non-flammable.

As a 20-year veteran of the fire safety industry, it is disheartening to see that despite all the research supporting the use of ammonium phosphate as the most effective active ingredient for fire retardants, and the continued advancements being made with long-term fire retardant, that fringe players in the industry are introducing new long-term retardant products that promote the use of chemicals that have already been proven to be detrimental and ineffective. What is worse is the fact that there are false performance claims being made and inaccurate information being spread to disparage ammonium phosphate-based retardants. If these deceptive comments are taken at face value and adopted as reality, the impact on fire fighting and people's safety could be devastating.

THE TAKEAWAY

When considering a retardant product, determine if that product is on the USFS Qualified Products List (QPL). Long-term fire retardants included on the QPL are the only retardants that can be used on federal lands in the United States. Before being added to the list, the USFS evaluates and approves retardants using its Wildland Fire Chemicals Test Procedures (WFCS). USFS conducts a risk assessment, tests for mammalian and fish toxicity, determines whether the components present a risk to humans, and reviews the chemical makeup of the product and test its effectiveness. With the QPL designation, users can have confidence that the product is effective and safe. Many companies make product claims regarding the safety of their product, its environmental friendliness, and its overall effectiveness, but if it is not on the QPL, you have no idea what the product's capabilities are, or how dangerous it could be.

The QPL process, based on the USDA Forest Service Specification 5100-304d, however, needs to be updated. As the agency considers new or alternate chemistries, those chemistries need thorough study – study beyond what is considered in the specification. In addition, the specification does not address mixtures of different retardant products. Mixing, in airtankers, is inevitable if multiple products are used in the field. This represents a potentially significant safety hazard as interactions between chemicals could result in dangers to life, airplanes, and the environment.

The retardant industry needs innovation. We need to keep moving forward to find new technologies to do our jobs better, to provide firefighters with new tools, to keep people safer, and to do a better job of preventing and fighting these fires. But, this has to be done in a thoughtful way that ensures there aren't unintended consequences. Retardant is being dropped out of planes on wildlands, people, and animals, and we need to fully understand the effects, the hazards, and how it should be used. We know the capabilities of phosphate-based retardants, their performance, and how they should be used. Testing has proven its effectiveness, and that is why phosphate-based retardants are included on the US Forest Service QPL.

CHEMICALS TESTED IN 1970 BLAKELY STUDY

- Ammonium chloride
- Ammonium phosphate (dibasic)
- Ammonium phosphate (monobasic)
- Ammonium sulfate
- Boric acid
- Calcium chloride
- Magnesium chloride
- Magnesium sulfate
- Phosphoric acid
- Potassium carbonate
- Potassium chloride
- Sodium tetraborate
- Sodium silicate

ABOUT THE AUTHOR

EDWARD GOLDBERG is CEO, Perimeter Solutions, a producer of firefighting products and lubricant additives.

PHOTO BY ANG BEAULAC.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EXTREME EVENTS

BY RICK MCRAE

I used to think I knew a lot about wildfires or bushfires. Then my operational experiences made me unsure. Due to what is now known to be the effects of climate change on extreme fires, it turns out I have spent the last couple of decades proving myself wrong. I would like to relate my tale and in doing so tell you why extreme wildfires have become such a major challenge. It is no longer enough to watch these fires and study them scientifically – we all must implement a lot of new learnings if we are to keep our communities safe into the future.

My colleagues and I heard stories in the 1990s about noteworthy wildfires in Australia that generated lessons to be learned – this was part of our professional development. We heard about the 1983 Ash Wednesday fires and the 1998 Linton fire and the significance of the wind change. There was clearly a pattern in the narrative, if not in the field. We had a lecture from Oakland Fire Chief Lamont Ewell about harrowing experiences in the Tunnel fire (Oct. 19, 1991; 38°N 122°W). We all knew about the Santa Ana winds and the resulting fire behaviour that was so difficult to control. Whew, at least we didn't get them in Australia.

I was the planning officer for the 2003 Australian Capital Territory firestorm (McIntyres Hut fire and Bendora fire, Jan. 18, 2003; 35°S 149°E). The impact on Canberra was devastating; four people died, more than 490 were injured, and 512 homes were destroyed or severely damaged.

I spent the next five years heavily involved the coronial inquiry into those fires. Coroners are empowered to explore the cause and origin of damaging fires. In doing so, the coroner made it unduly inquisitorial, so much so that I and three colleagues took her to the Supreme Court twice to consider bias in her conduct. Her findings were a list of "the usual suspects": training, communications, equipment, procedures, facilities, and so on. Her stance was that these all needed to be improved if a repeat was to be avoided.

One thing the coroner deliberately avoided considering (despite requests from lawyers) was the emerging science from those fires. Lawyers are quicker to reach conclusions than scientists, but there had already been some papers published that showed that these fires were, indeed, salient fires.

Mike Fromm, the leader of an international collaboration on fire thunderstorms, invited me to join scientists from the United States, Canada, Israel and Australia who were writing a paper about the 2003 fires. Another noteworthy past fire – the Berringa fire in Victoria (Feb. 25 1995; 40°S, 144°E) – had formed a thunderstorm in its plume; as with any thunderstorm near a fire, there were significant safety issues to watch for, such as downdraught winds. I had also watched, in satellite imagery, a fire in the Victorian high country form a storm that rained on the fire and put it out (at Caledonia River, Feb. 2, 1998; 37°S, 147°E). Was this just a storm or was it due to the fire?

Technically, fire thunderstorms have a formal name – pyrocumulonimbus – but it is shortened to pyroCb. PyroCbs were a clear sign of just how far off the scale the 2003 fires were. Plus, we had good data on the first ever confirmed fire tornado – a 2012 paper titled An Australian pyro-tornadogenesis event "demonstrate[d] that this was indeed a fire tornado . . . and not a fire whirl." With the field data on the fire and the plume, and the science on the upper atmospheric impacts, we had a useful case study. Internationally, there was a previous major case

THE LINK BETWEEN WILDFIRES AND CLIMATE CHANGE

Black Mountain, on Canberra's urban edge, in 2011 (a wet summer) and 2020 (the height of Black Summer's drought). Both photographs were taken at roughly the same place on the afternoon of Feb. 14 as part of a chronosequence project showing recovery after a wildfire in 1991. Three decades of data collection helped with preparedness and quantified just how severe Black Summer was. It was drought-affected stands like those in the lower panel that often produced unprecedented fire behaviour across eastern Australia. PHOTOS BY RICK MCRAE.

study from a fire in Canada, the Chisholm fire near Edmonton, Alberta (May 29, 2001; 55°N, 114°W). It became clear that we needed to build up case studies to improve our understanding of these events and their causes.

I was co-leader of part of a federally funded research project, the HighFire Project. HighFire Risk was run out of the University of New South Wales (UNSW) at the Australian Defence Force Academy (ADFA) in Canberra as part of the Bushfire Cooperative Research Centre. ADFA had a longstanding prominence in Australian bushfire research. The research team obtained the services of a young mathematician, Jason Sharples, who is now a tenured professor and leader in many scientific aspects of extreme wildfires.

This project led to a wide range of learnings, if not outright discoveries. We needed to understand what surface winds did to the 2003 fires, so we deployed weather stations across rugged landscapes. The results were surprising because meteorologists must avoid putting weather stations in the really interesting side slopes. We looked at imagery showing unexpected fire spread patterns; this showed a strong association with landform elements prone to the lee-slope eddy winds that we now knew were a key part of the story. With the awkward formal name of Vorticity-driven Lateral Spread, VLS is now globally known to be a leading cause of catastrophic fire escalation in rugged landscapes.

We worked on dew point depression anomalies and foehn wind events. We showed that foehn winds do cause rapid changes in fire danger in Australia, but good case studies were limited; we spent a decade looking for them, with limited results. We spent a lot of time on research dissemination. With the growing uptake of the fire behaviour analyst role over the last two decades, there was new cadre of people eager to learn about these processes. They were often especially interested in pyroCbs.

I maintained the Australian pyroCb register, with help from colleagues in Australia and overseas. Unfortunately, every few years we saw another uptick in the cumulative case count curve; it was clearly a new trend that needed understanding.

It became clear that this extreme fire behaviour was a major, global problem. Australia got world attention in 2003, and again during the 2006-2007 Victorian high-country fires (many fires, from Dec. 3, 2006; around 37°S, 147°E), and again on Black Saturday in Victoria (many fires; Feb. 7, 2009; 37°S, 145°E). We saw a cluster in the Great Victoria Desert (many fires; Oct. 18,2012; centred on 27°S, 126°E), most likely reflecting a pulse of plant growth after an infrequent inland rain event. So, with the same type of event occurring in arid lands, taiga, Douglas fir forests and Alpine Ash forests, there was a question to ponder about the role of fuel. There is still no obvious concept of a role for fuel load as a variable.

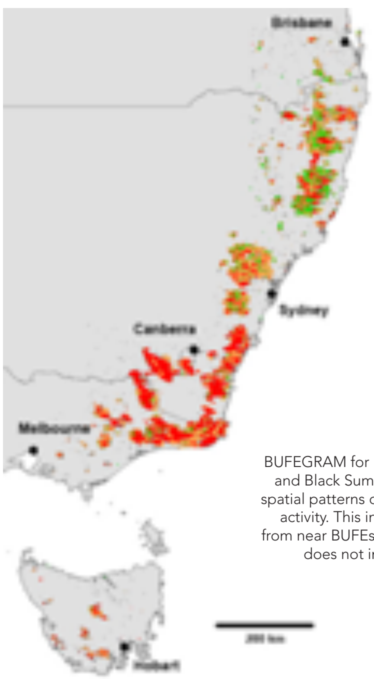
I was a fire behaviour analyst in British Columbia in 2017 when the record-breaking Pacific northwest event (PNE) occurred on Aug. 12; this was so far beyond what had been seen that satellite indices had to be rescaled. At least this time around I knew what was happening, and I opened an ops briefing with the claim that "Your fire has been making ice." The plume reached into the stratosphere, where the air temperature was perhaps -60 C. There were eight pyroCbs that evening as a cold front pushed through. The vast smoke plume was pushed over the Arctic to Russia and over the Greenland ice cap. This was what has become known as an outbreak of pyroCbs.

Back home, I began looking at what the fires had done on the ground; this was the real eye opener. The Chezacut fire (part of the Plateau Complex; Aug. 12, 2017; 51°N, 121°W) made a midnight run of 40 kilometres, passing right over a previously burned area nearly 10 kilometres wide. It was fortunate that this is an area that was not crewed at night.

About that time, a paper was published in which we carefully defined our terms. Normal fires follow steady-state processes – if you know the weather, terrain, and fuel then you know what the fire will do (with a few exceptions). Under certain conditions, a fire couples with the atmosphere above and becomes a dynamic fire. Now, you also need to know the stability and dryness of the atmosphere overhead (the profile), and you need to know the fire itself. Having the fire depend on the fire creates a potential for a feedback loop; this is a lot more complex. Dynamic fire forms what we called a Blow-Up Fire Event (BUFE). Any fire that includes one or more BUFEs is termed an extreme wildfire.

How does the coupling come about? Our pyroCb case studies told us that you need deep flaming under an unstable profile. Normal fire spread is by means of a fireline, which can be intense and fast spreading, but is a line. Deep flaming is when a fire polygon forms instead; this changes the way that the convection column evolves as it rises. If the column is still expanding and not mixing out when it reaches the cloudbase, the water vapour in the plume condenses and more heat is released, re-energizing the system; it is like turning on a very large extractor fan above the fire. This phenomenon dominates surface winds, and the rising air may be replaced by drier descending air, raising the fire danger. Then the feedback loop is in place.

So far there are seven documented potential causes of deep flaming. A strong wind will push even a steady-state fire a long way during the fuel burn-out time. A wind change (this is where the old ideas meet up with lots of new ones) may create a wider new headfire from a flank. As mentioned, VLS is the most efficient mechanism known. When fire enters a lee-slope eddy wind, the vorticity pushes fire sideways (at up to 5 km/hr) and causes dense spotting for kilometres downwind. A review of the Kings Cross tube station fire in London (Nov. 18, 1987; 52°N, 0°W) indicated eruptive spread and involves flame attachment in a trench-shaped channel. Sharples, Domingos Viegas, and others have studied this process in detail; it has caused a number of serious fireground burn-over incidents. Post-fire photos that I took in 2017 at the Elephant Hill fire in British Columbia (51°N, 121°W) showed that eruptive spread can occur in parallel and create deep flaming. Dense spotting can arise from several processes and spotfire coalescence has been studied in detail as a cause of enhanced fire intensity. The use of accelerant (drip torches or aerial) using long-established techniques under the direction of an incident action plan has created some of the most intense BUFEs if the ignition pattern changes the mixing of indraft air. Interior ignition is my working term for a hot fire mosaic across a landscape in North America where each area of the vegetation types present has an unsynchronized onset of full fuel flammability. The mosaic of areas that do light up on any day can act like deep flaming.



BUFEGRAM for February-March 2019 and Black Summer, showing varying spatial patterns of Blow-Up Fire Event activity. This includes only hotspots from near BUFEs and the main fires; it does not include inland activity.

Deep flaming links back to case studies, and thus to salient fires. An unstable profile is seen in weather balloon flights, flown in Australia by the Bureau of Meteorology and more recently by fire services due to coronial recommendations from the Wambelong fire in New South Wales (Jan. 13, 2013; 31°S, 149°E).

There was enough information in 2013 to try out a predictive model for BUFEs, called the Blow-Up Fire Outlook (BUFO, a reference to Cane Toads, Bufo marinus, which are a major pest in Australia). BUFO asked questions based on observations or forecasts to see if the conditions for deep flaming under an unstable profile was likely as a fire spreads. The model assumed elevated fire danger as a boundary condition. BUFO worked, producing several BUFO alerts that were passed on to bushfire operations centres.

PyroCbs continued to be at the centre of BUFO, as they were (mostly) readily confirmed – more so than a BUFE.

Then along came Black Summer, and all of this changed. In a pre-season operations briefing I put the tagline on my outlook, "As bad as it can get." It seems that I understated it. In hindsight, Black Summer really began in early March 2019, when a major outbreak of BUFEs and pyroCbs occurred in the eastern Victorian high country and central Tasmania. Some of what happened still cannot be explained. Then fires started in August behind Brisbane. As in most fire seasons, the activity pattern slowly moved southwards, ending in Victoria in February 2020.

Some highlights: the world's first "super outbreak" with unprecedented activity levels, the highest smoke ever recorded (in the ozone layer, above 35 kilometres); a doubling in the length of the Australian pyroCb Register; Canberra recorded the world's worst air quality; and so on. I worked on the fire side of a major collaborative paper on the super outbreak. A remarkable graph showed that, in broad terms, on Jan. 4, 2020, fire activity peaked at nearly one million megawatts due to a burn rate of almost 100,000 hectares per hour. Plume cloudtops passed 16 kilometres. This is an area that has seen a number of outbreaks this century.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Now the really interesting bit. North of Sydney, there have been pyroCbs recorded, even clusters of them, but no outbreaks. About 40 per cent of the nearly 140 BUFEs recorded that season were in the north. The profile was often not unstable, and at times quite stable. The first two confirmed dangerous Australian BUFEs due to the foehn effect had been recorded in the previous three years at Tathra (March 23, 2018; 37°S, 150°E) and Holsworthy (April 15, 2018; 34°S, 151°E). Australia suddenly went from two to nearly 50 foehn-driven BUFEs.

Having been trained as an ecologist, I switched from case studies to population statistics. Entirely new concepts became available for predictive use. BUFO2, the new version being finalized, is no longer concerned with pyroCbs, although a prediction of them is a by-product. The real concern is the BUFE on the ground, the events that destroyed vast tracts of Australia's forests over six months. BUFO2 ingests observation and forecasts and looks at the profile. However, it considers both ascending and descending air. Explicitly considering foehn winds in Australia now makes us worryingly similar to California and other regions plagued by fire winds. Suddenly Chief Ewell's report is a lot more relevant, and we need to have long chats with our colleagues in California and the Mediterranean.

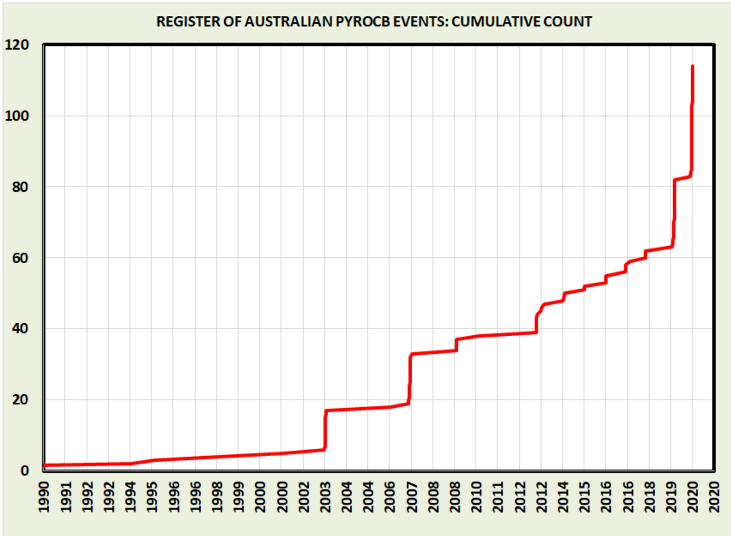
BUFO2 includes a statistical analysis of radiosonde data, covering the cloudbase height, convective cap, dew point depression near the cloudbase (equivalent to a dry slot in water vapour satellite imagery) and C-Haines (a continuous variant of the mid-level Lower Atmosphere Severity Index). Ascending BUFEs need small caps; descending BUFEs prefer large caps. Both can benefit from dew point depression events. A high cloudbase is ensured by the elevated fire danger boundary condition.

Switching to a statistical approach also strengthened an element that was problematic using case studies – avoiding biases. A predictive model should not just predict an event at "that fire there," but also not predict events on "those fires over there," Case studies have not looked at the second set.

PyroCbs cause mayhem, and as we saw north of Kamloops, B.C., (June 30, 2021; 51°N, 121°W), can start new fires through pyrogenic lightning. Air ops may be grounded. However, BUFEs are a far more serious problem for the incident management team. A dynamic risk assessment should indicate that during a BUFE the incident action plan has one objective – saving lives. BUFEs have been seen to run nearly 60 kilometres overnight, in unprecedented directions. One night during Black Summer there were five of these running side by side. How do you set an IAP for that?

I'm developing a technique to use satellite hotspot data to classify how fire burned across the landscape during extreme wildfires: minor activity; typical fire runs; complex burning out or interior ignition over many days; and BUFEs). This shows that BUFEs are not necessarily getting bigger, rather that extreme wildfires are forming more of them, and they are often overlapping. IMTs face extraordinary challenges handling this.

A lot of the extraordinary activity during Black Summer has all the hallmarks of climate change; things will continue to deteriorate while we wait for emissions reductions to occur. Due to climate change, BUFO2 may become obsolete quite quickly as we acquire and analyze data from new events. But where will the new data come from? Brazil? Sweden? Russia? South Africa? As I mentioned, lawyers are quicker off the mark than scientists. The gap between the products of the two groups cannot be allowed to grow.



The cumulative count graph from the Australian PyroCb Register. (Data and analyses from international pyroCb research group.)

I've recently retired from emergency services and am an adjunct professor at UNSW at ADFA working to finish the studies of Black Summer and to disseminate the material that I've discussed. A real challenge is convincing highly effective fire services of the need to adapt in a setting of conflicting messages. The 2003 coronial inquiry produced a long list of findings, many highly critical of senior officials such as me. The coroner's experts showed, after the fact, that the outcome of the fires could have been predicted, and therefore those in charge should hold some level of responsibility. There is now an alternative, scientifically backed, view of those fires – that they were perhaps the first major impact of climate change on an Australian city, and their complexity was unprecedented for Australia, if not the world. Fires near Perth, Melbourne, and Sydney have been almost as extreme. A solid proof of climate change's role is perhaps still to come, but can we afford to wait?

ABOUT THE AUTHOR

Rick McRae served as a headquarters technical specialist in what evolved to become the ACT Emergency Services Agency in Canberra from 1989 until his recent retirement. He worked in business planning, arson investigation, multi-hazard risk assessment, as planning officer for major incidents, weather specialist, and as a research scientist focussing on extreme wildfires. He is now an adjunct professor with the Bushfire Research Group at UNSW Canberra at ADFA.

THE FUTURE OF FORECASTING FIRE DANGER

DEVELOPING THE AUSTRALIAN **FIRE BEHAVIOUR INDEX**

ILLUSTRATION BY JENNIFER HOLLIS

BY JEN HOLLIS AND STUART MATTHEWS

To most Australians, fire danger forecasting is embedded within our cultural identity and history. It's as Australian as kangaroos, the Holden Ute and the Sydney Opera House.

For the last six decades Australians have relied heavily on the pioneering work of Alan McArthur who developed the Forest Fire Danger Index and Grassland Fire Danger Index. The system has served Australians well and with only minor adaptations to meet local needs, it remains largely unchanged. The most significant adjustment came after the 2009 Black Saturday fires in the state of Victoria which, in one afternoon, burned through more than 450,000 hectares and resulted in the devastating loss of 173 lives.

Following a Royal Commission investigation into the fires, it was recognised that McArthur's system was being applied well beyond the original design. As a result, categories were added, including one at the top end of the fire danger scale reflecting conditions beyond the existing maximum of 100. Importantly, it was also recognised that there was a need to incorporate new science and technological developments (for example, remote sensing, landscape mapping, higher computational capability) into the calculation and interpretation of fire danger.

Over the last two decades, advancements in weather forecasting and fire behaviour knowledge have improved our collective understanding of fire dynamics and its relationship with fuels and weather variables, fire-atmosphere interactions, potential impacts, suppression requirements and safety considerations. Fire authorities also have a better understanding of how to effectively communicate to the community to trigger necessary action. Our knowledge of atmospheric instability and potential for coupling has increased. Our understanding of fire behaviour and fire spread has expanded from grouping all vegetation into either forest or grassland to better reflect the diversity of vegetation around Australia, including grassy woodland, spinifex, shrubland, mallee-heath, pine and buttongrass vegetation types. The nature of the McArthur system however has dictated that very few of the advancements are able to be incorporated.

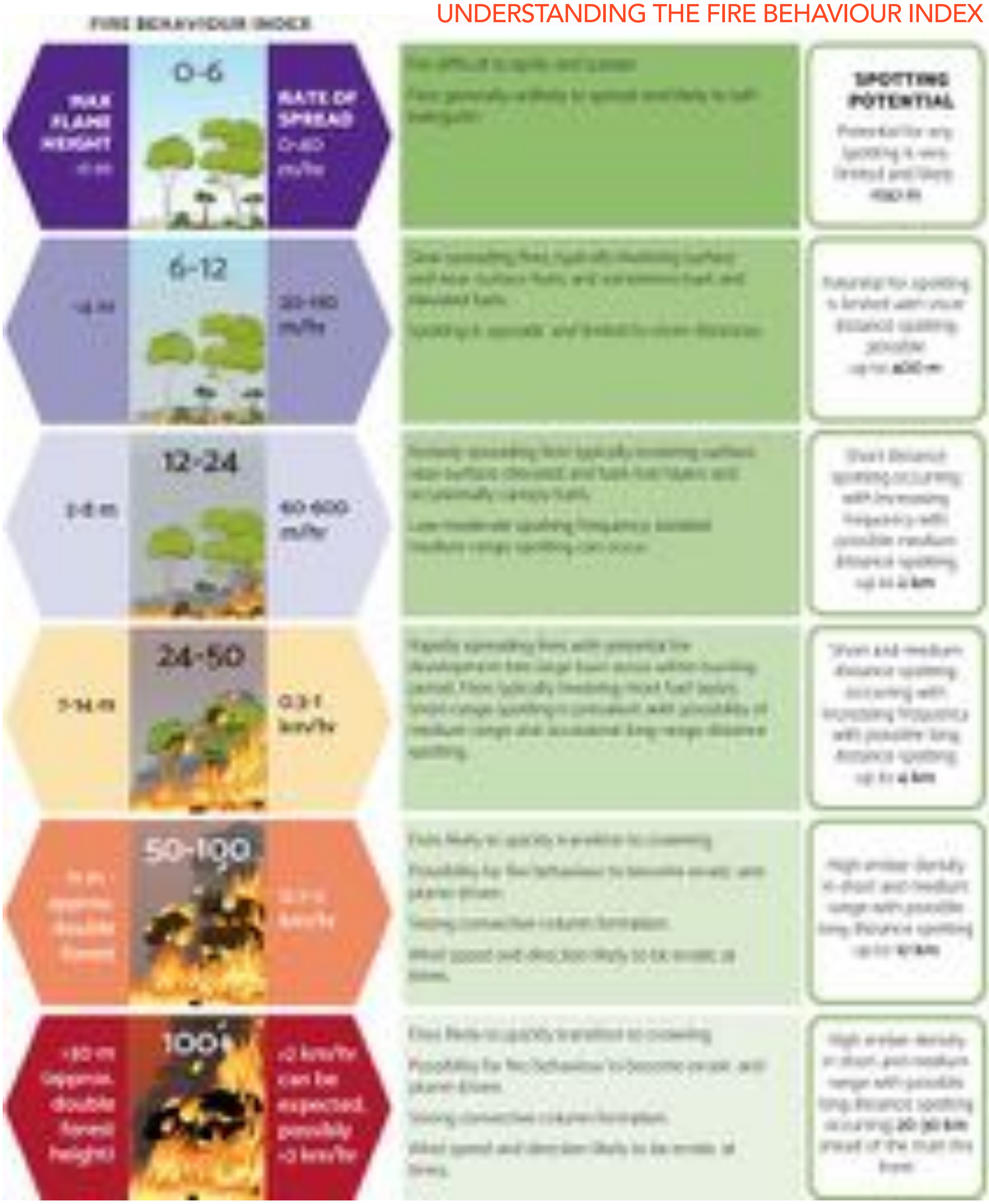
FIRE DANGER: WHAT DOES IT MEAN?

In Australia, fire danger has become a general term with many interpretations and applications that have evolved over time. Forty three years ago, McArthur summarized fire danger as: ". . . in a general sense, the rating of fire danger is an expression of probable fire behaviour in relation to a particular set of fuel and weather conditions."

Until recently, most fire management authorities found this was sufficient for representing suppression difficulty and for setting readiness levels however, interpretation and utilisation of fire danger forecasts vary a great deal. Some choose to align the forecast with the original descriptions of suppression difficulty, rate of spread, fire growth and flame heights. Others may refer to a modified version of that information to better represent local conditions and management styles. Often, people involved in fire management will interpret the forecast against their own experience or simply against the name of the rating, where a Low forecast fire danger can be interpreted as low fire danger or Catastrophic simply as being catastrophic. The outcome is a diversity of mixed understandings, where fire danger has become a little bit of everything and nothing that's consistently defined.

INDATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX



The Fire Behavior Index is determined through models for fire spread rate or other fire behaviour characteristics, such as likelihood of spread and crowning.

AUSTRALIAN FIRE DANGER RATING SYSTEM

In 2014, Australian governments agreed that the development of a new system was a national priority. Subsequently, project planning for an Australian Fire Danger Rating System began in earnest. With funding support from the Australian government's National Emergency Management Projects program and the New South Wales Rural Fire Service's Bush Fire Risk Mitigation and Resilience Program, development and testing of a research prototype began in 2017. The research prototype was largely based on fire behaviour and fire-spread calculations on a gridded spatial scale (linked to the Bureau of Meteorology's gridded weather forecast product), in eight major fuel types covering Australia. The objective of the research prototype project was to demonstrate that it was feasible to develop a fire danger rating system based on fire behaviour models that was national, modular, and open to continuous improvement. Testing of the research prototype over consecutive fire seasons around Australia showed that the research prototype performed better than the current system.

At the same time, work commenced to understand and improve community warnings and needs. Through surveys and small working groups, it was found that while many Australians could recall seeing fire danger rating information on roadside signs and forecasts, many people were unable to describe what fire danger is and could not recall taking actions in relation to fire danger. In response, four design principles were put forward to target how to provide fire danger forecasting information to the public including fewer levels, logical colours, simple English terms, and action-oriented messaging.

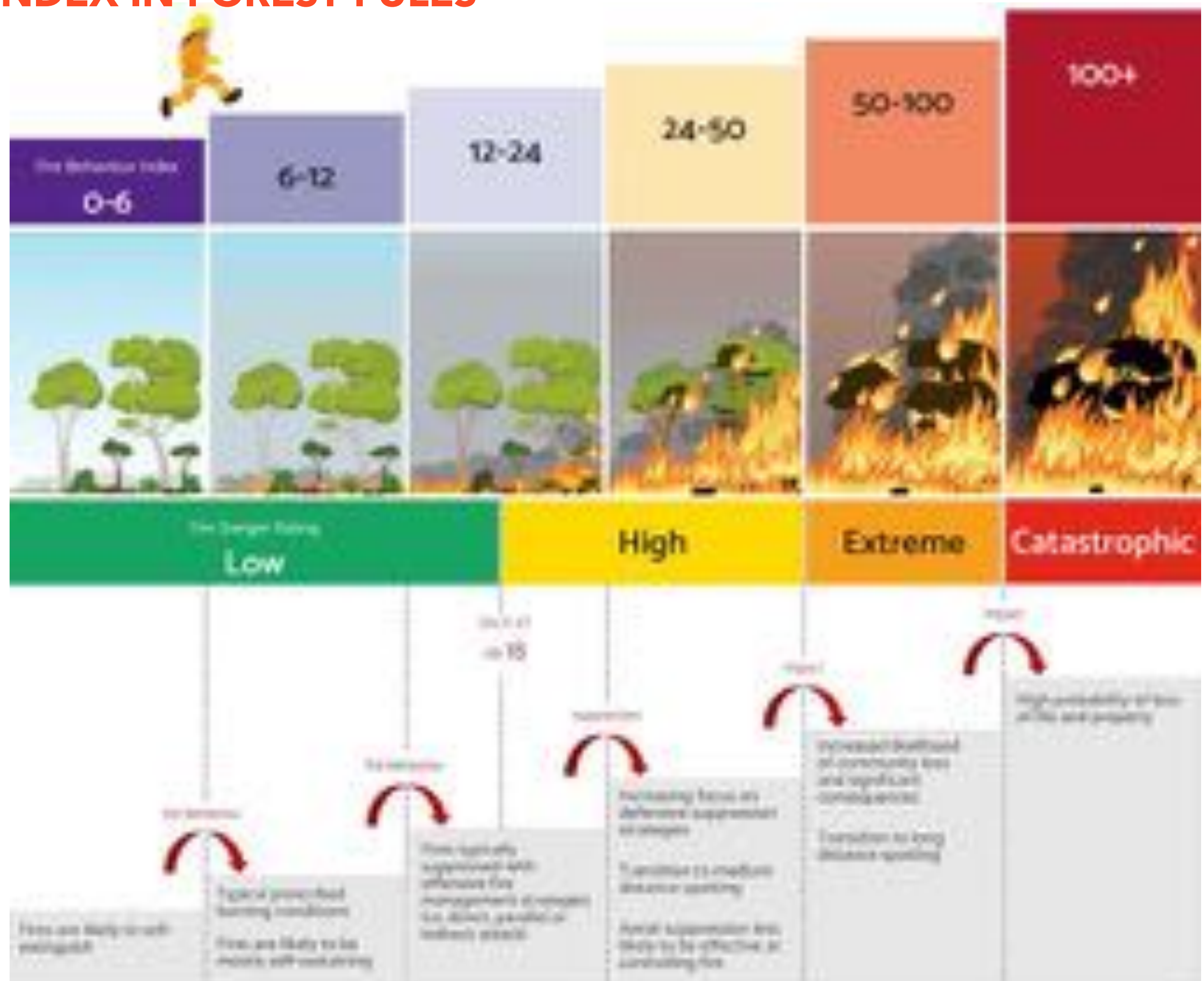
In 2019 the system build commenced. Implementation and go-live is planned for 2022 and until then the system continues to be built and refined.

Based on the different needs of fire operations and the Australian community, the Australian Fire Danger Rating System includes two components:

1) Fire Behaviour Index: A numerical scale of fire danger developed specifically for operational users and fire management decision making; and

2) Fire Danger Rating: Consisting of broad categories designed to quickly communicate the potential level of fire danger to the public. Categories are set against outputs of the Fire Behaviour Index.

UNDERSTANDING THE FIRE BEHAVIOUR INDEX IN FOREST FULES



Australia's Fire Behaviour Index is made up of step-ups, or transitions, that indicate a shift in category and are triggered by a change in fire behavior, suppression response, or potential for impacts. ILLUSTRATION BY JENNIFER HOLLIS

Fire Behavior Index Tables provide users with clear and consistent descriptions of indicative fire behavior and fire weather, implications for prescribed burning, fire suppression and containment, and potential for impact.

FIRE BEHAVIOUR INDEX: TRANSITIONS

To get the most out of the Fire Behaviour Index (FBI) and realise the opportunities intended to assist and improve decision making, it's important that users have a good understanding of the underlying structure and how it differs from the current system. Unlike the current McArthur system, which presents categories as pieces of a half-pie with fire danger increasing against McArthur's Fire Danger Index, the Fire Behaviour Index is made up of step-ups or transitions. These transition points indicate a shift in category and are triggered by a change in **1)** fire behaviour **2)** suppression response or **3)** potential for impacts.

For forest fuels (page 36) categorie are generally split into cool colours (variations of dark to light purple) and warm colours (yellow, orange and red). The bottom category (FBI: 0-6, dark purple) represents conditions in which fires are unlikely to spread. When conditions increase to support a spreading, self-sustaining fire, fire danger steps up to the next category (FBI: 6-12, purple). The range of conditions in this category are aimed at representing typical prescribed burning conditions. A step upwards in conditions is the point at which prescribed burning is generally no longer suitable, but fires are still mostly suppressed with offensive strategies (FBI: 12-24, pale purple).

The next transition is linked to a change in suppression response, when operations typically start moving away from offensive suppression success and increasingly focus on defensive suppression strategies (FBI: 24-50, yellow). This category may also trigger the need for additional resources and strategic placement of resources. The final two categories (FBI> 50, orange and red), are set based on increasing likelihood of community losses, more specifically houses, and potentially lives. The top two categories are very similar in that they represent particularly dangerous fire behavior, however the top category (FBI: 100+, red) is aimed at representing conditions where historically there have been significant life and house losses.

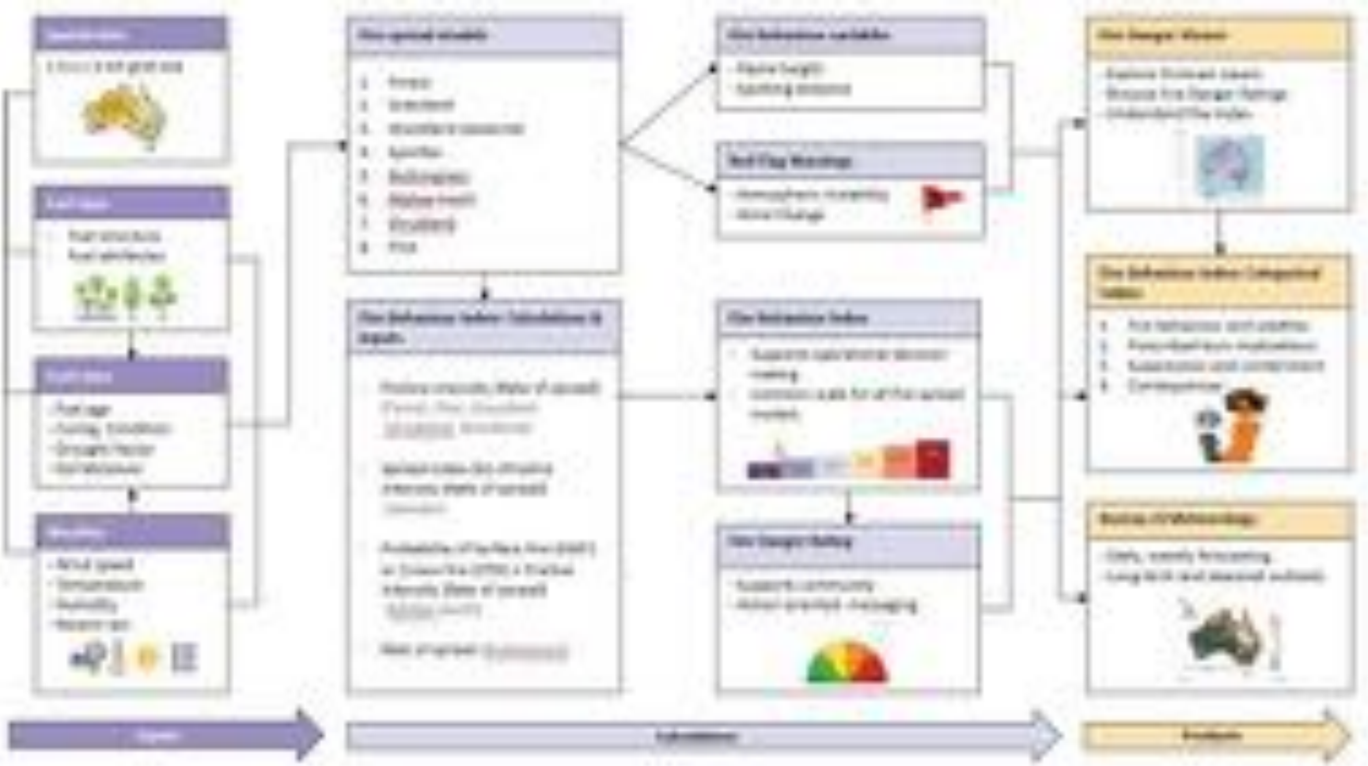
Consistent transitions across fuel types are established for each broad fuel type despite the diversity of fire behaviour, suppression response and potential for impacts often observed between each of the eight fuel types. Not all fuel types require the five transition points described for forest fuels to represent the unique characteristics, decisions and response required. As a result, three to five transition points are applied depending on fuel type.

THRESHOLD VALUES

Between each of the categories are threshold values that determine where the transition occurs. During the development of the research prototype, it was established that the points that define each category needed to be specific to each fuel type. For most fuel types, fireline intensity was identified as the most suitable variable since it is a simple calculation based on rate of spread, and because of existing alignments with suppression difficulty, firefighter safety, community impact and loss and fire behaviour. In some fuel types, the fire-spread model was suitably built to indicate the transitions aligned with model outputs including probabilities of specific fire behaviours.

HOW IS THE INDEX CALCULATED?

The Fire Behaviour Index is determined through models for fire-spread rate or other fire behaviour characteristics, such as likelihood of spread and crowning. Different fuel types have distinct fire behaviour characteristics driving the Fire Behaviour Index. Calculations for the AFDRS begin with input data at the 1.5 kilometre spatial scale across Australia to enable alignment



Fire Behavior Index Tables provide users with clear and consistent descriptions of indicative fire behavior and fire weather, implications for prescribed burning, fire suppression and containment, and potential for impact.

with the Bureau of Meteorology's gridded weather forecast. Inputs include fuel type and fuel state information, which are applied to calculate the variables needed for the Fire Behaviour Index. For most fuel types this variable is rate of spread which is used to then determine fireline intensity.

In addition to the Fire Behaviour Index, fire behaviour variables including flame height and spotting are calculated as supplementary information. Red flag warnings are also provided to accompany forecasts to indicate conditions that support atmospheric instability and forecast wind directional change. Supplementary variables and red flag warnings don't influence the forecast Fire Behaviour Index or the Fire Danger Rating, however fire managers are able to use the information to identify additional considerations.

The Fire Behaviour Index can be used at this point for operational decision making by applying the relevant categorical table/s of descriptions. The Fire Behaviour Index is also directly applied to determine the Fire Danger Rating, which provides community members with the information they require to actively respond to conditions. The forecasting information comes together and can be accessed via the Fire Danger Viewer or the Bureau of Meteorology's online forecasting products, which are provided for both short -term and seasonal forecasting.

CLEAR AND CONSISTENT DESCRIPTIONS

With established transition points that trigger each category, the Fire Behaviour Index is supported by clearly and consistently described forecast conditions. In this way, uncertainty is reduced and users are provided with information they need to assist decision making.

Information provided seeks to answer important questions:

1) What will a fire look and behave like (if it occurs)?

2) How difficult is a fire likely to be to suppress or contain?

3) Generally, how suitable are the conditions for prescribed burning?

4) What are the likely impacts based on actual historical community losses?

Information is provided in tables for each category, for each fuel type. The same descriptions are also provided by information type, for each fuel type. allowing easy comparison across '

GO LIVE

Forecasts of fire danger in Australia are planned to switch to the Australian Fire Danger Rating System in 2022. There is a lot to accomplish and prepare before the system gets officially turned on, including development and testing of suppression, ignition and impact indices to support fire danger forecasting, an operational trial for the Fire Behaviour Index and Fire Danger Rating and continued work with operational users to prepare for the change.

THE LEGACY OF ALAN MCARTHUR

The Australian Fire Danger Rating System incorporates advances in our collective understanding of fire danger that began many years ago with the work of McArthur and his team. As we move forward into the future of fire danger forecasting in Australia we give a nod, tip our hats and say our thanks for providing us with a system that has stood the test of time and provided the foundation for us to progress and improve our understanding of fire behaviour and fire danger in Australia. Through a modular platform the Fire Behaviour Index will continue to improve by incorporating scientific advancements and developments.

AUTHORS' NOTE

We acknowledge that many people and contributions have made this work possible and bought us to the position we are today. From those who have mapped bushfire fuels in their local areas to national and international researchers who have committed their years to better understanding fire behaviour and fire danger, we say thank you! Development of the Fire Behaviour Index has also relied on the expertise and participation of many people involved in fire operations as well as national and international researchers, whose efforts and support have been greatly appreciated.

The Australian Fire Danger Rating System has been funded by the Australian government and each state and territory government, working together to improve fire danger ratings and community safety as a national priority.

Additional information on the Australian Fire Danger Rating System can be found at https://www.afac.com.au/initiative/afdrs. For further reading on fire behaviour and fire spread in Australia, we recommend A Guide to Rate of Fire Spread Models for Australian Vegetation by Cruz et al. (2015).

ABOUT THE AUTHORS

Jennifer Hollis is a research officer and a fire behaviour analyst of the New South Wales Rural Fire Service. Hollis is working on development of the Australian Fire Danger Rating System, specifically on the Fire Behaviour Index and its operational application. Previously, Hollis has conducted bushfire research and worked on a diverse range of research projects including development of the framework for an Australian Bushfire Fuel Classification, modelling woody fuel consumption, assessing the effectiveness of aerial suppression, establishing better techniques for the determination of grassland curing, and quantifying capacity for carbon storage within West Australian forest ecosystems. Hollis completed her PhD in mathematics and statistics in 2011 with the University of New South Wales at Australian Defence Force Academy.

Stuart Matthews, PhD, is a principal project officer of the New South Wales Rural Fire Service. Matthews is responsible for developing tools and systems to support fire behaviour predictions, including an ensemble modelling system. He has also been closely involved in supporting research projects to develop improved fire behaviour models. Stuart leads the New South Wales Rural Fire Service contribution to the implementation of the Australian Fire Danger Rating System.

CANADA TACKLES WORKPLACE CULTURE

LGBTQ PERSONNEL REPORT HIGHER LEVELS OF DISSATISFACTION

BY LAURIE VANDESCHOOT AND NINA VAUGHAN

Over the last few years, the Canadian Interagency Forest Fire Centre (CIFFC) and its member agencies have proactively begun discussions to address culture change in the Canadian wildland fire community in response to some distinct, yet compounding issues around diversity, inclusion, and respect in the wildfire culture.

To that end, an equity, diversity, and inclusion (EDI) survey was conducted in the second half of 2020 to better understand the experiences of people deployed by CIFFC in recent years and to assess the deployed members' experiences and perceptions about diversity, inclusion, and respect during CIFFC deployments.

CIFFC is owned and operated by the federal, provincial and territorial wildland fire management agencies and co-ordinates resource sharing, mutual aid, and information sharing.

CIFFC executive director Kim Connors said the agency is committed to ensuring everyone who is deployed is safe – physically and psychologically.

"We know that not everyone is experiencing deployments in the same way," Connors said. "Let me be unequivocal: CIFFC and its member agencies find no place for harassment, bullying, or other forms of disrespectful workplace behaviors by deployed personnel or contractors.

"We have been working with our CIFFC team and our consultants to better understand the issues and develop a plan for moving CIFFC and all deployed members to a more inclusive and safe working environment."

The survey was open for two months, from Aug. 11 through Oct 9, 2020, to allow for the largest number of responses from deployed personnel. Of the 8,092 deployments made through CIFFC in the last three years, 530 individual members responded to the survey, with 503 completing the entire survey. This response rate is statistically significant with a 99 per cent confidence rate and five per cent margin of error, suggesting that the findings can be assumed to represent the entire population of deployed members.

EMPLOYEE INFORMATION

> Understanding the current experiences of overrepresented and underrepresented groups can assist with the development of future strategies and can provide a baseline for measuring success.

The breakdown of survey participants provided a good cross section of employees with a fairly even split among employee demographics.

The initial demographic information acquired was valuable in understanding who goes on a CIFFC deployment, and what makes them unique. The data allowed for additional analysis, and helped to assess what, if any, groups were experiencing workplace issues with greater frequency than others. The collected data can be used as a starting point for future initiatives and a benchmark for measuring the outcomes of those efforts.

> "...there appears to be very high levels of intentional incivility, harassment, and discrimination being experienced and witnessed."

RESPONDENT DEMOGRAPHICS

	25% females **75%** males
	56% permanent **44%** seasonal or temporary
	5% First year or season **60%** 2-10 years or seasons **34%** More than 10 years or seasons
	39% Age <34 **26%** Age 35-44 **34%** Age >45
	17% IMT member, deployed as a team **9%** Single resource, fire centre support **17%** Single resource, part of an IMT **13%** Single resource, fire line operations **37%** Fire crew
	15% Indigenous **6%** Visible minority **4%** Person with a disability **13%** LGBTQI+ identity

WORKPLACE CULTURE

> Recognizing which workplace behaviours are tolerated, accepted, and rewarded shines a light onto understanding the culture of an organization.

The survey results revealed an interesting dichotomy in responses. While respondents felt very positive about their deployment experiences, they also revealed some areas that require attention related to workplace culture and workplace behaviors.

- 95 per cent of respondents were satisfied with their experience while deployed
- 93 per cent of respondents felt valued while on deployment
- 93 per cent of respondents felt that their direct supervisor treated them with respect
- 90 per cent of respondents felt their workplace was an inclusive workplace

Questions about workplace culture also revealed some areas worth examining further. For example, 27 per cent of all respondents disagreed that they had been properly briefed by the receiving agency on how to report workplace concerns while on deployment. In addition, 10 per cent did not feel they could discuss workplace issues with their direct supervisors, and nine per cent did not feel that humour was used appropriately in the workplace.

Overall, members of minority groups reported higher levels of disagreement with all the culture-related questions, particularly LGBTQ respondents, who reported the highest levels of disagreement for all groups. Of female respondents, 16 per cent disagreed with the statement regarding the use of humour and 17 per cent disagreed that their deployment was an inclusive workplace.

- "Agency briefings covered operations and safety well, but not the procedures around bullying, harassment, etc."
- "Although I had a supportive supervisor, I witnessed some bullying from other supervisors to their direct reports."
- "As a young female I experienced sexism and ageism from contracted pilots/AMEs, as well as members of our own management."
- "I was disrespected by my crew leader and crew boss, by making sexual comments because of me being a girl."
- "A few people from provincial agencies on the deployment had an 'old school' or 'old boys' club' type of mentality. This was not always prevalent but on occasion there were biases displayed towards women, people of different political persuasion, or younger/newer ways of doing things."

WORKPLACE ENVIRONMENT

> Data in the workplace environment section is helpful to identify what the greatest number of negative experiences are, where they are occurring, and how frequently they are occurring, so that targeted approaches can be taken.

Questions regarding the workplace environment on deployments revealed some concerning results. First, there appears to be very high levels of intentional incivility, harassment, and discrimination being experienced and witnessed. In addition, there are concerning levels of workplace violence and hazing occurring, and finally, more than two-thirds of respondents did not report the incident they had experienced or witnessed. Of all respondents, 27 per cent experienced and 35 per cent witnessed a disrespectful workplace incident.

In other surveys, researchers have found that when asked a series of questions about types of disrespectful behavior, the number of respondents who experienced an incident decreases as the seriousness of the incident increases. That is not true however, in these survey results.

According to the survey results, the key reasons for not reporting the incident included fear of retribution, fear of being ostracized, and a belief that nothing would have been done about it. The majority of incidents reportedly occur either on the fire line or in camp, so an opportunity exists for a targeted response to these issues in those locations.

SUMMARY AND RECOMMENDATIONS

Overall, the survey provided a rich source of data that allows for a strategic approach to advancing the issues identified through the development of an EDI framework. That framework will assist in advancing CIFFC's desire to integrate EDI into the Canadian wildland fire community, and enhance the deployment experience, making it a safe, diverse, and inclusive experience for all involved.

The research identified some key areas for attention as well as strengths that can be leveraged moving forward. Overall, the results indicate that deployed members love their jobs, and like being deployed through CIFFC, but they are willing to put up with high levels of disrespectful workplace behaviours to do so.

KEY AREAS OF DIFFICULTY
High levels of workplace incivility.
Lack of reporting of workplace incidents.
High levels of disrespectful workplace behaviors against all minority groups.
KEY AREAS OF STRENGTH
Committed, passionate and competent personnel who overwhelmingly believe deployment is something they would recommend to coworkers
A strong CIFFC commitment to continuing to cultivate a respectful, supportive, and inclusive environment.
A strong agreement that people are satisfied with their deployment experience (95 per cent).

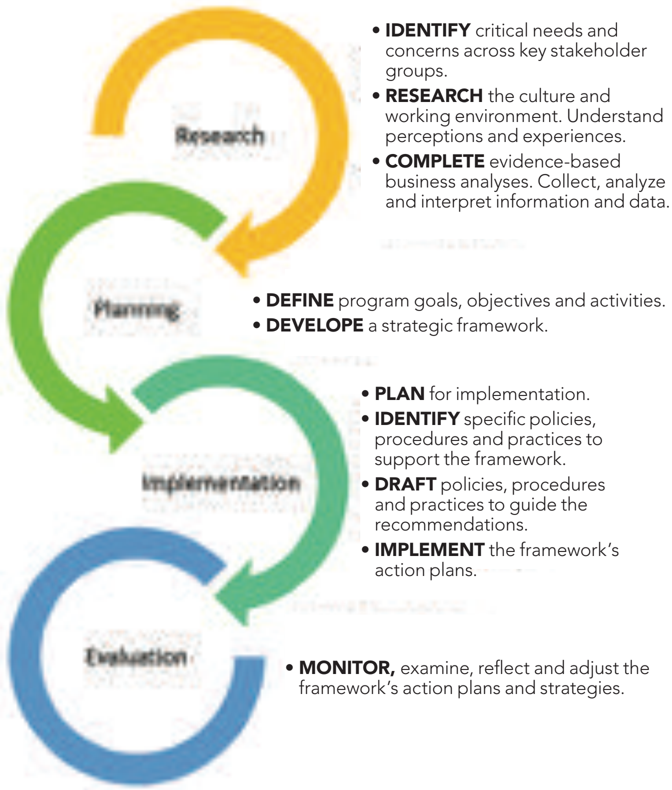
NEXT STEPS

The intended outcomes for this project were:

- to measure perceptions of deployed personnel and discover the strengths and weaknesses of the culture
- to raise awareness of EDI issues
- to provide a baseline against which to measure future progress
- to act as a leadership tool to help promote EDI culture transformation.

AREAS OF ATTENTION

- **Two out of every five** women and **one out of four** men have experienced disrespectful workplace behaviours
- **One-third** of those experienced more than five incidents
- **57 per cent** of LGBTQI+ members have experienced incidents
- **10 per cent** of men and **4 per cent** of women have experienced workplace violence on a deployment
- **Half** of those > 25 years of age experienced hazing
- **65 per cent** of incidents occurred on the fire line or in camp
- Almost **two-thirds** of incidents are **NOT** reported



While these outcomes have been achieved, this component of the project should be the first step of a four-phase approach to CIFFC achieving its desired impact of a culture transformation within the Canadian wildland fire community.

The next component of this project, which was approved in 2020, will complete the research phase by conducting focus groups and an audit of CIFFC policies and ancillary documents. At the completion of component two, CIFFC will receive a full respectful-workplace culture assessment report that integrates all the findings from the first two components. This report will be an objective, detailed analysis of CIFFC's EDI environment and of the deployment experience for the Canadian wildland fire community.

The final two components of the project should include component three, the development of a national strategy focused on EDI through the development of a CIFFC-specific EDI framework. That framework would act as a guide for CIFFC and a best practices recommendation for partner agencies.

Finally, component four would see the identification of specific policies and practices to support the psychological health and safety of deployed members and can be seen as the implementation phase of this project.

ABOUT THE AUTHORS

Laurie VandeSchoot is deputy chief with Calgary Fire Department and president of consultancy Satya Inc.

Nina Vaughan had a 29-year career in policing and is president of Vaughan Consulting in Calgary.

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A LEGACY OF LEADERSHIP

EDITOR'S NOTE: Thoughts on Leadership columnist Michael DeGrosky retired in June from his position as the Fire Protection Bureau Chief for the Montana Department of Natural Resources and Conservation. DeGrosky's fire career began as a volunteer firefighter while he was still in high school and spanned more than 40 years; he was a hotshot, fire management specialist, fire management officer, volunteer fire department captain, career fire department training officer and, for 20 years, a consultant and leadership advisor to fire and emergency service organizations. Editor Laura King talked to DeGrosky about his role with the IAWF and his longtime contribution to Wildfire magazine. The interview is edited for length and clarity.

LK **How are you staying involved with wildland fire and wildland fire fighting?**

MD I'm still doing informal coaching and mentoring with former colleagues. I am also attending the occasional virtual conference workshop or webinar to stay connected with people that I don't see or contact regularly. IAWF has been awesome in that regard. I caught a little bit of the Cohesive Strategy Workshop. And the Ignite Talks have been really a good way to stay in touch. I'm writing the column and that feels good; it gives me a way to still have a little bit of influence. And I do a bit of work for money here and there. For example, I recently facilitated an after-action review for the National Park Service.

LK **You've played some important roles with IAWF. How did you become a member and eventually a board member, and what did you and/or the board accomplish during that time**

MD I've been trying to put my finger on exactly when I joined; it was in the early nineties, shortly after the association appeared on the scene as an association, which was 1991. My entry point was Wildfire magazine. I got exposed to wildfire magazine at work, and became a subscriber. I was interested in the association. And that led to me making a pilgrimage out to Fairfield, Washington, to meet Jason Greenlee and Maria Greenlee, the folks who helped dream up the idea of the IAWF and had formed the organization that had been IAWF's embryo . . . and I tried to be as active of a member as I could, after joining. And then as far as the board goes, in 1997, I received an interesting offer; Jason contacted me and asked me to join the board, and at the same time asked me if I would be the board president.

I just found a set of board minutes from before I was on the board where they discussed me and, and that idea. The board president at the time resigned her position – she was the first board president, Dr. Andi Koonce – and nobody wanted to step up and be the president, and several people were leaving the board. They had discussed inviting me to join the board and simultaneously inviting me to be the board president, because Jason knew that I had been doing a fair amount of work with nonprofits. So after some negotiation, I accepted that role and that began my tenure with the board. I served two terms then stepped away when I took a new job. At the end handing the president reigns over to Bruce Suenram. I've been a member ever since.

The thing that was most important that we accomplished was the survival of the association. I took over the board at a time when the association both lacked a fully functioning board and faced some enormous challenges. Our first accomplishment was to reestablish a governing board. There were a couple of people from the previous board who were willing to stay on, and Jason had some ideas. I had some friends that I thought might join, and we put the board of directors back together. Soon after, we realized that the association was financially insolvent and faced some other big challenges.

Assuring the survival and the continuation of the association was huge, as was establishing the association's strategic direction. I just went and took a quick look at the association's website just a few minutes ago and realized that while there's been a lot of very positive evolution over the intervening 24 years, we put the association on a path – the mission we established back in the 1997 remains the core of the IAWF today.

The association continues to carry out that mission in such great ways. So I think putting the association on its strategic footing was really big. And I think that's proven out by the fact that that strategy has endured for 25 years.

Part of that was to make a very intentional pivot. The association's roots were really in creating the international Journal, running a printing operation, and managing a large database. It was oriented toward providing some very needed things for the


"FIRESTORM '77 IS A VALUABLE CONTRIBUTION TO OUR KNOWLEDGE OF AMERICAN FIRE HISTORY. IT'S PARTICULARLY EXCITING TO SEE THIS OFTEN OVERLOOKED FATALITY FIRE GET THE ATTENTION IT MERITS."
STEPHEN J. PYNE, EMERITUS PROFESSOR
ARIZONA STATE UNIVERSITY, TED SPEAKER
"FIRESTORM '77, A TIMELY RETELLING OF THE 1977 HONDA CANYON FIRE, GRIPPED ME FROM THE FIRST MOMENTS THROUGH THE TELLING OF THE HORRIFIC EVENTS BY PARTICIPANTS, THEIR EMOTIONS STILL RAW, TO THE EXAMINATION OF LESSONS LEARNED-AND UNLEARNED."
JOHN N. MACLEAN, AUTHOR
FIRE ON THE MOUNTAIN
Central Coast Filmmaker Showcase
SAN LUIS OBISPO INTERNATIONAL FILM FESTIVAL
2021
BEST FEATURE FILM
WINNER
BBFS AWARD:
Best US Documentary Feature
BIG BEAR FILM SUMMIT 2021
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2021
"HELL OF A FILM!"
GABRIEL HORN
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NOW STREAMING ON
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research community. And that has been, and remains, extremely valuable. The IJWF is the go-to journal for people working in wildland fire research, but we made a very intentional pivot to become more of a membership organization in the 1990s.

One thing that did occur during my board tenure was our partnership with CSIRO, which essentially assured the continuation and ongoing success of the IJWF.

At the time we had to beg people to come and join the board. People would come onto the board and then choose to leave because they were concerned about conflicts of interest with their day job. We had to go out and beat the bushes and beg people to be on the board. And now it's a desirable thing, it's competitive; you can apply for a board and not get accepted because there are more people interested than there are positions.

Jason had an amazing vision for what the association could be. And I think the board during my tenure picked up that vision and turned it into reality by broadening the appeal of the association to a much larger slice of the wildland fire community.

LK **What were the biggest and most important issues that you tackled during your tenure on the board?**

MD Firefighter safety. That was right at the time of the first Wildland Fire Safety Summit. It started out as the Canada/U.S. Firefighter Safety Summit; it expanded into the Canada, Australia, U.S. Safety Summit, which eventually became the combined Wildland Fire Safety Summit and Human Dimensions Conference we know today. That was a huge, what the association has done to advance and communicate and provide leadership regarding the issue of firefighter safety. Of course, it was very important that we continued to provide the two key publications, the Journal and Wildfire, one serving an essential role in the research community, and the other serving a really important role in the practitioner community. Wildfire has evolved to serve a broader readership now. Those were big issues, firefighter safety, and continuing those publications. Our conferences were also very important.

Conferences were a thing that the association was doing every two or three years. When we established the strategic direction for the association in 1997, we decided that conferences were an essential part of what the IAWF needed to do. We've continued to build that service as a core part of our brand. Through partnerships, we're filling a niche that nobody else even comes close to filling.

LK **IAWF did a readership survey in which members listed some areas of importance to them; I'm interested to know what you think are the most important issues IAWF needs to tackle.**

MD Well, I think, I think the current focus interest on diversity, equity and inclusion within the wildland fire service is the one of the big topics of our time. I think fire-adapted communities and community adaptation to fire is just huge. I think smoke is going to be an issue that will drive fire policy into the future, the health effects of smoke on firefighters and public health will be a driving issue. The other one is a continuation of what the association already does – linking practitioners and the research, not just the physical science, but the social science.

LK **What is your motivation to continue to write Thoughts on Leadership?**

MD The history of the column is that in 2001, Lark McDonald, who is the president and CEO of Mission-Centered Solutions, approached me about becoming more active in the association and wondering how he and his company might make some contribution to the association. We conceived of this idea of Lark writing a regular column for Wildfire. I think the name Thoughts on Leadership was Lark's chosen name. Lark wrote the column for about a year. As his business started to grow, I would fill in when he couldn't make the deadline. I was working on my master's in leadership studies. And then, I think it was about 2004, Lark's company really took off and his commitments were such that he had to step back and I took over the column.

As far as motivation, honestly, it is the place where I get to merge my two passions – wildland fire and leadership. About 20 years ago I started studying leadership formally, first in a master's program, then doing a PhD. Helping people learn about leadership is a big passion. And wildland fire is what I've been doing my entire life. It's a place where I get to merge those two things. And that's my motivation. Retired or not, I'm very interested in improving the wildland fire community, helping the wildland fire community be as good as it can be, and I really love helping people understand leadership and being the best leaders they can be. The column is a great way to merge those two things.

ABOUT THE AUTHOR

Mike DeGrosky recently retired as chief of the Fire Protection Bureau for the Montana Department of Natural Resources and Conservation, Forestry Division. He taught for the Department of Leadership Studies at Fort Hays State University for 10 years. Follow Mike on Twitter @guidegroup or via LinkedIn.


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