LETTERS

Edited by **Jennifer Sills**

Integrated data could augment resilience

The massive November 2018 Camp Fire set the record for the deadliest and most destructive wildfire in California's history (*1*). By the time the blaze was contained, it had scorched 153,336 acres, destroyed 18,804 structures, displaced approximately 52,000 people, and killed 85 people (*1*, *2*). Insured losses are estimated to be between $7.5 and $10 billion (*3*). The damages and losses will likely increase, as there is a risk of potential cascading hazards, such as toxic ash, poor air quality, and mudslides and debris flow (*4*). California has experienced an increase in wildfire activity over the past few years (*5*), and the trend is projected to continue (*6*). Going forward, scientists must help decision-makers and first responders prevent extreme hazards like the Camp Fire from turning into massive human disasters.

Lack of an integrated framework for circulating information among decision-makers and passing it to residents exacerbated the devastating impact of the wildfire. Reports unanimously point to shortcomings in disseminating critical information to residents before and during the wildfire (*7*). The data crisis further increased in areas where cellular and telecommunication infrastructure was damaged, limiting internet access (*8*).

Investment in an integrated data system for identifying, harnessing, synthesizing, and communicating pertinent data will enable decision-makers and communities to better anticipate, prepare for, respond to, and recover from extreme events such as the Camp Fire. We must identify relevant stakeholders, examine the required data, collect public and relevant private data efficiently, and develop platforms for processing datasets such as weather data, cell phone GPS data as proxy for people, social media feeds, and traffic cameras and sensors. We then need strategies to convert datasets into usable information by using artificial intelligence technologies for decision-support systems. To communicate the resulting information effectively, we need a reliable data infrastructure for real-time analysis that could alert residents by email, phone messages, text warning, television, radio, and "reverse 911" (*9*).

California's wildfires are just one example of emerging compound natural hazards. By augmenting existing resiliency platforms, we can mitigate the destruction caused by future natural disasters. These augmented platforms will require regionalized resiliency indices that can be tested, verified, and updated after each extreme event. Successfully integrating and communicating data cannot be achieved without close collaboration with data stakeholders, community-level stakeholders, and state-level institutions.

Farshid Vahedifard[1]*, Alireza Ermagun[1], Kimia Mortezaei[1,2], Amir AghaKouchak[3]
[1]Department of Civil and Environmental Engineering, Mississippi State University, Mississippi State, MS 39762, USA. [2]Center for Advanced Vehicular Systems (CAVS), Mississippi State University, Mississippi State, MS 39762, USA. [3]Department of Civil and Environmental Engineering, University of California, Irvine, CA 92697, USA.
*Corresponding author.
Email: farshid@cee.msstate.edu

REFERENCES

1. "Top 20 most destructive California wildfires," CalFire (2018); www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Destruction.pdf.
2. "Camp Fire incident update, Date: 11/25/2018, Time: 7:00 a.m," CalFire (2018); http://cdfdata.fire.ca.gov/pub/cdf/images/incidentfile2277_4326.pdf.
3. "Latest Estimates of Insured Losses from California Wildfires at $9B to $13B," *Insurance Journal* (2018); www.insurancejournal.com/news/west/2018/11/19/509677.htm.
4. A. AghaKouchak *et al.*, *Nature* **561**, 458 (2018).
5. National Interagency Fire Center, "2018 national year-to-date report on fires and acres burned" (2018); https://gacc.nifc.gov/sacc/predictive/intelligence/NationalYTDbyStateandAgency.pdf.
6. J. D. Radke *et al.*, "Assessing extreme weather-related vulnerability and identifying resilience options for California's interdependent transportation fuel sector" (Center for Catastrophic Risk Management, University of California, Berkeley, 2018); www.climateassessment.ca.gov/techreports/docs/20180827-Energy_CCCA4-CEC-2018-012.pdf.
7. E. Levenson, "Many Camp Fire victims didn't get emergency alerts. Those who did got them too late," CNN (2018); www.cnn.com/2018/11/15/us/california-fire-emergency-alert/index.html.
8. "California Camp Fire threatens fiber optics," GeoTel Communications (2018); www.geo-tel.com/2018/california-camp-fire-threatens-fiber-optics/.
9. J. Rainey, "Paradise Fire survivors say warnings were too little, too late," NBC (2018); www.nbcnews.com/news/us-news/paradise-fire-survivors-say-warnings-were-too-little-too-late-n935846.

10.1126/science.aaw2236

Wildfires: Opportunity for restoration?

Wildfires are increasingly making global headlines due to their destructive effects. In many parts of the world, climate change (*1*), accelerating land-use alterations (*2*), and other factors are making large wildfires more frequent and their ecological effects more severe (*3*). Most organisms in the world's fire-prone ecosystems have evolutionary adaptations to cope with natural fire cycles (*2*). However, ongoing changes in fire regimes, coupled with drier climate and other associated natural and anthropogenic disturbances (*4*–*6*), can surpass the capacity of organisms to cope with disturbance (*7*) and ultimately trigger ecosystem collapse (*5*). As a result, wildfires are one of the major drivers of change in forest cover worldwide (*8*). Yet, under some circumstances, wildfires can also provide an opportunity for ecosystem restoration.

About 2 billion hectares of the world's terrestrial ecosystems are considered degraded and in need of ecological restoration (*9*), and most ecosystems are under the threat of changing climatic conditions. Wildfires can provide a window of opportunity in which scientists and forest managers can

Better data integration and dissemination could mitigate the effects of hazards such as the November 2018 Camp Fire.

take action to restore degraded ecosystems, eradicate undesirable species and pests, and favor vegetation that is better adapted to future climatic conditions. For example, dense, monospecific pine plantations from the 20th century, which are often unproductive because of climate and soil limitations, abound across the Mediterranean Region (*10*). They were originally planted to retain soil and regain plant cover, but they now generate many ecological challenges, such as increasing the risk of high-intensity fire and hindering the development of native vegetation (*10*). Wildfires may thus release the native vegetation from the fierce competition of the dense pine canopy [e.g., (*11*)] and provide management opportunities to favor more diverse and resilient—and less flammable—communities, including species adapted to future fires and to drier conditions. Such management can involve letting preexistent natural communities, previously oppressed by competitive planted canopies, regenerate on their own through passive restoration, or providing some help through population reinforcement. In other cases, postfire restoration could be a time to conduct assisted migration to reduce forest vulnerability to future fire and drought conditions (*6*).

Wildfires generally trigger management actions and attract funding to implement them. Forest managers and scientists should leverage these opportunities to address long-term goals that could not be easily achieved in the absence of wildfires because of public opposition, lack of access through dense vegetation, lack of funding, or too much bureaucracy. Moreover, forest policy should include contingencies for wildfires so that, in case one occurs, appropriate management actions are predefined to address not only the imminently necessary treatments identified during the emergency situation but also mid- and long-term goals.

We do not minimize the problems and risks associated with wildfires, nor do we wish to stimulate the spread of uncontrolled fires with potentially tragic consequences. However, once a wildfire has occurred and the immediate danger has passed, we urge scientists and forest managers to seize the opportunity to rethink forest management and foster more resilient landscapes.

Alexandro B. Leverkus[1]*, Pablo García Murillo[2], Vicente Jurado Doña[3], Juli G. Pausas[4]

[1]Field Station Fabrikschleichach, Department of Animal Ecology and Tropical Biology (Zoology III), Julius-Maximilians-University Würzburg, 96181 Rauhenebrach, Germany. [2]Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, E-41012 Sevilla, Spain. [3]Departamento de Geografía Física y Análisis Geográfico Regional, Universidad de Sevilla, E-41004 Sevilla, Spain. [4]Centro de Investigaciones sobre Desertificación (CIDE-CSIC), 46113 Montcada, Valencia, Spain.
*Corresponding author.
Email: alexandro.leverkus@uah.es

REFERENCES

1. R. Seidl *et al.*, *Nat. Clim. Change* **7**, 395 (2017).
2. J. G. Pausas, J. E. Keeley, *Bioscience* **59**, 593 (2009).
3. C. I. Millar, N. L. Stephenson, *Science* **349**, 823 (2015).
4. A. B. Leverkus, D. B. Lindenmayer, S. Thorn, L. Gustafsson, *Glob. Ecol. Biogeogr.* **27**, 1140 (2018).
5. D. B. Lindenmayer, C. Sato, *Proc. Natl. Acad. Sci. U.S.A.* **115**, 5181 (2018).
6. C. D. Allen, D. D. Breshears, N. G. McDowell, *Ecosphere* **6**, 1 (2015).
7. J. F. Johnstone *et al.*, *Front. Ecol. Environ.* **14**, 369 (2016).
8. P. G. Curtis, C. M. Slay, N. L. Harris, A. Tyukavina, M. C. Hansen, *Science* **361**, 1108 (2018).
9. R. Cernansky, *Nature* **560**, 542 (2018).
10. J. G. Pausas, S. Fernández-Muñoz, *Clim. Change* **110**, 215 (2012).
11. A. B. Leverkus, J. M. Rey Benayas, J. Castro, *Ecology* **97**, 2628 (2016).

10.1126/science.aaw2134

Protect Catalonia's corals despite politics

The Mediterranean red coral (*Corallium rubrum*), sold as a precious organic gemstone and homoeopathic product, is classified as endangered by the IUCN (*1*–*3*). In January 2017, a regional report concluded that 90% of red coral populations in Catalonia had failed to reach the minimum harvest size and were on the verge of collapse (*3*). In response, the Catalan Parliament declared the first moratorium of red coral in the Mediterranean basin (*4*). In October 2017, the General Fisheries Commission for the Mediterranean (GFCM) made a recommendation consistent with Catalonia's decision: The GFCM declared that if a Mediterranean country finds that

25% of the total red coral catch, in a given zone, is undersized (less than 7 mm basal diameter), then that country should close the area to red coral fishing as a precautionary measure to protect red coral stocks (*5*). As the GFCM recommendation confirmed, Catalonia's action was consistent with scientific evidence and the protection afforded by European regulations (*6*). However, politics has undermined Catalonia's efforts.

On 27 October 2017, Catalonia declared its independence (*7*). Three days later, the Spanish government applied Article 155 to gain control over all Catalan institutions (*8*). In November 2017, the Spanish Ministry of Agriculture disregarded Catalan's coral moratorium and granted 12 red coral fishing licenses in Catalonia's exterior waters, under Spanish jurisdiction (*9*). In May 2018, Catalonia regained control of its institutions. A month later, the government of Spain was disbanded after a vote of no confidence due to corruption, and the parties formed a new government (*10*). Despite hopes of a new era of diplomacy between Spain and Catalonia, on 14 November 2018, the new Spanish Ministry of Agriculture upheld the red coral fishing licenses (*11*). A few days later, more than 80 research institutions, nongovernmental organizations, and activists sent a letter (for the third time) asking the ministry to revoke the decision (*12*), but no action has been taken.

The European Commission has the authority to protect endangered marine species through several conservation mechanisms supported by international policies and management strategies (*6*). Member states are responsible for complying with GFCM regulations. Given that Spain is not honoring Catalonia's moratorium, the commission should use its powers to protect red coral not only from overexploitation but also from political conflicts that endanger its persistence.

Nur Arafeh-Dalmau[1]*, Cristina Linares[2], Bernat Hereu[2], Hernan Caceres-Escobar[1,3], Duan Biggs[1,4,5], Hugh Possingham[1,6]

[1]ARC Centre of Excellence for Environmental Decisions, Centre for Biodiversity and Conservation Science, School of Biological Sciences, University of Queensland, Brisbane, QLD 4072, Australia. [2]Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Institut de Recerca de la Biodiversitat (IRBIO), University of Barcelona, 08028 Barcelona, Spain. [3]National Environmental Science Programme Threatened Species Recovery Hub, The University of Queensland, Brisbane, QLD 4072, Australia. [4]Environmental Futures Research Institute, Griffith University, Nathan, QLD 4111, Australia. [5]Department of Conservation Ecology and Entomology, Stellenbosch University, Matieland 7602, South Africa. [6]Office of the Chief Scientist, The Nature Conservancy, Arlington, VA 22203–1606, USA.
*Corresponding author.
Email: n.arafehdalmau@uq.net.au

REFERENCES

1. M. M. Otero *et al.*, "Overview of the conservation status of Mediterranean anthozoans" (IUCN, Malaga, Spain, 2017); pp. 36–41.
2. A. W. Bruckner, *Mar. Ecol. Prog. Ser.* **397**, 319 (2009).
3. J. Garrabou *et al.*, "Informe sobre l'estat de les poblacions de coral vermell (*Corallium rubrum*) a les aigües de Catalunya," (Generalitat de Catalunya, 2017); www.cibsub.cat/rcs_actu/2017_Informe_estat_poblacions_corall_costa_catalana.pdf [in Catalan].
4. Order ARP/59/2017 of 18 April 2017, *Diari Oficial de la Generalitat de Catalunya*, No. 7351 (2017); https://portaldogc.gencat.cat/utilsEADOP/PDF/7351/1604661.pdf [in Catalan].
5. Recommendation GFCM/41/2017/5 on the establishment of a regional adaptive management plan for the exploitation of red coral in the Mediterranean Sea (2017); www.fao.org/gfcm/decisions/en/.
6. C. Regulation, No. 1967/2006 of 21 December 2006, *Official Journal of the European Union L, 409* (2016); http://publications.europa.eu/resource/cellar/f7b0a754-4a19-4cf9-8040-aeae2faace38.0005.01/DOC_1.
7. Proposta de resolució que regula la proclamació de la República Catalana, of 27 October 2017, No. 72032 (2017); www.ara.cat/2017/10/27/255_00004_11_RG72032_GP_JxSI_GP_CUP_20171027-1.pdf [in Catalan].
8. Order PRA/1034/2017 of 27 October 2017, *Boletín Oficial del Estado*, No 260 (2017); www.boe.es/boe/dias/2017/10/27/pdfs/BOE-A-2017-12328.pdf [in Spanish].
9. Order APM/1101/2017 of 16 November 2017, *Boletín Oficial del Estado*, No. 278 (2017); http://noticias.juridicas.com/base_datos/Admin/608222-om-apm-1101-2017-de-2-nov-convoca-el-procedimiento-de-autorizacion-para-la.html [in Spanish].
10. S. Jones, "Mariano Rajoy ousted as Spain's prime minister," *The Guardian* (2018); www.theguardian.com/world/2018/jun/01/mariano-rajoy-ousted-as-spain-prime-minister.
11. Order APA/1186/2018 of 14 November 2018, *Boletín Oficial del Estado*, No. 277 (2018); www.boe.es/boe/dias/2018/11/16/pdfs/BOE-A-2018-15612.pdf [in Spanish].
12. F. Segura Castro (Ecologistes en Acció de Cataluunya), "Letter to: Teresa Ribera Rodríguez (Minister of Ecological Transition) and Luis Planas Puchades (Minister of Agriculture, Fisheries and Food)" (2018); www.ecologistasenaccion.org/wp-content/uploads/2018/11/20181126-Carta-Coral-Rojo-relación-entidades.pdf [in Spanish].

10.1126/science.aav8710

The Spanish government has disregarded Catalonia's efforts to protect red coral (*Corallium rubrum*).

PHOTO: CRISTINA LINARES

TECHNICAL COMMENT ABSTRACTS

Comment on "Tropical forests are a net carbon source based on aboveground measurements of gain and loss"

Matthew C. Hansen, Peter Potapov, Alexandra Tyukavina

Baccini *et al.* (Reports, 13 October 2017, p. 230) report MODIS-derived pantropical forest carbon change, with spatial patterns of carbon loss that do not correspond to higher-resolution Landsat-derived tree cover loss. The assumption that map results are unbiased and free of commission and omission errors is not supported. The application of passive moderate-resolution optical data to monitor forest carbon change overstates our current capabilities.

Full text: dx.doi.org/10.1126/science.aar3629

Response to Comment on "Tropical forests are a net carbon source based on aboveground measurements of gain and loss"

A. Baccini, W. Walker, L. Carvalho, M. Farina, R. A. Houghton

The Hansen *et al.* critique centers on the lack of spatial agreement between two very different datasets. Nonetheless, properly constructed comparisons designed to reconcile the two datasets yield up to 90% agreement (e.g., in South America).

Full text: dx.doi.org/10.1126/science.aat1205

Comment on "Impacts of species richness on productivity in a large-scale subtropical forest experiment"

Hua Yang, Zhongling Guo, Xiuli Chu, Rongzhou Man, Jiaxin Chen, Chunjiang Liu, Jing Tao, Yong Jiang

Huang *et al.* (Reports, 5 October 2018, p. 80) report significant increases in forest productivity from monocultures to multispecies mixtures in subtropical China. However, their estimated productivity decrease due to a 10% tree species loss seems high. We propose that including species richness distribution of the study forests would provide more meaningful estimates of forest-scale responses.

Full text: dx.doi.org/10.1126/science.aav9117

Response to Comment on "Impacts of species richness on productivity in a large-scale subtropical forest experiment"

Helge Bruelheide, Yuxin Chen, Yuanyuan Huang, Keping Ma, Pascal A. Niklaus, Bernhard Schmid

Yang *et al.* have raised criticism that the results reported by us would not be relevant for natural forests. We argue that productivity is positively related to species richness also in subtropical natural forests, and that both the species pools and the range of tree species richness used in our experiment are representative of many natural forests of this biome.

Full text: dx.doi.org/10.1126/science.aav9863

Wildfires: Opportunity for restoration?

Alexandro B. Leverkus, Pablo García Murillo, Vicente Jurado Doña and Juli G. Pausas

Science **363** (6423), 134-135.
DOI: 10.1126/science.aaw2134