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Unmanaged heathland – A fire risk in subzero temperatures?

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A R T I C L E I N F O

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A B S T R A C T

Parameters leading to the severe Flatanger and Frøya (Norway) January 2014 subzero wildfires, respectively burning 15 km^2 and 10 km^2 Atlantic heathlands (dominated by heather, *Calluna vulgaris*) and destroying 64 structures, have been analyzed. Traditional heathland management, including anthropogenic fire regimes, had not been performed in these areas over the last 50+ years. As a result, the vegetation composition consisted of degenerated old and woody *Calluna* stands, bushes and shrubs, with high amounts of accumulated (live and dead) biomass. Adiabatically heated subzero temperature easterlies dried the *Calluna* stands. When ignited, the lack of snow cover and the strong winds resulted in rapid fire spread. Rugged terrain, few hours of daylight at 64.4°N and the lack of roads and manmade fire lanes made controlling the fires very challenging. Drying experiments were conducted to learn how quickly *Calluna* plants dry at 20°C and 50% relative humidity from rain-wet conditions. Based on the surprisingly rapid drying of the lower (dead) canopy, vapor pressures and diffusion theory, it is concluded that the Flatanger and Frøya *Calluna* stands represented a severe fire risk within two days of exposure to 50% relative humidity air at 0°C. Young and more vigorous plants in the building phase (6–15 years old), as well as freeze drought damaged (typically some dead small branches) old but still live plants, showed different drying characteristics and dried more slowly. When understanding how degenerated *Calluna* stands, from Portugal to the Arctic Circle, dry in the wintertime, warnings may be issued when appropriate. This paper may also serve as input to discussions regarding the several-thousand-year tradition of prescribed burning versus potential raging wildfires in unmanaged *Calluna* stands.

1. Introduction

The Atlantic heathlands of north-western Europe, from Portugal to the Arctic Circle, are part of an old cultural landscape that originated soon after the introduction of livestock husbandry. It is now of international conservation importance, according to the EC Habitat Directive 92/43/EEC [1,2]. Anthropogenic fire regimes have traditionally been used to increase pasture value and herbivore production in the heathlands [3], and combinations of grazing and burning are crucial for maintaining vegetation composition and successional dynamics in this semi-natural environment [4,5].

Fire has important ecological mechanisms, as it removes old vegetation and prevents shrubs and trees from re-establishing in the habitat [4]. After fire, a number of grasses and herbs establish, and *Calluna* regenerates through resprouting from stems, subterranean organs and from seeds [6]. Fire frequencies are set by the local land-use, and 10–20-year burning rotations are common, although regional and local variation occurs [7–10]. In some areas, despite some years with difficult weather conditions, prescribed fire management works well [11]. In Mediterranean *Calluna* stands, where fast rates of scrub and woodland encroachment are observed, combinations of prescribed fire, mowing and increased grazing/browsing will be necessary to achieve the long-term conservation of heathlands [12,13].

There are indications of species-specific adaptations to these regular burning cycles such as smoke-adapted germination, i.e. significantly increased germination probabilities in response to smoke treatment, which is evident in *Calluna* populations from traditionally burnt Norwegian coastal heathlands [14]. Nowadays, however, this unique coastal landscape is classified as endangered through the lack of traditional management, resulting in older *Calluna* stands, accumulated biomass, nature-type degeneration and a succession of bushes and shrubs [15]. Heathland conservation is therefore one of the main focuses of Europe's environmental conservation vision, as several types of this vegetation are listed in the European Union's Habitats Directive (92/43/EEC). In particular, fire suppression leaves the plants to grow larger and increases the amount of dead material on the ground (as litter), as well as in the standing vegetation (dead plants).

In old *Calluna* stands, the lower canopy consists mainly of dead branches [16]. Burning experiments in young and old heather stands showed more intense fires in old stands (more than 50 years since last

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burning), compared to young stands (approximately 10 years old) [17]. Additionally, unmanaged Norwegian heathlands often gradually develop a vegetation composition where species like juniper, pine, spruce and birch enter the heathlands as part of a succession, additionally contributing to a build-up of biomass. In particular, the juniper (*Juniperus communis* L.) makes a considerable contribution to the spread of fire with its very flammable resinous foliage [18]. Lack of management, such as grazing and fire-suppression, has also caused an increased concern about the fire risk outside the ecology and fire safety communities. As an example, large wildfires may result in significant economic losses in tourism related activities [19]. Fire weather index systems have therefore been developed to predict fire risk.

When studying the fuel moisture content (FMC) of gorse (*Ulex europaeus* L.) shrub fuels, Anderson and Anderson [20] tried to refine the Fine Fuel Moisture Code (FFMC) of the Canadian Fire Weather Index System to predict the moisture content of fine fuel (gorse particles of less than 5 mm). The FFMC poorly predicted the elevated dead fuel moisture content, and their attempts to improve the accuracy through regression modeling were unsuccessful.

The study of Davies et al. [16] showed that live *Calluna* stems had the same moisture content with height for dry periods during the wintertime. They also experienced rapid changes in moisture content in the live stems when the ground was frozen. During field studies in Scotland, Davies and Legg [21] discovered a threshold value of lower-canopy dead fine fuel moisture content between 60% and 70% for sustained burning when spot and line fires were ignited on site.

Fire behavior in heathlands is considered to be complex and influenced by several factors, such as stand age (influencing fuel load, structure and height (e.g. [22])), the quantity of dead fuel [23], fuel moisture content [24], and wind speed (e.g. [22,25]). Recent results indicate that critical differences in burn intensity and fuel consumption can also be linked to the flammability of ground fuel layers [26].

Better knowledge of fire behavior is an urgent requirement, as the combination of land-use change and climate change (including extreme weather events, such as drought) is likely to increase the future fire risk. A significant increase in the number of fires in the period 1950–2006 has already been recorded at the North Western Alaskan tundra by Joly et al. [27]. They also reported a 2007 late September slightly subzero temperature fire that burned an area of 1000 km^2. Understanding the increasing fire risk is of interest for all stakeholders.

This study describes the wildfires in the Atlantic heathlands at Flatanger and Frøya, Norway, 1.9° (210 km) south of the Arctic Circle in January 2014. Major wildfires like these, in Norway in January, must be extremely rare as there are no recorded previous events. The fires are discussed based on the management conditions of the *Calluna* stands as well as the weather conditions prior to, and during, the fires. Attention is given to the drying characteristics of live and dead *Calluna* stems, and it is intended to prove that dead plants dry faster than live plants. Diffusion theory is used to estimate drying rates at low temperatures in order to evaluate how fast *Calluna* fire risk changed prior to the investigated fires. Other factors that may have contributed to the fire intensity, and/or limited the possibility of controlling the fires, are also discussed. The main objective is to be able to predict future fire risk in *Calluna*-dominated landscapes in order to ensure better proactive and reactive measures for handling this increasing fire risk.

2. The Flatanger and Frøya wildfires January 2014

2.1. The communities and the fires

Flatanger is a 460 km^2 rural coastal community of about 1100 inhabitants located in Sør-Trøndelag County, Norway. On January 27th, 2014, just after 22:00 local time, a fire started close to two private vacation homes in the hamlet of Uran (N 64.416, E 10.638). Just prior to the fire, it was observed that gale-strength wind (mean wind speed 20 m/s (8 Beaufort)) resulted in suspended electrical power cable contacts (short circuits) and spark formation. Sparks from these power cables igniting dry, snow-free grass/heather were therefore concluded to be the ignition source [28]. This ignition source is quite frequent in dry windy conditions [29,30].

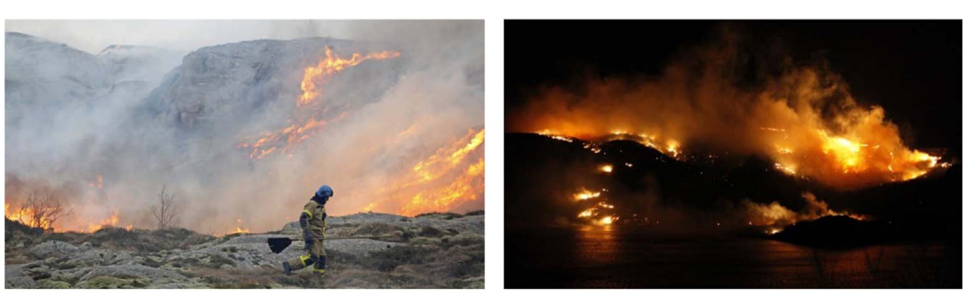
The inhabitants were evacuated before the fire became life-threatening. The firefighters managed to guide the fire to some extent and succeeded in stopping it on the third day. It burned 15 km^2 of heathlands and destroyed 63 structures, among these 23 villas and vacation homes. With respect to the number of lost structures, it was the largest fire in Norway since World War II, i.e. larger than a villa fire, which destroyed 40 structures ten days earlier, i.e. on January 18th, 2014 [31].

At 11:00 local time on January 29th, a similar wildfire started on the island of Frøya, a 241 km^2 community of 4600 inhabitants, located in Sør-Trøndelag County (N 63.713, E 8.810), 120 km south west of Flatanger. This fire, which was started by children playing with fire during a school excursion, burned 10 km^2 of *Calluna*-dominated wilderness. It destroyed only one structure, i.e. a small rental hut [28].

2.2. Firefighting challenges

The two fires have many similarities, such as the fire fuel, rugged landscape, difficult access and lack of access roads. In the Flatanger fire, Fig. 1, there were hardly any natural or manmade barriers that could be utilized to prevent the fire from advancing to the hamlets of Håstad, Hasvåg and Småværet during the 18-h-long Nordic winter night. The inhabitants were quickly evacuated during the first night of the fire, i.e. before the fire destroyed structures in these hamlets. By January 29th, the fire was either extinguished or terminated at the North Sea. It did, however, grow again and threatened four villas on Hasvåg on February 1st, before being extinguished by a massive firefighting effort, helicopter assistance, etc. The firefighters were withdrawn from duty on February 5th.

At Frøya, the fire could (during daylight) be guided towards, and terminated at two 3-km-long, narrow lakes, Langvatnet and Kjerkdalsvatnet, oriented at 90° to the fire-spread direction. This prevented the fire from reaching populated areas 1–2 km further downwind.



a) b)

Fig. 1. The Flatanger fire a) during daylight and b) at night. Ove Magne Ribsskog (Flatangernytt.no). Reproduced with permission.