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Perception of wildfire behaviour potential among Swedish incident commanders, and their fire suppression tactics revealed through tabletop exercises

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ABSTRACT

Background. Swedish wildfires are handled by multipurpose municipal rescue services, raising questions about how non-specialist incident commanders (ICs) perceive and interpret wildfire behaviour. **Aims.** Elucidating ICs' interpretations of fire behaviour, fuel complexes, weather, landscape structure and the role of these in tactical decisions. **Methods.** We exposed Swedish ICs to questionnaires and tabletop exercises for different standardised fire scenarios. **Key results.** Despite minimal formal wildfire training, ICs showed reasonable consensus in rating of fuels, fire behaviour, hose-lay production rates, etc. Tactics were to access the fire from the nearest road with hose-line laid from the engine and water ferried on trucks. In a scenario where initial attack failed, they typically fell back to roads, without burning off. This indicates a fundamental flaw in tactics employed for high-intensity fires, which easily breach forestry roads, and invite outflanking. **Conclusions.** The IC wildfire knowledge is built on personal and group experience rather than formal education. We found reasonable competence, despite the organisations being designed primarily for other purposes. However, tactical understanding of complex, large incidents was poor. IC training should emphasise potential hazards of such incidents to enhance group competence despite their low frequency. **Implications.** Standardised tabletop exercises can provide insight into decision-making of ICs that is otherwise hidden.

Keywords: boreal, expert judgement, fire behavior, fire fighting, fuel type, incident commanders, perception, tactics.

Introduction

Despite being a heavily forested country dominated by flammable coniferous forest (Engelmark and Hytteborn 1999; Vermina Plathner *et al.* 2022), Sweden lacks a specialised wildfire organisation. Instead, forest fires are handled by multipurpose rescue services organised at the municipal level. The municipalities have extensive autonomy, and although they are obliged by law to organise and pay for fire protection, there are no set targets regarding resource levels or formal wildfire training of the staff. There are as many as 290 municipalities and most of them are rather small; the median population is 16 300 and 25% have a population density ≤ 10 inhabitants/km^2.

On average, there are ~5000 dispatches to wildfires across Sweden annually, of which approximately half are classified as forest fires, i.e. burning mostly forest land (Sjöström and Granström 2023). The other half are fires on open land, typically burning grass litter in spring. However, wildfires constitute only a fraction of the workload for the rescue services, the bulk being car accidents and structural fires. Most wildfires are rapidly contained, which is made possible because of high road densities and mostly short distances from fire stations, but annually, 270 forest fires grow beyond 0.5 ha and between 1996 and 2020, 63 fires were larger than 100 ha (Sjöström and Granström 2023).

Scandinavian climate projections suggest increasing frequency of high-risk days, particularly in the south-eastern parts (Yang *et al.* 2015). The future wildfire situation will, however, depend also on the preparedness and capacity of the response organisations. This can only be achieved by motivated personnel with appropriate forest-fire training, but owing to municipal autonomy, no national wildfire-fighting doctrine or detailed tactics manual yet exists.

The law regulating fire suppression (Act 2003: 778, LSO 'Law for protection against disasters') requires that certain criteria are met (immediacy, value at risk) for the rescue service to respond. This is done at no cost to the landowner but once the fire is controlled, mop-up becomes the responsibility of the landowner, provided they have the resources to handle it. The law gives wide-ranging authority to the Incident Commander (IC) leading the operation. Except in the largest municipalities, the ICs are employed part-time and have undergone schooling for a minimum of 15 weeks, covering all types of disaster management.

In order to elucidate perceptions of wildfire behaviour as well as tactical decisions taken by such relatively 'non-specialist' wildfire incident commanders, we exposed a sample of Swedish ICs to a standardised test scheme. First, they answered a questionnaire regarding personal background and perceived interpretation of fire behaviour, hose-lay production rates, etc. We then ran structured tabletop exercises using four different wildfire scenarios, from alarm to extinguishment. In wildfire operations, decisions typically evolve over time, as more information becomes available to the IC on fire behaviour and effects of various actions, and the tabletop exercise aimed to simulate this. Expert opinion has earlier been used to estimate firefighting variables such as situation-specific hose-lay production rates (Parker *et al.* 2007) but we are not aware of any previous research where tabletop scenarios have been used for elucidating fire knowledge and tactics. Tabletop exercises are, however, standard tools in many countries for training wildfire officers (see e.g. Durrell 1946 or Sperling 2009).

The tabletop exercise scenarios presented information to the ICs similar to what would be encountered throughout a live wildfire operation, and through this semi-realistic approach, we aimed to answer specific questions that are otherwise difficult to assess. Do ICs distinguish the degree of threat of a reported incident due to weather, terrain and other initial factors and does this influence their initial deployment? What tactics are then employed, in relation to available resources and likely fire behaviour?

Methods

We first contacted the rescue services in 10 municipalities, from the southern (55th parallel) to the northern (65th parallel) part of Sweden and asked for permission to engage their ICs, to which all agreed. We travelled to the municipalities and were then offered contact with the ICs currently on duty at the station. In total, we interviewed 20 ICs, of which 17 were men and 3 women. Each IC first answered a questionnaire (see Supplementary Appendix S1) detailing their own experience with forest fires and formal and on-the-job training relating to wildfire suppression. They were also asked to estimate potential fire behaviour (estimated rate of spread (ROS)) in two different forest fuel complexes shown on pictures (Fig. 1), under a given detailed weather scenario: the fire was said to occur after '2 weeks of good summer weather without precipitation, during a day with noon temperature 25 °C, relative humidity of 30% for the last few days and wind speed 18 km h^{-1}'. We used this description of conditions instead of fire danger indices because we could not assume all ICs were familiar with these. For reference values to compare with, we used estimates from the Canadian Forest Fire Behaviour Prediction System (Taylor *et al.* 1996), assuming that Forest Fuel Complex 1 is representative of Canadian fuel type C-4 (immature jack- or lodgepole pine) and Forest Fuel Complex 2 of C-3 (mature jack- or lodgepole pine). We then assumed that the weather scenario given to the ICs (see above) resulted in index values of Build-Up Index (BUI) 70 and Initial Spread Index (ISI) 16 in the Canadian Forest Fire Weather Index System (CFFWIS, Van Wagner 1987).

ICs were also asked to judge rate of spread in two pictures of live fires (Fig. 1). Here, we had actual spread rates for reference, observed by us when the photos were taken. Further, they were asked to estimate hose-lay production rates for a five-person crew through forest terrain, with and without simultaneous watering of a 5-m wide belt (not in direct contact with fire). Earlier Swedish field tests (Wretlind 1948) determined that 1 mm of water on a moss-dominated fuelbed is sufficient to momentarily stop fire spread. Finally, they were asked to give a rate of advance for a two-person crew when doing mop-up of a 5-m wide belt at the perimeter of the fire after the fire had been stopped, using the already established hose-line. This was assumed for a situation when there had been a prolonged drought prior to the fire (i.e. indicating dry humus and risk of prolonged smouldering).

After the initial questions, we performed guided tabletop exercise tests with one to three ICs present in each session, totalling 13 sessions. Rules for the tabletop and the interaction between respondent and interlocutor are given in Supplementary Appendix S2. Four different wildfire scenarios were run in sequence (Table 1), spanning from simple (easily controllable fire) to complex (fire certain to escape initial attack), based on fire weather, wind direction and position of the fire with respect to important geographical features (topography, roads, wetlands), presented on a map. All scenarios contained at least one additional 'challenge' to the fire suppression operation, which we wanted to see if the ICs observed (Table 1).

At the onset of each tabletop case, time of alarm and point of ignition were presented on a topographic map (see example in Supplementary Appendix S2). Current weather (wind speed and direction, RH, temperature) and the fire danger (FD) class were also given (Table 1). Regarding fire danger, the FWI index of the CFFWIS is, in Sweden, split into six fire danger classes termed Very low (FWI $\leq$ 1.5),

Fig. 1. Left: forest fuel complexes presented to ICs for grading potential fire behaviour. Right: fire scenes (scene A, headfire; scene B, backing fire) for assessing ROS. Photos: Anders Granström.

Table 1. Weather and fire danger conditions for the four wildfire scenarios of the tabletop exercises.

Order of presentation	No. 3	No. 2	No. 1	No. 4
Relative Humudity (RH)	48 %	42 %	33 %	31 %
Temperature	18 °C	25 °C	21 °C	18 °C
Wind speed (km h^{-1}, 10-m open wind)	3.6	7.2	10.8	23.4
Fire danger class	Moderate	Moderate	Very high	Extreme
FWI value	11.4	16.4	22.4	35.3
DMC, BUI, DC	33, 55, 437	40, 56, 228	47, 68, 317	43, 54, 177
FFMC, ISI	88, 3.9	89.9, 6.1	91, 8.0	92, 18.6
Challenges	Poor road access. Persistent smouldering expected	Steep slope that impacts ROS/direction	Possible new head if flank not secured	Extreme fire behaviour. Fire moving away from access road

Current weather and fire danger class was presented together with a topographical map at the start of each scenario. The various indices (Fire Weather Index (FWI), Duff Moisture Code (DMC), BUI, Drought Code (DC), Fine Fuel Moisture Code (FFMC), and ISI) of the Canadian Forest Fire Weather Index system (Van Wagner 1987) was available to the ICs on request. Cases are here ordered by increasing FWI value, but Order of presentation below refers to the chronology during the exercise. Wind speed was presented to ICs in metres per second, according to the Swedish standard, but here is given in kilometres per hour. 'Challenges' refer to particular sites and other circumstances with consequences for fire suppression that should be evident to experienced ICs. Rules for the tabletop are given in Supplementary Appendix S2.

Low (FWI 1.5–6.5), Moderate (FWI 6.5–16.5), High (16.5–21.5), Very high (21.5–28.5) and Extreme (>28.5). In most communication on fire danger within the country, these danger classes are used rather than the actual underlying FWI values (although these are available for ICs), which is why we gave only the danger class at the start of each case. ICs were also told that they could ask the interlocutor for any supporting information they normally would obtain from officers back at the fire station. This could potentially include e.g. CFFWIS indices (see Table 1) or the weather forecast, although we did not detail *a priori* what information would be available, in order not to influence their deliberations.

CFFWIS has been used in the country since 1996, but to date, no detailed nationwide training module or manual as to its use has been issued.

Based on this initial information, the ICs decided on the size and structure of their deployment. During the entire exercise, the interlocutor noted all decisions taken by the IC and asked for clarifications in case of ambiguity. All positioning of vehicles, crews, hose-lays, etc. were progressively marked by the IC on a topographical map. The progressive expansion of the fire over time was drawn on the map by the interlocutor, according to a pre-determined spread rate. There are no published data on rate of spread in Swedish fuel types in relation to fire danger codes. In order to obtain 'unbiased' fire behaviour for the respective cases under the current weather and fire danger, we therefore extracted rate of spread (heading and backing) from the Canadian Fire Behaviour Prediction (FBP) system (Taylor *et al.* 1997), using fuel type C-3 as surrogate for *Pinus sylvestris*-dominated forests and S-1 (jack or lodgepole pine slash) for clear-felled areas.

For all four fire scenarios, the alarm was assumed to have occurred 10 min after ignition, and travel time from the nearest fire station to the road position nearest to the fire was set to 30 min. Once the first person in the initial response crew had arrived at the fire site, the size of the fire (length/width of the perimeter) was presented to the respondent. Information on fire behaviour was communicated verbally (flame lengths) and with photos from real equivalent fires, showing vegetation, smoke, flames, etc. (see examples in Supplementary Appendix S2). This is similar to what happens in a real situation where the IC mostly stays close to the vehicles but gets information, including pictures, from firefighters near the fire, or sometime from drones or airplanes.

All scenarios were said to occur on land owned by a large forest company. If called for (i.e. if the IC asked for this), the company could send a mop-up crew of six, with basic equipment (shovels, portable pump, 300-m hose) within 2 h.

All decisions and actions and their assumed timing were logged by the interlocutor separately, including verbal comments from the ICs. Tactical decisions (attack routes, water sources and hose-lays, crews and vehicles) were noted by the ICs on maps. Scenarios were sequentially run as semi-directed interviews (Huntington 2000) with follow-up questions in case of ambiguities. For example, if ICs asked headquarters for the current weather prognosis, the interlocutor first asked for which variables before delivering these.

Each session took between 2 and 3 h, including both questionnaire and tabletop exercise tests.

Results

Experience and training

The respondents had on average 12.6 years experience as ICs. Over the last 5 years, they had led on average 5.8 wildfire deployments. Their average wildfire training during initial schooling as fire officers was 4.6 days of theory and 2.4 days of practical training. However, none of this training had involved actually setting fire to vegetation and observing fire behaviour first hand in the field. Forty-five percent had gone through follow-up training, averaging <1 day over the last 5 years. One IC had participated in prescribed burning.

Perceptions of fire behaviour and production rates for hose-lays

When asked in which of two forest vegetation scenes (illustrated with photos) fire would spread the fastest, all identified Forest Fuel Complex 1 (Fig. 1). All pointed to differences in fuel structure causing fire to spread faster there. Some specifically pointed to species differences in the bottom- and field-layer vegetation and to structural differences ('more lichens', '*Calluna* dwarf shrubs', 'canopy fuels with dead branches lower to the ground').

Most ICs underestimated ROS in the two different forests fuel complexes relative to what the Canadian Fire Behaviour Prediction System (CFBPS) indicates for similar fuel types. On average, ICs suggested ROS of 12.7 m min^{-1} in Complex 1 and 4.9 m min^{-1} in Complex 2 (Table 2). For this weather scenario, CFBPS indicates ROS of ~25 m min^{-1} in Complex 1 and 15 m min^{-1} in Complex 2.

When provided photos of real fires (fire scenes A and B in Fig. 1), the respondents instead overestimated the ROS, on average, compared with the real spread rates observed when the photos were taken (Table 2).

Production rates when constructing hose-lays were fairly consistently estimated, ~25 m min^{-1} for the first 500 m from the engine without watering and twice the time if watering (Table 2). A wet-line was considered secure for nearly 2 h on hot, windy days and could be re-wetted at ~18 m min^{-1}. Mop-up of a 5-mwide belt at the fire perimeter, using an already established hose-line, was estimated at ~6 m min^{-1} (Table 2).

Deployment vs fire danger

Initial deployment varied with 'fire danger' expressed as indices and current weather. There was a near-linear relationship between FWI values and the initial number of firefighters deployed (Fig. 2). Normally, rural fire stations have a crew of one officer and four firefighters stand by, and here, ICs typically deployed a minimum of two 'units', implying a total of two officers or foremen and eight firefighters, from two different stations. Each unit would travel with one fire engine (~3 m^3 internal tank, one fixed pump, one mobile pump, ~500 m of hose and hand tools), one tanker (8–10 m^3) and the officer riding in a separate vehicle. If needed, 1–2 All Terrain Vehicles (ATVs) were brought on trailers. The function of IC is delegated to the officer arriving first at the scene, but can later be transferred.

Table 2. Estimates from ICs regarding fire ROS and rate of hose-line construction.

Question	Average	Reference
ROS in Fire scene A?	5.4 m min^{-1} (range 1–15)	2–3 m min^{-1} (observed)
ROS in Fire scene B?	1.7 m min^{-1} (range 0.5–5)	~0.5 m min^{-1} (observed)
Highest fire intensity potential? (Forest Fuel Complex 1 or 2, see Fig. 1)	Forest Fuel Complex 1 (everyone)	Forest Fuel Complex 1
ROS[A]: Forest Fuel Complex 1 (RH 30%, wind 18 km h^{-1})	12.7 m min^{-1} (range 2–25)	25 m min^{-1} (FBP C-4)
ROS[A]: Forest Fuel Complex 2 (RH 30%, wind 18 km h^{-1})	4.9 m min^{-1} (range 1–15)	15 m min^{-1} (FBP C-3)
Rate of advance? Five-person crew laying a 500-m 42-mm hose line in flat forest terrain, from the fire engine, without watering	24.9 m min^{-1} (σ = 12.3)	
As above including watering of hose-lay	13.1 m min^{-1} (σ = 6.8)	
Rate of advance? Additional extension of 500 m, with manual transport from the fire engine	8.6 m min^{-1} (σ = 5.5)	
For how long is a wet-line secure during 'hot and windy' conditions?	1.6 h (σ = 0.7)	
Rate of advance when re-wetting a 500-m hose-lay?	17.8 m min^{-1} (σ = 15.5)	
Rate of advance for a two-person crew to mop up 5-m wide belt at the fire perimeter?	5.6 m min^{-1} (σ = 5.8)	

σ denotes standard deviation.
[A]After two precipitation-free summer weeks. For the reference FBP predictions of ROS, we used an ISI value of 16 and BUI of 70.

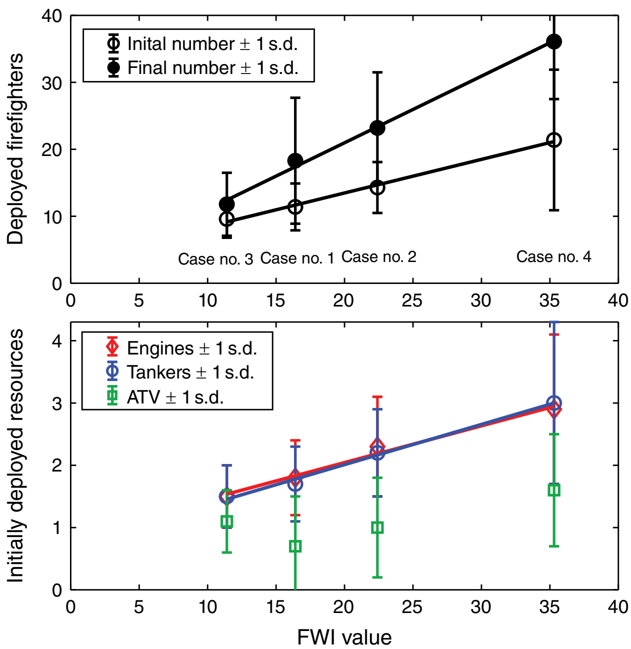

Fig. 2. Initial resource deployment in the four different tabletop scenarios against scenario FWI value (average ± 1 s.d.).

This basic initial deployment was, if needed, increased by progressively adding units. Initial deployment varied between respondents but even for the most severe scenario, 46% of the respondents initially deployed only two units, but immediately requested substantially larger forces once they had arrived at the scene and saw the smoke column (pictures, see example in Supplementary Appendix S2).

On alarm, ICs told station officers to contact landowners, as well as to survey available helicopters. This was done regardless of perceived fire danger level, in case the need should arise later. For the most severe scenario (Case no. 4, Table 1, Supplementary Appendix S2), helicopters were called early on and one third of ICs also requested 40–50 people from the military (home guard). One informant detailed how to mix these (1 + 1) with professional firefighters according to a system they had developed and trained locally.

Generally, deployment sizes relied on ICs' own deliberations, which they said were guided by their traditional handling, but with consideration for wind speed and the six-grade FD class. However, two different municipalities had independently developed their own rules-based dispatching schema, using FD class for initial crew sizes.

Fire suppression strategies and tactics

The standard procedure was to drive to the road position closest to the fire, then send 1–2 line scouts (sometimes with a drone), and start hose-laying from the engine once the fire location was verified. Hose-lays started with 76- or 63-mm hose from the engine and then transitioned to 42 or 38 mm when getting close to the fire. Frequently, ICs initially kept one unit at a distant staging point, to attack from another direction if needed (e.g. in case of difficulties locating the fire or deciding the best access route). When the fire was far from road access (2 km, Case no. 3), ATVs were often used to increase mobility and situational awareness for the crew, and for transport of material.

Water to supply the hose-lays was typically ferried by tankers filled at nearby accessible lakes, but occasionally, smaller pumps were placed in nearby streams or lakes to feed hose-lays locally. Only two respondents used swatters/brooms on low-intensity backing and flanking flames. None of the informants used the landowner crews in the suppression stage.

Most ICs recognised and accounted for challenges inherent in the different fire scenarios, such as the influence of slope on ROS and direction of the fire progression (Case no. 2), or the danger implicit in Case no. 1, where the head of the fire would stop on reaching a small lake, only to later, unless the flank was secured, develop a new high-intensity head fire once the lake was circumvented. However, for the most severe scenario (Case no. 4), where fire danger was very high and fire was moving away from the access road (Supplementary Appendix S2), the tactics ICs employed were unlikely to have succeeded. Most ICs concentrated on the fire head, without securing the flanks from an anchor point (cf. Alexander and Thorburn 2015). On this fire, several ICs also worked exclusively along roads with hose-lays or watering from vehicles, setting up control lines far from the fire perimeter, thus adding risks in case of wind shifts. As the high-intensity head reached the prepared lines, only two ICs pre-positioned crews to control potential spot fires across the line. Two of the ICs discussed expanding the width of firebreaks (e.g. roadways) using burn-out operations (Cooper 1969), but only one had relevant prior experience of this.

The time suppression units spent on mop-up varied significantly, e.g. between 1 and 12 h for Case no. 1, after which landowner crews continued. Often hose-lines, and sometimes a pump, were left on site as a precaution, in case the fire re-ignited. Typically, the ICs did not consider the DC when anticipating time and efforts for mop-up.

Discussion

Even in structured, hierarchical fire suppression organisations, such as in those in the USA, risk perception among ICs vary (Black and McBride 2013) but in the decentralised Swedish organisation, this would be expected to be more pronounced. Here, we believe the competence of ICs is highly dependent on individual and group field experience, developed through local rather than national organisational cultures. Most ICs had only minimal formal theoretical and practical wildfire suppression training and their understanding of wildfire instead would have been formed through their own field experience and exchange with close colleagues. This is somewhat of a parallel to the collective traditional fire knowledge observed in the general population in regions where fire is actively used in land management (Johansson *et al.* 2012). There was, however, a considerable consensus in perception and judgement between ICs, despite them coming from different municipalities. For example, the estimates of ROS for fires shown on pictures, as well as grading of fuel types, suggested that the respondents had gained a reasonable degree of knowledge from the field.

Decisions on initial deployments were rarely rules-based. Instead, they depended on intuitive scaling of resources in relation to perceived fire behaviour, but always with a minimum deployment of two 'units' (i.e. ~10 people) in cases of a verified forest fire. Most likely, ICs primarily based their decisions on the six-grade FD class, as few referred to FWI values or its subcomponents. However, wind speed was also considered a separate risk factor and, once on site, the colour and size of smoke columns were important signals that the ICs clearly responded to.

Owing to budget constraints within the municipalities, initial resource deployment has to be weighed against the perceived risk of the fire escaping initial attack (Lee *et al.* 2013). Another factor mentioned by the ICs was resource conservation, to buffer in case of simultaneous additional emergencies within the municipality, be it other fires or road accidents. Direct costs were also an issue, clearly seen with regard to helicopter use, as ICs were reluctant to call for helicopters early, before they were manifestly needed. In Swedish firefighting, helicopters are used primarily for watering, using buckets. After a number of catastrophic fires in 2018 (Granström 2020), a government-funded program for helicopter assistance was introduced in summer 2019, allocating helicopter assistance to the municipalities free of charge, but on a priority basis. Later, the program was supplemented with four scooping airplanes (AT 802F). The tabletop exercises were all done prior to these reforms, which likely has resulted in a shift towards more helicopter and airplane use in wildfire suppression than before.

Line construction rates have never been issued or discussed within Sweden's firefighting community, so the estimates provided by the ICs would have been based entirely on their own experience. Interestingly, the estimates provided here were on par with previous expert opinions from Canada (Hirsch *et al.* 1998, 2004). Having reliable rates for hose-laying and re-wetting is important, particularly as these often become limiting factors when fires escape initial attack. No other empirical data are available for comparison and the average IC estimates noted here could serve as a rough guideline for operational use and for modelling (Duff and Tolhurst 2015).

The standard tactic of ferrying water by tanker ties up considerable resources throughout the whole operation and is potentially vulnerable. First, the typical 76-mm hose-lay from an engine means that the standard $3\,m^3$ tank capacity on the engine is already emptied by filling the first 660 m of line. Then, to supply four nozzles ($75\,L\,min^{-1}$ each) implies that one tanker (~$10\,m^3$) has to arrive every 30 min. Thus, one stationary engine and two rotating tankers can feed a hose-lay continuously but will tie up at least half of a two-unit crew of 10. Alternatives to water were rarely employed by the ICs, although swatters and steel brooms are nearly always brought on the fire engine.

Once fires were reached, the crews mostly proceeded to circle them close to the perimeter but sometimes well ahead of the fire, which was most evident for the worst-case scenario with high ROS and elongated perimeter. Here, flanks were not secured from safe anchor points (cf. Alexander and Thorburn 2015), inviting a risk of outflanking. Further, strategies for controlling spot fires when high-intensity fire was approaching a barrier (road) were not planned for. In fact, this scenario was based on a disastrous fire in 2014 with a similar response (Anonymus 2015), suggesting these results are indicative of the typical response in case of fast-spreading and intense fires.

Until the mid-1900s, forest fires were handled primarily by the forest owners and in case of large fires through mass conscription of the rural population, military units, etc., led by a designated forest fire officer, typically a trained forester. It was only gradually that municipal fire brigades started to be employed also for forest fires, beside their primary duty, which was structural firefighting. This shift depended on reasonably good road access, to bring fire engines, pumps and hose into the forest. It began in the late 1940s in the southern more densely populated part of the country with better roads (Anonymus 1960) and may have been completed throughout the country by the late 1970s (Wångmar 2009). Parallel to this, the participation of forest owners and managers decreased and today, their people and resources are only used in the mop-up and monitoring phase. Thus, the shift to a 'professional' firefighting organisation likely led to improved initial response but at the same time the capacity to engage very large forces was lost.

An analysis of wildfires over the period 1996–2020 showed that the time to initial attack varies greatly with population density within Sweden, because lower population density translates into longer distances between fire stations (Sjöström and Granström 2023). Further, the risk of an ignition growing beyond 10 ha increases with decreasing population density at the regional scale. The present-day system with few professional firefighters relies on Sweden's dense forest-road network (average distance <500 m already in 1990), (Anonymous 1991). Road density correlates positively with fire occurrence and negatively with burnt area (Pinto *et al.* 2020). Median driving time to reach the fire sites is only 15 min (Sjöström and Granström 2023) and if a 500-m hose-lay can be in position within 20 min, two standard 1 + 4 units may in fact be adequate for suppressing most low-intensity fires. Interestingly, the 1 + 4 unit size is mandated by national safety rules for structural firefighting, but may also serve reasonably well for forest firefighting.

It is evident from statistics that the standard deployment is sufficient in most situations. Of all forest fires, 89% are controlled before reaching even 0.5 ha (Sjöström and Granström 2023). However, for fires with a rapid ROS and high intensity, such small forces can quickly be overwhelmed. In many situations, water bombing from helicopters can help knock down the flames, but securing the perimeter permanently requires a substantial number of people on the ground once the fire has grown 'large'. The number of firefighters on standby within rural regions of the country is not high. The average number of firefighters used by our informants on the worst fire scenario was approximately 40. This would be considered a very large incident, draining a large geographic area of its available rescue service personnel on duty. Still, this force would be very thinly stretched on even a 50-ha fire, which would likely have a perimeter between 2500 and 3000 m.

It seems that the inherent limits with regard to manpower will be problematic any time there is a high-intensity fire where initial attack has failed. Our results indicate this is not the only problem. The tactics employed make the operation vulnerable, e.g. the consistent tendency by ICs to neglect flanks and fall back on roads to be used as fire breaks, but without burning off fuels ahead of the fire. This is, however, to be expected, given that most ICs seldom if ever have been confronted with a complex fire that has escaped initial attack, and have not been trained to actively use fire, a technique that itself entails risks (Cooper 1969).

In conclusion, our study suggests a fairly high capacity for suppressing forest fires, despite the organisation being primarily set up for other purposes and ICs having minimal formal wildfire training. Two trends may pose a problem for the future. First, fire climate will likely become more severe (Yang *et al.* 2015). Second, the continuing depopulation of the countryside (Lindblad *et al.* 2015) will pressure municipalities to reduce their rescue services. Already, the cost of the rescue service per inhabitant is nearly four times higher in the most sparsely populated municipalities than in more urban areas (Anonymus 2014). To counter these trends, a higher level of central command may be needed, but also better basic training of firefighters and ICs.

To our knowledge, this study is the first to quantify the level of wildfire knowledge in a population of fire officers and to uncover the rationale behind tactical decisions in a standardised way using tabletop techniques. Such information can of course be obtained for individual cases by post-factum reviews, which are often done after disastrous wildfires (Phipps 2021). However, tabletop test schemes such as ours make it possible to cover interviewing a large number of officers under standardised conditions, and thus identify critical misconceptions. This may be particularly useful in regions where ICs are rarely exposed to large and complex wildfires, as is the case in Sweden and the rest of Fennoscandia (Gauthier *et al.* 2015).

Supplementary material

Supplementary material is available online.

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Data availability. The data behind the results comprise papers written during the sessions.

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