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Abstract:	This deliverable provides an overview of the GEO-SAFE project's Human Behaviour Study. Survey data were collected from residents in the South of France, Australia, and Central Italy, with the aim of identifying, quantifying, and calibrating behaviours occurring during wildfire evacuations. The evidence base generated by this study provides an understanding of various behaviours including evacuation decisions, response actions, and associated times. This data can be used to assist the development of an agent-based evacuation model, urbanEXODUS. In turn, this tool can be used by professionals involved in wildfire management to aid learning, decision-making, and planning.
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V0.7			
V0.8			
V0.9			
V1.0			
V1.1			

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Common abbreviations

Abbreviation	Meaning
BI	Behavioural itinerary
BNHCRC	Bushfire and Natural Hazards Cooperative Research Centre
CFA	Country Fire Authority
CNVVF	Corpo Nazionale dei Vigili del Fuoco (Italian National Fire Corps.)
CRC	Cooperative Research Centre
DELWP	Department of Environment, Land, Water and Planning (formerly the DSE)
DSE	Department of Sustainability and Environment (now the DELWP)
ER	Experienced Researcher
ESR	Early Stage Researcher
FSEG	Fire Safety Engineering Group
FRS	Fire and rescue service
GEO-SAFE	Geospatial based Environment for Optimisation Systems Addressing Fire Emergencies
INFOCA	El Plan de Emergencia por Incendios Forestales de Andalucía (Emergency Plan for Forest Fires in Andalusia [forest firefighting])
PM	Person Months
RMIT	Royal Melbourne Institute of Technology
SDIS 2B	Service Départmental d'Incendie et de Secours de la Haute Corse (now called SIS 2B)

SIS 2B	Service d’Incendie et de Secours de la Haute Corse (fire and rescue service for Haute Corse; formerly SDIS 2B)
UoG	University of Greenwich
WG	Work Group
WP	Work Package
WUI	Wildland-Urban Interface or Intermix

Executive Summary

This deliverable provides an overview of the Human Behaviour Study related to Task 2.5 in Work Package 2, Work Group 6 – phase 2 of the GEO-SAFE project. The Human Behaviour Study is the collection of new survey data, aimed at identifying, quantifying, and calibrating behaviours displayed by residents during wildfire evacuations. The evidence base generated by the collected data can, in turn, be used to assist the development of an agent-based evacuation model, urbanEXODUS. This computer simulation software is an example of a tool that can be used by professionals involved in wildfire management to aid learning, decision-making, and planning.

The procedure employed in the Human Behaviour Study, and described herein, can be summarised as follows. A survey was designed in questionnaire form, suitable for completion by adult residents who either (a) had recent actual experience of a wildfire or (b) lacked such experience but resided in an area that was at-risk of wildfires. The three regions where the survey was administered were:

- The island of Corsica and other parts of the South of France
- The state of Victoria, in Australia
- Three villages in the municipality of Gualdo Tadino, in Central Italy

The survey was made available in the official languages of those regions (French, English, Italian). It was either completed by the residents themselves, online, or completed during a face-to-face interaction with crews comprising firefighters and civil protection officers. This interaction was part of an evacuation exercise, where crews went door-to-door, simulating the emergency response (i.e. notification of residents of an evacuation order) to a wildfire threat.

In the first two regions, the full questionnaire was administered. This included questions on:

- pre-event aspects (e.g. socio-demographic characteristics, prior experience, preparedness)
- peri-event aspects (e.g. 'behavioural itineraries', the evacuation decision, evacuation movement)
- post-event aspects (e.g. a decision about future protective action)

In the third region, data collection mainly focused on the section of the survey relating to 'behavioural itineraries', i.e. the response actions carried out by residents between becoming aware of the approaching fire and commencing evacuation movement. This section also asked residents to estimate the time they would commit to each action. These times were then summed to provide an overall time for each resident's behavioural itinerary. In the evacuation exercise, residents also had the option of simulating their behavioural itinerary; that is, they could actually perform the gathering of belongings, pets, etc. and the overall time taken was recorded by the crews' Go-Pro cameras.

Through the above methods, an evidence base containing data on the human behavioural responses of several hundreds of residents was generated. This data allows for the identification and quantification of various key aspects such as how many residents will decide to evacuate in a wildfire, what actions residents will undertake prior to leaving, and how such actions delay evacuation. This data also allows for the calibration of behaviours, by providing insight into whether other factors related either to the resident or to external sources have an influence. Implications of this study for the development of evacuation models and for aspects of wildfire management are discussed.

1. INTRODUCTION

Wildfires (aka bushfires or forest fires) are a growing problem across many parts of the world. These fires start in areas of combustible vegetation, increase in size to become very large, and spread rapidly to nearby areas of human settlement. In just a single incident, thousands of hectares of land can be burned, multiple residences can be rendered uninhabitable, other structures can become similarly unusable, and anything from tens to thousands of lives can be threatened, some even lost.

Given the environmental, economic, and social costs of these fires, governments have recognised the importance of wildfire management. This involves the collaboration of various organisations, in order to: (a) prevent a wildfire from happening in the first place; (b) mitigate the potential severity of a wildfire in case one should happen; (c) prepare communities for the event of a wildfire; (d) respond to a wildfire when one starts; and (e) recover from the damage and losses following a wildfire. These tasks are complex and resource intensive, and there is a continual need for improvement. Not only because of what can happen if wildfire management fails but also because various elements of wildfires are ever evolving, meaning that the risk level is being maintained or even elevated. For instance, while developments are being made in one area (e.g. technological advancements in fire suppression, positively impacting wildfire response), other developments are simultaneously taking place elsewhere (e.g. climate change resulting in increasingly hot, dry seasons, negatively impacting wildfire prevention and mitigation).

With the aim of enhancing public safety, researchers have been working in conjunction with practitioners to create or advance methods to tackle the issue of wildfires. The GEO-SAFE project is a prime example of this, with an international network of collaborating partners from across Europe and in Australia exchanging knowledge, ideas, and experience. One type of method being looked at as part of GEO-SAFE is the use of modelling tools. Several tools already exist to model either fire, pedestrian (i.e. human) behaviour during evacuations, or vehicular traffic movement. However, if integrated, these three types of model could be used to simulate wildfire incidents and demonstrate outcomes (e.g. survival/fatality rates). As such, they could be used to learn lessons from what happened and why in past events, monitor strategies and manage resources in real-time during present events, and plan for various eventualities in future events.

As work progresses on the software development of an integrated model, it is also important that work progresses on the collection and analysis of the data that would need to be entered into such a model. For the modelling output to provide a reasonably accurate picture of what does or could happen in a wildfire, it is important that the input provides a similarly accurate representation of the different elements involved.

This report focuses on data relating to human behaviour during wildfire evacuations. There are currently quite a number of gaps in knowledge about such behaviour. While some seminal research has been conducted in Australia, particularly following the bushfires that affected the state of Victoria in 2009, research on human behaviour in European wildfires is seriously lacking. The work described within this report documents the collaboration between GEO-SAFE partners in different parts of Europe and in Australia to help address this issue. The outcomes from these exchanges will help the development of innovative methods to improve wildfire management and, in turn, help protect lives.

1.1 Objectives of D2.5

This deliverable describes work undertaken for *Task 2.5: Develop and implement behavioural responses unique to wildfires within the modelling environment*. The objectives of T2.5 were to:

- Develop a database of human responses to wildfires, based on questionnaires studies involving those who have experienced evacuation from wildfires and those who may need to evacuate from a wildfire situation (Objective 2.1)
- Identify, quantify and calibrate appropriate behaviours identified in the questionnaire study (Objective 2.2)
- Develop and implement behavioural responses unique to wildfires within the evacuation simulation tool based on data collected through the Human Behaviour Study (Objective 2.3)

This report, D2.5, focuses on the Human Behaviour Study. Its objectives are to:

- Summarise key elements of evacuation models that relate to human behaviour
- Summarise relevant findings from past research on human behaviour in fire as well as in other disasters requiring large-scale evacuation
- Highlight aspects of human behaviour that need considering in relation to wildfires specifically
- Outline how the GEO-SAFE secondments provided background, context, insight, and data on wildfires and associated human behaviour in the studied regions
- Summarise the survey (questionnaire) methods that were used to collect new data on human behaviour in wildfires and evacuations in the studied regions
- Summarise the evidence base of collected data on human responses to wildfires
- Summarise key behaviours that were identified, quantified, and calibrated using this evidence base
- Highlight implications for wildfire management and for the development of evacuation models regarding the implementation of such human behaviour data

1.2 Work Methodology

First, existing literature was reviewed. This was done to gain an understanding of the nature of wildfires, the scale of the threat they pose, the nature of associated evacuations, and the response to date from researchers regarding wildfires and egress from large-scale areas. The knowledge gained from this literature review was supplemented by information about evacuation modelling, gathered from software developers, and about relevant survey methods, gathered from previous international research on fires and other disasters.

Having built this foundation of knowledge, the GEO-SAFE secondments were then commenced. During these work trips, hosted by four different organisations (SDIS 2B, RMIT University, INFOCA, and CNVVF), further sources of relevant information were identified. These sources were not only within the host organisations but also with external organisations. The individuals included both decision-makers and implementers. Other external sources included academics and media outlets or networks. Furthermore, on occasion, verbal and pictorial information was gathered from face-to-face interactions with residents.

The main source of information described in this report was the questionnaire survey of residents. This survey was created specifically for this research. It was administered to samples in two European countries (France, Italy) and to samples in a third country (Australia). These samples included individuals who had actual experience of a recent wildfire and individuals who were inexperienced but resided in at-risk areas. Select results from the survey of residents are presented and discussed. Sources providing further detail about the survey and the results are referenced in this report.

1.3 Structure of the deliverable

This deliverable starts with an overview of human behaviour focusing on the areas of interest to the Human Behaviour Study and Task 2.5. That is, behaviour in relation to evacuation models, fires (smaller-scale incidents), other disasters (larger-scale incidents) and, more specifically, wildfires and associated evacuations [SECTION 2].

It continues with a description and discussion of the various secondments and their outcomes relevant to Task 2.5. Included here are information gained from these trips and the human behaviour data collected from the survey of residents [SECTION 3].

The report next presents some concluding comments about the evidence base developed from the survey of residents, the key behavioural aspects identified and quantified from this evidence base, and the key contextual aspects that need to be taken into account for the calibration of such human behaviour data. Moreover, some implications for the development of wildfire evacuation models and wildfire management are highlighted [SECTION 4].

At the end of this deliverable, the authors: acknowledge the contribution of others; provide a list of references cited herein (which readers are encouraged to peruse further); and provide a list of credits for the photographs included, most being taken during the secondments [SECTIONS 5, 6, and 7].

1.4 Caveat

The information presented here is often that gained at the time of the secondments. Given the need (and duty) for authorities to take urgent action to address their wildfire risk, and changes in the political and environmental landscape in the last few years, it is possible that some of the information has since been superseded. Additionally, much of the information was gathered in the language of the country where the secondment took place. While efforts were taken to ensure that information was translated correctly into English, some misinterpretations cannot be ruled out.

2. HUMAN BEHAVIOUR: EVACUATIONS AND DISASTERS INCLUDING WILDFIRES

This section will cover information related to four areas: (i) agent-based evacuation models, (ii) human behaviour in fires and other disasters, (iii) human behaviour in wildfires – the need for data, and (iv) the collection of new human behaviour data.

2.1 Agent-based evacuation models

In simple terms, agent-based models are computational models – i.e. tools involving applied computer science and mathematics – used to simulate complex scenarios. Agents can represent human beings (e.g. residents), who may act alone or be grouped with others in scenarios. Scenarios may reflect real incidents that have already occurred, and so the model can be used to help explain what happened. Alternatively, scenarios may represent current or potential incidents, and in this case the model can be used to foresee outcomes (positive, negative) depending on what decisions are made and the known presence/absence of external factors (e.g. hazards such as smoke and heat). A simulation can provide end users with output in numerical and visual form, thereby both informing and illustrating.

So, agent-based models are useful for learning lessons from the past, making appropriate decisions in the present, and planning for the future. This makes them a potentially valuable tool for professionals involved in wildfire management. Numerous agent-based models exist although relatively few have been designed or are appropriate for simulating evacuation [1] and fewer still for simulating evacuation due to a wildfire [2].

One agent-based evacuation model that could be used for simulating wildfire evacuation scenarios is urbanEXODUS – indeed, it already has [3]. This tool, based on the buildingEXODUS software [4, 5, 6, 7], is capable of simulating the evacuation of large populations (measured in the hundreds of thousands) in large-scale environments (entire towns or parts of towns measuring tens of km^2/thousands of hectares). EXODUS can also be used for the analysis of pedestrian dynamics/circulation, i.e. more general movement of people through, around, and between structures in the built environment. The software has been developed to meet the challenging demands of performance-based safety codes. Based on a highly sophisticated set of submodels, it shatters the mould of traditional engineering analysis to produce realistic people-people, people-fire and people-structure interactions. As a result, end users can test more options in less time to reach the optimal solution, free of the high cost and potential danger associated with evacuation trials (i.e. experiments where actual humans have to move around the environment).

In EXODUS, each agent is defined by a set of attributes. The attributes fall broadly into four categories:

- physical (e.g. age, gender, agility, mobility)
- psychological (e.g. patience, drive, response time)
- experiential (e.g. distance or time travelled, time waiting in congestion)
- physiological (e.g. respiration rate, impact of narcotic and irritant gases, impact of heat)

These attributes have the dual purpose of defining all agents as individuals while allowing their progress and condition during the evacuation to be tracked.

Agents in EXODUS can also be provided with itineraries (i.e. a series of actions to undertake), which can modify their behaviour prior to and during the evacuation process. For example, an agent may decide to perform a number of actions within their residence or may even decide to travel to another building, such as a school, to collect their family members, all prior to commencing evacuation movement to a place of safety.

EXODUS is a hybrid model, capable of utilising several methods of spatial representation: discrete (either coarse node or fine node) and continuous [4]. The continuous method models the fluid movement of individual agents through and around spaces such as rooms with furniture. It is therefore appropriate for simulating smaller-scale incidents such as a fire in a single building. However, it is too resource-intensive for modelling larger-scale evacuation. Thus, in urbanEXODUS, the coarse and fine node methods – where space is segmented and therefore movement less fluid – have been utilised, with the former providing quick preliminary results at a faster-than-real-time rate (because the environment is represented in less detail; as if 'zoomed out', in layperson terms) and the latter providing more refined results but requiring longer simulation run times (because the environment is represented in finer detail; as if 'zoomed in').

The coarse node model in urbanEXODUS employs 'location estimation' techniques by estimating the location and spread of agents within the region. This is to partially compensate for inherent uncertainties associated with pure coarse node modelling, thus improving the accuracy of the movement model and, hence, the overall predictions. It also allows for the calculation of population densities within sub-regions of the coarse nodes. Furthermore, the coarse node model employs varying walking speeds depending on whether the agent is traversing paved paths or off-road paths. Junctions such as road junctions are modelled as special coarse nodes, which can represent multi-directional flow. More information on the large-scale evacuation model has been provided in another GEO-SAFE deliverable, D2.6.

Thus, agent-based evacuation models can simulate various stages of an evacuation process in a wildfire. That is, they can represent some of the individual variation in the experiences of affected populations, as the incident unfolds and residents become aware of the approaching fire at different times, therefore displaying different levels and types of activity in any given moment. For instance, the simulated scenario could have some residents still unaware of the need for evacuation and in a more passive state (i.e. not yet notified and therefore not taking any emergency action), while others could be in the response stage (i.e. notified and undertaking actions to prepare for evacuation), and others still engaged in evacuation movement (i.e. already left their residences and travelling across land to a place of safety).

2.2 Human behaviour in fire and other disasters

While agent-based evacuation models such as urbanEXODUS already have the capability to incorporate some human factors data (e.g. socio-demographic characteristics such as the resident's age and gender, behaviours such as actions to be undertaken, and movement such as different walking speeds across different terrain), the question is: what data exists that can be used?

Human behaviour in fire has been an area of study for more than a century. However, for many decades, the focus was solely on movement. Additionally, the movement data (walking speeds, flow rates) were typically collected during fire drills or even during normal circulation rather than from actual emergencies. Moreover, the areas being 'evacuated' were commercial or public buildings and other structures such as shops, office blocks, and transport hubs [8].

The study of human actions as opposed to movement, in actual fires, affecting residences as well as other types of structure, did not really begin until the 1970s [9]. There was a relatively brief period of continued attention in this area, with the influence of socio-demographic characteristics on actions also being considered [10, 11]. However, it was not long before researchers once again turned towards non-residential buildings/structures and towards incidents that were not necessarily fires (e.g. terrorist attacks [12, 13, 14, 15]). When residences were included in the focus of the human behaviour studies, it was usually with regards to modelling vertical evacuation (i.e. exiting high-rise buildings) [16, 17].

A 2010 review of the then existing literature on human behaviour in building fires highlighted several key behavioural factors [18]. Some of these, it is argued here, would be relevant to wildfires. For instance:

- The ability to perceive cues to a fire may be compromised (e.g. residents could be asleep initially)
- When cues are perceived, there is usually some uncertainty as to the danger, which impacts protective action (e.g. even if residents realise there is a fire, they may not understand how fast and far the smoke and flames will spread, and so will not tend to evacuate immediately)
- Social influences may have an impact (e.g. residents may wait for others present to initiate action, family members may attempt to group together)
- When evacuation is attempted, there will be a willingness among some to pass through smoke but the smoke may hamper evacuation (e.g. even if it does not kill, smoke can decrease visibility, cause problems with respiration and cognition, and induce fear, all leading to reduced wayfinding abilities and mobility)
- During evacuation, familiarity influences the route taken to reach safety (i.e. residents may opt not to go towards that which is unfamiliar to them, even if that is a quicker route to safety)

It is questionable whether some other factors highlighted in this review would be relevant to behaviour during wildfires. For example, in building fires, the smell and sight of smoke are most commonly the initial cues perceived. In a wildfire, environmental cues may be the first cues perceived but, due to the scale of the fire and the area being affected, it is possible that more social cues will be perceived, either from official sources (e.g. authorities) or from peers (neighbours, relatives, friends).

Additionally, the review argues that evacuation will be attempted once a personal, serious threat is believed to exist. However, in building fires, the threat will be sited within the building, whereas in a wildfire, the threat will (at least initially) be sited outside of the building. Thus, it is not clear if evacuation will be chosen over staying put. A more recent review of human behaviour in fires, from 2018, focusing specifically on dwelling fires, highlighted that residents will be more likely to attempt to protect property in the event of a fire affecting their home, due to their relationship with that space [19]. Moreover, other research has emphasised how individuals may make several attempts to seek information before deciding upon protective action [20]. This could be likely in a wildfire where the hazard's location, size, speed, and trajectory could all be uncertain for some time or rapidly changing. Thus, it is not clear whether evacuation, staying put (to shelter or to defend property), or even waiting first to see how the situation unfolds, will be more prevalent in a wildfire.

However, as mentioned, the above research has focused on human behaviour in incidents affecting buildings (i.e. one or a small number of structures, where the place of safety was simply outside the main exit door). What about human behaviour in incidents affecting communities (i.e. many structures, where the place of safety may be some greater distance away)? A 2016 meta-analysis was conducted on studies of hurricanes, examining the decision to evacuate or stay put [21]. This revealed that households are most likely to evacuate in the following circumstances:

- If they expect severe personal impacts (e.g. believe the hurricane will result in someone from their household getting hurt or in their property getting damaged by the wind, etc.)
- If they receive a warning from an official source
- If they perceive other social cues (e.g. see peers evacuating and businesses closing)
- If they reside in an at-risk area
- If they perceive environmental cues (e.g. notice intense wind and rain)
- If they reside in a mobile home (i.e. a structure that is unlikely to withstand the hazard)

These findings suggest that an awareness of being vulnerable and a desire to protect loved ones might drive the decision to evacuate. The vulnerability might exist prior to the incident, due to one's residential circumstances (with transient groups such as tourists being particularly vulnerable here), and might become more apparent during the incident as environmental conditions change. However, these findings also suggest that the behaviour of residents in a large-scale incident might be strongly influenced by social cues, either explicitly or implicitly conveying the need to take action and leave. So, protective action might be decided upon during the unfolding situation rather than having been planned in advance.

The meta-analysis revealed several other interesting points, at least in relation to hurricanes. Firstly, that socio-demographic characteristics such as age and gender had no reliable association with evacuation decisions. Secondly, that having prior experience of a hurricane, or prior experience of an 'unnecessary' evacuation (i.e. a situation where residents had been advised to evacuate but then the hurricane did not reach their residence), also had no reliable association. These findings reinforce the idea that decisions about protective action may be more dependent on the unfolding situation than on pre-event factors.

Lastly, the meta-analysis demonstrated that useful information about human behaviour in large-scale evacuations may be gained from residents who lack real-life experiences to draw from. That is, responses produced in studies employing a hypothetical hurricane scenario were found to be comparable to responses produced in studies of actual hurricane experiences for around three-fifths of the examined variables for which a direct comparison could be made.

Another study has also demonstrated that intentions about what to do in a hurricane can correspond with actual behaviour in a hurricane, in this case through longitudinal methods [22]. The study additionally collected estimations from participants about how much time they would and then did commit to response actions while preparing for evacuation. However, the estimated time gathered in the first survey differed significantly from that in the second survey. This was in a large part due to the fact that the first survey presumed participants would be at work when they realised there was a threat. Thus, the actions asked about in that survey included preparing to leave work and then travelling home. However, most participants were already at home when the hurricane actually occurred and therefore did not perform such actions.

2.3 Human behaviour in wildfires: the need for data

So, there is a body of research already existing on human behaviour in building fires, in other disasters that are of a larger scale, and in associated evacuations. However, it is not clear whether these findings can be generalised to human behaviour in wildfires and evacuations associated with that kind of disaster.

Moreover, there remain several gaps in knowledge about human behaviour, despite the insights provided by these studies. For instance, regarding what people do, the research focus has tended to be on what protective action is taken – evacuation or staying put – and the factors that influence this choice. While obviously important, this means that there is little understanding of what else people do during an incident, i.e. the response actions undertaken prior to commencing evacuation movement. Such actions delay evacuation, necessarily or otherwise, even if residents have decided that leaving is what they will do. Therefore, response actions should not be overlooked.

Data on the time it takes people to commence evacuation movement is also lacking. Where time data is available from evacuation studies, this is usually in relation to evacuation movement. Moreover, such data is often only applicable to vertical movement (e.g. travel speeds on stairs), movement on purpose-built walkways (e.g. travel along the floors inside buildings), and movement under more optimal conditions (e.g. during daylight hours with no hazardous conditions present).

Nevertheless, some researchers have already identified that there is a need for human behaviour data specifically on wildfires and associated evacuations. This work has been spearheaded by a collaborative network of partners in Australia, and gained momentum following some particularly devastating bushfire incidents in the state of Victoria in 2009. Details about that work are covered later in this report, in section 3.5.2.

However, just as it is unclear whether findings from other types of disaster can be generalised to wildfires, it is also unclear whether findings about wildfires from one part of the world can be generalised to another part of the world. For instance, an earlier, international project on human behaviour relating to crisis situations (including fires in residences and other buildings, floods, earthquakes, and terrorist attacks, but not wildfires) found some commonalities but also some differences across countries [[23]]. Therefore, as well as looking at data from Australia, it is also important to gather data from other parts of the world that are of interest. For the GEO-SAFE project, that meant parts of Europe.

2.4 Collection of new human behaviour data

In section 3 that follows, the collection of new data on human behaviour in wildfires and associated evacuations is described and discussed. This data collection took place during the GEO-SAFE secondments undertaken in several different European regions, with one further secondment taking place in Australia. A summary of each secondment and the data collected therein are presented in turn.

The following section also summarises the research methods employed and key results. Moreover, background information, also mainly collected during the secondments, is presented in order to provide regional context for the study design, data collection, and findings.

3. SECONDMENTS RELEVANT TO THIS TASK

3.1 ER secondment 1 – Corsica, France

Dr Lynn Hulse (Fellow ID: 21) is a psychologist who, since 2005, has worked for the University of Greenwich (UoG)'s interdisciplinary research group FSEG on various projects related to safety and security. For GEO-SAFE, this experienced researcher (ER) undertook two split-secondments to SDIS 2B (now called SIS 2B), who are located in Corsica. The first took place in Spring 2017 and the second in Summer 2017. The duration of both totalled a secondment lasting one person-month (PM). This secondment was focused on Task 2.5 for WP2, WG6. In other words, it centred on the gathering of information related to human behavioural responses to wildfires, including evacuation. In addition, Dr Hulse was there in a supervisory capacity, overseeing some of the work of her PhD student who was also undertaking a GEO-SAFE secondment.

During the secondment, Dr Hulse had meetings with key members of staff from SDIS 2B. She also visited the SDIS 2B operations centre, to understand the processes involved in surveilling for signs of fire and the emergency response to such signs. Along with the ESR, she participated in interviews with various professionals involved in wildfire management in Corsica. These included government representatives (e.g. a mayor), personnel from government agencies (e.g. the National Forests Office), firefighters and incident commanders, civil security coordinators, and decision-makers for residential areas outside of the main settlements (e.g. a campsite manager). Additionally, Dr Hulse visited locations across the island that had been affected by wildfire, as well as areas where evacuations took place, speaking with some of the residents who had been exposed to such activity. Furthermore, she sought, translated into English, and reviewed various risk documentation, and also participated in other GEO-SAFE-related activities (e.g. attending and presenting at the GEO-SAFE project review meeting, where she networked with personnel from other collaborating organisations).

3.2 ESR secondment 1 – Corsica, France

Mrs Sandra Vaiciulyte (Fellow ID: 20) is a doctoral candidate who joined UoG-FSEG in 2016. For GEO-SAFE, this early-stage researcher (ESR) undertook two split-secondments with SDIS 2B: one in Spring 2017 and another in Summer 2017. The duration of both totalled a secondment lasting three PMs. This secondment was focused on Task 2.5 for WP2, WG6. Again, this meant the gathering of information related to human behavioural responses to wildfires and evacuation. During this secondment, Mrs Vaiciulyte was supervised at times in person and at times remotely by her PhD supervisor, Dr Hulse.

While in Corsica, Mrs Vaiciulyte's activities were similar to those of Dr Hulse described above, e.g. she had meetings with key members of staff from SDIS 2B (as well as from SDIS 2A), visited the operations centre, led interviews with various professionals involved in wildfire management, and visited locations across the island that had been affected by wildfires and evacuation. Additionally, Mrs Vaiciulyte sought, translated, reviewed then extracted relevant data from local mass and social media sources. She also consulted with SDIS 2B personnel to refine, finalise and translate study materials. Moreover, she devised and enacted a participant recruitment plan for a survey, and she also managed the survey data collection. Furthermore, she engaged in other GEO-SAFE-related activities (e.g. attending, presenting, and networking at the GEO-SAFE project review meeting).

3.3 Select outcomes of secondments in Corsica

Below are details of some of what was learned during this secondment. Unless otherwise referenced, the information was gained via personal communication with SDIS 2B personnel and/or the ER and ESR's personal observations.

3.3.1 Introduction

Host organisation	Service Départemental d'Incendie et de Secours de la Haute-Corse, aka SDIS 2B (now called Service d'Incendie et de Secours de la Haute-Corse, aka SIS 2B)
Location	The island of Corsica, part of the South of France

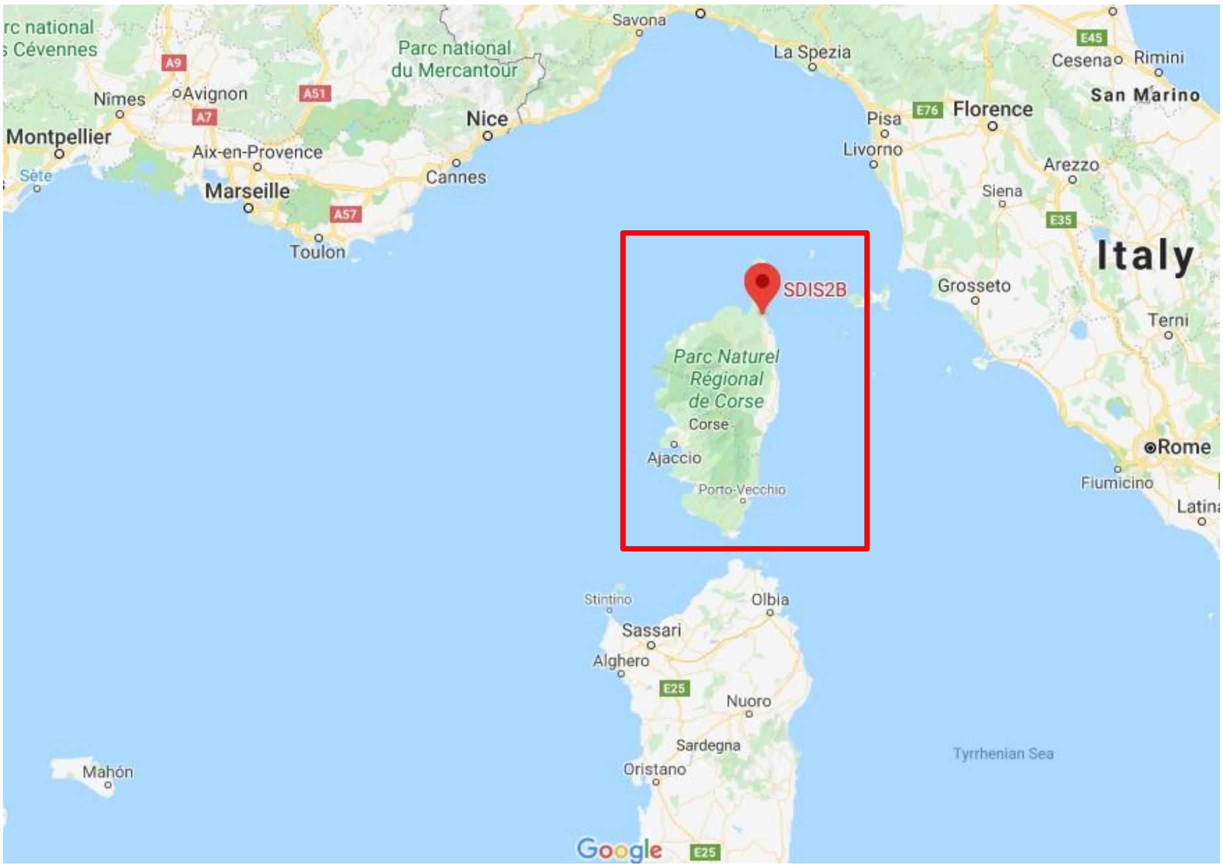

Fig. 1. SDIS 2B headquarters (marked) on the island of Corsica, France

SDIS 2B is the fire and rescue service (FRS) for the northern part of Corsica, Haute-Corse (SDIS 2A is the FRS for the southern part, Corse-du-Sud). The SDIS 2B headquarters are situated in the commune of Furiani (marked on Fig. 1), and it is here where the operations centre (CODIS) is located. However, the FRS' operations are spread across two-thirds of Corsica's 360+ communes, while SDIS 2A oversees operations across the remaining third on the island. As of the beginning of 2017, there were 257 professional *sapeurs-pompiers* (i.e. firefighters) and 1,064 volunteer firefighters working for SDIS 2B [24] (so a ratio of 19% professional to 81% volunteer).

The FRS is divided into several organisational groups, all under the overall direction of *le chef de corps*, who was at that time Colonel Charles Baldassari. The SDIS 2B personnel with whom the ER and ESR repeatedly liaised during their secondments were Commandant Patric Botey (then Chief of the Balagne Group and also with the FRS' research and development service), Commandant Marien Setti (then Chief of the Operations Group [see Fig. 2]), and Capitaine Hervé Duvermy (with CODIS).

Fig. 2. Lynn Hulse (UoG), Sandra Vaiciulyte (UoG) and Marien Setti (SDIS 2B) in Corsica [a]

SDIS 2B's main responsibilities are to prevent, protect and fight against fires, as well as other disasters and incidents. In the pursuit of this, their priority is the safeguarding of people first, then property and the environment.

3.3.2 People (residents)

In 2017, the estimated population of Haute-Corse was 177,689 individuals, of which 51% were female and 29% were aged 60 years or more; the situation was similar in Corse-du-Sud (estimated population in 2017 = 157,249 individuals, share of females = 52%, share of those aged 60+ years = 30%) [25]. A large amount of the population in the north and south continue to be concentrated in and around the port cities of Bastia (located just a few miles north of Furiani in Haute-Corse) and Ajaccio (in Corse-du-Sud), meaning that many of the more rural areas tend to be lowly populated. This is particularly the case as residents increasingly turn away from agriculture and turn instead to tourism, and therefore the service sector, as the basis for their careers and income [26].

However, during the summer months, Corsica's population changes in several ways. There is an annual influx of residents from mainland France and tourists from other countries who come to spend time in their second homes or otherwise holiday. For example, from June to August 2017, a total of 496,700 French visitors and a total of 188,380 foreign visitors stayed in hotels in Corsica [27]. This means that in summer 2017 – typical of every summer – the island's population doubled. In fact, this is an underestimation as these figures do not appear to include visitors staying in other types of accommodation such as villa-style houses and particularly campsites, of which there are well over 200 in Corsica. Moreover, these transient groups do not restrict themselves to residing in Bastia and Ajaccio. They can found throughout the island, in coastal towns and villages such as those in the Balagne region or Bonifacio, which are popular with people who like picturesque beaches and sea-based activities, as well as in the more mountainous areas such as along the GR 20 route, which is popular with hikers. Thus, it is not only the urban centres that experience a sharp rise in inhabitants but also some of the more rural areas.

An additional change is the number of languages spoken by the population. While the majority of visitors are from France, and therefore the official language of Corsica (French) remains most common, many others are nevertheless present. A study of hotel arrivals in 2013 showed that, out of the top 10 foreign nationalities visiting Corsica, seven were non-French speaking; they instead had six different official languages [28]. This can prove challenging as almost all oral and many written communications on the island are only in French or occasionally in the Corsican language (*Corsu*).

3.3.3 Property (residences)

In Corsica, there are several types of residence. Firstly, there are houses, i.e. typically detached or semi-detached homes, comprising one or more storeys, and housing a single household. Some are these houses are traditional Corsican residences, which are simple-looking and constructed using local stone (granite or schist) with tiled roofs. These tend not to have shutters; instead the windows are designed to be smaller to keep out the sun or wind. Moreover, the stairwell is often external rather than enclosed inside the building. Modern houses are usually also built with stone but tend to be slightly more ornate and/or colourful, e.g. have a few accoutrements such as a roof terrace or decking, and perhaps larger windows accompanied by shutters. Holiday homes will most likely be modern houses as the traditional Corsican houses are generally kept within the family – inherited rather than bought or rented.

Secondly, there are apartments. These are found in the cities or other towns usually by the coast and most retain an older Mediterranean style, with simple facades and sloping tiled roofs. There are, however, some more modern builds, with window terraces as standard and flat roofs. Apartments, as with houses, are made of stone, and while many may be classed as medium-rise buildings, none appear to reach the heights of a high-rise building. Another feature that houses and apartments in Corsica share is that the perimeter to the property (if a modern build at least) may be gated. Fig. 3 provides examples of these different styles of residence.

Fig. 3. Examples of house and apartment-style residences in Corsica [b, c]

Fig. 4. Campsite manager, Lynn Hulse, Sandra Vaiciulyte; mobile homes behind [d]

In addition to houses and apartments, there are 'mobile' homes. While some travel with the resident (i.e. tent, caravan), others are actually static, remaining on campsites (see Fig.4). The materials used for the construction of these residences are not so robust or fire resistant (e.g. canvas, wood).

3.3.4 The environment (climate, vegetation, terrain, roads)

The climate of Corsica, especially in the coastal areas, is typical of a Mediterranean location, i.e. winters that are wet from rain yet mild, plus summers that are hot and dry with little cloud coverage. The summer months tend to see around 11-12 hours of sunshine per day and temperatures reaching around 28°C [[29]]. Strong winds are also present during the summer but continue throughout the year.

Vegetation thrives on the island, both in terms of the range of flora that is resident and in terms of the area of land that it covers. The abundance of vegetation is in part due to the aforementioned rural-to-urban migration and, consequently, the abandonment of agricultural land to nature. While there are forests, a lot of the vegetation comes in the form of *maquis* – dense fragrant scrub comprising mostly evergreen shrubs. Some of the flora are more resistant to fire (e.g. holm and cork oak trees, honeysuckle), while others are highly flammable (e.g. eucalyptus trees).

Fig. 5. Example of settlements located on Corsica's slopes as well as flat areas [[e]]

Corsica's terrain is largely mountainous. Much of the land is on a steep slope, save for the ports and the valley floors. As a result, residents have settled in the elevated mountain sides as well as in the lower flatter areas (Fig. 5).

Given the terrain and remoteness of some settlements, the main method of getting around the island is overwhelmingly by car, rather than on foot or by public transport. However, to get from A to B on the roads takes some time, since Corsica has no motorways. Most roads on the island are narrow and winding single-carriageway or even single-lane routes. Parked cars can narrow roads further. Also due to the terrain and remoteness, settlements may often have just one ingress/egress route.

3.3.5 Wildfire risk and wildfire management

Residences and other human developments in Corsica, such as the roads, do appear to typically be surrounded by vegetation. Sometimes, this vegetation overhangs the residences and roads (Fig. 6). Consequently, much of the island could be classed as a wildland-urban interface or intermix (WUI). A WUI is defined as a place where human development (in particular, residences) meets or is interspersed with wildland vegetation, and this encroaching of one on the other poses the potential for problems, especially the problem of wildfires [30]. A study from 2016 – which mapped WUIs across European regions using legally-referenced spatial dimensions gathered from various countries – classified a much lower proportion of Corsica as being a WUI [31]. However, it is noted that that study utilised land use/land cover data from 2006, which could be somewhat out of date now, and the authors themselves acknowledged that their data source was likely to be biased towards larger-scale WUIs.

Fig. 6. A road and residences in Corsica surrounded by overhanging vegetation [f]

WUIs vary in their type, depending on both the configuration of the residences (isolated through to very densely clustered) and the structure of the vegetation (vegetation not in contact through to continuous vegetation) [32]. Taking the aforementioned observations about property and the environment and applying them to this typology, Corsica's WUIs appear to more often be characterised by vegetation that is structured in a continuous or discontinuous way, but the residences appear to be less densely clustered. This means that, were a wildfire to start and approach, the flames as well as the smoke would likely reach and surround residences. It also means that residents would likely receive environmental cues (e.g. the smell of burning, the sight of smoke/flames) to alert them to the presence of a fire but might not receive as many social cues (e.g. residents would be less able to see/hear what their neighbours were doing, it could take longer for authorities to reach their homes and conduct door-knock notifications).

European statistics show that many wildfires do indeed start in France's Mediterranean region. For example, 1,117 fires were recorded in just the summer of 2017, burning 14,601 hectares in total (Fig. 7); the most destructive of these occurred in Haute-Corse in late July 2017, with 2,260 hectares burnt during that incident [33].

Fig. 7. Example of burnt vegetation following an August 2017 wildfire in Corsica [9]

Previous research found that the majority of wildfires in Corsica (around two-thirds in Haute-Corse and around one-third in Corse-du-Sud) were caused by deliberate human actions, such as pyromania, pastoral fires, or fire-setting related to land-use conflicts with hunters [34]. It also found that human *imprudence* (recklessness or carelessness, for example with regards to the disposal of cigarettes or the extinguishing of barbeques) accounted for a high percentage (more than a quarter) of Corsica's wildfires. Only 6% of wildfires were found to be caused by a natural source involving no human contribution whatsoever (i.e. a lightning strike). Thus, the mere presence of humans greatly raises the likelihood of a wildfire starting. Given the previously discussed population increase during the summer months in Corsica, the scale of that increase, and the fact that holidaying individuals may be less aware of the risks and more carefree in their actions, this season faces a particularly heightened likelihood of experiencing wildfires.

Once a fire starts, the fact that there is plentiful fuel in the form of the dense vegetation, and the fact that the vegetation is likely to be rather dry due to the climatic conditions, means that the fire will spread and do so rapidly. The winds will add to the quick fire spread, as will the terrain, since slopes – especially steeper ones – affect heat transfer and drafts, thereby influencing the speed and intensity of the fire, as well as the concentration of the smoke emitted.

If the fire is not halted, and appears to be approaching residences, a decision will have to be made about protective action. Due to the aforementioned robustness of the properties in Corsica, and the limitations in the number and width of ingress/egress routes, the official preference of the authorities is for residents to stay put (*confinement*). Not to defend their properties but rather to shelter indoors. This preference is reflected through policy and practice. For example, prefects – who represent the national government at the departmental level, e.g. for Haute-Corse – publish a document called the *Dossier Départmental sur les Risques Majeurs* (DDRM) [35]. This document identifies, defines, and describes the major risks present for each of the communes in the area, it outlines the prevention and safeguard measures in place, and it provides instructions on behaviour. A similar document, the *Document d'Information Communal sur les Risques Majeurs* (DICRIM), is sometimes published by the mayors of communes, with more locally-relevant information [36]. With regards to wildfires, the prevention measures mentioned in Haute-Corse's DDRM include educational programmes, targeted at children through school projects – the idea being that the prevention behaviours become ingrained at a young age and the children then pass on their learning to the adults in their family. The safeguard measures include plans for schools (*Plans Particulier de Mise en Sûreté*), which aim, among other things, to keep the children (and staff) at the school during a wildfire, until rescuers arrive. Consequently, parents are prevented from attempting to come to schools and take their children away themselves. Regarding the behaviour of the public at large, the DDRM mentions that when the disaster warning siren (tested on the first Wednesday of each month across all parts of France) is sounded in the event of a wildfire, residents should tune in to the recommended media channels for official guidance. In Haute-Corse, the TV channel *France 3 Corse* and the radio channel *France Bleu RCFM* are the recommended channels. The role of these channels is to assist not only during a disaster (by passing on information from the government and instructing residents on what action to take) but also before and after (i.e. warning of the risks and providing information about appropriate prevention and protection measures, as well as signalling the end of the emergency and helping the situation return to normal as quickly as possible). The DDRM does encourage households to make their own safety plan (*Plans Familial de Mise en Sûreté*), prompting them to think about evacuation routes and accommodation. However, presently, this advice is only in relation to another major risk, floods. A copy of the DDRM for Haute-Corse is available for the public to view at the town hall in Bastia and can also be found online at the prefecture website (www.haute-corse.gouv.fr). Likewise, copies of the DICRIM for some communes are available to the public in town halls and/or online.

More instruction on staying put in the event of a wildfire has been issued by authorities to the public in short infographic form, e.g. flyers. Advised actions include: getting inside the nearest robust building, e.g. one's own residence; closing the doors and windows to the residence (and shutters, if any) to prevent smoke and embers from entering; moving flammable outdoors furniture and equipment inside the residence; opening the gates to the property to allow the FRS to enter and tackle any flames, if need be; and avoiding making phone calls that might overload the network. Taken together, the official advice in long and short form encourages residents to take actions to protect life/health and property, encourages them to passively wait for information from the authorities and discourages them from seeking information from other sources, as well as discourages attempts to group together with family members if apart at the outset. It also consolidates the notion that evacuation is not the default option and is not to be decided upon at the individual or household level, rather only by the authorities.

The exception to staying put indoors would be for transient groups residing in mobile homes. As such structures would not be robust, they would not be appropriate shelters. However, due to tourists' lack of familiarity with the local area and the limited ingress/egress routes connecting campsites to other areas, these transient groups would not be advised to self-evacuate. One campsite manager spoken to personally in Haute-Corse explained his procedure in the event of a wildfire: guests would be alerted via megaphone to assemble inside the site's communal building (constructed of stone) or, if too many to fit inside that, to assemble at the swimming pool. Another alternative would be for guests to run to the nearby beach and shelter by the water there. However, since an area around the campsite had been cleared, it was believed that this would offer a fire break and therefore guests would be better staying put.

The law on clearing (*débroussaillement*) appears relatively straightforward, applies to all properties, and is enforceable with sizeable fines (up to 1,500 EUR) [37]. Those persons responsible for properties must clear vegetation that is within 50 metres of the walls of buildings. That means all dead vegetation and cuttings should be completely removed, and remaining vegetation should be pruned so that it is not too densely concentrated. Also, if the remaining vegetation comprises trees, the lowest branches should be pruned to ensure they are at least two metres off the ground (and not overhanging buildings). However, despite making this clearing a legal requirement, not all property owners comply. This is sometimes due to aesthetics and privacy, i.e. properties may be perceived as more attractive by tourists or home buyers if they are surrounded by lush vegetation. Vegetation can also offer some shade, and therefore relief, from the hot summer sun, which can otherwise be lacking.

Even if robust, not all properties will be able to withstand all fires. Some may catch alight in particularly intense fires. Others may avoid catching alight, but smoke and radiant heat will still likely affect those sheltering inside, both physically and psychologically. This was highlighted by research on the 2009 'Black Saturday' bushfires in Victoria, Australia, where over half of fatalities lost their lives while sheltering inside a residence and survivors described the negative physiological, cognitive, and emotional effects experienced when staying put [38]. Individuals unable to find a nearby robust building during a wildfire and instead sheltering in the open will likely be affected in an even greater way. Thus, residents may come to perceive evacuation as a better option – whether or not the authorities have instructed taking such action.

In 2017, several wildfire evacuations were reported in Corsica. For example, as mentioned earlier, a serious fire began in late July of that year. It started in Olmeta-di-Tuda and quickly spread to threaten residents in nearby Biguglia, all close to Furiani. The initial advice from the authorities was to stay put; meanwhile, firefighters tackled the fire from the ground and from the air [39]. However, over 24 hours later, hundreds of residences were evacuated as the fire continued, abetted by strong winds [40]. Then, just a few weeks later, another serious incident occurred. This time, the fire originated in Nonza, further north on the island. While firefighters were bringing it under control in this area, other nearby areas were being affected by flames and particularly smoke, again all being fanned by the wind. The wind was also hindering firefighters from tackling the fire from the air, as the planes were unable to take off at times. Consequently, almost 1,000 residents were evacuated, several hundred from Sisco and more than twice as many from Pietracorbara. Around 200 evacuees were permanent local residents. However, the majority were tourists who had been residing at two separate campsites. Those in Sisco (also around 200) were evacuated under the instruction of the authorities while those in Pietracorbara (around 500) were evacuated under the instruction of the campsite manager, who anticipated an official evacuation later and did not wish the guests to have to leave then, when it would be late in the night [41]. The evacuation destination was often a school building, and evacuees moved to such destinations using cars or sometimes travelled on foot.

In the event of authorities officially ordering an evacuation, the decision maker will be the mayor of the affected commune or, if the fire is more major and affecting multiple communes, then the decision will be made at a higher governmental level, i.e. by the prefect. Particular thought will be given to vulnerable groups, such as the elderly; the mayor will have data on where such groups reside in their commune and should have plans in place for evacuation destinations that should offer safe shelter (usually robust buildings such as school halls or churches located in town). Such provisions are especially important in a region such as Corsica, where the share of the population who are aged 60+ years is greater compared to Europe in general (24% in 2017) [42].

The police are in charge of implementing an official evacuation order. However, since the police's main priorities are to uphold law and order and to manage the roads, and since there may not be sufficient police officers to cover all of the affected area, the FRS may also play a significant role in evacuations, in addition to their firefighting activities. That is, the FRS may help notify and remove people from areas under threat. Removal may be in the form of physical rescue of individuals, but it may also be in the form of co-ordinating and guiding a convoy of people evacuating via car from more remote threatened areas (Fig. 8). The *Sécurité Civile* (the civil defence and security directorate, which comprises both civilian and military personnel) may also be involved, both in (aerial) firefighting and in rescue activities.

Fig. 8. Patric Botey, SDIS 2B during evacuation of a forested area in Corsica [h]

The ideal scenario for authorities in Corsica would be that, in the event of a wildfire, residents would not evacuate unless ordered to do so by them. Moreover, where an evacuation order was issued, residents would comply with this instruction, and do so swiftly, thereby minimising the response time spent at the property and thus minimising the risk of exposure to highly hazardous conditions. However, residents do not always behave in the ways professionals expect them to. Therefore, it was important to build an understanding of what people do when faced with a wildfire in Corsica, why they do it, and how long it takes them to do it.

3.3.6 Study design: survey of residents

In order to understand how residents might behave in a wildfire, particularly one where evacuation takes place – whether ordered by the authorities or not – several sources of data were consulted. These included published materials found in the mass and social media (e.g. articles, photographs, videos). This also included interviews with professionals involved in wildfire management, where they were asked for their observations. However, in order to collect detailed first-hand accounts, not just about individuals' outwardly-visible behaviour but also about their internal thoughts and states, a survey was designed to be administered to residents. The following sections summarise certain aspects of the research involving the survey of residents. More information on all this work can be found in other GEO-SAFE-related publications [43, 44].

The survey, available online in both French and English, was in the form of two questionnaires:

- One for residents who had actual experience of a recent wildfire, and would answer questions about their recent experience (AE questionnaire)
- One for residents who had no experience of a wildfire, either recently or at all, but who lived in an at-risk area; this sample would instead answer questions about a hypothetical wildfire (H questionnaire)

The structure and questions in both questionnaires were designed to be similar, thereby allowing (where possible) a direct comparison of actual behavioural responses to a wildfire versus hypothetical behavioural responses. The questions were structured in the following way:

(a) Pre-event – examples include:

- Socio-demographic characteristics – e.g. age; gender; type of resident
- Prior experience – e.g. how often residents had directly experienced a wildfire previously; how often residents had experienced an evacuation previously due to a wildfire
- Preparedness – e.g. from which sources (if any) residents had gained information about preparing for a wildfire; whether residents had prepared a safety plan

(b) Peri-event – examples include:

- 'Behavioural itinerary' – i.e. actions undertaken once residents have been alerted to a wildfire, but prior to commencing evacuation movement to a place of safety; the time committed to undertaking these actions ('behavioural itinerary time')
- Evacuation decision (**AE questionnaire only in part**) – e.g. whether residents ultimately decided to evacuate or stay put; reasons behind decision-making
- Evacuation movement – e.g. the destination if residents opt to evacuate; any ingress attempts

(c) Post-event – examples include:

- Decision in future (**AE questionnaire only**) – i.e. what decision about protective action residents would make if they were to experience a similar fire again

The participant information page at the start of the survey described what would be involved; along with details about how their data would be treated and the right to withdraw from the research at any time, residents were also advised to consider first speaking with a counsellor or medical practitioner if concerned about the subject matter. Additionally, at the end of the survey, residents were provided with information on where disaster-related practical advice and confidential support could be sought.

3.3.7 Survey data collection and analysis

Given their more likely involvement in individual decision-making and action-taking, and also ethical considerations, the online survey was designed for adults aged 18 years or older. Those who resided in Corsica full-time (permanent resident) and those who belonged to a transient group, i.e. were a tourist or were staying in their second home in Corsica (temporary resident), were eligible to take part.

Since the identities of wildfire survivors are neither recorded nor stored following incidents, and therefore are unknown to researchers, as are the identities of others merely residing in at-risk areas, convenience sampling was employed. Recruitment methods included advertising the survey and its web link via research and SDIS 2B-related social media accounts (Twitter, Facebook), utilising geo-targeting, and also via an article in the French regional newspaper, *Corse Matin*. Recruitment took place during the summer of 2017.

Almost 100 completed questionnaires (N = 98; n_{AE} = 48, n_H = 50) were received and suitable for inclusion in the data analysis. They came from participants located across the northern and southern parts of the island, including from communes such as Biguglia, Sisco and Pietracorbara.

Participants' data were analysed using the software package SPSS Statistics (version 25). Inferential statistical analysis was in the form of tests of 2 x 2 or 2 x 3 cross-tabulations (i.e. Chi-Square and Fisher's Exact tests). An alpha level of .05 was used as the cut-off for statistical significance.

3.3.8 Survey results and discussion

Pre-event: socio-demographic characteristics

Participants' ages ranged from early 20s through to mid-70s (AE: 20-71 years; H: 21-75 years); the mean age was mid-40s (AE: M = 45.93 years, SD = 14.91; H: M = 43.50 years, SD = 13.47). This shows that the survey recruitment was successful in reaching adults of a wide-range of ages, from young and middle-age and, importantly, from the older age category (i.e. 60+ years) as well.

The gender ratio was rather even for the AE sample (51% male, 49% female). It was less so for the H sample (38% male, 62% female). However, this was not a significant difference ($X^2[1] = 1.68$, $p = .196$).

The majority of participants were permanent residents (AE: 59%; H: 69%). That said, a sizable portion of temporary residents were also in these samples (AE: 41%; H: 31%). Thus, despite being in Corsica for a limited time, time that was meant for leisure activities, some tourists and other types of transient nevertheless were willing to take part in this survey, indicating that they saw the value of research on wildfires.

Pre-event: prior experience

To complete the AE questionnaire, participants had to have experienced at least one wildfire recently. However, this recent experience was rarely AE participants' only exposure to a wildfire; 81% of this sample reported having experienced a wildfire more than once and just 19% reported that their recent wildfire experience was their sole exposure. As expected, the majority of H participants (54%) had never experienced a wildfire, although 18% had experienced a wildfire once in the distant past and 28% had had multiple wildfire experiences in the distant past. These results demonstrate the ongoing challenge that Corsica faces with regards to wildfires. While efforts to detect and fight the outbreak of fires continue, and technological aids to such efforts also advance apace, this can nonetheless be counteracted or undermined by other progressions relating to vegetation, the climate, and human activity. So, residents may end up experiencing wildfires repeatedly, at different periods throughout their lives.

Despite the AE sample having more prior experience of wildfires, the majority (60%) did not have prior experience of a wildfire evacuation. Only two-fifths of AE participants had evacuated previously. This is in line with the official preference for residents to stay put in the event of a wildfire, and suggests that policy and practice have influenced residents' behaviour.

Pre-event: preparedness

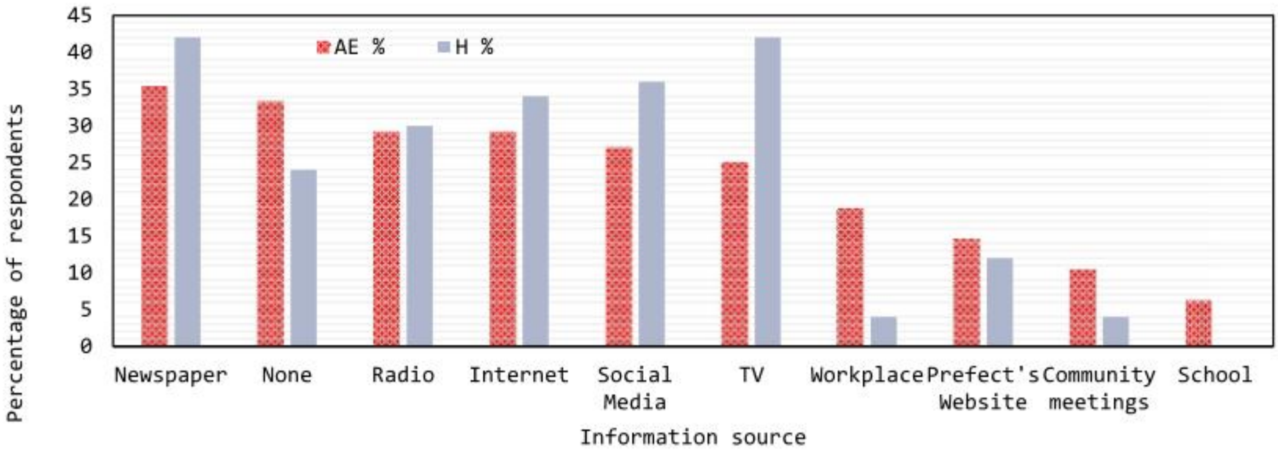

Fig.9. AE and H participants' sources of information about preparing for wildfires [43]

Newspapers were identified by both AE and H participants as the main source from where they had gained information about preparing for wildfires (Fig. 9). This demonstrates that, in Corsica, the traditional form of mass communication is still more popular than the newer forms.

School was reported to be the least informative source. However, the latter result is likely due to the question being aimed at the last 12 months (before the recent wildfire, for AE participants, and before the questionnaire, for H participants) rather than at any point in the participants' lives. Given that the majority of participants were middle-aged adults, it is understandable why higher education institutions would be less frequently reported here. Thus, this finding is no indictment of the aforementioned school programmes being run by those involved in wildfire management.

TV was also a main source of information for H participants but less so for AE participants. Instead, the AE sample gained slightly more from the radio, internet and social media. This shows that residents in Corsica do not rely on a single source for information, and may also be digesting information while on the move. Additionally, the findings about the internet and social media likely reflect in part the fact that the samples contained tourists, who may have been seeking information online that was in their own language rather than reading local newspapers or tuning in to local TV and radio.

Sources of information dedicated to wildfires (i.e. the prefecture website and community wildfire meetings) were less frequently reported. This suggests that Corsican authorities have more work to do in reaching out to their communities and getting them to actively play a part in educating themselves and each other.

The fact that around one-fifth of AE participants had gained information from their workplace suggests that this may be another useful channel for communicating safety advice. However, compare this result with that for the H sample; if the workplace is in an area that has not experienced a wildfire, ever or recently, then the management might not have considered the impact of such a disaster on their business or on the personal lives of the staff. Therefore, they might not have much information to pass on to the staff regarding wildfire preparation, leaving the staff less informed in turn.

Of some concern is the fact that around a third of AE participants and around a quarter of H participants had gained no information at all on wildfire preparation in the 12 months previous. Given that the samples as a whole showed that information was being received via multiple sources, this finding does not appear to reflect a problem with information accessibility. Rather, it could point to a lack of interest on the participant's part. That is, while it might be acknowledged that a wildfire could occur in the location and maybe even affect the property, there might be an accompanying sense of denial that a fire could ever have consequences for them personally, hence no need to prepare for one. It is also possible that the message of 'stay put' was being interpreted as 'take no action'.

The lack of perceiving a need to prepare was also revealed through the results on planning. Around only one-fifth of AE participants (19%) and just a tenth of H participants had prepared their own safety plan (this was again with regards to the 12 months previous). However, it was noticed that quite a percentage of participants (AE: 42%; H: 32%) reported 'knowing what to do' in their minds even if they had not formalised their plan of action. The remainder (AE: 39%; H: 58%) reported having no plan at all. It was noticed that having no plan at all was significantly associated with having gained no information in the 12 months previous. This was the case both for the AE sample ($X^2[2] = 6.03$, $p = .049$) and for the H sample ($p = .030$).

<u>Peri-event: evacuation decision</u>

Permanent residents more often decided to stay put than evacuate (72% compared to 28%, respectively). The same trend was seen with temporary residents (88% compared to 12%, respectively). As such, the nature of AE participants' residency was not significantly associated with their decision-making regarding whether to evacuate or not ($p = .628$).

The majority of AE participants (73%) who had greater prior experience of wildfires (i.e. had multiple exposures) decided to stay put; the remainder of those with such experience (27%) decided to evacuate. The tendency for deciding to stay put was the same when looking at AE participants who had only one prior wildfire experience, albeit even stronger. That is, all of those participants with a single prior experience stayed put; none decided to evacuate. This difference was not a significant one, however; prior experience of wildfires was not found to be significantly associated with decision-making ($p = .542$).

Perhaps surprisingly, all of the AE participants who had prepared a safety plan of some sort (either a formal plan or an informal plan in their minds) decided to stay put. It was somewhat different for AE participants who had prepared no plan at all: 73% decided to stay put while 27% evacuated. Again, however, this difference was not significant ($p = .542$). Thus, it can be said that participants' decision-making was unaffected by pre-event planning. Moreover, it appears that planning might have been focused on staying safe while staying put rather than envisaging evacuation as an option.

Since the majority of the AE sample decided to stay put rather than evacuate, it reinforced the notion that the official preference – as expressed through policy and practice – had been absorbed by residents and consequently was an overriding factor in their behaviour. For those who went against the official preference (i.e. evacuated), it was of interest to understand why they did so. Unfortunately, only a small number of evacuating AE participants (n = 6) gave their reasons for taking such a decision. However, all H participants stated what their reasons would be for choosing evacuation if faced with a wildfire. Thus, a qualitative comparison between the two samples follows.

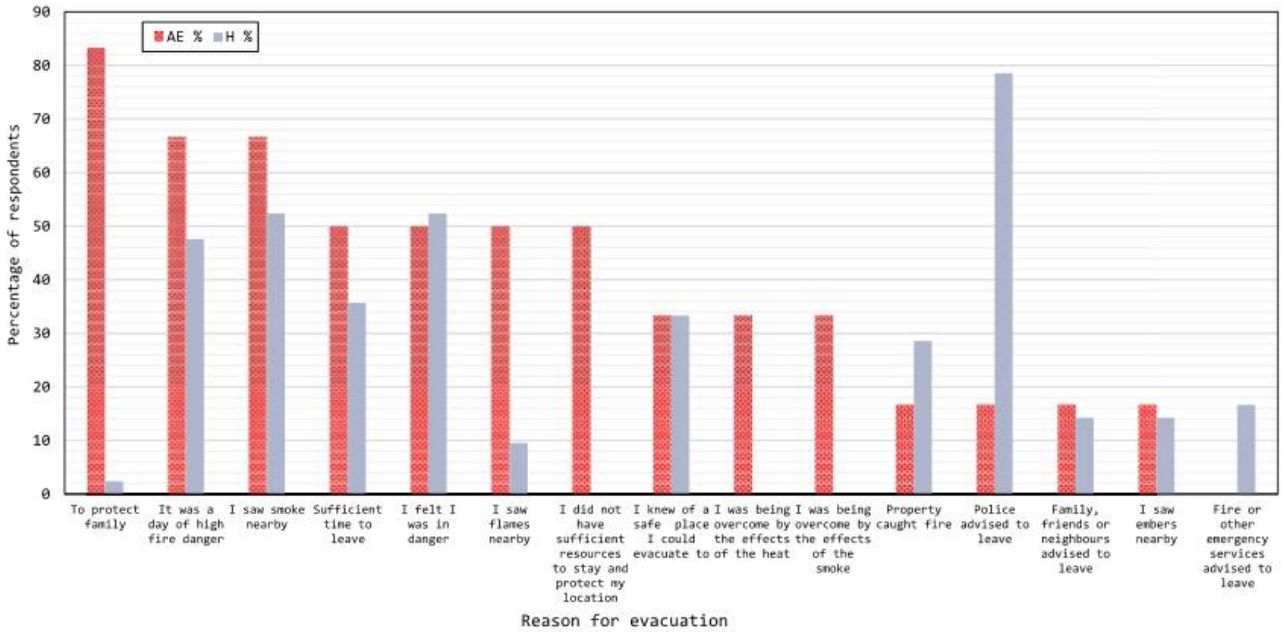

Fig. 10. AE and H participants' reasons for deciding to evacuate [43]

The subsample of AE participants most frequently reported deciding to evacuate because of a desire to protect their family (83%; Fig. 10). In contrast, only 2% of H participants stated this would be their reason for evacuating. Other reasons commonly cited by the AE subsample but hardly ever, if at all, reported by H participants included seeing flames nearby and not having sufficient resources to stay and protect their location (50% each).

Conversely, H participants most often stated that they would decide to evacuate if the police advised them to leave (79%), a reason that only 16% of the AE subsample reported. It was noticed that 16% of H participants also stated that they would leave if other emergency services such as the FRS advised them to, while none of the AE subsample gave this reason.

There were, however, some occasions where the two groups were more congruent in their decision-making process. For example, the reasons for evacuation cited by approximately half or more of participants from both groups included it being a day of high fire danger (AE: 67%; H: 47%), seeing smoke nearby (AE: 67%; H = 52%), and feeling personally in danger (AE: 50%; H: 52%).

Bearing in mind the low number of AE evacuees who responded to this question, some tentative conclusions may nevertheless be proposed about the above findings. That is, both groups clearly recognised that a wildfire poses risks. However, it would appear that H participants tended to surrender the decision about evacuation to others, the authorities. In other words, this sample would appear to have been swayed by official policy and practice, which emphasised the authorities as being the decision makers. So, less experienced individuals might anticipate their role in a wildfire to be a more passive one. In contrast, the decision-making of those who actually experienced a wildfire and evacuated appeared to be more influenced by the situation, i.e. an awareness or realisation of the seriousness of (a) the fire itself and (b) the potential consequences for themselves and their loved ones. This awareness or realisation was being derived somewhat from the authorities' early warning about the fire danger that day but more often from their own perception in the moment. So, their role was in fact a more active one. Consequently, those with less experience of a wildfire could find themselves mentally unprepared for what may have to be done when facing a serious fire, especially if the authorities are not able to get to them quickly to either notify or rescue them.

A final point regarding reasons for evacuating is that a lower amount of both groups (AE: 17%; H: 14%) indicated that their decision-making would be influenced by peers, i.e. family, friends, or neighbours. This again could be a sign of absorbing the message conveyed by official policy and practice to avoid phoning others. It could also reflect the geography, i.e. the fact that residences in Corsica might often be in further proximity from neighbouring properties. So, not only might residents be less minded to consult neighbours, they might also be less able to see or hear how their neighbours are reacting in the moment and therefore lack certain social cues.

<u>Peri-event: evacuation movement</u>

AE participants who evacuated most often went to a nearby town or village to seek shelter (80%). The remaining 20% neither evacuated to another residence nearby, nor to another building such as a hall or church, nor to an open area such as a beach. Instead, they reported evacuating to a destination beyond these options provided in the question.

H participants also most often opted for a nearby town or village as their destination, in the event of a wildfire evacuation (44%). A small percentage (8%) of H participants opted for another residence nearby, a slightly larger percentage (12%) opted for a building such as a hall or church, while almost a quarter (24%) opted for an open area like a beach. The remaining 12% stated that they did not know where they would seek shelter in the event of a wildfire evacuation.

The above results from AE participants somewhat contradict the message from authorities that residents in their community will evacuate, if necessary, to a robust building that is nearby, in town. This suggests that the designated shelters need to be more widely advertised to residents. Of course, it could also suggest that the fires were severe and that the whole town (or village) was therefore threatened and in need of evacuation. However, the fact that most H participants also chose somewhere out of town, despite not actually being presented with details of (hypothetical) fire severity, indicates that awareness of designated shelters is indeed lacking. This notion is bolstered by the number of H participants who chose an open area instead or reported not knowing where to go.

Additionally, the results have implications for travel. If going out of town, then it is important that this evacuation movement begins early on in the incident, to allow residents the time and ability to safely reach their evacuation destination. First, they will need a car or other motorised vehicle for this longer journey. They will also need sufficient fuel for their vehicle. Additionally, flames and wind can cause debris such as fallen trees or branches to obstruct roads. Thus, the intended route might not be passable. Similarly, even if the fire front is not in close proximity, thick smoke could still be present, obscuring visibility on the roads to the point where drivers become disoriented or a collision occurs with others who are unsighted. Furthermore, police may block roads for safety or operational purposes, and thus this could cause congestion on other available routes, further limiting residents' means of egress. As mentioned before, the roads in Corsica are already limited in their number and width, and their winding nature also reduces the speeds at which drivers can safely reach and maintain.

As well as egress, some residents may attempt ingress while a wildfire incident is still underway. Among the AE participants, only two said they actually tried and accomplished returning to their residence before authorities had declared it safe to do so. However, among the H participants, a very large percentage (87%) stated that they would attempt ingress. The two AE participants had been motivated by concern for their property (i.e. had it survived the fire up to this point and could they go back and defend it?) but H participants mainly envisaged attempting ingress in order to check on the safety of loved ones from whom they were apart (50%). This latter result suggests that it might be difficult for family members to heed some of the aforementioned safeguarding measures put in place by the government regarding grouping behaviour. Therefore, this could be one area where official policy is not followed in such great numbers.

Another motivation for ingress that H participants envisaged was returning home early if, in their own opinion, the threat had passed (41%). This could be dangerous behaviour if residents' risk assessments are not accurate. However, even if residents' risk assessments regarding the fire are accurate, the roads still might need to be kept clear for other safety reasons (e.g. due to the risk of strewn burning debris causing hazardous obstacles, or the risk of burnt trees falling over onto the road) or for operational purposes (e.g. to allow FRS and other emergency service vehicles access).

<u>Post-event: decision in future</u>

AE participants with prior experience of a wildfire evacuation were more likely to decide to evacuate in future (56%) than decide otherwise (44%). AE participants with no such prior experience were far less likely to decide to evacuate in future (9%) than decide otherwise (91%). This difference was significant ($p < .001$). The result suggests firstly that the past evacuation must have been deemed reasonably successful or beneficial by participants for them to wish to go through that process again. Secondly, the result suggests that past behaviour might be somewhat difficult to overcome. Thus, if residents are used to staying put then it could be harder for them to consider evacuation in the event of another fire.

3.3.9 Survey outcomes: summary

The survey of residents in Corsica allowed several aspects of behavioural responses to wildfires to be identified and quantified. These covered pre-, peri-, and post-event aspects. So, it allowed for an examination of what residents will do during an incident, whether pre-existing factors might influence that behaviour, and how that might also influence future behaviour. Additionally, the survey allowed for a direct comparison of residents' intended responses (H questionnaire) and residents' actual responses (AE questionnaire).

However, the tendency to stay put in the event of a wildfire was dominant in the samples here. This presented a challenge for the focus of this piece of GEO-SAFE research, i.e. human behaviour during wildfire evacuations. In particular, it meant less data to examine the behavioural itineraries that would be undertaken prior to commencing evacuation movement and times associated with these response actions. Hence, it was decided that survey data collection would continue but be extended, not only to other wildfire-prone Mediterranean parts of the South of France (e.g. Provence-Alpes-Côte d'Azur) but also to other wildfire-prone parts of the world where research on communities' responses to wildfires and evacuations is already quite advanced (e.g. Victoria, Australia).

3.4 ESR secondment 2 – Victoria, Australia

Mrs Sandra Vaiciulyte next undertook a secondment with RMIT University, who are located in Australia. This secondment took place in Summer 2018, lasting two PMs. This secondment was focused on Task 2.5 for WP2, WG6. Again, this meant the gathering of information related to human behavioural responses to wildfires and evacuation. Her PhD supervisor, Dr Hulse, was not present on this secondment and supervised remotely.

While in Australia, Mrs Vaiciulyte's activities included having meetings with researchers and consultants from RMIT and other Australian universities. She also met with: representatives from local and state government; personnel from two of Victoria's FRSs, the Country Fire Authority (CFA; a volunteer-based organisation) and the Department of Environment, Land, Water and Planning (DELWP; formerly the DSE, and an agency for whom firefighting is but one of their roles relating to public land); personnel from the Victoria police force; and representatives of disaster-related professional bodies such as the Victoria State Emergency Service (VICSES) and the Australasian Fire and Emergency Service Authorities Council (AFAC; now called the National Council for Fire and Emergency Services). Furthermore, she reviewed bushfire survivor accounts published by the 2009 Victorian Bushfires Royal Commission and visited locations in Victoria that had been affected by bushfires and evacuation. Additionally, Mrs Vaiciulyte launched the residents' survey in Australia and managed the survey data collection. Lastly, she engaged in other GEO-SAFE-related activities (e.g. attending, presenting, and networking at the monthly GEO-SAFE MoMeet virtual meetings).

3.5 Select outcomes of secondment in Victoria

Below are details of some of what was learned during this secondment. Unless otherwise referenced, the information was gained via personal communication with RMIT personnel and/or the ESR's personal observations.

3.5.1 Introduction

Host organisation	RMIT University (formerly known as the Royal Melbourne Institute of Technology)
Location	The state of Victoria, in Australia

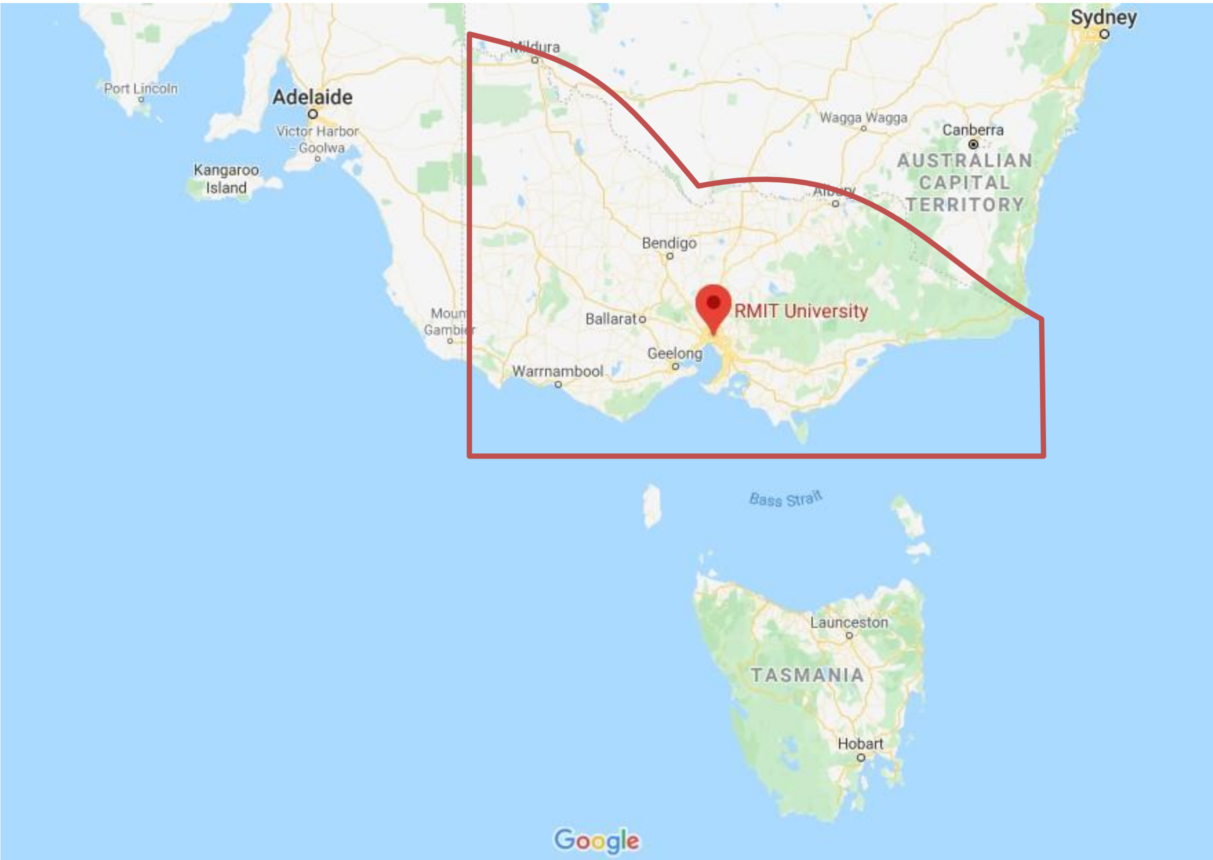

Fig. 11. RMIT University main campus (marked) in the state of Victoria, Australia

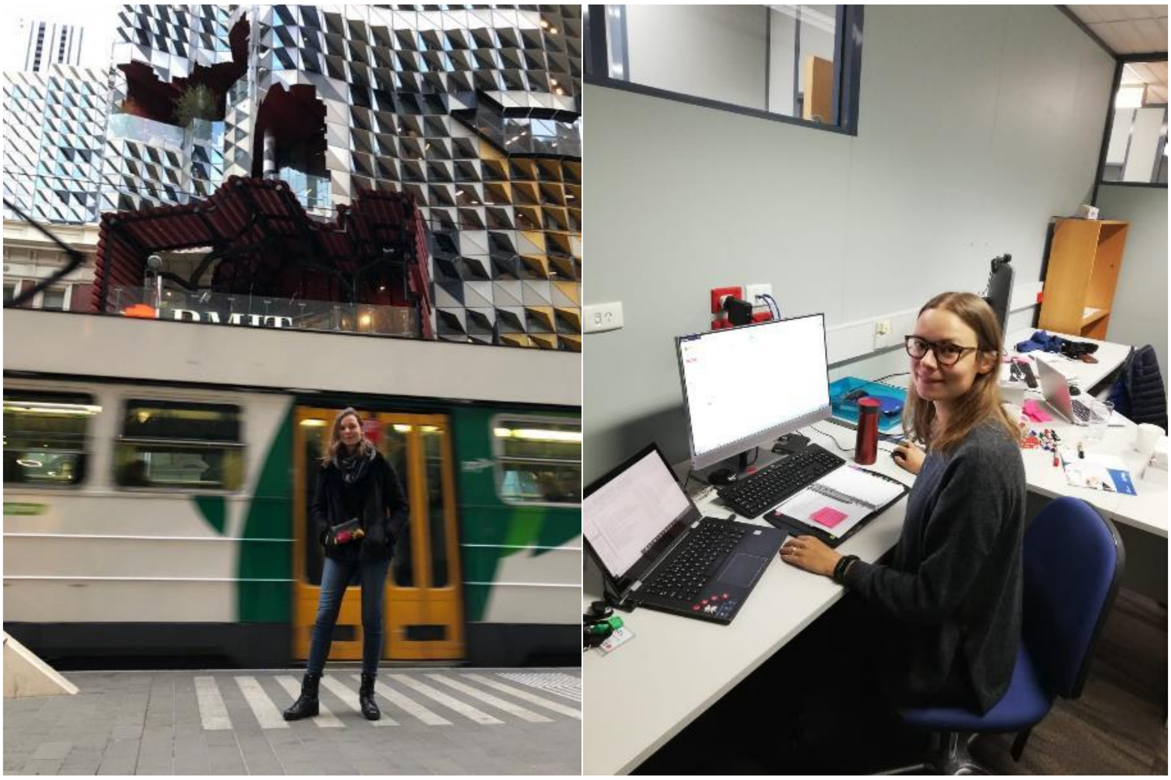

Fig. 12. Sandra Vaiciulyte (UoG) at RMIT University in Melbourne [i]

RMIT University is one of the largest universities in both the state of Victoria and in Australia as a whole. Its main campus is situated in the city of Melbourne (marked on Fig. 11; also Fig. 12). The university provides higher and vocational education to tens of thousands of students each year. It is also very active and internationally renowned with regards to its research, particularly applied research. The main point of contact for the ESR during the secondment with RMIT was Associate Professor Marc Demange (from the School of Science, with research interests including operational research).

RMIT University was one of the partners in the Bushfire Cooperative Research Centre (Bushfire CRC), which operated from 2003 to 2014. The Bushfire CRC was set up to conduct research into the various impacts (e.g. social, economic) of major bushfires and to address key issues arising from that. For example, it aimed to help communities become more self-sufficient in managing bushfire risks. The Bushfire CRC has since been succeeded by the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC), which has a similar but expanded remit. RMIT University is also a partner in this successor.

3.5.2 Wildfire evacuation example: Marysville, Black Saturday

One of the major bushfire incidents studied by the Bushfire CRC and BNHCRC has been 'Black Saturday'. This was not a single bushfire but rather multiple separate bushfires that started in different locations across the state of Victoria, all on the same day, Saturday 7 February 2009. The state government had warned about the high danger of fire the day before, due to the extreme temperatures and strong winds forecast for Saturday, but also due to the fact that the preceding days had experienced an ongoing heatwave, leaving vegetation at its driest. Unfortunately, fires did break out and the resultant death toll was high: 173 lives in total were lost, with some small towns experiencing particularly high numbers of fatalities, e.g. Marysville (Fig. 13), which recorded 34 fatalities and also saw most of its residential, commercial and public buildings destroyed [45]. A further Marysville resident died just days later, as a result of the physical and emotional stress of the fire and its consequences exacerbating pre-existing medical conditions [45].

Fig. 13. Displays on Black Saturday in the Phoenix Museum, Marysville [j]

Evacuation did take place in Marysville. However, it was rather uncoordinated. This is perhaps to be expected given that the Municipal Emergency Management Plan for the shire in which Marysville is located contained no plan for evacuation [45]. The 2009 Victorian Bushfires Royal Commission's final report provided a timeline account of the unfolding incident in that part of Victoria [45]. Details from there are summarised below, supplemented by some personal observations.

The fire that went on to affect Marysville (known as the 'Murrindindi fire') was first detected by a DSE fire tower operator at 14:55 on Saturday afternoon. A colleague later described it as 'a tiny little trundle of smoke' spotted in the distance. At this point, the fire was in a location that was over an hour's drive away from Marysville. The first firefighters (belonging to the CFA, who had been alerted along with the DSE) attended the fire at 15:08 but it was already growing in size and moving south-eastwards fast, abetted by the dry vegetation and wind. A radio station, UGFM, started issuing warnings about the fire's existence at 15:16, although this was a community radio station, not the larger, officially-designated broadcaster (774 ABC).

A second fire tower operator, located in another area, was certain that the fire would pose a risk to Marysville. He came to this conclusion at 15:30 but was prevented from passing information on to the incident management team for some time because the phone and radio networks were being overloaded with calls. By the time he got through to the team, around 16:00, and over the next half hour before he himself evacuated, the second operator said the fire was 'massive […] just full of ember, ash, burning materials. This thing was absolutely alive'. However, the incident management team did not consider evacuating Marysville, or any other town in the vicinity, as this was not usual practice. Instead, the incident management team focused their attention on attempting to control the fire, for the purposes of 'community and asset protection'. This was a difficult task; aerial firefighting activities did commence, to supplement activities on the ground, but were later called off due to the strong wind and turbulent air making the efforts ineffective and the flights dangerous.

Around 16:00, the police initiated the set-up of the Municipal Emergency Coordination Centre. However, when the police sergeant in charge arrived at 17:05, set up was still taking place. Moreover, little information was subsequently received about the fire's trajectory. Many incoming calls were instead about police operations such as the creation of roadblocks.

Meanwhile, the fire had reached the Toolangi State Forest (comprising mainly eucalyptus trees) and, by around 16:15, had managed to ascend a steep ridge there called the Black Range. A little later, around 16:30, fire spotting began to become a major issue. In other words, new fires were being created away from the fire front due to burning debris being carried some distance (up to 15 km) by the wind from this higher location. Around this time, UGFM radio station was warning that the fires could threaten some settlements on the eastern side of the Black Range; however, Marysville was not one of those mentioned. This was also the case at 16:47, when the ABC radio station broadcast an urgent warning, and at 16:55 and 17:10, when the CFA posted warnings on their own website. It was not until 17:11 that Marysville was reported as being at risk. However, this was again during a UGFM broadcast and the warning appears to have been presented in a less-than-authoritative manner: 'This is unofficial I must say to you but residents in the Marysville area should enact their bushfire plan I would think at this point in time'.

Prior to this warning being broadcast, between 16:30 and 17:00, the VICSES Deputy Controller for Marysville heard on the CFA radio channel that the fire had reached Narbethong – a hamlet about 10 minutes' drive south-west of Marysville – and thus enacted the VICSES evacuation plan for Marysville. This involved notifying residents who were on the VICSES list of vulnerable groups, e.g. older adults. Notification took the form of telephoning the residents or driving to the addresses to notify in person. Those who requested assisted evacuation were told to assemble at a local hotel and spa to wait for further instruction. Those self-evacuating were told to go to Alexandra, a larger town about 30 minutes' drive north of Marysville. Some other residents had already made their own decision to self-evacuate earlier on during the incident.

Notification activities were still underway at 17:45 when they were halted; a tree had fallen, trapping a resident inside her car. Once she had been extracted, it was clear that Marysville was being directly threatened by the fire. However, when the VICSES staff got to the hotel and spa to evacuate those who had been waiting there, they discovered that they were too late; the owner had already taken it upon themself to evacuate the waiting residents to Alexandra. That hotel and spa was ultimately destroyed in the fire.

Around the same time as the resident got trapped in her car, and over the next hour, official sources (i.e. the ABC radio station, the CFA website) began issuing warnings for Marysville and other settlements in the vicinity. Also around that time, a senior CFA officer was informed that a change in wind direction was being forecast to occur in approximately 1.5 hours' time. However, the warnings that were issued did not report what was likely to happen if such a change took place. The first mention of the predicted wind change came at 18:36, during an interview broadcast on UGFM.

A little after 18:30, several police officers started advising residents in Marysville to evacuate. Notification took the form of the officers driving around town, using their cars' sirens to alert residents or knocking on doors, and then issuing the advice about taking this protective action in response to the fire that was closing in on the town. However, quite a large group of residents (c. 200) had already been assembling at a park oval in Marysville. These people sheltering in the open were by now exposed to hazardous environmental conditions, with the adjacent trees aflame and thick smoke permeating the air. When the police officers found them, just before 19:00, they shouted to the crowd that they had only a few minutes to leave, and that they needed to get into their vehicles and calmly drive in a convoy to a school in Alexandra. The majority of the assembled crowd followed this instruction. Note, the action taken by the police officers was not policy but rather an on-the-spot judgement made by these individuals based on the risk that they perceived. Some VICSES volunteers also drove around Marysville, using their vehicles' public-address systems to tell residents to head to Alexandra.

Around the time this evacuation notification and movement was taking place, the wind changed direction. This had numerous dangerous effects, across Marysville and across a number of other areas. It prompted the senior CFA officer to order the evacuation of firefighters in Marysville. He instructed them to go to the park oval. The smoke on the way to the oval was so thick that some firefighters recalled running off the road on occasion, while the raining embers set fire to kit being stored in the back of vehicles, and some metal and plastic vehicle parts melted in the intense heat. One of the residents who had remained at the oval – believing that he stood a better chance of surviving there than in a car in the evacuating convoy – ended up submerging himself in a nearby lake, ducking under the water to avoid being hit by embers as the fire front swept through Marysville.

Surprisingly, a number of official sources, including the CFA website, issued statements later on Saturday evening, and on Sunday 8 February, that 'everyone is safe in Marysville and are assembled at Gallipoli Park'. It was later discovered that 'everyone' was meant as a reference to CFA and DSE firefighters, not Marysville residents. Many of those had died, inside their homes, in their yards, inside other buildings, out on the street, and inside cars. Although none of the fatalities found in or near cars had been part of the convoy that left the oval, those evacuating residents who reached the school in Alexandra were not completely safe. They experienced the effects of smoke and heat there when the fire – which had continued spreading and spotting in different directions – later threatened that town. Nonetheless, no lives were lost there.

3.5.3 Behavioural responses and time to evacuate

The case of Marysville provides an example of how evacuation, and evacuation to quite some distance away, may be the safest form of protective action to take in a wildfire. It also provides an example of how that realisation might not occur swiftly, either in the minds of professionals or in the minds of residents. From the time when the fire was first detected to the time when the fire front passed through Marysville was a little over four hours. The first warning to suggest Marysville was at risk was not broadcast for at least 2.25 hours, thereby leaving just over 1.75 hours to commence evacuation movement, at the latest. Moreover, that warning, by UGFM, was not authoritative, not necessarily recommending evacuation, and not broadcast to all. Indeed, research by the BNHCRC indicated that only around 5% of survivors across Victoria who said they received an official warning about the fire threat during their incident did so via a radio station that was not ABC [[46]].

When residents in Marysville did become aware of the threat to their town, the initial decision made was often to stay put to defend property [[45]]. This is likely due, at least in part, to the AFAC policy at the time, which was for residents to either stay or go early (otherwise known as the 'prepare, stay and defend, or leave early' policy) [[47]]. The policy was intended to empower residents, bringing them into the decision-making process and helping them prepare mentally and physically for a challenging situation. It was also intended to protect lives, by avoiding having residents be caught out in the open or having them evacuate too late, when they would likely be exposed to hazardous conditions [[48]]. However, it is possible that the placement of staying and defending before leaving early in the policy title unconsciously (or not) emphasised the former type of protective action over the latter. Such emphasis was also implied in supporting documentation about the policy. For example, a 2006 fire note, issued by AFAC and including contributing comments from Bushfire CRC, stated the following: 'With proper preparation, most buildings can be successfully defended from bushfire. People need to prepare their properties so that they can be defended when bushfire threatens. They need to plan to stay and defend them, or plan to leave early. It must be recognised that in limited cases, some buildings […] cannot for all practical purposes be defended against high intensity bushfires. In these circumstances, householders should be encouraged to relocate early if the intensity of an approaching bushfire is likely to make conditions unsafe.' [[49]] Note the contrasting language used for staying and defending ('**most** buildings can be successfully defended', 'People **need** to') versus evacuating early ('in **limited** cases', 'householders should be **encouraged**').

Other problems were apparent with the policy title and fire note. For example, the policy title presented the two types of protective action as an either-or choice when residents should have been preparing both for staying and for evacuating, given plans could be forced to change. Also, the fire note explicitly stated that 'mass evacuation is not the favoured option' and further stated that 'Mass evacuations can increase the tendency to panic'. Again, these messages are likely to have minimised the value of evacuating. Moreover, they potentially propagated unhelpful myths about panic during disasters [[50]]; contrast such notions with the calm orderly evacuation of around 200 residents observed at the park oval in Marysville.

Shortly after the 2009 bushfires in Victoria, there was a shift in the policy and in the language used. In October of that same year, the National Bushfire Warnings Taskforce published revised arrangements for bushfire advice in Australia [[51]]. In this document, it was announced that the message had become 'Prepare. Act. Survive'. The importance of evacuation was no longer lesser than staying and defending; in fact, the latter was noticeably downplayed and the former enhanced. References to staying referred explicitly to sheltering while defensive action was more alluded to. Immediately under the heading of 'Survive' was the statement 'The safest place is to be away from the fire'; in other words, if residents want to survive, then they need to get away (evacuate). The Royal Commission's final report, published in July 2010, supported evacuation with an explicit statement: 'Leaving early, before there are fires, is the safest option' [45]. However, it did not downplay staying and defending to the same extent. Rather it stated that 'staying to defend a well-prepared, defendable home is a sound choice' adding 'in less severe fires for those who are mentally and physically able'. The final report also criticised the 'binary approach' taken previously, recommending that residents prepare contingency plans.

While documenting various areas where policy and practice could be improved, and urging the emphasis to be on preparing for what to do in a fire, before a fire starts, the final report conceded that 'the reality is people will continue to wait and see' [45]. Thus, it can be expected that a considerable percentage of residents will not enact a plan of protective action until after being warned about a direct threat of fire. Therefore, time again becomes a critical factor. As mentioned above, residents of Marysville had, at best, around 1.75 hours to commence evacuation movement from the point of being warned (by social cues other than peers) that their town was at risk. However, few received that warning. The clearest and most authoritative communication of a threat to Marysville (other than the presence of the fire itself), and of the need for evacuation, was arguably that which came from the police officers when they went from street to street. That activity started not long before the wind changed and thus gave residents less than 30 minutes at most to commence evacuation movement. Additionally, evacuation during that window of time was still somewhat risky due to the hazardous conditions that had already formed in Marysville.

A similar picture was illustrated by the results of a Bushfire CRC mail survey, conducted with households in several affected settlements, including Marysville, after the 2009 bushfires. Of those survey respondents who evacuated during their incident, the majority (more than two-thirds) reported commencing evacuation movement less than two hours before the fire reached their settlement [45]. That is, 15% left between one to two hours beforehand, 17% left between 20 and 60 minutes beforehand, 16% left less than 20 minutes beforehand, while most in this group (20%) did not commence evacuation movement until after the fire had reached their settlement.

For evacuation to produce the best chance of a good outcome (i.e. not only survival but also minimal physical or mental injury), it is vital that no time is unnecessarily lost prior to commencing evacuation movement. In other words, once residents realise what is happening – however they learn of the approaching fire – any subsequent delay to evacuation should result from the undertaking of useful response actions, not inessential activities, or passive waiting/indecision. Moreover, these useful response actions should not be too time-consuming.

To date, research on human behaviour in wildfires (as with other types of disaster) has tended to focus on what decision about protective action residents make after becoming aware of the fire threat, and factors associated with the decision-making process [52, 53, 54, 55, 56]. Little attention has been paid to what actions residents take after becoming aware but before commencing evacuation movement. In the case of Marysville, there were reports of survivors and fatalities undertaking several actions after becoming aware [45]. These included actions relating to: the protection of property (e.g. clearing away flammable items from the outside of the residence, filling baths and other receptacles around the residence with water); the protection of the lives/health of selves and others (e.g. putting on clothing such as a hat or trousers, gathering pets to take when evacuating); seeking information (e.g. calling the emergency services to ask for information on which direction to take when evacuating, checking in on neighbours, relatives, and friends); and gathering belongings (e.g. packing personal possessions, grabbing a few unspecified items). There were also reports of residents undertaking other actions that were more related to everyday life (e.g. pausing to have a sit-down meal) [45]. However, these reports contained little information to specify how long residents spent on their actions, other than an occasional vague estimation such as '[a] few minutes'.

A more quantitative-based, systematic collection of data about actions and associated times could prove very useful and informative. If it is known what type of response actions residents undertake then this data can be incorporated into evacuation modelling tools in the form of behavioural itineraries assigned to agents. If more specific time estimations can be associated with these actions then time data can also be fed into evacuation models. Consequently, end users such as professionals involved in wildfire management can run scenarios and observe how the time taken to perform behavioural itineraries affects incident outcomes. End users can also gain insight into which types of actions most time is spent on and whether the time is being spent wisely. In turn, they can use this information in their community safety education programs. The educational information could be imparted via written advice (e.g. on websites or flyers), verbal advice (e.g. in presentations to schools), or could be imparted in a more interactive way (e.g. by having residents run some simple scenarios themselves to see what impact their preferred itinerary might have on evacuation delay).

3.5.4 Study design: survey of residents

As mentioned earlier, the survey data collection in Corsica was extended to other parts of the South of France (SoFR) and the survey was also subsequently run in Australia (AUS), with the state of Victoria as the target region. This would allow the dataset of human behaviour in wildfires to be expanded in size. It would also provide insight into whether and which behaviours in wildfires tend to be generalisable or more region-specific.

The same questionnaires as before (AE and H) were administered, in the same way (online; in French and English for SoFR and in English only for AUS), and in the same structure (that is, pre-, peri-, and post-event). Only small modifications were made, to tailor the survey appropriately (e.g. regarding the listed local organisations from where participants could seek practical advice or confidential support).

The following sections summarise just key data on behavioural itineraries. More detailed information about the behavioural itinerary data, including further results, will be available in a forthcoming GEO-SAFE-related publication [57]. Detailed information about the rest of the survey data collected in SoFR and AUS will appear in another GEO-SAFE-related publication [44].

The survey presented participants with a list of more than 20 discrete response actions. AE participants were asked to select the actions they did after they had become aware of the fire but before they had commenced evacuation movement, while H participants were asked to select the actions they would intend doing in this period of a hypothetical wildfire evacuation. These discrete actions, which comprised participants' behavioural itineraries, were subsequently grouped into five categories (Table 1).

Table 1. Action categories and associated discrete actions

Category	Discrete Actions
Protecting property	Fill sinks/bathtub/building gutters with water; Tidy up the garden/outdoors; Open the gate to the residence (to allow fire service entry to tackle fire); Turn the gas off
Protecting life/health	Get pets ready to leave; Shut the windows; Get dressed; Pack first-aid items/medication; Turn the air conditioning off
Seeking information	Check travel directions; Find out what neighbours are doing in response to the fire; Call family and friends; Charge mobile phone
Gathering belongings	Pack personal belongings; Pack money/wallet; Pack passport/driver's license; Pack documents (e.g. insurance policy, birth certificate); Pack children's items; Prepare food/drinks to take away with you; Load my vehicle for evacuation*
Other miscellaneous	Use the bathroom (e.g. use toilet); Eat; Other activities not listed

**Only included in AUS survey; added after a review of the preliminary results from SoFR.*

When selecting their actions, participants were also asked to estimate the time they did (AE questionnaire) or would (H questionnaire) commit to each. They did so by selecting one answer option from a list of 12 approximate times. These time estimations were subsequently coded into specific times using either the minimum or maximum stated or the mid-point, as appropriate (Table 2). Following that, the times were summed to produce a behavioural itinerary (BI) time. So, for example, if a participant selected three discrete actions and reported committing up to 10 minutes on the first, up to 5 minutes on the second, and less than 1 minute on the third, then their BI time was 15.5 minutes.

Table 2. Participants' time estimations and how they were coded

Estimated Time	Time Entered in Analysis
Less than 1 minute	0.5 minutes
1 minute	1 minute
2-3 minutes	2.5 minutes
Up to 5 minutes	5 minutes
Up to 10 minutes	10 minutes
Up to 15 minutes	15 minutes
Up to 20 minutes	20 minutes
Up to 30 minutes	30 minutes
Up to 40 minutes	40 minutes
Up to 50 minutes	50 minutes
Up to 60 minutes	60 minutes
More than 60 minutes	60 minutes

Given that AE participants would have become aware of the fire at different times and therefore would have had more or less time available to commence evacuation movement, H participants were randomly assigned to three groups: one was told they had no more than 60 minutes available to commence evacuation movement, another was told they had no more than 30 minutes, while the third was told they had no more than 15 minutes. It was of interest to see if the H participants' time estimations and BI times would remain within these 'safe' windows for evacuation.

3.5.5 Survey data collection and analysis

Convenience and snowball sampling were employed. Recruitment methods included advertising the survey via physical and/or electronic advertisements displayed in public spaces (e.g. libraries), regional news media, local universities, and geo-targeted social media sites, as well as via word of mouth. Recruitment took place during the respective summer months of France (2017) and Australia (2018).

A total of 762 completed questionnaires were received. Almost 300 (N = 293; n_{SoFR} = 149, n_{AUS} = 144) were suitable for inclusion in the data analysis on behavioural itineraries. Of the AE samples, most participants indicated that the fires they were responding about had occurred within the last 3-4 years. Across all samples, ages ranged from late teens through to late 70s (i.e. 18-78 years), with the mean age being in the early to mid-40s (SoFR-AE: M = 42.31 years, SD = 14.01; SoFR-H: M = 44.34 years, SD = 13.40; AUS-AE: M = 45.56 years, SD = 12.85; AUS-H: M = 44.47 years, SD = 12.24). Also across all samples, there were more females than males (SoFR-AE: male = 27%, female = 73%; SoFR-H: male = 49%, female = 51%; AUS-AE: male = 29%, female = 71%; AUS-H: male = 27%, female = 74%.

Participants' data were analysed using the software package SPSS Statistics (version 25). Descriptive statistics are presented here.

3.5.6 Survey results and discussion

<u>Peri-event: behavioural itinerary</u>

The action that came first (i.e. was most frequently reported) in each group's top 5 was often an action relating to protecting life/health (Table 3). In SoFR, this action was always shutting windows to prevent smoke from entering the residence but, in AUS, this action was always gathering pets to be ready for evacuation. This indicates that SoFR participants were more inclined to staying put or at least waiting initially while AUS participants were more inclined to consider evacuation. These results are in line with the two regions' policies, where staying put is the preferred protective action in SoFR and early evacuation the preferred protective action in AUS.

Table 3. Top 5 actions (categories) in behavioural itineraries per group of participants

Group	Most Commonly Selected Actions				
	1st	**2nd**	**3rd**	**4th**	**5th**
SoFR-AE	Protecting Life/Health	Protecting Life/Health	Seeking Information	Gathering Belongings	Gathering Belongings
SoFR-H (60)	Protecting Life/Health	Gathering Belongings	Protecting Property	Gathering Belongings	Protecting Life/Health
SoFR-H (30)	Protecting Life/Health	Gathering Belongings	Protecting Property	Gathering Belongings	Gathering Belongings
SoFR-H (15)	Gathering Belongings	Protecting Life/Health	Gathering Belongings	Gathering Belongings	Protecting Property
AUS-AE	Protecting Life/Health	Gathering Belongings	Gathering Belongings	Gathering Belongings	Seeking Information
AUS-H (60)	Gathering Belongings	Gathering Belongings	Gathering Belongings	Protecting Life/Health	Gathering Belongings
AUS-H (30)	Protecting Life/Health	Gathering Belongings	Gathering Belongings	Gathering Belongings	Protecting Life/Health
AUS-H (15)	Gathering Belongings	Gathering Belongings	Gathering Belongings	Gathering Belongings	Protecting Life/Health

Noticeably, the action that came first for the H participants in both regions who had the least time available to commence evacuation movement (15 minutes) was different. Instead, it was an action relating to gathering belongings. In SoFR, the belongings being packed were personal possessions. In AUS, it was money or a wallet. These results suggest that, when under greater time pressure, SoFR participants were thinking more of what held personal (emotional) significance to them while AUS participants were more mindful of practical aspects, i.e. what would be useful to have if leaving one's home for a day or several days, or even forever. It indicates that SoFR residents might be less psychologically prepared for a wildfire than AUS residents and less well positioned to recover from such a disaster.

The AUS-H group with no more than 60 minutes available to commence evacuation movement also most frequently selected to pack money/a wallet. It is not clear why this group behaved differently to most other groups, given they were under less time pressure. However, it again shows that AUS participants were more mindful of evacuating and the practical aspects associated with that.

The remainder of all groups' top 5 tended to be dominated by actions relating to gathering belongings. These belongings were again personal possessions and money or a wallet, but also documents such as an insurance policy or birth certificate, and passports. Therefore, many of the belongings that participants in both regions were mindful of gathering were ones that would be of practical use in the event of evacuation due to disaster striking. As such, they would seem worth delaying evacuation for, as long as the time spent on this was not too great.

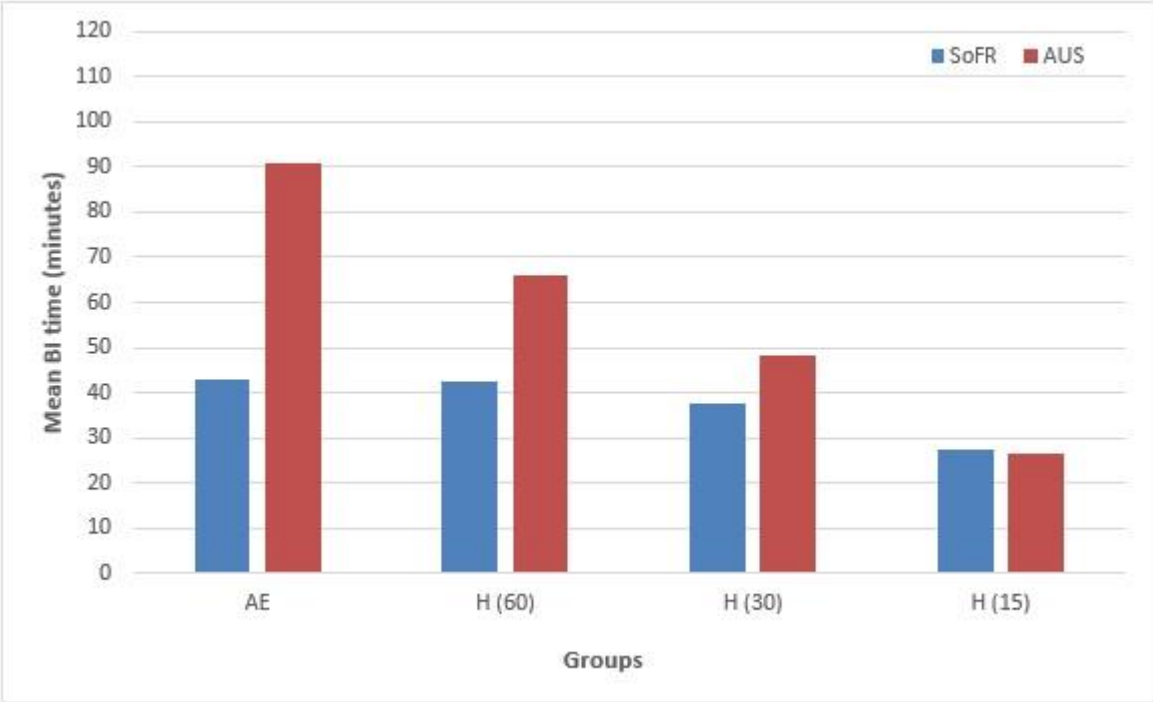

Fig. 14. Mean time committed to behavioural itineraries by AE and H participants

When the mean time committed to behavioural itineraries was examined (Fig. 14), several things were clear. Firstly, looking at the AE participants, the mean BI time for those in AUS was between one to two hours, showing that rapid evacuation is unlikely. Also, compare this finding with the Bushfire CRC mail survey results from the earlier Black Saturday bushfires in 2009 [45]. Those showed that residents most often evacuated less than two hours before the fire arrived. While it is possible that the AUS-AE participants left long before the fire's arrival and so the time spent on behavioural itineraries was time to spare, it is also possible that evacuation was not commenced until much later. The wider results from the AUS survey show that evacuation was often triggered by the sight of smoke nearby rather than the sight of embers or flames [44]. This indicates that AUS-AE participants did not leave at the very last minute but nevertheless shows them leaving when environmental conditions were hazardous. Thus, even though policy has changed since 2009 to more strongly encourage early evacuation, this finding from the current study suggests that the majority of residents will still not leave early enough, if they do leave at all. It would therefore be wise for professionals involved in wildfire management to plan for this accordingly.

Secondly, SoFR participants tended to commit less time to their behavioural itineraries than did AUS participants, particularly when they had actually experienced a wildfire but also when imagining a hypothetical wildfire. This could be interpreted in different ways. On the one hand, it could mean that SoFR participants were more efficient in getting prepared to leave. On the other hand, it could mean that SoFR participants were less mentally prepared for evacuation and therefore did not do everything that would have been wise for them to do prior to commencing evacuation movement. The latter explanation seems more likely when recalling what the SoFR participants' most frequent actions were. Moreover, the wider results from the SoFR survey, showing that evacuation was often triggered by the sight of flames nearby, supports the idea that these participants were performing their behavioural itineraries right up until the last minute, and therefore were likely rushed [44].

Fig. 14 highlights a change, however, when participants were under the most time pressure to commence evacuation movement. That is, when H participants had no more than 15 minutes available to them, regional differences in the mean BI time were almost negligible. Nonetheless, a closer look at the BI times, broken down by action category, reveals that these H participants were not always prioritising that time in the same way (Table 4). Both groups committed most time (approximately 9 minutes on average) to gathering belongings but some other categories of action, such as seeking information, were given more time by one group and less time by the other (approximately 8 minutes in SoFR versus approximately 5 minutes in AUS, on average). So, it might be the case that, if given only a relatively short amount of time to commence evacuation movement, residents in both regions will feel able to prepare for this evacuation and begin movement. However, the level of practical preparedness for then heading out onto the roads might not necessarily be equal across regions. If residents are leaving rather late during an incident, then those in SoFR for example could find themselves at risk (e.g. driving towards the fire rather than away from it, or encountering roadblocks, because they were less informed).

Table 4. Top 5 actions (categories) in behavioural itineraries per group of participants

Group	Prioritisation of Time in Behavioural Itinerary				
	1st	2nd	3rd	4th	5th
SoFR-H (15)	Gathering Belongings	Seeking Information	Protecting Life/Health	Other Miscellaneous	Protecting Property
AUS-H (15)	Gathering Belongings	Protecting Life/Health	Seeking Information	Protecting Property	Other Miscellaneous

The regional difference in time prioritisation reported above might seem small. However, some larger differences were also observed. For example, SoFR-AE participants committed approximately 7 minutes on average to gathering belongings (16% of their mean BI time). In contrast, AUS-AE participants committed more than three times that amount, i.e. approximately 23 minutes on average (25% of their mean BI time). Even if all the belongings were highly useful for evacuation movement and for the recovery phase of the disaster, over 20 minutes of just packing while faced with an emergency situation still appears excessive. This finding highlights an area where community safety education programs could help, i.e. in enhancing how efficient residents are with their preparations and therefore minimising the time they take to commence evacuation movement.

A final point is worth noting about the data in Fig. 14. All of the H groups, barring the SoFR-H (60) group, had mean BI times that exceeded the time they were told was available to commence evacuation movement. While these participants were responding to a hypothetical scenario, and thus there were no actual consequences to be incurred, similar behaviour in a real-life wildfire could mean the difference between surviving or dying. Research has already highlighted the grave effects of leaving it too late to take protective action, whether that is attempting to flee in hazardous conditions or ending up staying to shelter but passively [46].

3.5.7 Survey outcomes: summary

The survey of residents in the South of France and Australia allowed for a better examination of behavioural responses to wildfires during the response phase, i.e. after becoming aware of the fire but before commencing evacuation movement. Details about the discrete actions undertaken during this phase (behavioural itineraries) were collected, thereby identifying what residents do (AE questionnaire) or intend to do (H questionnaire). By coding the discrete actions into categories, it was possible to see what types of action are most common in behavioural itineraries. Then, by collecting and analysing data on the estimated time committed to actions (BI time), it was possible to identify which categories residents commit most and least time to. It was also possible to see how much time overall it might take to complete a behavioural itinerary and whether that time might exceed the 'safe' window for evacuation.

Altogether, the findings provide insight into residents' priorities and allow other interested parties to examine whether such priorities are sensible, and whether evacuations are being delayed unnecessarily or not. The data also allows evacuation delays to be quantified. Furthermore, the data indicates which aspects of behavioural responses are likely to be generalisable and where regional differences might be found. It also quantifies regional differences, thereby allowing the findings to be calibrated.

The next step in this piece of GEO-SAFE research was to attempt to marry this type of survey data with other relevant data (e.g. times taken by authorities to notify residents) in order to understand better how much time would be needed to implement an evacuation in the event of a wildfire. The focus remained on doing this in a European region, given the less attention this part of the world has received thus far with regards to human behaviour in wildfires.

3.6 ESR secondment 3 – Andalusia, Spain

Mrs Sandra Vaiciulyte undertook her third secondment with INFOCA, located in Andalusia. The secondment took place in Autumn/Winter 2018, lasting two PMs. This secondment was focused on Task 2.5 for WP2, WG6. Again, this meant the gathering of information related to human behavioural responses to wildfires and evacuation. Her PhD supervisor, Dr Hulse, was not present on this secondment and supervised remotely.

While in Andalusia, Mrs Vaiciulyte's activities included having meetings with senior personnel from INFOCA in various parts of the region. She also met with other personnel to gain insight into the community education programmes (wildfire prevention) and technical operations (wildfire analysis). Furthermore, a number of interesting cases of wildfires involving evacuation, occurring in different parts of the region, were identified in conjunction with *el Grupo de Emergencias de Andalucía* (GREA, the Andalusian Emergency Group) and subsequently examined. Additionally, Mrs Vaiciulyte attended a conference on civil protection, hosted by the Andalusian government; during this event, the INFOCA Regional Director spoke about the role that civil protection volunteers can play in the emergency response to wildfires. Mrs Vaiciulyte also visited some WUI areas that were either at-risk or had already experienced a wildfire and evacuation. Lastly, she collected and managed survey data from professionals involved in wildfire management.

3.7 Select outcomes of secondment in Andalusia

Below are details of some of what was learned during this secondment. Unless otherwise referenced, the information was gained via personal communication with INFOCA personnel and/or the ESR's personal observations.

3.7.1 Introduction

Host organisation	El Plan de Emergencia por Incendios Forestales de Andalucía, aka INFOCA Plan
Location	The region of Andalusia, in Spain

Fig. 15. The region of Andalusia (highlighted), in Spain

INFOCA is a wildfire protection plan, created by the *Junta de Andalucía* (the regional government of Andalusia) in 1995 and modified periodically since then. Its purpose is to prevent and fight against wildfires in the Andalusian community. As such, operations take place across the region (Fig. 15), with a regional operations centre (COR), headed by Juan Sánchez Ruiz, located in Seville and provincial operations centres (COP) located in additional cities such as Córdoba (Fig. 16), Málaga and Granada. A number of *bomberos* (i.e. firefighters) are involved with INFOCA (as of 2019, there were reportedly a total of 4,462 firefighters employed in this effort [[58]]).

In addition to the operations centres, there are also multiple forest defence centres (CEDEFO) located across the region in forested areas, as well as a small number of bases hosting specialised brigades (BRICA/BRIF) located in the provinces of Málaga, Granada and Huelva. During the secondment, the ESR's primary contacts from INFOCA were on the operations side: César Vicente Fernández (Deputy Director of the COP in Córdoba), Adriano Vásquez Mora (Director of the COP in Malaga), and Francisco Senra Rivero (Forest Fire Analyst at the COR in Seville).

Fig. 16. Sandra Vaiciulyte (UoG) at INFOCA's operations centre in Córdoba [k]

3.7.2 Secondment outcomes: summary

Through this secondment, the ESR was able to gain useful information about wildfires, WUIs, and how aspects related to people, property and the environment can combine to create dangerous situations. That information both consolidated what was learned in Corsica (South of France) and in Victoria (Australia) and extended it to the local context in Andalusia. For example, she was able to look at cases such as the wildfire that affected the municipality of Lújar in Granada in July 2015, which resulted in 80% of the area being burned and the town of Lújar along with other settlements in the vicinity (more than 620 residents in total) being evacuated (Fig. 17).

Fig. 17. Lújar in recovery three years after the major wildfire [l]

The ESR was also able to identify sources that could provide time data (i.e. times related to the activities of the authorities and the overall evacuation time). However, while the ESR was able to collect some further information, on residents' behaviour during wildfires, this was in the form of observations from professionals involved in wildfire management. The timing of the secondment (during the colder months and outside of the wildfire season) did not afford an opportunity to administer the residents' survey in Andalusia and therefore no first-hand data about residents' responses – especially their behavioural itineraries – was collected. Thus, details of this secondment are not discussed further here.

3.8 ER secondment 2 – Central and Northern Italy

Dr Lynn Hulse next undertook two split-secondments to CNVVF, who are located in Italy. The first took place in Summer 2019 and the second in Autumn 2019. The duration of both totalled a secondment lasting one PM. This secondment was focused on Task 2.5 for WP2, WG6. Again, this meant the gathering of information related to human behavioural responses to wildfires and evacuation. In addition, at times, Dr Hulse was there in a supervisory capacity, overseeing some of the work of her PhD student who was also undertaking a GEO-SAFE secondment.

During the secondment, Dr Hulse had meetings with multiple members of staff from CNVVF, with various responsibilities and working in various locations across Central Italy. She also met with several local government representatives (mayors, councillors) to understand the decision-making processes during wildfire planning and response phases, and with civil protection staff to understand how various agencies work together when managing a wildfire and associated evacuation. Dr Hulse visited several locations in Central and Northern Italy that had been affected by wildfires and had experienced evacuations. She also visited several locations that had been affected by other disasters, to understand the safety culture and attitudes to risk that residents have developed with such cumulative experience. Moreover, she learned about the conflicts that may arise between tourism and safety (e.g. the tendency for mass gatherings of tourists, along with permanent residents, in areas where the historic nature of the surroundings could negatively impact evacuation, staying to shelter, and FRS ingress). Other places visited included the *Istituto Superiore Antincendi* (CNVVF's training institute, as well as the host location for conferences and community project meetings) in Rome, and the University of Bologna (for literature on disasters, fires, evacuation, and emergency psychology). Furthermore, Dr Hulse learned about and reviewed some of the statistical data that is collected by CNVVF (on wildfires and related evacuations) and published by organisations (e.g. ISTAT, Italy's national institute of statistics). She also consulted with CNVVF personnel to refine, finalise, and translate study materials for an evacuation exercise, took part in the exercise and data collection, manually entered the raw survey data from that exercise, and began coding of the data.

3.9 ESR secondment 4 – Central Italy

Mrs Sandra Vaiciulyte also undertook two split-secondments with CNVVF. Both took place in Summer 2019 and their duration totalled a secondment lasting one PM. This secondment was focused on Task 2.5 for WP2, WG6. Again, this meant the gathering of information related to human behavioural responses to wildfires and evacuation. During this secondment, Mrs Vaiciulyte was supervised at times in person and at times remotely by her PhD supervisor, Dr Hulse.

While in Italy, Mrs Vaiciulyte's activities were similar to those of Dr Hulse described above, e.g. she had meetings with various personnel from CNVVF, civil protection, and with representatives of local government. Likewise, she learned about tourism/safety conflicts, visited locations affected by wildfires, evacuations, and other disasters, as well as visited CNVVF's training institute. Additionally, Mrs Vaiciulyte interviewed personnel who specialise in forest fires, i.e. in monitoring for, detecting, and fighting fires in forested areas of the region of Umbria. She also learned about some political changes that had impacted the way in which different agencies operate and interact in the pursuit of wildfire prevention and community safety education. Moreover, she gathered information on some of the communication methods used to notify residents during past wildfires as well as learned about new technology (apps) that are being developed to notify residents in the future. Finally, Mrs Vaiciulyte consulted with CNVVF personnel over the design of study materials for the evacuation exercise and over the logistics for data collection.

3.10 ER secondment 1 – Central Italy

Dr Anand Veeraswamy (Fellow ID: 23) is a researcher who, since 2006, has worked for UoG-FSEG on projects involving evacuation modelling. His work has included the modelling of large-scale evacuations resulting from wildfires. For this part of GEO-SAFE, this ER undertook a split-secondment, lasting 19 days, with CNVVF in Autumn 2019. A second split-secondment, lasting 11 days, was scheduled for Spring 2020. This would have included visits to parts of Southern Italy (e.g. L'Aquila in the Abruzzo region). A workshop was planned to take place, providing civil protection authorities with an overview of the latest developments in large-scale evacuation modelling. This workshop was also meant to include a hands-on session allowing authorities to test these developments on an easy-to-use web interface. Together, the split-secondments would have totalled a secondment lasting one PM. However, due to the COVID-19 outbreak, the second split-secondment was cancelled. The split-secondment that was undertaken was focused on Task 2.5 for WP2, WG6. In other words, it centred on the gathering of information related to human behavioural responses to wildfires and evacuation.

During the split-secondment, Dr Veeraswamy met with various personnel from CNVVF, civil protection, and representatives of local government. He also liaised with CNVVF personnel to refine and finalise study materials for the evacuation exercise, and took part in the exercise and data collection. Additionally, along with CNVVF staff, he participated in public dissemination activities, advertising the evacuation exercise to the print and broadcast media. Moreover, he visited some locations previously affected by disasters that resulted in the relocation of residents. He also worked on a program that allows the import of population data from OpenStreetMap to evacuation models. Lastly, he undertook other GEO-SAFE-related activities (i.e. project management).

3.11 Select outcomes of secondments in Italy

Below are details of some of what was learned during this secondment. Unless otherwise referenced, the information was gained via personal communication with CNVVF personnel and/or the ERs and ESR's personal observations.

3.11.1 Introduction

Host organisation	Corpo Nazionale dei Vigili del Fuoco, aka CNVVF
Location	Across Italy

Fig. 18. CNVVF operations centre (marked) in Rome, Italy

CNVVF is Italy's National Firefighters Corps, which comes under the remit of the *Ministero dell'Interno* (Ministry of the Interior) via the *Dipartimento dei Vigili del Fuoco, del Soccorso Pubblico e della Difesa Civile* (Department of Firefighters, Public Rescue and Civil Defence). Both the Ministry and CNVVF's main operations centre (marked on Fig. 18) are situated in the Italian capital, Rome. However, CNVVF's operations spread across the country. The latest data available shows there were 34,594 firefighters working for CNVVF in 2017 [[59]]. Earlier data suggested a ratio of 79% professional to 21% volunteer firefighters [[60]].

CNVVF is divided into several organisational groups, all under the overall direction of *il Capo del CNVVF*, Fabio Dattilo. The main personnel with whom the ERs and ESR repeatedly liaised during their secondments were the Fire Chief – General Manager Stefano Marsella (CNVVF's Regional Director for Abruzzo), Fire Captain Marcello Marzoli (based at CNVVF's Rome headquarters), Fire Captain Danilo Anastasi and Fire Captain Oriano Anastasi (both based at CNVVF's Perugia headquarters; see Fig. 19), and Fire Battalion Chief Giovanni Fresu (based at CNVVF's Sassari headquarters).

Fig. 19. Oriano Anastasi (CNVVF), Anand Veeraswamy (UoG) and Danilo Anastasi (CNVVF) in Italy [m]

CNVVF's main responsibilities are the same as those of SDIS 2B in Corsica: to prevent, protect and fight against fires, as well as other disasters and incidents. Likewise, CNVVF's priority is the safeguarding of people first, then property and the environment.

3.11.2 People (residents)

In 2019, the estimated population of Italy was 60,359,546 individuals, of which 51% were female and 29% were aged 60 years or more [61]. As in Corsica, a large amount of the population is concentrated in and around cities, such as Rome (in Central Italy) and Milan (in Northern Italy). Many villages remain relatively populous, however, although smaller rural settlements have declined. While residents have been drawn to the more urban areas to work in the service and industrial (metallurgical/engineering) sectors, some have remained in the rural areas since certain types of agriculture (mainly crop-based, e.g. the making of olive oil, wine) continues to bring in revenue [62] and is even a tourist attraction (*agriturismi*, i.e. working farms that guests visit in order to dine and/or holiday there).

For many years, Italy has been one of the world's most popular tourist destinations. Therefore, it has many temporary as well as permanent residents, particularly during the summer months. For example, from June to August 2019, a total of 49,693,863 visitor arrivals were recorded in Italy, of which 25,034,886 visitors were foreign [63]. However, while tourism may peak in the summer, Italy continues to see visitors arrive during other parts of the year due to its multitude of attractions, including world-famous historical sites, works of art, luxury fashion and car products, religious architecture and artefacts, cultural festivals, cuisine, and picturesque mountains, lakes and coastlines. Since such attractions are located across the country, transient groups can likewise be found all over, both in the built-up areas and in the countryside.

Of the top five foreign nationalities visiting Italy, none speak Italian as one of their official languages (German, English, French and Mandarin dominate) [64]. While English and French may be the next most spoken languages in Italy, after Italian, it is still only a small percentage of the permanent resident population that is conversant with these other languages [65]. Thus, most oral and written communications take place in Italian.

3.11.3 Property (residences)

In Italy, the majority of residents live in apartments. This is especially the case in and around the cities and towns but apartments are also found in villages. With the exception of some in the larger cities, apartments in Italy tend to be low-rise or medium-rise rather than high-rise buildings. There are quite a number of modern build apartments as well as older builds.

Houses may be terraced, semi-detached or detached homes, and typically comprise more than one storey. They range from small and simple to large and palatial. Houses tend to be found in rural areas and, like apartments, may be modern or older builds.

Fig. 20. Examples of apartment and house-style residences in Italy [n, o]

The features of apartments and houses vary across Italy, depending on wealth and weather to a large extent. However, both types of residence tend to be made of stone or brick (sometimes concrete), and have sloping tiled roofs and shuttered windows. The exceptions to this tend to be in the more Alpine parts of Northern Italy, where residences may be made partly or wholly of wood, and in parts of Southern Italy, where flat roofs can be common; the traditional *trulli* houses in the South are even more distinct, having conical roofs and barely any windows at all. Holiday homes may be any of these types of residence. Fig. 20 provides some examples of the different styles found in Italy.

3.11.4 The environment (climate, vegetation, terrain, roads)

At first glance, Italy's climate is rather typical of a Mediterranean location, with wet winters and hot summers. However, in Northern Italy winter can be relatively colder and summer more humid, in Central Italy both seasons can be milder, while Southern Italy experiences relatively warmer temperatures all year round; winds such as the sirocco contribute to the warmer temperatures, but across the whole country [66]. The three regions tend to see between 8-11 hours of sunshine per day and temperatures reaching 30°C in the summer months [67].

Increasing areas of Italy are becoming forested, again in part due to agricultural land abandonment resulting from rural-to-urban migration. Latest estimates indicate that almost a third of the land in Italy is forest area [68]. While trees dominate, other diverse vegetation is present in Italy, including some of the maquis (*macchia*) kind. Several flora (e.g. cork oak trees, olive trees) are more fire resistant, others less so (e.g. juniper), while there is some debate over whether another type of flora common in parts of Italy (cypress trees) is good or bad in relation to fires [69, 70].

Quite a significant amount of Italy's terrain is hilly or mountainous, with the Alps in the north and the Apennines running down the country's spine. Some larger urban areas are on flatter land, although access to them can sometimes involve ascending steep slopes. Similarly, smaller settlements can often be found on more elevated and/or sloping parts of the countryside.

In the larger urban areas, residents will often travel on foot and via public transport. This is likely due to a multitude of factors, including but not restricted to: certain traffic prohibitions in historic centres; limited parking facilities; heavy congestion; and streets that are too narrow or otherwise difficult to navigate via car. However, outside of these areas, the car is one of the most popular modes of transport. In villages, roads can be few and, again, narrow. However, when emerging from villages, drivers can soon join wider and faster roads, including motorways (*autostrade*). Therefore, getting from A to B in Italy via the roads – at least for mid-length journeys (within regions) – can sometimes be quite quick. For longer journeys (between regions), residents will often opt for trains.

3.11.5 Wildfire risk and wildfire management

The aforementioned 2016 study that drew on land use/land cover data from 2006 to map WUIs across Europe illustrated that Italian regions vary in their concentration of WUIs [31]. It identified parts of Northern Italy (Liguria, Lombardy) as having the highest occurrence of WUIs in the country and parts of Southern Italy (Molise, Apulia) as having the least.

Applying the aforementioned WUI typology [32] to the observations about Italian property and environment, Italy's WUIs would appear to more often be characterised by vegetation that is structured in a discontinuous way, but with residences more densely clustered. While vegetation was frequently seen close to residences and roads, it was less often seen to overhang them (Fig. 21). Thus, if a wildfire were to start and spread, the roads might be relatively free of flames, which could aid the passage of evacuating traffic. However, smoke could still be present and affect visibility. Moreover, the number of residents in the area exiting onto the roads could cause congestion. On the other hand, the fact that some of the roads are wider, and otherwise designed for driving at faster speeds, could mitigate this somewhat.

Fig. 21. Example of the proximity of vegetation to residences and roads in Italy [P]

Given that Italy shares many characteristics with Corsica regarding people and the environment, it is perhaps not surprising that this part of Europe has also experienced some large wildfires. However, the patterns of wildfire occurrence are not always predictable in Italy. For example, the year 2018 was hotter than normal, yet there were also periods of heavy rainfall, and so the peak wildfire season was less eventful than might have been expected based on preceding years [71].

Following the relatively uneventful summer, however, on the evening of 24 September 2018, a serious fire started up on Monte Serra, in the province of Pisa (Fig.22). The fire was believed to have been started deliberately [72]. It was detected around 22:00 but, due to very strong winds, it was not possible to tackle the fire by air initially. Since the fire was spreading rapidly, the mayor of the municipality of Calci ordered residents in the main settlement to evacuate. This evacuation (c. 350 residents) took place between around midnight and 02:00 on 25 September. During this time, the fire had continued to spread, and change direction. So, the village of Montemagno was also forced to evacuate. That evacuation took place between 01:00 and 03:00. A further location in the Pisa province, Vicopisano, was later threatened when the fire changed direction once more. Altogether, at least 500 residents were evacuated, using cars mostly but some individuals left on foot. Notification took place via several means: via the mayor's social media channels; via telephone (an automated system, calling all numbers on a list if in the affected area and relaying a recorded message); and via door knocks (conducted by firefighters, volunteers, and the *Carabinieri* [police]). In addition, a number of residents evacuated of their own volition, after having seen the fire or experienced smoke entering their homes.

Fig. 22. Sandra Vaiciulyte (UoG) points to a home that was saved in the province [q]

Wildfires are recognised as a national risk, although tend to be considered as a lesser risk than other types of disaster such as earthquakes [73]. So, residents may be less experienced in wildfires and authorities may have made less provisions for wildfires. As a result, it is not clear whether there is an official preference for residents to take a particular kind of protective action in the event of a wildfire. However, the continuing threat and, in some cases, prior experience of other disasters means that some authorities and residents will be prepared for evacuation more generally. In Calci, a training exercise had taken place prior to the fire of 2018, as part of community safety work. During that, the authorities had communicated to residents what risks their localities faced and where they should go in the case of an emergency. Such preparedness is also wise due to other vulnerabilities within Italian communities. That is, Italy has an older population compared to Europe in general (where the share of the population aged 60+ years in 2019 was 25% [74]). So, more residents could need assistance in the event of evacuation.

3.11.6 Study design: evacuation exercise

In order to understand how residents might behave in a wildfire evacuation in Italy – that is, understand what response actions they might undertake after being notified and how much time they would commit to these actions prior to commencing evacuation movement – an evacuation exercise was devised. The following sections summarise certain aspects of the exercise. Once data analysis is completed, more details of the exercise will be made available in a further GEO-SAFE-related publication.

The exercise was jointly designed by CNVVF and UoG-FSEG, with the collaboration of the *sindaco* (mayor) of the Gualdo Tadino municipality in Umbria, Massimiliano Presciutti (Fig. 23). The aim was to collect data on both the emergency response (e.g. the time taken to coordinate a plan of action and deploy crews following the receipt of an order to evacuate, the time taken to drive to the affected areas, the time to go from door to door notifying residents) and on the residents' responses (e.g. the time taken to reply to the door knock, as well as the behavioural itineraries and associated BI times). Only those individuals responsible for the design and authorisation of the exercise were fully informed of what would happen. This meant that, for most, the evacuation exercise was unannounced and would therefore produce more spontaneous, naturalistic responses.

Fig. 23. [Clockwise from top left] Marcello Marzoli (CNVVF) briefs crews of personnel including Giovanni Fresu (CNVVF); deployment of crews is coordinated; crews notify residents while observers including Lynn Hulse (UoG) record details; Massimiliano Presciutti (Mayor of Gualdo Tadino), Stefano Marsella (CNVVF) and Anand Veeraswamy (UoG) brief the press about the exercise [[r, s]]

3.11.7 Data collection and survey analysis

The exercise took place over two days at the end of Summer/start of Autumn 2019. On the morning of each day, crews comprising CNVVF firefighters and civil protection officers were gathered at a central location for briefing following the 'evacuation order' from the mayor (note, police officers were also asked to attend but, due to a temporary shortage of staff, had to decline). The 'threatened' areas were three villages in the municipality: two villages on Day 1 and a third, larger village on Day 2. The combined population of these three villages was 488 residents.

Time data relating to the emergency response were collected primarily via actions being continuously recorded on Go-Pro cameras carried by the crews and CNVVF observers. Additionally, the crews used an app on their mobile phones – devised by Danilo Anastasi – to click and timestamp critical moments related to their actions when conducting the notification of residents. Moreover, using watches, pens and paper data entry sheets, observers from UoG-FSEG manually recorded the times of critical moments, from the outset of the exercise through to its completion.

Notification was conducted by knocking on the doors of residences. The time it took for residents to come to their doors or otherwise appear and interact with the crews was also recorded via the methods described above. Scripts were pre-prepared and given to crews to ensure that they verbally delivered the same details to residents regarding the warning about the approaching fire and the need for evacuation. Note, residents were also notified that this was an exercise, and that they did not actually have to leave their homes. However, they were asked to take the warning seriously and to respond as they would if it were a real-life situation.

Many but not all residents were home at the time of the exercise. Also, a few of those who were in did not answer their doors, while some others answered but declined to take part. In two cases, the person answering the door agreed to participate but doubts were subsequently raised over the reliability of their answers and so those cases were excluded. As a result, recruitment was deemed successful for 91 residences comprising a total of 268 residents. The exercise ended once all residences in the villages were believed to have been visited, attempts made to notify the residents, and survey data completed.

The survey (in paper form on this occasion) comprised the behavioural itinerary questions from the AE/H questionnaires used in the South of France and Australia, along with some socio-demographic questions about the household. Minor modifications were made to tailor the survey to the Italian context. Moreover, it was first prepared in English and then translated into Italian for the crews to administer. If residents chose to participate following notification, they could choose to do one of two things:

- Residents could decide to perform their response actions (i.e. go around their house gathering belongings, etc.), the results of which would be recorded by the crews on the survey form once the residents had completed their behavioural itineraries and returned to the crews, ready to 'leave'
- Alternatively, residents could decide to verbally list what response actions they would undertake, continuing until they felt they had described everything and were ready to 'leave', with the crews recording the answers on the survey form

For those residents who performed their response actions, only an overall BI time was recorded (on camera, from the moment they went inside to begin their actions until the moment they returned to the crew). For those who chose to verbally list actions, they were asked to then estimate the time they would commit to those actions, which would subsequently be summed as per the usual procedure for calculating BI time.

Afterwards, both groups of residents were prompted by crews for any other actions they might undertake but had not thought about up until this point. That is, crews then read through the list of discrete actions on the survey form, asking residents if there was anything extra they would do and how much time they would commit to these extra actions. This allowed for the identification of what people would do spontaneously, under time pressure, and what people might do if allowed further time and information to consider their response.

The paper survey forms were collated at the end of each day. The raw data were then manually entered into an Excel file, to undergo quality checking and coding subsequently. Following that, the data were transferred to an SPSS Statistics (version 25) data file. Inferential statistical analysis reported here includes Mann-Whitney U and Chi-Square tests. An alpha level of .05 was used as the cut-off for statistical significance.

3.11.8 Survey results and discussion

Pre-event: socio-demographic characteristics

Crews only spoke with adult residents when visiting each home. Participants provided socio-demographic information about their households. The age categories of household members ranged from very young children (0-4 years) through to older adults (75+ years). The modal age category was 50-64 years old. So, the sample here was somewhat older than the samples from the South of France and Australia. The age distribution data collected in the exercise was compared with population statistics collected from the Gualdo Tadino municipality. They did not differ significantly ($U = 60185.00$, $p = .322$). Thus, the sample was found to be representative of the population in this respect.

Regarding the gender of household members, there were slightly more females (53%) than males (47%). The ratio of males to females observed in the sample was compared to that observed in the population statistics from the municipality. No significant differences were detected ($X^2[1] = 0.06$, $p = .808$) and so the sample was again found to be representative of the population.

Peri-event: behavioural itinerary

The majority of participants decided to verbally describe their behavioural itinerary, although some did perform their response actions. Performing rather than describing did not result in fewer actions being recorded. On the contrary, preliminary analysis indicated that slightly more (0.79 times more) actions were recorded for those who performed their behavioural itinerary. Thus, while it could be argued that those performing might have felt under greater time pressure, given that they knew the crews were waiting for them but could not wait indefinitely given there were other residences to notify, it seems that this did not lead residents to curtail their activities disproportionately.

Nevertheless, the pressure of the situation in general did seem to have somewhat of a curtailing effect. That is, when subsequently prompted with the full list of discrete actions, both those participants who performed their behavioural itinerary and those who verbally described it agreed that there were several extra actions that they would like to undertake prior to commencing evacuation movement in the event of a wildfire. This finding supports the idea that preparing for a wildfire in advance of one actually occurring is beneficial. Under ill-defined, stressful conditions, residents may not generate and consider as many options [75, 76].

Preliminary analysis indicated that the action that came first (i.e. was most frequently reported) in the top 5 was an action relating to protecting life/health. This was the case whether participants verbally described their behavioural itinerary or whether they performed it; it was also the case when looking at both groups of participants combined (Table 5). This is consistent with the findings from the South of France and Australia. So too is the additional finding that the remainder of the top 5 for each group appeared to be dominated by actions relating to gathering belongings.

Table 5. Top 5 actions (categories) in behavioural itineraries per group of participants

Group	Most Commonly Selected Actions				
	1st	**2nd**	**3rd**	**4th**	**5th**
Described	Protecting Life/Health	Gathering Belongings	Protecting Life/Health	Gathering Belongings	Gathering Belongings
Performed	Protecting Life/Health	Gathering Belongings	Gathering Belongings	Gathering Belongings	Gathering Belongings
Combined	Protecting Life/Health	Gathering Belongings	Protecting Life/Health	Gathering Belongings	Gathering Belongings

Time estimations for actions were less prevalent in this evacuation exercise. This is likely due to the fact that many participants were verbally describing what they would do. So, it could have been challenging for them to consider times for each currently mentioned action while simultaneously attempting to retain the list of previously mentioned actions in their working memory. This challenge was anticipated, hence why crews were recording what was said on the survey form (i.e. so they could read it back if the participant needed a reminder). Nevertheless, it might be a task that is easier for residents to carry out by themselves, at relative leisure, with the full list visible.

Nonetheless, some time estimations were provided. Also, the cameras captured how long it took those performing actions to complete their behavioural itinerary. Thus, the exercise was able to produce useful data to calculate BI times. Preliminary analysis suggests that participants in this sample might have committed a relatively greater percentage of time to actions relating to protecting life/health compared to participants in the South of France and Australia. However, further analysis is required to confirm how time was prioritised here and why. Nonetheless, it is perhaps worth reiterating that this sample was relatively older than the others and thus health could have been a more salient issue among these residents.

3.11.9 Survey outcomes: summary

The survey of residents in villages from the municipality of Gualdo Tadino, Umbria (Central Italy), allowed for a further examination of behavioural responses to wildfires during the response phase, i.e. what people do after becoming aware of an approaching fire and how long it takes them to commence evacuation movement. It extended the available data on human behaviour in wildfire evacuations in general, but also in particular for European regions, further addressing the gap in knowledge there.

Additionally, the survey data was collected concurrently with data about the emergency response. This not only shows how the survey methods can be incorporated into a practical exercise involving multiple agencies, it also allows for an examination of how the time taken by both residents and professionals contribute to the overall evacuation time. Moreover, the exercise and particularly the survey gave residents several useful opportunities: first, the opportunity to consider the risk they might face from such a natural hazard; second, how prepared they are; third, what is important to them in the event of evacuation; and fourth, if their priorities diverged from what is most essential and least-time consuming, then an opportunity to discuss more appropriate responses with fire and civil protection officers.

4. CONCLUSIONS

The work described and discussed in this report demonstrates very fruitful collaborations between UoG-FSEG and the hosts with which they undertook GEO-SAFE secondments (SDIS 2B, RMIT University, INFOCA, CNVVF). Together, these organisations from the UK, France, Australia, Spain, and Italy were able to pool their professional experience, share and conceive innovative ideas, and expand knowledge.

Through these collaborations it was also possible to run the Human Behaviour Study and collect new data on human behaviour in wildfires and evacuations. The data were collected from three different regions in the world, two of them in Europe. In so doing, this study advances the field of fire safety in several ways. For example, together with the seminal work of researchers in Australia, and some subsequent complementary work in the USA [55, 77], this study consolidates the expansion of 'human behaviour in fire'. That is, it continues to widen the focus beyond fires threatening buildings to fires threatening numerous residences across larger urban areas. Moreover, it ensures that the scope of human behaviour also remains wide, examining actions and underlying cognitions and not just movement. In addition, this study adds to the broader field of disaster research, where quantitative analyses have thus far focused more on evacuations prompted by natural hazards such as hurricanes. Furthermore, this study addresses the unfortunate fact that, despite the growing incidence and intensity of wildfires experienced in European regions, there had been no systematic investigation of behavioural responses in this part of the world to date.

The evidence base generated by the GEO-SAFE survey data collection produced the following samples:

1. Data from almost 100 residents located across the island of Corsica
    - Questionnaires were completed online
    - Residents included locals who resided in Corsica permanently as well as transient groups such as tourists
    - Responses included those concerning a recent real-life experience of a wildfire (actual behaviour) and those concerning a hypothetical wildfire affecting the resident's at-risk area (intended behaviour)
2. Data from almost 300 residents located across the South of France and Victoria, Australia
    - Questionnaires were completed online
    - Responses were again in relation to actual behaviour and intended behaviour
    - Responses also described actions from the period between becoming aware of the approaching fire and commencing evacuation movement
    - Moreover, time estimations were provided for these 'behavioural itineraries'
3. Data from almost 100 households, comprising 268 residents, across three villages, located in the municipality of Gualdo Tadino in Central Italy
    - Data were collected during an evacuation exercise involving crews going door-to-door notifying residents of an 'evacuation order'
    - Residents' responses again included 'actual' behaviour (performed behavioural itineraries) and intended behaviour (verbal descriptions of behavioural itineraries)

- Time estimations were provided for the actions that were verbally described while the time for performing actions was recorded on camera

The above samples allow for a qualitative and quantitative analysis of human behaviour in wildfires and evacuations. Both types of analysis can inform end users such as professionals involved in wildfire management. For instance, qualitative analysis can identify what residents do and what they do not do, thereby providing insight that can be useful for the training of crews (e.g. informing them of the types of behaviours they might encounter and have to accommodate, as well as shattering some prevailing myths about supposed irrational responses).

Qualitative analysis can also assist with the training of the public. For example, it can provide a better platform to educate communities, one which can help residents evaluate their own capabilities, priorities, and time management during a wildfire incident.

Quantitative analysis can assist with the development of tools that can aid wildfire management, tools such as agent-based evacuation models. That is, such analysis can quantify how many agents will likely perform certain types of action and how long they may remain in one place before moving to another place. It can also inform of the likelihood of where the agents will ultimately be found (e.g. either staying put in their residences or seeking shelter in a variety of places, ones that may not be the designated safe shelters). As such, model developers will better understand not only what behaviours need to be added to the itineraries of agents but also what locations need to be added to the simulated space. Moreover, model end users will better understand what aspects of their current strategies did or are likely to work well and what aspects need further consideration and planning (e.g. regarding the number of resources [time and personnel] required, how and where personnel need to be deployed, how much compliance they are likely to encounter from residents, and so forth).

Lastly, qualitative and quantitative analysis of the human behaviour data will provide insight into whether and where behaviours need calibrating. For instance, the results of this study suggest that several pre-event factors relating to individuals do not appear to significantly influence evacuation decisions but other pre-event factors, such as those relating to official preferences, could be highly influential. Thus, when developing and using evacuation models, there might be no need to adjust certain behaviours on the basis that the studied population comprises transient groups or lacks wildfire experience, for example. Instead, allowances may need to be taken for the policy and practices of the studied region. For example, do they explicitly or implicitly support one form of protective action over another? If so, certain types of behaviour may be more prevalent in certain regions.

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6. REFERENCES

[1] Abar, S., Theodoropoulos, G.K., Lemarinier, P. & O'Hare, G.M.P. (2017). Agent Based Modelling and Simulation tools: A review of the state-of-art software. Computer Science Review, 24, pp. 13-33.

[2] Ronchi, E., Kuligowski, E. & Gwynne, S. Guest editorial: special issue on advances in evacuation modelling. Fire Technology, 55, pp. 387-389.

[3] Veeraswamy, A., Galea, E.R., Filippidis, L., Lawrence, P.J., Haasanen, S., Gazzard, R.J. (2018). The simulation of urban-scale evacuation scenarios with application to the Swinley Forest fire. Safety Science, 102, pp. 178–193.

[4] Chooramun, N., Lawrence, P.J. & Galea, E.R. (2012). An agent based evacuation model utilising hybrid space discretisation. Safety Science, 50(8), pp. 1685–1694.

[5] Galea, E.R., Sharp, G. & Lawrence, P. (2008). Investigating the representation of merging behavior at the floor stair interface in computer simulations of multi-floor building evacuations. Journal of Fire Protection Engineering, 18(4), pp. 291–316.

[6] Galea, E.R., Hulse, L., Day, R., Siddiqui, A. & Sharp, G. (2012). The UK WTC 9/11 evacuation study: an overview of findings derived from first-hand interview data and computer modelling. Fire and Materials, 36(5–6), pp. 501–521.

[7] Pretorius, M., Gwynne, S. & Galea, E.R. (2013). Large crowd modelling: an analysis of the Duisburg Love Parade disaster. Fire and Materials, 39(4), pp. 301–322.

[8] Bryan, J.L. (1999). Human behaviour in fire: the development and maturity of a scholarly study area. Fire and Materials, 23, pp. 249-253.

[9] Wood, P.G. (1972). The Behaviour of People in Fires (Fire Research Note 953). Borehamwood: Fire Research Station.

[10] Bryan, J.L. (1977). Smoke as a Determinant of Human Behavior in Fire Situations (Project People) (Report No. NBS-GCR-77-94). Washington, DC: National Bureau of Standards.

[11] Canter, D.V. (1996). An overview of behaviour in fires. In: Psychology in Action (pp. 159-188). Hampshire: Dartmouth Publishing Company.

[12] Fahy, R.F. & Proulx, G. (1997). Human behavior in the World Trade Center evacuation. In: Proceedings of the 5th International Symposium of Fire Safety Science (pp. 713-724). Boston, MA: IAFSS.

[13] Gershon, R.R.M., Magda, L.A. Riley, H.E.M. & Sherman, M.F. (2012). The World Trade Center evacuation study: factors associated with initiation and length of time for evacuation. Fire and Materials, 36(5-6), pp. 481-500.

[14] Averill, J.D., Mileti, D.S., Peacock, R.D., Kuligowski, E.D., Groner, N., Proulx, G., Reneke, P.A. & Nelson, H.E. (2005). Occupant Behavior, Egress, and Emergency Communication: Federal Building and Fire Safety Investigation of the World Trade Center Disaster (NIST NCSTAR 1-7). Gaithersburg, MD: NIST.

[15] Day, R.C., Hulse, L.M. & Galea, E.R. (2013). Response phase behaviours and response time predictors of the 9/11 World Trade Center evacuation. Fire Technology, 49, pp. 657-678.

[16] Fahy, R.F. (1991). EXIT89: an evacuation model for high-rise building. In: Proceedings of the 3rd International Symposium of Fire Safety Science (pp. 815-823). London: Elsevier.

[17] Ronchi, E. & Nilsson, D. (2013). Fire evacuation in high-rise buildings: a review of human behaviour and modelling research. Fire Science Reviews, 2:7.

[18] Kobes, M., Helsloot, I., de Vries, B. & Post, J.G. (2010). Building safety and human behaviour in fire: a literature review. Fire Safety Journal, 45(1), pp. 1-11.

[19] Thompson, O.F., Hulse, L.M. & Galea, E.R. (2018). A review of the literature on human behaviour in dwelling fires. Safety Science, 109, pp. 303-312.

[20] Kuligowski, E. (2013). Predicting human behavior during fires. Fire Technology, 49, pp. 101-120.

[21] Huang, S.-K., Lindell, M.K. & Prater, C.S. (2016). Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies. Environment and Behavior, 48(8), pp. 991-1029.

[22] Kang, J.E., Lindell, M.K. & Prater, C.S. (2007). Hurricane evacuation expectations and actual behavior in Hurricane Lili. Journal of Applied Social Psychology, 37(4), pp. 887-903.

[23] Schmidt, S. & Galea, E.R. (Eds.) (2013). Behaviour – Security – Culture (BeSeCu): Human Behaviour in Emergencies and Disasters: A Cross-Cultural Investigation. Lengerich: Pabst Science Publishers.

[24] SDIS 2B (2018). Enquête sur les rémunérations et le temps de travail des personnels de la sécurité civile, agents de l'État et agents des SDIS. Bastia: Chambre Régionale des Comptes de Corse.

[25] Insee (2019). Series of population estimates [online]. Accessed from: https://www.insee.fr/en/plan-du-site/famille-bdm/102775111

[26] European Commission (2020). Regional Innovation Monitor Plus: Corsica [online]. Accessed from: https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/corsica-0

[27] CEIC (2020). France hotels statistics: guest arrivals [online]. Accessed from: https://www.ceicdata.com/en/france/hotels-statistics-guest-arrivals?page=2

[28] Statista (2020). Number of foreign tourist arrivals in the hotel industry in Corsica in 2013, by geographical origin [online]. Accessed from: https://www.statista.com/statistics/766047/arrivals-hotels-nationality-corsica-la-france/

[29] Corsican Places (2020). Weather in Corsica [online]. Accessed from: https://www.corsica.co.uk/guide/weather

[30] Stewart, S.I., Volker, C.R., Hammer, R.B. & Hawbaker, T.J. (2007). Defining the wildland-urban interface. Journal of Forestry, 105, pp. 201-207.

[31] Modugno, S., Baltzer, H., Cole, B. & Borrelli, P. (2016). Mapping regional patterns of large forest fires in Wildland-Urban Interface areas in Europe. Journal of Environmental Management, 172, pp. 112-126.

[32] Lampin-Maillet, C., Jappiot, M., Long, M., Bouillon, C., Morge, D. & Ferrier, J.P. (2009). Mapping wildland-urban interfaces at large scales integrating housing density and vegetation aggregation for fire prevention in the South of France. Journal of Environmental Management, 91, pp. 732-741.

[33] Joint Research Centre (2018). Forest Fires in Europe, Middle East and North Africa 2017. Ispra: European Union.

[34] DREAL Corse (2013). Les risques. In: Profil Environnemental Régional de la Corse 2012 (pp. 86-134). Ajaccio: Préfecture de Corse.

[35] DDRM 2B (2015). Dossier Départemental sur les Risques Majeurs de la Haute-Corse [online]. Accessed from: http://www.haute-corse.gouv.fr/IMG/pdf/DDRM2B-JUILLET2015.pdf

[36] DICRIM Porto-Vecchio (2011). Document d'Information Communal sur les Risques Majeurs. Porto-Vecchio: La Mairie de Porto-Vecchio.

[37] Préfet de la Corse-du-Sud (2013). Le débrousaillement [online]. Accessed from: http://www.corse-du-sud.gouv.fr/le-debroussaillement-a179.html

[38] Whittaker, J., Blanchi, R., Haynes, K., Leonard, J. & Opie, K. (2017). Experiences of sheltering during the Black Saturday bushfires: Implications for policy and research. International Journal of Disaster Risk Reduction, 23, pp. 119-127.

[39] Laurent, F. (2017). Feu de Biguglia: 700 hectares brûlés selon le CODIS 2B. Corse Matin [online]. Accessed from: https://www.corsematin.com/articles/feu-de-biguglia-700-hectares-brules-selon-le-codis-2b-74811

[40] BBC News (2017). France wildfires force mass evacuation. BBC News [online]. Accessed from: https://www.bbc.co.uk/news/world-europe-40725294

[41] C.P. (2017). Corse: deux Incendies font rage a Sisco et en Balagne. Le Parisien [online]. Accessed from: http://www.leparisien.fr/faits-divers/cap-corse-un-incendie-a-deja-ravage-une-centaine-d-hectares-de-maquis-11-08-2017-7187424.php

[42] PopulationPyramid.net (2019). Population Pyramids of the World from 1950 to 2100: Europe 2017 [online]. Accessed from: https://www.populationpyramid.net/europe/2017/

[43] Vaiciulyte, S., Galea, E.R., Veeraswamy, A. & Hulse, L.M. (2019). Island vulnerability and resilience to wildfires: a case study of Corsica. International Journal of Disaster Risk Reduction, 40: 101272.

[44] Vaiciulyte, S. (2020). When Disaster Strikes: Human Responses to Wildfires and Evacuation in the South of France and Australia (doctoral dissertation). London: University of Greenwich [under review].

[45] 2009 Victorian Bushfires Royal Commission (2010). The 2009 Victorian Bushfires Royal Commission Final Report [online]. Accessed from: http://royalcommission.vic.gov.au/Commission-Reports/Final-Report.html

[46] Handmer, J., Van der Merwe, M. & O'Neill, S. (2019). The risk of dying in bushfires: a comparative analysis of fatalities and survivors. Progress in Disaster Science, 1: 100015.

[47] AFAC (2005). Position Paper on Bushfires and Community Safety. Melbourne: AFAC.

[48] Haynes, K., Handmer, J., McAneney, J., Tibbits, A. & Coates, L. (2010). Australian bushfire fatalities 1900-2008: exploring trends in relation to the 'Prepare, stay and defend or leave early' policy. Environmental Science and Policy, 13(3), pp. 185-194.

[49] AFAC and Bushfire CRC (2006). The Stay and Defend Your Property or Go Early Policy (Fire Note Issue 7) [online]. Accessed from: https://www.bushfirecrc.com/sites/default/files/managed/resource/bcrcfirenote7staygo.pdf

[50] Drury, J., Novelli, D. & Stott, C. (2013). Representing crowd behaviour in emergency planning guidance: 'mass panic' or collective resilience? Resilience: International Policies, Practices and Discourses, 1(1), pp. 18-37.

[51] AEMC – National Bushfire Warnings Taskforce (2009). Australia's Revised Arrangements for Bushfire Advice and Alerts – 2009/2010 Fire Season [online]. Accessed from: https://knowledge.aidr.org.au/media/6003/aus-arrangements-bushfire-advice-alerts.pdf

[52] Whittaker, J., Haynes, K., Handmer, J. & McLennan, J. (2013). Community safety during the 2009 Australian 'Black Saturday' bushfires: an analysis of household preparedness and response. International Journal of Wildland Fire, 22, pp. 841-849.

[53] Handmer, J. & O'Neill, S. (2016). Examining bushfire policy in action: preparedness and behaviour in the 2009 Black Saturday fires. Environmental Science and Policy, 63, pp. 55-62.

[54] McLennan, J., Elliott, G.A., Omodei, M. & Whittaker, J. (2013). Householders' safety-related decisions, plans, actions and outcomes during the 7 February 2009 Victorian (Australia) wildfires. Fire Safety Journal, 61, pp. 175-184.

[55] McCaffrey, S., Wilson, R. & Konar, A. (2017). Should I stay or should I go now? Or should I wait and see? Influences on wildfire evacuation decisions. Risk Analysis, 38(7), pp. 1390-1404.

[56] Paveglio, T., Prato, T., Dalenberg, D. & Venn, T. (2014). Understanding evacuation preferences and wildfire mitigations among Northwest Montana residents. International Journal of Wildland Fire, 23(3), pp. 435-444.

[57] Vaiciulyte, S., Hulse, L.M., Veeraswamy, A. & Galea, E.R. (2020). Cross-cultural comparison of behavioural itinerary actions and times in wildfire evacuations. Safety Science [under review].

[58] Piedra, J.L. (2019). Rapid-reaction plan activated as Andalucía faces higher wildfire risk this summer. SUR in English [online]. Accessed from: http://www.surinenglish.com/local/201906/14/rapid-reaction-plan-activated-20190614092426-v.html

[59] MEF Dipartimento della Ragioneria Generale dello Stato (n.d.). Andamento dell'Occupazione [online]. Accessed from: https://www.contoannuale.mef.gov.it/ext/Documents/ANDAMENTO%20DELL'%20OCCUPAZIONE.pdf

[60] EPSU (2020). Numbers of firefighters by country and category [online]. Accessed from: https://www.epsu.org/article/numbers-firefighters-country-and-category

[61] ISTAT (2018). Population and households [online]. Accessed from: https://www.istat.it/en/population-and-households?data-and-indicators

[62] Encyclopaedia Britannica (2020). Italy: economy [online]. Accessed from: https://www.britannica.com/place/Italy/Economy

[63] CEIC (2020). Italy visitor arrivals [online]. Accessed from: https://www.ceicdata.com/en/italy/visitor-arrivals/visitor-arrivals

[64] OECD.Stat (2020). Inbound tourism [online]. Accessed from: https://stats.oecd.org/Index.aspx?DataSetCode=TOURISM_INBOUND#

[65] LanguageKnowledge.eu (2012). Languages in Italy [online]. Accessed from: https://languageknowledge.eu/countries/italy

[66] Weather Online (2020). Climate of the world: Italy [online]. Accessed from: https://www.weatheronline.co.uk/reports/climate/Italy.htm

[67] SunPope (n.d.). Best time to visit Italy [online]. Accessed from: https://www.sunpope.com/italy/

[68] Trading Economics (2020). Italy – forest area (% of land area) [online]. Accessed from: https://tradingeconomics.com/italy/forest-area-percent-of-land-area-wb-data.html

[69] FIRESafe MARIN (2019). Fire-hazardous plants: identifying fire-prone plants [online]. Accessed from: https://www.firesafemarin.org/plants/fire-prone/alphaindex/c

[70] Hansman, H. (2015). Can cypress trees help suppress wildfires? Smithsonian Magazine [online]. Accessed from: https://www.smithsonianmag.com/innovation/can-cypress-trees-help-suppress-wildfires-180956597/

[71] Joint Research Centre (2019). Forest Fires in Europe, Middle East and North Africa 2018. Ispra: European Union.

[72] Allaby, E. (2018). 500 evacuated as forest fire strikes near Pisa. The Local [online]. Accessed from: https://www.thelocal.it/20180925/500-evacuated-as-forest-fire-strikes-pisano

[73] National Civil Protection Department (2018). National Risk Assessment [online]. Accessed from: http://www.protezionecivile.gov.it/documents/20182/823803/Documento+sulla+Valutazione+nazionale+dei+rischi/57f337fd-a421-4cb0-b04c-234b61997a2f

[74] PopulationPyramid.net (2019). Population Pyramids of the World from 1950 to 2100: Europe 2019 [online]. Accessed from: https://www.populationpyramid.net/europe/2019/

[75] Johnson, J.G. & Raab, M. (2003). Take the first: option-generation and resulting choices. Organizational Behavior and Human Decision Processes, 91(2), pp. 215-229.

[76] Kuligowski, E.D., Gwynne, S.M.V., Kinsey, M.J. & Hulse, L. (2017). Guidance for the model user on representing human behavior in egress models. Fire Technology, 53, pp. 649-672.

[77] Edgeley, C. & Paveglio, T. (2019). Exploring influences on intended evacuation behaviors during wildfire: what roles for pre-fire actions and event-based cues? International Journal of Disaster Risk Reduction, 37: 101182.

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