FIRE, SCIENCE AND SOCIETY AT THE URBAN-RURAL INTERFACE

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Abstract
The drama of urban-interface fire is a feature of summer newscasts in south-eastern Australia. Fire-suppression agencies report fire threats to homes and their calculated responses to them. At another level, scientists grapple with the problems of predicting fire spread, recommending house-construction methods, advocating human-safety measures and anticipating environmental effects. Householders can be largely unaware of a fire threat or have expectations of total protection courtesy of suppression agencies. Houses can burn down and fatalities can occur: this paper considers a number of the issues surrounding this 'bushfire problem'. Using examples based on the fire event experienced under extreme weather in Canberra, Australia, in 2003, simple models and calculations are presented for: the fire-awareness of householders; the proportion of 'knowledgeable' householders; capacity of the brigade suppression system; demands for water from the mains; and, house loss in relation to householder occupancy during fire. The general socio-political problem is how to meet a rare, extreme, short-term demand for resources that far exceeds normal supply. The assumption that householders need to be self reliant is apparent. The general scientific problem is one of too many variables and too few data for statistical analysis.

Additional key words: house occupancy, stay or go, suppression.

Introduction
It is 3.30 on a long hot summer afternoon but it has turned to dark from smoke. The roar of the approaching fire is intimidating. The gloomy air becomes permeated by a storm of red-hot embers blown into the urban interface by the strong dry wind. People are hosing their houses but other houses are catching alight and seem doomed. There is no fire-suppression appliance present.
This graphic description depicts the scene of a major bushfire arriving at an urban edge. When houses and lives are lost it is the beginning of a major social problem that can last for years. This is an international problem and one with many facets and complications (Gill 2005).

Fire, science and society meet in circumstances of death and destruction at the urban-rural interface. What can householders – and society in general - expect? Can science provide any insights into this situation? Can testable hypotheses be formulated and, therefore, data collected intelligently?

In this contribution a limited set of issues is addressed. Here, the house is considered to be a major asset of the interface (see also Gill 2005). Two responsiveness groups of householders are created and their proportions in the community estimated. Staying with the home or not during a major fire event is considered along with the chances of saving a house using an urban water supply; the situation faced by fire-suppression authorities in extraordinary circumstances is also considered. It is necessarily somewhat speculative but attempts to be stimulative.

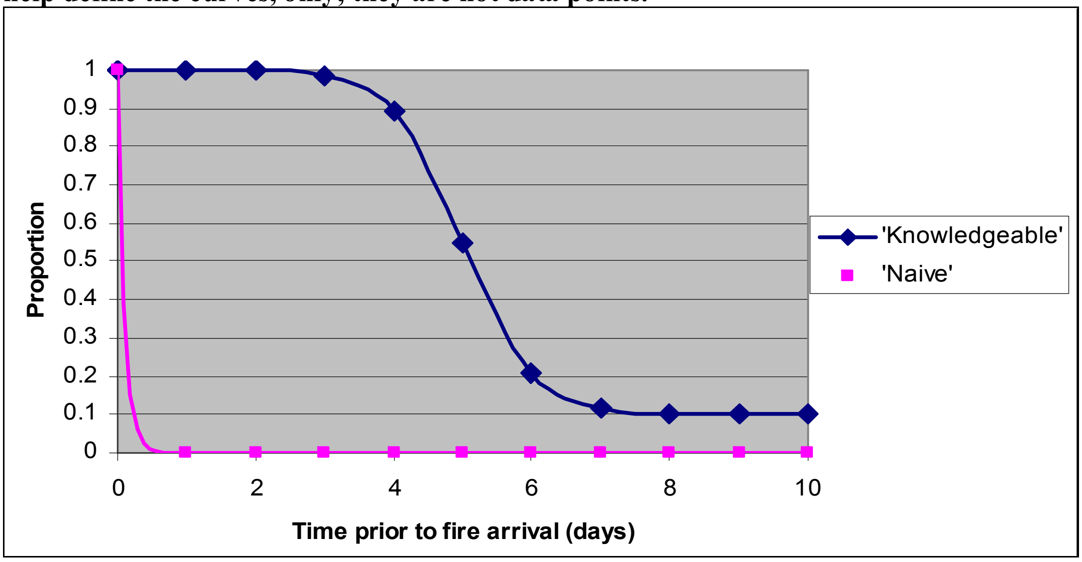
Householder Responsiveness to Fire
Consider a fire that starts within a hundred metres or so of the urban edge, runs up a slope before a strong dry wind and destroys a house or two (*e.g.* in the manner of the fire at the edge of the Canberra suburb of Yarralumla, Australian Capital Territory – ACT - fire of December 2005). In this situation there is very little time for residents to become aware of the threat they face or for agencies to warn anyone of the approach of the fire, let alone respond in time to prevent house loss. The proportion of fire-responding residents in such cases may follow curves like those in Figure 1 but at a scale of minutes rather than days.

'Responsive' behaviour is considered to have occurred when the threat has been recognised and action considered, and possibly taken, by the resident in response to the fire. Action may be limited to mental plans or involve fuel

modification, suppression action or a decision to stay and defend the property, or stay and shelter, or move away. The time scale at which awareness is graphed depends on the situation. 'Hours' or 'days' may be appropriate in some situations as opposed to the 'minutes' in the above case: the Canberra, ACT, fires of January 2003 (McLeod 2003) burned for 10 days before reaching the urban edge of Canberra thereby providing a considerable period for reflection and preparation in response to that event – compared with the general preparedness that is a seasonal routine of some households. It was observed by the author from a small sample that most people were completely unprepared in Canberra even close to the time of the fire's arrival; individual published narratives support this (*e.g.* see Matthews 2003).

Responsiveness Categories
Two contrasting categories of households are here recognised in relation to their 'responsiveness' to an impending fire. The first consists of those people who are seasonally unprepared, apathetic, unconcerned or vague; they might believe that 'the authorities have everything in hand' or that they are covered by insurance so perceive that they 'need not think about it' or that 'it won't happen to me' or that 'it can't happen here'. This group is called the 'naïve' group. Their counterparts are those who are seasonally prepared, fire-experienced or well informed, watchful, concerned and alert. This group is called the 'knowledgeable' group. The responsiveness of the two groups considering an actual fire starting well away from the interface is speculatively depicted in Figure 1.

Figure 1. **Hypothetical cumulative proportion of responding households, among those eventually affected, within the 'naïve' and 'knowledgeable' groups in relation to a distant ignition. Graph-points are included to help define the curves, only; they are not data points.**



The proportion of 'knowledgeable' households will vary from place to place and at any one place with the passage of time; contributing affects may be the recency of fire experience in the area, official and unofficial warnings and information supply, and observation and learning. Residents who have been through a Community Fireguard (Boura 1999) or other community fire awareness program are more likely – perhaps much more likely - to be in the 'knowledgeable' category than others.

According to the hypothetical relationships depicted in Figure 1, all households in which people are present become aware of the fire when it arrives but the proportion of the 'knowledgeable' group aware of the possibility of impending fire rises sooner than that of the 'naïve' group. The 'naïve household' is likely to make a decision to stay or leave at the last minute while the former have time to consider their position, make final preparations for the arrival of the fire and their responses to it, and may be more likely to stay and defend their property. It is the impression of the author that in the unprecedented Canberra fires of 2003, the 'naïve' group was the larger of the two but there is no definitive evidence to support or refute this.

Note that according to the hypothetical graph depicting the 'knowledgeable' group in Figure 1 that some of their members are responsive well in advance of any fire: this may be seen as being responsive to weather forecasts, chance of ignition and fuel conditions.

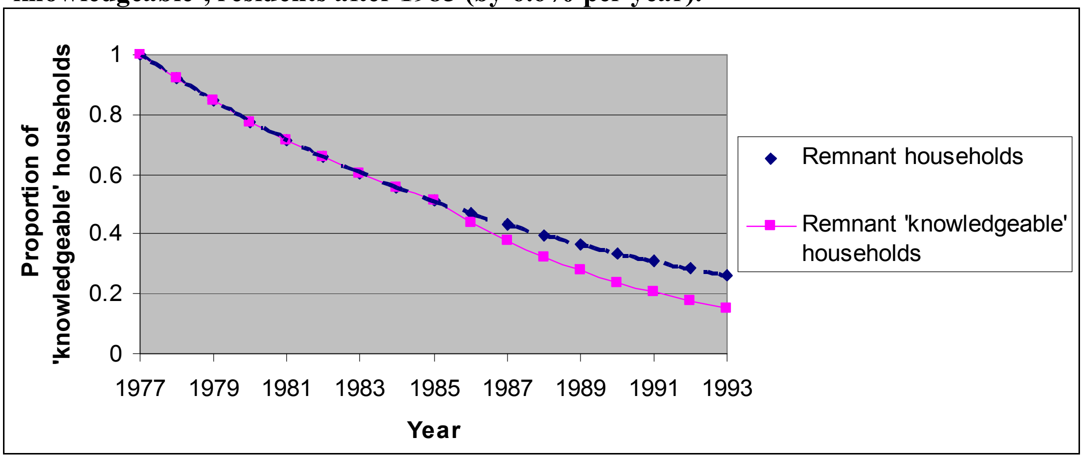
Only two categories have been discerned here for convenience. It may be sensible in the future to more rigorously define more groups that the two used for illustration here.

Membership of Response Categories

The ideas expressed in Figure 1 do not in themselves say anything about the proportions of households in the two response-groups at any one time. Starting at the end of a socially-disastrous fire, rather than leading up to it as in Figure 1, we may assume that all affected residents at the interface are part of the 'knowledgeable' group even if they were absent from their homes at the time of the fire because, on return, they would experience the devastation of the neighbourhood, hear the stories of those who stayed and read an extended media coverage of the event. Thus, the major fire event provides us with a starting point for an exploration of year-year changes in the proportion of 'knowledgeable' and 'naïve' households in a community.

Consider an interface of residents who have recently experienced a fire and who are subject to normal rates of selling and buying of houses. Let us assume that 'knowledgeable' residents are replaced by 'naïve' ones when a house is sold because new residents will most likely be from a city core rather than from another fire-affected interface. This is in conformity with the observations of Cunningham and Kelly (1994) in the Blue Mountains of New South Wales and the inference drawn by Coleman (1995) in California but other possibilities exist. In a village or small town, the interface may be large relative to the whole area; new residents may be from country areas (and possibly 'knowledgeable') or from the city (and likely to be 'naïve'). Residents can change in a rental house while house ownership remains the same. As a measure of the membership of fire-response categories of urban residents then, the proportions of those who have experienced a fire – 'knowledgeable' – and those who have not – 'naïve' – are estimated, only, from figures for the sale of houses. In the example illustrated later, the figures used are for Canberra suburbs as a whole, not for the fire-affected parts only. But, before delving into the figures for Canberra, previous work is examined.

Figure 2. A model of the number 'knowledgeable' households in the Blue Mountains after the 1977 fire (after Cunningham and Kelly 1994). Added to the attrition of 'knowledgeable' residents due to the here-assumed turnover rate of households (8.05% per year, upper line) is the decreased awareness of remnant, 'knowledgeable', residents after 1985 (by 6.6% per year).



In Cunningham and Kelly's (1994) survey in the Blue Mountains, there were 26% of 'knowledgeable' residents - in this interpretation - 16 years post fire. Assuming that these people were from different households, and were representative of the population buying and selling houses at a constant and random rate per year, this suggests a house sale rate of just over 8% per year. Equivalent sale rates in California have been set at 20% per year (Coleman 1995). The effects of house sales at 8% per year on the presumed proportions of 'knowledgeable' residents is shown in Figure 2. In addition to turnover of residents, Cunningham and Kelly (1994) identified a loss of awareness with time from

within the 'knowledgeable' group; we can call this a 'backsliding' effect. In Cunningham and Kelly's (1994) case this seemed to begin at 8 years post fire. These influences are modelled in Figure 2.

One reason for the decline within the 'knowledgeable' group could be the incorrect perception that the longer it has been since the last fire, the less likely there will be another fire; further perceptions, perhaps misleading, may be that 'these fires only occur cyclically' (Edgell and Brown 1975); *e.g.*, 'it's not that long since the last one' and 'fire management must have improved since last time' so 'there is nothing to worry about at the moment'.

Figures for the house sales in parts of Canberra affected by the 2003 bush fires were obtained from *ACTPLA*, the Australian Capital Territory Land and Planning Authority. These were able to be expressed as proportions when data on the number of houses per suburb in the 2001 census were obtained from the Australian Bureau of Statistics web site. The ten-year average – for the period 1996-2005 - was 6.6% per year for the Canberra suburbs of Chapman, Duffy and Holder; this is a little less than that used for the Blue Mountains in Figure 2. Given that it is likely that there will be a higher turnover than 'normal' soon after fire as a household's considerations about whether or not to move can be precipitated by the fire event and residents may be more inclined to move because of the changed social situation and streetscape after a fire, proportional sales in 2003, compared with the average, were graphed for seven affected suburbs using house-loss data for the 2003 fires from the *ACT Department of Urban Services*. There was a positive correlation between proportional house loss and proportion of houses sold in 2003 thereby supporting the idea of greater turnover soon after fire: this could be modelled by using a lower value for the 'knowledgeable' group at the outset rather than assuming a value of one as in Figure 2.

The models used above provide us with some indication of what is likely but cannot be assumed to be accurate reflections of what is reality in terms of the proportion of 'knowledgeable' residents. In particular, the turnover of people in rental accommodation is not known. Residents may be long or short term. The proportion of rented houses in seven affected Canberra suburbs was estimated to be between 8 and 25%. Another complication is the partial sale of houses between joint owners and what effects this might have; partial sales were not considered above.

Target audiences for fire-safety messages are likely to be continually changing (Coleman 1995) as people move into and out of potentially fire-affected suburbs.

Expectations of Fire Brigade Presence: Limits to Agency Suppression Capacity

Both 'knowledgeable' and 'naïve' groups may be expecting protection from the urban fire brigade in the event of an urban-interface fire. In 2006, the main groups involved in fire suppression in the ACT were the *ACT Fire Brigade* (urban predominantly), the *ACT Rural Fire Service* (rural, consisting of volunteers from urban and rural locations), the new *Community Fire Units* (specially-trained local householders with access to local fire hydrants but under the command of the *ACT Fire Brigade*), general householders (without access to hydrants), and 'farmers' (individual rural lessees). The *ACT Fire Brigade* and the *ACT Rural Fire Service* are part of the *ACT Emergency Services Authority*. The vehicle fleet for house-fire suppression in the *ACT Fire Brigade* (personal communication) consists of 14 pumpers, 5 tankers and, for the first time, 4 compressed-air-foam tankers - a total of 23 possible urban-interface fire-suppression vehicles. Two helicopters are currently available seasonally.

On January 18th, 2003, over 400 houses were burnt at the urban edge of Canberra (ACT Government 2003). Assuming one tanker or pumper to each threatened house, then the entire ACT urban capacity is mopped up by just 23 threatened or burning houses at any one time; if local rural tankers are included, the number nearly doubles. Given that several thousand houses were threatened and hundreds burnt over a period of several hours in the Canberra fires of 2003 (ACT Government 2003; Leonard and Blanchi 2005), the maximum demand for suppression services can greatly exceed supply. When property protection is paramount there is no suppression of the moving perimeter of the fire either in rural or urban areas. Equipment breakdown and further outbreaks of fire can exacerbate the situation; alleviating the situation somewhat can be the availability of appliances from other jurisdictions. The capacity of rural (Gill 2005) and urban fire-suppression services can be quickly overcome when many structures are threatened, or already alight.

Would society ever allow governments to spend the money necessary to establish a full-time fully-equipped professional fire-suppression force with adequate equipment and training for dealing with large rare high intensity fires burning into the urban-interface under the worst possible weather and fuel conditions? If it did, such supply would be

excessive for the vast majority of the time, year after year. This problem is at a different time scale to that involved in the catering for within-year variations and which are addressed by having brigades of city and rural volunteers and by employing, apparently increasingly, paid seasonal fire fighters. If an adequate number of volunteers offered their services for the extreme year, and they were fully equipped with vehicles, there would be no 'action' for many of them year after year; as a result, many could be expected to lose their enthusiasm and drift away.

Householders can expect that they will be without agency support in the event of a large fire at the urban edge or in the few minutes it takes a small fire starting nearby to reach houses and ignite them; there is an optimum range of conditions in which agencies can best assist the public through fire suppression. Defining what this range is remains a challenge. Householders who are in the 'knowledgeable' group may be expected to react more appropriately to these circumstances.

Fire Suppression and Urban Water Reticulation

The most common resource for all the participants in fire suppression at the urban interface is water. From the urban perspective, this is supplied by a network of catchment storages, local reservoirs and mains by a government, or semi-government, agency. Farm dams, water tanks and streams supply rural brigades but once near the urban edge, hydrants can be tapped.

Canberra's water is piped from open storages in the mountains to enclosed concrete reservoirs in the hills surrounding the suburbs - from whence it is distributed by gravity to householders through a network of pipes sectored according to reservoir source. A fire may impinge on a long or short edge of a network sector and so affect the demand for water differently. Neighbours on opposite sides of a street may be in different network sectors and so may experience different water pressures.

While water is the common resource, the tools for its application and the ways in which it is used vary considerably. Urban Brigades have pumpers and tankers of varying capacity and apply water with or without foams (with or without compressed-air enhancement); rural brigades apply water with or without flame retardants (including foams); farmers, householders and Community Fire Units use water without special treatment.

In the urban environment, there is undeclared competition for the water from the mains in the event of a major urban interface fire. However, people with independent sources and application techniques – such as swimming pools with pumps and hoses – have no competition.

In the major Canberra fires of 2003, there were two sources of water-supply inadequacy for fire fighting and there is a need to distinguish these:

1. The first source was apparently characterised by sudden loss of pressure - and one not necessarily experienced by neighbours. There were many informal reports by householders of the failure of the water pressure in their garden hoses, some perhaps being due to the burning through of plastic pipes being used as part of a garden-sprinkler system (McFeat 2004).
2. The second type, experienced by the urban fire brigade and householders using the mains water supply can be regarded as neighbourhood-wide.

The water pressure at any pipe outlet in the suburbs is influenced positively by the 'head of water' (the difference in elevation between the water level in the reservoir and that at the outlet), and negatively by friction in the pipes. The total frictional losses are dependent on many physical properties of the of the network including the diameter and length of the pipes as well as the resident's plumbing system and the location and quantity of water being drawn from various parts of the network. A householder who has joined garden hoses to gain access to a wider area will find a reduced flow due to greater friction.

Having an alternate – temporal or permanent - water supply to that from the mains is ideal in a major event. This may be a swimming pool or a tank, for example. Alternatively, an 'experienced' resident will fill the bath, bins and other containers as a backup in case mains pressure fails. Turning off vulnerable, pressurised, garden-sprinkler systems not in use is advisable.

Modelling pipe network performance under different water-demands – and testing the predictions - seems like a worthwhile exercise designed to find weak points in the system and plan strategies for best water use by residents, brigades and Community Fire Units.

Mitigation of Risk to Life and Property

Residents have two basic and obvious options when fire threatens their house: they may stay or they may leave. However, there are variations on this theme as some may be ordered to leave rather than leave voluntarily and some may stay and defend their property or stay and shelter only. Those who leave may do so at various times during the event. Those who stay may try to protect neighbour's houses as well as their own. 'Knowledgeable' residents will, by definition, have a different view of the event than 'naïve' residents, and be better prepared.

Leave Early

The prevailing paradigm of Australasian fire authorities is one of 'leave the potential fire scene early' if one considers it unwise to stay for various reasons, or 'prepare, stay and defend the home', the rationale being that it is safer to stay with the protection of a building – temporarily if it catches alight - than to flee from the fire at the last moment (see McLeod 2003, Handmer and Tibbits 2005).

'Prepare, stay and defend' or 'leave early' both imply a necessary minimum time. In the first instance, time is needed to prepare water sources, don suitable clothing and make last-minute preparations to the house while, in the second, time is needed to exit the potential fire-affected area before the fire arrives and before egress is affected. For the purposes of illustration let us assume that one hour is the absolute minimum time necessary in both cases. Where will the fire be one hour before the fire arrives? If I can see the flames nearby, have I left it too late? Cheney *et al.* (2001) used this approach in the context of fire-fighter safety in a forest fire; here it is applied to the urban-interface dweller.

The maximum predicted distance that a line of fire can travel in one hour on level ground in one hour under the extreme weather conditions experienced in Canberra in completely cured grass (*i.e.* no green grass present) or in eucalypt forest is substantial - 15.5km, 13.2 and 6.6 km in 'natural', 'cut/grazed' or 'eaten-out' grassland categories respectively (Cheney *et al.* 1998) and 5.1 km in forest (after Cheney *et al.* 2001). These are extremes and not the usual. However, such long distances would be even longer if there was an upward slope or extreme spot fire activity in the direction of the wind, and somewhat shorter for fire travelling against the wind or slope. In forest, the rates of spread are substantially lower than in grasslands.

Given such rapid rates of spread, leaving for a safe haven when the fire is still far distant is wise if one is going to leave. Note that one hour is not necessarily enough time; one hour is used purely for illustration.

Stay and Defend (or just Shelter)

Data from major fires shows that house occupancy is important to house survival. However, if everyone was at home and capable, there is still a chance that some houses would be lost. On the other hand there is a chance that even if all the homes were unoccupied some would survive. In this section we speculate upon the relationship across the spectrum of possibilities assuming the absence of fire-fighters. The parameters of the equations could be changed to describe the effects of more or less severe conditions, the presence of fire fighters, loss of water supply, house type *etc*. but there is no attempt to do that here. The idea (Figure 3) provides a background as to what the situation of 'stay-or-go' might mean in different situations in terms of house loss.

Actual data are rare and do not cover the spectrum of possibilities. The dashed lines in Figure 3 mark out a domain according to the circumstances noted; these circumstances are somewhat artificial. Also, even if there was 100% occupancy some houses are likely to be lost under the most severe conditions; even if there was no one present, some houses might survive despite being unprotected. The neat relationships in Figure 3 would be modified as to intercepts and slope, and, possibly, shape, in the real world. Available data are shown in Figure 4.

Figure 3. A model of loss of houses (n=100) when each household saves their own house and, where indicated, that of a house next door if unoccupied.

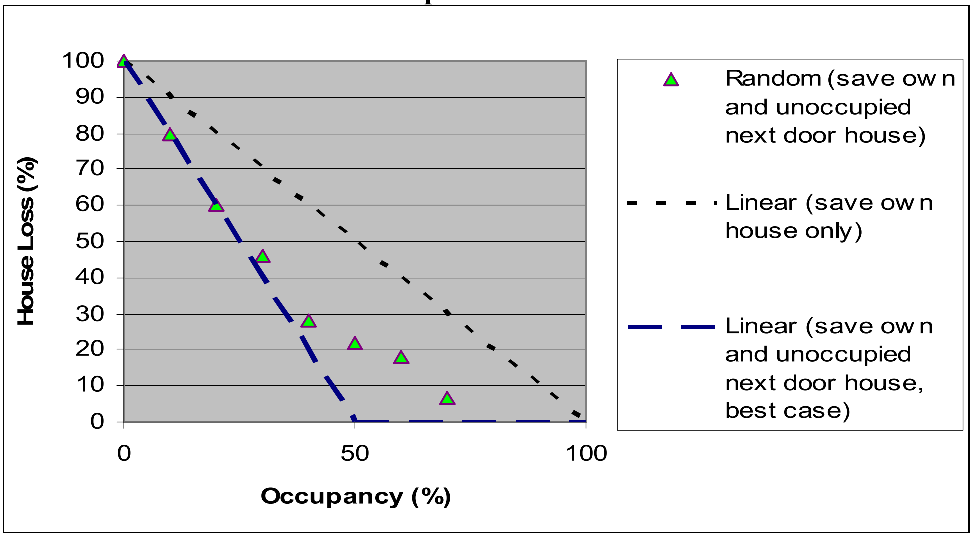
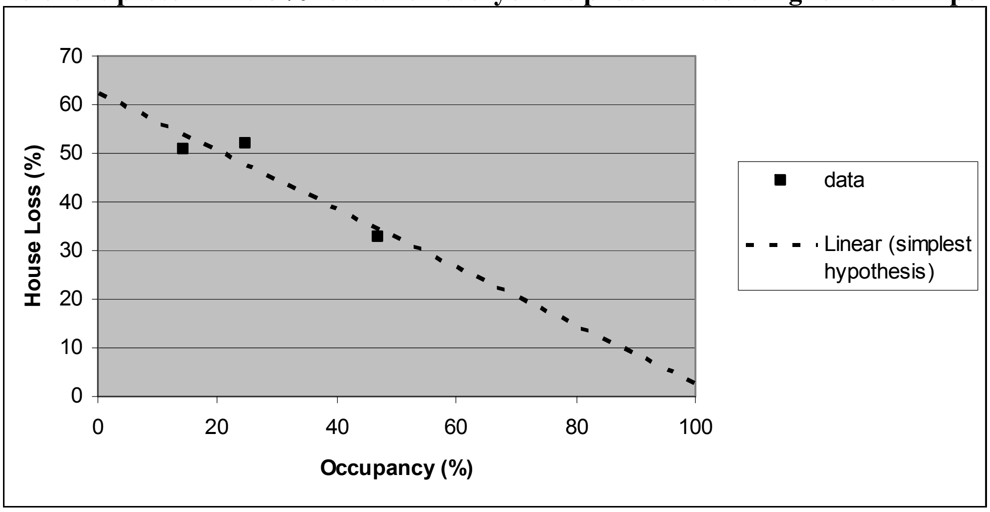


Figure 4. The dotted line shows the extrapolated trend for data from Wilson and Ferguson (1986) and Leonard and Blanchi (2005, and personal communication for the Otways Fire, Victoria). Note the 62% house loss when no one is present and 3% loss when everyone is present according to the extrapolation.



The linear extrapolation of the trend line for real data in Figure 4 represents the simplest hypothesis.

Discussion and Conclusions

There are numerous facets to the problem of landscape fires entering the urban-interface (Gill 2005). Only a small subset of possible topics has been addressed here. Some others topics of importance are: town and landscape planning; building and garden design and construction; disaster recovery; restoration of property and businesses; environmental effects including those on water supply, biodiversity, air and stream quality; warnings; communication of fire information; fire behaviour; and, fuel management. Reports of various Inquiries canvas many topics which, while not always directed at interface fires, have relevance there (see, for example, Esplin *et al*. 2003 and Ellis *et al*. 2004).

Time-scale emerges as an important variable to consider with respect to fires and the damage they may do at the urban-rural interface during extreme weather conditions. Houses at the urban edge may be affected in a very short time by a fire ignited nearby– so short, in fact, that even urban appliances cannot reach the site before damage to property has

occurred. On the other hand, the very large fire with long distances to travel may be so large that fire-suppression forces are simply not numerous enough to cope. In both of these cases, the householder who is 'knowledgeable' will be better able to cope. There are limits to effective suppression responses and attaining a general recognition of these by communities and governments is important if fire problems at the urban interface are to be suitably addressed.

The general problem for society is how to deal with a rare and extreme event like a major unplanned fire burning under extreme weather conditions and causing loss of homes and human lives – another scale problem. It would appear that the costs of being able to address the most extreme event in a comprehensive way, at least for fire suppression, are prohibitive; the question of the possibility of more comprehensive, but potentially routine, fuel treatments and how they might affect the situation has not been addressed here. How to integrate preparedness and response among the many private and government stakeholders involved when extreme fires reach the urban interface remains an important challenge to all affected, or potentially-affected, societies.

Data issues in tackling the topics of this contribution are substantial. There are too few data and too many variables to consider. This makes conventional scientific analysis impracticable yet policy formulation, even laws, are created or contemplated on the few available data or on perceptions of the circumstances of fires and their impacts on the urban-rural interface. International co-operation in the sharing and analysis of data is recommended. In this contribution, the approach has been to take the scraps of available data and use what appear to be appropriate surrogates, like house-sale information, to develop some testable hypotheses as another step on the way toward greater understanding.

There is a need for collaboration between the public, scientists, land managers and governments to learn as much as possible from rare and tragic social circumstances such as devastating fires at the urban-rural interface.

Acknowledgements

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