The folly of a misquote: how a misquote leads to the wrong conclusion

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This article shows how even the best brains in the land can accept scientific findings without question, can misquote them and can promulgate them as facts to the ruling establishment.

It starts with the following statement from the Victorian Bushfire Royal Commission (VBRC, 2010). The VBRC makes an implicit recommendation that the CFA's 100m buffer distance from vegetation should be greater. It will be assumed that the VBRC depended on its advisers for scientific knowledge.

> The distance of 100 metres appears to have been chosen initially as a convenient margin and was retained when a 1999 study by Ahern and Chladil (1999) found that **85 per cent of houses were destroyed within 100 metres of vegetation.** … These data, and the CFA's practice in relation to 'neighbourhood safer places' (see Chapter 1), suggest that something beyond 100 metres would be a more conservative choice from the perspective of safety. The Commission supports the view that the 100-metre margin should be reviewed.

Clearly, the VBRC has accepted this advice on the basis of the Ahern and Chladil study, which purportedly endorsed the hypothesis that fewer houses are destroyed as distance from vegetation increases. If this recommendation is accepted, the downstream implications will influence construction requirements and costs via Wildfire Management Overlay planning, building requirements in Bushfire-prone Areas and location and design of refuge areas. This paper examines the nature of this advice.

Analysis of the quote

There are two problems with this advice. Firstly, the Ahern and Chladil study did not make this finding, and secondly, their study did not establish any evidence that distance to vegetation was a significant causal factor in house loss.

Firstly, the findings of the Ahern and Chladil study
A The Ahern and Chladil study found that 85% of burnt houses were within 100m of vegetation. Either the advisers of the VBRC have misconstrued the findings of the study or have failed to correct the VBRC interpretation prior to publication.
RC – "**85% of houses were destroyed within 100 metres of vegetation.**"
Actual study – "**85% of burnt houses were within 100m of vegetation**"

These statements have very different meanings. The difference is very significant, as illustrated in the box below. The ratio of black and white marbles refers to the burnt to unburnt house ratio in a given area.

> Say there are 1000 marbles, 350 black and 650 white. Throw them twice at random at a wall. Measure distances out from the wall. Now ask the same questions, and observe the different answers.
>
> 1st throw results - 85% of black marbles are within 100 cm of wall
> Read: 85% of burnt houses are within 100 m of vegetation
>
> | | |
> |---|---|
> | How many black marbles are within 100cm? | = 85% x 350 = 297 |
> | How many white marbles are within 100cm? | = based on random chance, probably = 85% of 650 = 552 |
> | How many total marbles are within 100cm? | = 297 + 552 = 849 |
> | How many black marbles are beyond 100 cm? | = 15% x 350 = 53 |
>
> 2nd throw results - 85% of marbles within 100 cm of wall are black
> Read: 85% of houses within 100 m of vegetation are burnt
> As a point of reference, assume all the black marbles are within 100 cm.
>
> | | | |
> |---|---|---|
> | How many black marbles are within 100cm? | = 350 | = 85% x 411 |
> | How many white marbles are within 100cm? | = 71 | = 15% x 411 |
> | How many total marbles are within 100cm? | = 411 | = 350 / 0.85 |
> | How many black marbles are beyond 100 cm? | = 350 - 350 = 0 | |

B Ahern and Chladil said their distribution charts (eg, Fig 1) indicate “that the majority of burnt houses were positioned relatively close to the vegetation boundaries and fewer were more than 250m away”. They found 85% of burnt houses fell within 100m of vegetation. 85% is a clear majority. Therefore, case proven – it is therefore too risky to build within 100 m of vegetation …… Or is it?

Figure 1 clearly shows that the Ahern and Chladil study found that 85% of burnt houses were within 100m of vegetation, but it also shows that 20% of burnt houses were within 10m of vegetation. If the same VBRC misquote is applied to this finding, it would read - **20% of houses are destroyed within 10m of vegetation**. Using the same logic, fire agencies could then say that loss rate as low as this is acceptable, so it’s OK to build within 10m of vegetation.

Fig 1 Ahern and Chladil’s Chart

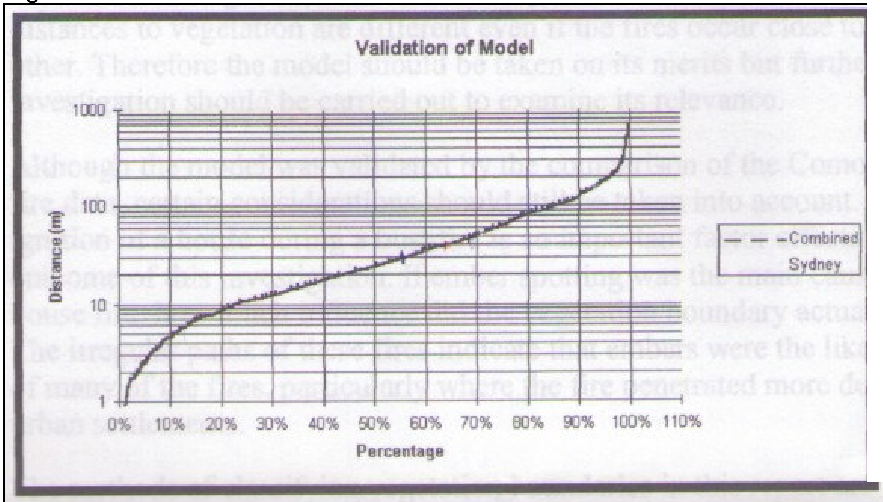


Figure 5. Distribution of Como/Jannali houses and their distances from vegetation.

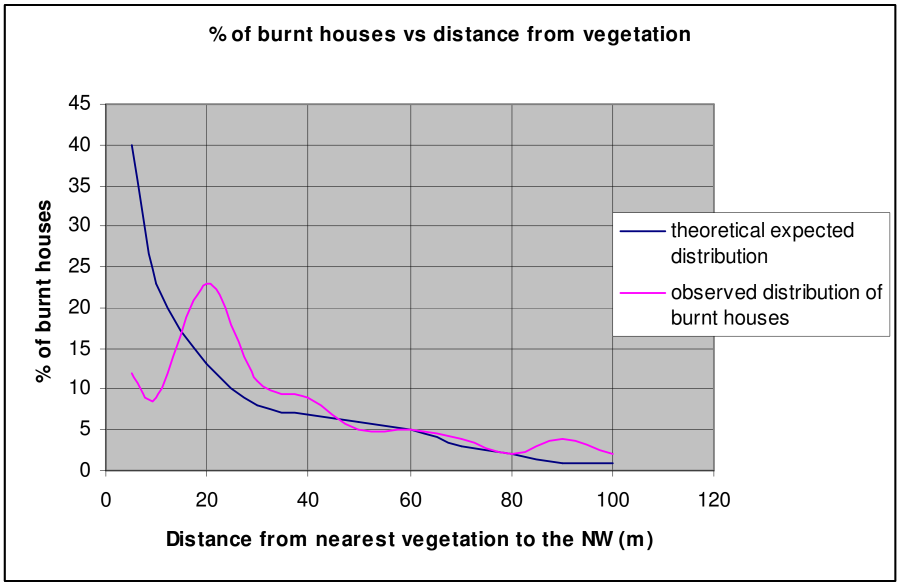
Conclusion

This report identifies the relationship between houses burnt in bushfires and the distance they stand from a vegetation boundary. The model produced to investigate this association shows that 70% of burnt houses will stand 50m or less from the vegetation boundary 80% are 80m or less and 95% are 180m or less, leaving just 5% at a greater distance than 180m from vegetation. For the worst case scenario, in this report, which was Moggs Creek, 70% of burnt houses were <90m and 80% were <140m and 95% were <250m from vegetation.

The advisers would have known that real meaning of the Ahern and Chladil chart is that as distance from burnt vegetation increases, more and more burnt houses are counted. It means nothing more than this … For example, say their target area had 1000 destroyed houses, they would have counted 20% (= 200) within 10m of burnt vegetation, 70% (= 700) within 50 m, and 95% (= 950) within 180m.

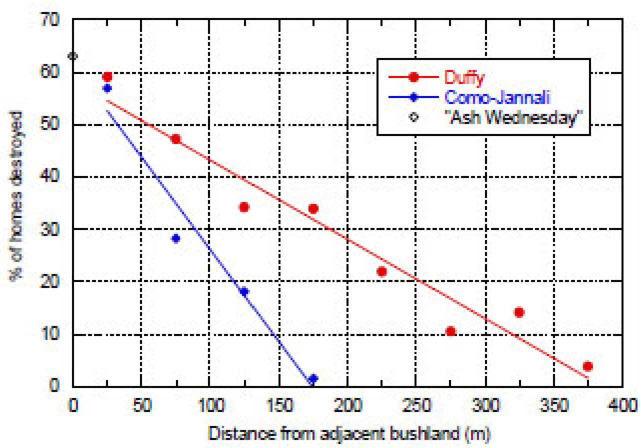
C The Ahern and Chladil hypothesis is that more burnt houses are closer to vegetation, ie, the shorter the distance to vegetation, the higher probability of house loss. The expected chart for this hypothesis would look something the blue line in Fig 2, but their actual results were very different (see pink line in Fig 2). There was a peak in % burnt houses around 20m, but the % fell when houses were closer to vegetation. This means their findings did not support their hypothesis.

Figure 2 Ahern and Chladil re-presented (1)



D The Ahern and Chladil study counted all the burnt houses and measured distance from each house to nearest vegetation to the NW. There were also unburnt houses, but they did not count them nor measure their distances to vegetation. This is critical missing evidence and proves the study is unable to be quoted as a reference for house loss ratio. Instead, other research (available to the VBRC advisers) is needed to demonstrate house loss rate (eg, Fig 3).

Figure 3 House loss rate vs distance from vegetation (Chen and McAneney, 2004)



Secondly, what is the evidence that vegetation is the culprit, or that distance to vegetation was a significant causal factor in house loss? Is the relationship coincidental or causal?

The Ahern and Chladil study does not coherently list the three recognised mechanisms of house loss - radiation, flame contact and ember attack, nor link them to the presence of vegetation. They quote from a Ramsay and McArthur study that houses with dense vegetation close by are at greater risk of destruction from radiation.
They single out trees near houses as a problem, but they quote research that found tree-generated embers travel long distances. They implicate the <u>bush</u>. “The community structures of the houses destroyed in the Otway fires … were all surrounded by bush”

Their study defined vegetation as trees and shrubs. Why trees and shrubs? “The primary source of ignition of many houses in Hobart and Otway ranges is likely to have been from air-borne embers. Grassland burns intensely in bushfires but does not produce much flying debris, which would cause a house fire. Therefore trees and shrubs are more likely to have been the source of ignition.”

They defined vegetation as “presence of trees and shrubs being present before and after the fire”. The study made measurements from black and white aerial photographs at 4,000m height. They did not include dead grass as “vegetation”. Their study chose three major bushfires and measured distance from each burnt house to the nearest vegetation boundary to the North West**.** The Otways and Hobart fires were characterised by a mix of houses amongst bush. They verified their chart against the Como-Jannali fire where the bushfire stopped at the edge of the residential area.

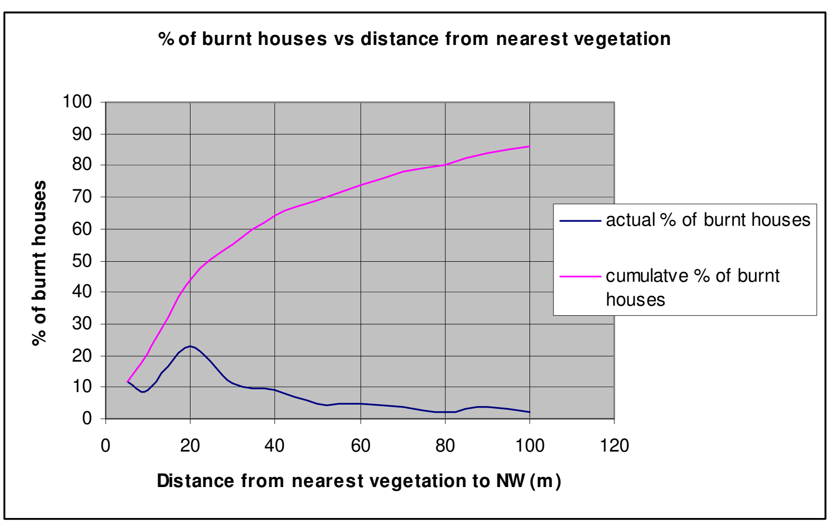
They listed the following limitations of their findings, and clearly, these comments devalue the credibility of using distance from vegetation as an indicator. They also weaken the causal link between nearby vegetation and burnt houses.

- The vegetation data had accuracy problems - it was “subjective and unfortunately not very consistent”.
- They questioned “if ember spotting was the main cause of house fire, how much influence did the vegetation boundary actually have?”
- They questioned if other factors (eg, roof and wall material, attendance, presence of flammable objects nearby, vegetation type) were more influential than distance to nearby vegetation.
- They questioned if the embers that ignited the houses came from closest vegetation or from further away.

Despite these serious reservations, they concluded that their study identified a relationship between houses burnt in bushfires and the distance they stand from a vegetation boundary. They present the model as a cumulative distribution chart (see Fig 1), but the foregoing reservations indicate the relationship is coincidental, not causal.

As a finally observation, their chart is unusual because the independent variable on the x-axis is “% burnt houses”. It would be more appropriate to have distance to vegetation on the x-axis because it is the independent variable (re-presented in Fig 4) in their study.

Fig 4 Ahern and Chladil re-presented (2)

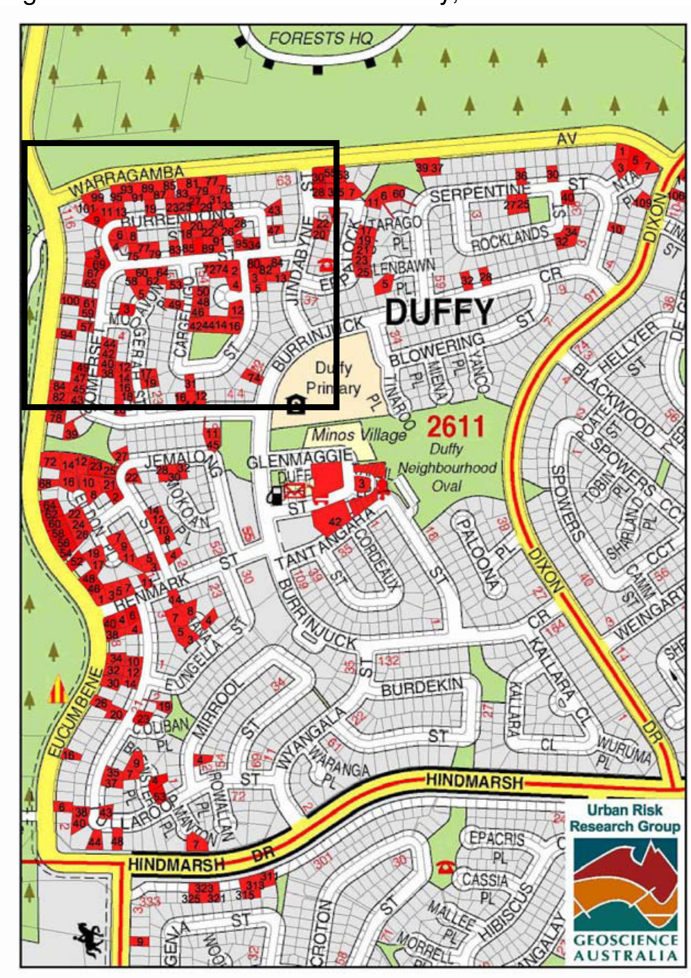


Discussion

Better references were available

The reference used by the VBRC to make this recommendation was an unfortunate choice, not only because it does not support the recommendation, but also because much better references were available that could have led to more logical and relevant findings. For example the following visual example (Fig 5) comes from the Inquiry into the 2003Canberra Fire, which was available to the VBRC advisers. It is outlined here to reinforce the point about better information. The small square insert suffered considerable house loss. There was a dense pine plantation to the north and west of this square and the NW corner of the square was the top of the hill. An important piece of additional information is that these houses were largely not defended. This is a very significant fact because other credible research found that 90% of defended houses in the Ash Wednesday disaster were saved (Wilson and Ferguson, 1984)

Fig 5 House losses at Duffy, Canberra 2003



The following figures are approximate, for the purposes of illustration.
Of the 350 houses within this square, 130 burnt down. The average destruction rate is 35%.
Two types of evidence that destruction rate falls with distance from vegetation can be presented:

A There was 40 - 50m gap (firebreak plus road) between the pine plantation and the first line of houses. Within the next 50m, 50 houses burnt, and 40 were not burnt. This means the destruction rate was 55%. (50 / 90)

Within the next 50m, the destruction rate was 50% (30 / 60)
Within the next 50m, the destruction rate was 35% (20 / 56)
Note: These figures refer to the fate of undefended houses.

B	Within this square, 90 houses occur within 100m of nearest vegetation.
This means:
25% of all houses fall within 100m (= 90 / 350)
38% of burnt houses fall within 100m (= 50 / 130)
18% of unburnt houses fall within 100m (= 40 / 220)
These percentages are significantly different, which is preliminary evidence that house destruction rate is higher when closer to vegetation.
Note: These figures refer to the fate of undefended houses.

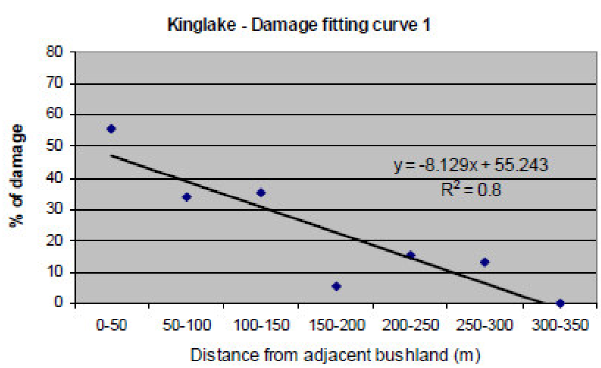
The VBRC advisers would have known that the major culprit in house loss is spotting (Ramsay and McArthur, 1991). They would have known that if a patch of vegetation catches alight on a severe weather day, it can cause short, medium or long distance spotting, depending on abundance of spotting material, which is related to its age, type and structure (Luke and McArthur, 1978).

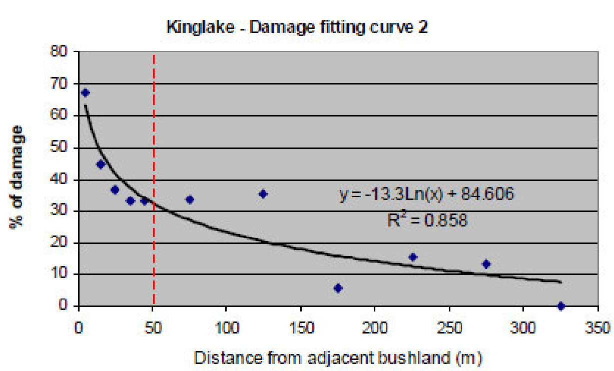
Short distance spotting in a severe bushfire can extend 2 – 500 m downwind of the head fire. If the head fire stops at the boundary of the vegetation, short distance spotting is thrown ahead according to a pattern described by Vesta (2007), ie, highest density (firebrands per sq m) near the firebreak and decreasing exponentially as distance from firebreak increases. This inverse relationship is reflected in the house loss rate pattern at Duffy and Como- Jannali (Fig 3), where the head fire run stopped at the edge of the residential area and hurled embers into the houses.

Where the bushland areas occur within the townships, the head fire runs or jumps inside the town boundaries. This scenario was observed in the Ash Wednesday fires at Macedon, Cockatoo area and the Otways. The bushfire in Marysville township can be classified as houses amongst bushland. In Kinglake, there was a mixture of bushland incursion and firebreak edge effect (observations made by author).

The following data from Kinglake was also available to the advisers of the VBRC.
The pattern is similar to other fires where the house loss rate decreases as distance from vegetation increases.

Figure 6 Kinglake house loss rate (Chen and McAneney 2010)





The above data is presented as the type of evidence that the VBRC should have used to reference its destruction rate conclusion that "**85% of houses were destroyed within 100 metres of vegetation.**" They would also have understood that the 85% figure was outrageously inflated.

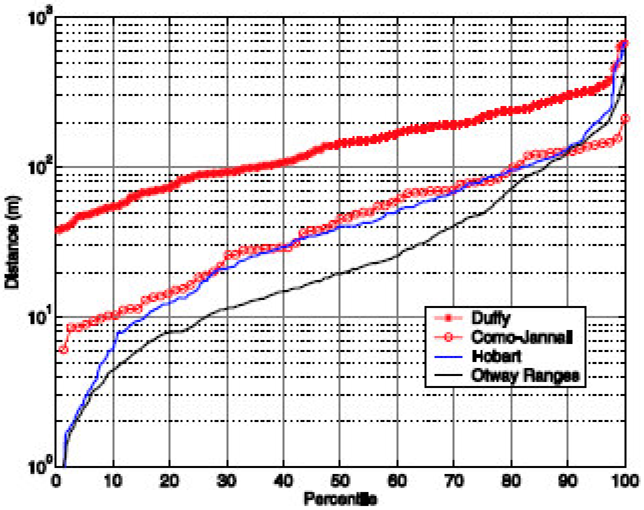
Misquoting continues

Unfortunately, evidence of misquoting continues unabated amongst the scientific fraternity. The paper that provided a useful chart (Fig 3) of house destruction rate (McAneney et al, 2007) included two significant scientific flaws. Firstly, it added a dissimilar data set onto the Ahern and Chladil's chart (Fig 7) and secondly it combined different types of ember attack fires into the one chart

Firstly, the dissimilar data set: The Ahern and Chladil study defined vegetation as "presence of trees and shrubs being present before and after the fire". No minimum area was specified. Chen and McAneney (2004) defined vegetation as a continuous bushland boundary. Their focus was on identifying large areas of continuous bushland, where large fires can run. Their minimum area was 0.5 km^2 (= 50 ha).

Secondly, the dissimilar ember attacks: The Duffy and Como headfires stopped at the edge of the residential area whereas the other areas had bushland amongst the houses that allowed deeper entry of flames.

Figure 7 Chart from McAneney et al (2007)



Despite these flaws, they used this chart (Fig 7) to make predictions of house losses in mega fires. The authors made this quote: Figure 7 "allows us to estimate the numbers of homes destroyed within the first 50 m during so-called mega-fires during the last 50 years as 2500". This estimate is based on 84 houses burnt / year x 50 years = 4200 houses x 60%. Figure 7, they said, shows that 60% of burnt houses occur within 50m of nearby bushland. They could also have said that say 840 (= 20%) burn down within 10m of vegetation, or that 3570 (= 85%) burn within 100m. Whatever way, it is a scientifically invalid estimate, and should not be used in a learned dissertation.

What is the scientifically valid way to use the Ahern and Chladil chart to make predictions?

The Ahern and Chladil (Fig 1) chart means this: In a large bushfire, 85% of destroyed houses will occur within 100m of vegetation (as defined by A & CH). House loss will be probably caused by ember attack. It is not clear if these findings derived from houses that were undefended or defended.

Can this figure be used to predict losses? Eg, If 1000 houses occur within 100m, how many will be lost? According to the VBRC statement, the answer is 850. This is incorrect.

The correct answer = **X**, where x is an unknown number that cannot be determined.
The key question for the fire protection planners and people in bushfire prone areas is this - what determines **X**?

What determines X?

What determines the destruction rate of houses?

- Passive protection measures that manage bushfire behaviour factors such as proximity of building to flame, size of flame and duration of flame.
- Passive protection measures required by statute such as Wildfire Management Overlay (WMO) and building design requirements
- Quality of advice to residents by fire agencies and their degree of reliance on it
- Active protection measures such as is the property defended or not, either by fire fighters or residents.

The VBRC quoted research (submission SUBM.600.001.0001) that found 38% of houses within the burnt area were destroyed in the Black Saturday fires. The total number destroyed was 2131 houses (VBRC), which means therefore a total of 5600 were exposed to the bushfires.

*The effect of bushfire behaviour factors on **X***

The impact of these factors is powerful in affecting the destruction rate of houses. The author has argued elsewhere that fire agencies are using irrelevant and invalid fire behaviour science to shape their policies and guidelines (O'Bryan, 2006), and that they therefore have limited capacity to reduce X significantly. Appendix 1 outlines the relevant bushfire behaviour science and how to use it to reduce X.

*The effect of WMO planning on **X***

The VBRC recognised the WMO as the primary planning tool for managing bushfire risk, but doubted its effectiveness because only 41% of destroyed houses (= 850) were within the WMO area. It was also concerned that the WMO provisions apply only to new houses.

The above research examined 4288 houses and found that 1632 were destroyed (38%). It found that 1412 of the 4288 houses (33%) fell within WMO areas and of these 569 (40%) were destroyed. It found that 51 houses within WMO areas were referred to the CFA, and 6 of these were destroyed (11.7%). The researchers concluded that the WMO permit process caused a significant reduction in house loss 11.7% vs. 40% within WMO areas.

The VBRC found these conclusions encouraging, but noted that they must be treated with some caution because the data did not state whether a house was actively defended or whether it was built according to the latest bushfire construction standards.

Note: Within a WMO, basic requirements such as water supply, access and vegetation management are specified as permit conditions to new house construction and property developments. Compliance with these permit conditions is the responsibility of the owner of the land, but there is no checking process. There is no requirement that an existing building or subdivision need to comply with the requirements set out in a WMO. This is identified as a substantial limitation on the effectiveness of WMOs (Municipal Association of Victoria submission to VBRC).

*The effect of building regulations on **X***

The Building Commission found that 177 of the 2,131 houses destroyed by the Black Saturday fires had been built in accordance with the post 1991 Australian Building Standards in bushfire prone areas. Their data did not state whether the houses fell within a WMO or whether the house was actively defended. If, as is likely, they fell within a WMO, houses built to a bushfire standard were 20% (177 / 850) of all houses destroyed. This is uncomfortably high. Presumably, if building standards were effective as a stand alone defensive factor, very few houses built to a bushfire standard should have been destroyed.

Statistics were not available showing how many were not destroyed because they met the Australian Standard. Unfortunately, the Building Commission was unable to advise the VBRC of any conclusions about the effectiveness of construction standards in preventing house destruction.

*The effect Fire Agency advice on **X***
[Note: The advice of CFA and other fire agencies is very similar]
The VBRC reported that many of the houses and many of the 173 people who died had been trying to defend their home and that a number of these homes had been well prepared in accordance with Country Fire Authority advice. The VBRC, however, did not question the quality or the accountability of CFA advice.

To attempt to determine the influence of CFA advice, the author analysed VRBC evidence on 65 properties where deaths occurred in the Kilmore East and Murrindindi fires. The study found that approx 50 - 60% of properties planned to stay, 20 - 30% planned to leave, 5% planned to leave if the fire was too severe, and on 10 - 20%, the intentions were unknown. Almost all of the plan-to-stay and plan-to-leave group were active in local CFA Project Fireguard groups, and placed great faith in CFA advice.
Almost all the bodies in the plan-to-stay group were found in the rubble of their homes. Most of these properties had useful clearings either on their properties or on adjacent roadways and were equipped with fire equipment. They died within their burning homes, apparently following consistent CFA advice, when these clearings would have allowed their survival. About half of the bodies in the plan-to-leave group and the leave-if-the-fire-was-severe group and the unknown group were found in their homes and the other half were either on the road or at what they were told was a safer house. Almost all of these properties had not been prepared with clearings or equipment.

*The effect of houses being defended or vacant on **X***
The advisers to the VBRC were aware that Wilson and Ferguson (1984) found that a significant factor in house loss is whether they were defended or vacant. If their findings are applied to the 1000 houses (all other variables being equal), the expected outcomes are dramatically different.

- If all 1000 houses are occupied by able-bodied defenders, 10% are destroyed = 100.
- If all 1000 houses are vacant, 70% are destroyed = 700.

It is a remarkable omission that the VBRC was not advised to canvas the impact of the on site defensive strategies vs. evacuation strategies on house destruction rate. This evidence alone would have led them to understand that other factors were much more relevant to house loss than proximity to vegetation.

Conclusion

By misquoting a reference, The VBRC has legitimised an incorrect finding, which may lead to the creation of a mistruth in the field of bushfire protection that is already awash with opinions, myths and mistruths. Furthermore, it has quoted from research that is meaningless for other than academic interest because a causal link was not established between house loss and distance to vegetation. The link is coincidental, not causal. The absurdity of basing a policy recommendation of a coincidental relationship can be illustrated with the following example. Readers may remember a study that found a substantial percentage, eg, 60% of fatalities occur within 10 km of the home. Applying the logic of the VBRC recommendation, the government can achieve huge reduction in road fatalities if it bans driving within 10 km of homes. Clearly, there is no casual link between the home and road fatalities. Yet this fact has escaped the best brains in the land.

By quoting this reference as authoritative, it may have the effect of demonising bushland and promoting the concept that bushland is inherently dangerous. If the reference had included a reference to bushfire behaviour science, it would have explained bushfire behaviour in bushland can be proactively managed for both flame height and spotting potential. This may have led planners and policy makers to the conclusion that bushland is not inherently dangerous.

Finally, by misreading the findings, the advisers may have prevented the VBRC from minimising confusion and also recommending policies that cause unnecessary cost to people. This partly explains why there is confusion about design and location of safer places, and why Marysville oval now fails the safer place test, despite hundreds safely sheltering at the height of the ember attack. It will probably lead to excessive and unnecessary costs in house construction and renovation.

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APPENDIX

How use of relevant bushfire behaviour science reduces the risk of house loss

The three long recognised causes of house loss in a bushfire are flame contact, radiation and ember attack. This brief note illustrates that these three threats can be controlled by managing what the flame does or does not do on or near the house. There are three fire behaviour elements that the resident needs to manage - proximity of flame to building, size of flame and duration of flame.

Flame contact

For flame contact to ignite a house the flame must be licking the house.
The flame can be a moving flame or stationary flame.
What is a moving flame? A flame that runs up to the house or occurs at the house
What is a stationary flame? A flame that occurs next to the house, eg, in a garden bed or on the house, eg, in the gutter or eaves or veranda or window sill.

How close does the flame need to be to ignite the house? If the flame is tall, say 5 m, a strong wind can force it to lie over horizontally for up to 5 m. This is called flame rollover. If the flame is short, say 50 cm tall, a strong wind can force it to lie over horizontally for up to 50 cm. Therefore, if you construct a fuel free gap around the house and make it wider than the flame height, the flame cannot lick the house.

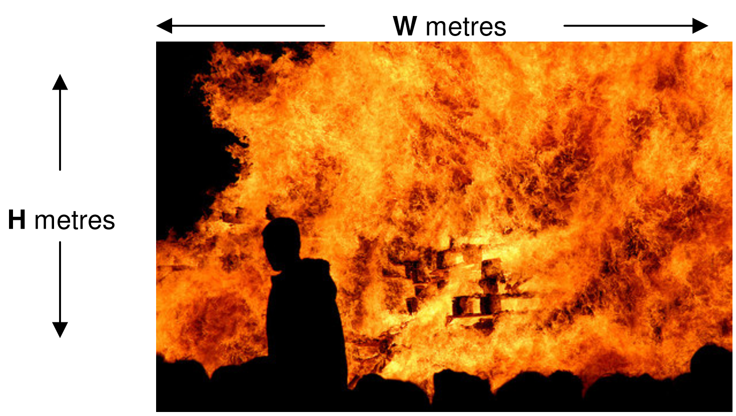
To do this effectively, the resident needs to be able to estimate the flame height next to the house on a severe fire day. The empowering thing for the resident to know is that he / she can manage the flame height next to the house because he / she can manage the fine fuel load in the fuel bed on the ground.

Therefore in summary, the threat of flame contact from the fuel bed near the house can be managed quite simply by the resident by managing flame height or width of the fuel free gap.

Radiation

For radiation to ignite a house, the wall has to receive sufficient incident radiation for a minimum time. This is called auto ignition by radiation. It requires a minimum thermal load = incident radiation x duration
Eg, 50 kW / sq m for 20 sec or 70 kW / sq m for 10 sec

The source of the radiation is the bushfire flame. Imagine the bushfire is a solid wall of flame **H** metres high and **W** metres wide. Assume the resident is planning for a bushfire flame expected on a very severe weather day.



A bushfire in dead grass or dead litter bed in a forest emits radiation from the wall of flame at approx 100 kW / sq m of flame face.
A bushfire in a shrubby fuel emits radiation from a wall of flame at approx 50 kW / sq m of flame face. The radiation is lower because the vegetation is alive, which means it is moist, and moisture reduces emitted radiation levels.

The resident needs to know two things about incident radiation from a wall of flame of width W m. The level of incident radiation on a house wall is proportional to flame height and inversely related to distance from flame. This means that if the flame is made smaller, or if the flame is kept far enough away, the incident radiation on the wall decreases.

The resident also needs to know how the duration of the flame changes with the type of fuel bed or vegetation. The following examples illustrate how flame height and duration vary and how they affect the threat of radiation damage.

1 A short (dead) grass fuel bed burns with a 1 m tall flame height that lasts for 10 sec (called residence time). This means when the grass flame burns up to a fuel free gap, the grass at the edge burns with a 1 m tall flame that emits full flame radiation for around 10 seconds.

How close to the timber wall before it auto-ignites? To ignite, the wall needs 70 kW / sq m incident radiation for 10 sec. Radiation charts confirm that if the flame is closer than 1m, the timber wall will ignite. This means that if the fuel free gap keeps the flame more than 1m away, the wall cannot ignite.

How close can a person approach this flame before their skin experiences radiation damage? If a person's skin is clothed, he / she will suffer unbearable pain if incident radiation exceeds 6 kW / sq m for 10 sec. This will occur if they are closer than 7m to this flame. This means that if the person keeps this flame more than 7m away, he / she will not experience unbearable pain.

2 Similarly, if the grass is taller, the grass at the edge of the gap burns with a 3 m tall flame that emits full flame radiation for around 15 - 20 seconds.

How close to the timber wall before it auto-ignites? To ignite, the wall needs 60 kW / sq m incident radiation for 15 sec. The flame needs to be closer than 2 m. This means that if the fuel free gap keeps the flame more than 2m away, the wall cannot ignite.

For a person with clothed skin, this flame causes unbearable pain if incident radiation exceeds 4.5 kW / sq m for 15 sec. This will occur if they are closer than 15m to this flame. This means that if the person keeps this flame more than 15m away, he / she will not experience unbearable pain.

3 By comparison, consider a shrubby fuel bed with a 5m tall wall of flame that burns with 20 seconds residence time. The wall of flame emits 50 kW / sq m from the flame face.

How close to the timber wall before it auto-ignites? To ignite, the wall needs 50 kW / sq m incident radiation for 20 sec. The flame needs to be closer than 1m. This means that if the fuel free gap keeps the flame more than 1m away, the wall cannot ignite by radiation. This gap is too narrow to prevent ignition of the house by flame contact.

For a person with clothed skin, this flame causes unbearable pain if incident radiation exceeds 4 kW / sq m for 20 sec. This will occur if they are closer than 20m to this flame. This means that if the person keeps this flame more than 20m away, he / she will not experience unbearable pain.

4 Finally, consider the extreme example - a forest flame with a 30m flame height lasting for 5 minutes residence time.

How close to the timber wall before it auto-ignites? To ignite, the wall needs 15 kW / sq m incident radiation for 300 sec. The flame needs to be closer than 50 m. This means that if the fuel free gap keeps the flame more than 50 m away, the wall cannot ignite by radiation.
For a person with clothed skin, this flame causes unbearable pain if incident radiation exceeds 1 kW / sq m for 300 sec. This will occur if they are closer than 70 - 80 m to this flame. This means that if the person keeps this flame more than 70 m away, he / she will not experience unbearable pain.

These examples illustrate how radiation can ignite a timber wall and how a flame in different fuel bed or vegetation types can vary the amount of radiation emitted and its duration. It also illustrates how reducing flame height and increasing the fuel free gap around the house can reduce the amount of incident radiation at the house wall. The resident will also be aware that he / she can manage flame height in the fuel beds near the house and the width of the fuel free gap around the house. The resident is therefore capable of reducing flame height and flame duration or eliminating flame height and duration in whatever area around the house they choose.

Therefore in summary, the threat of radiation from flame in the fuel bed near the house can be managed quite simply by the resident by managing flame duration or flame height or width of the fuel free gap.

Ember attack

Embers can come from short, medium or long distance spotting. It does not matter where they come from, because the resident simply needs to know they will come. The key concern is how to manage the threat of ember attack because they can land on or near the house.

What happens when a live ember lands near the house?
If an ember lands in a flammable fuel bed, it can ignite, grow into a small flame and if allowed to develop, grow into a large flame. When small, the flame is relatively easy to extinguish. If an ember lands in a fuel bed of short dead grass (as above), it will burn with a 1 m tall for 10 seconds residence time.
If it lands in the shrubby fuel bed, it will produce a 5 m flame with a duration of 20 sec.
If an ember lands in a non flammable fuel bed, it will extinguish.
Therefore, the key to managing the threat of ember attack near the house it to manage the flame height and duration in fuel beds so that flame contact and radiation do not cause damage.

What happens when a live ember lands on the house?
If the ember lands on a flammable surface it will ignite, smoulder and flame up. If it grows into a large flame on or near the house, chances are high that it cannot be stopped and the house will burn down.
If it lands in a non flammable surface, it will extinguish.
Therefore, the key to managing the threat of ember attack on the house it to maximise the flammable surfaces, minimise the flammable surfaces and extinguish the small spot fires while small.

How does the resident know if it is safe enough to stay at the house to extinguish the embers that land on the house? The resident has already made sure that the fuel free gap around the house is wide enough to prevent flame contact and radiation-caused ignition on the house. If the resident enlarges the fuel free gap to ensure that incident radiation levels on clothed skin are below the pain thresholds, there will be no danger form either flame contact or radiation around the house. Thus for example, if the adjacent fuel bed is tall grass that will generate a 3m flame on a severe weather day, the fuel free gap has to be a minimum of 15m. If the resident is able to reduce the flame height in this fuel bed to 1m (by managing grass height), the fuel free gap can be a minimum of 7m.

Conclusion

By managing the fuel beds near house to reduce or eliminate the threat from flame contact and radiation, the resident is managing the three critical mechanisms of house loss by bushfire - proximity of flame to the house, size of flame and duration of flame. The source of the flame does not matter. It can be the head fire or the flank fire. It can originate from ember attack. It can be a moving flame or a stationary flame.