Reply

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In our article (Crompton et al. 2010) we normalized bushfire building damage to current societal conditions by multiplying historical loss records by the factor change in total dwelling numbers from when the event occurred to 2008/09. The dwelling number factor was calculated at the state level and we tested the validity of this resolution using two historic case studies: the 1967 Hobart and 1983 Ash Wednesday bushfires. No trend in building damage was found after normalization.

Nicholls (2011) speculates that the absence of an upward trend in normalized building damage may reflect a bias introduced through our use of state level normalization factors and presumed reductions in vulnerability over the time period examined: 1925–2009. Here we explain why the factors that Nicholls states as being unaccounted for either miss the most important points, are uncertain and unquantifiable, or are negligible in extreme impact events such as the 7 February 2009 Black Saturday bushfires. The extreme impact events are critical as these dictate the pattern in normalized building damage.

The first issue raised by Nicholls (2011) is that state level normalization factors do not account for the increasing urbanization of Australia and that this is important because capital city populations are generally far less vulnerable to bushfires than those living in small towns or isolated communities. Our estimate of population distribution change is not as dramatic as that reported by Nicholls: according to the Australian Historical Population Statistics [available from the Australian Bureau of Statistics (ABS) online at http://www.abs. gov.au], the proportions of the population *outside* each of the capital cities of Victoria, New South Wales, and Tasmania in 1958 were 37%, 45%, and 68% and

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equivalent figures for 2007 (the latest year for which data were available) were 27%, 37%, and 58%. If we adopt the ABS classification on urban and rural dwellings (the ABS defines urban areas to be those with 1000 or more people), the change of rate is even less pronounced over a similar timeframe: the proportions of rural dwellings in Victoria, New South Wales, and Tasmania in 1961 were 16%, 15%, and 33%, only slightly decreasing to 11%, 11%, and 29% in 2006 (dwelling data are contained in the census of population and housing and are available from the ABS). Note that these three states of southeast Australia account for over 90% of total normalized building damage.

In focusing on urbanization and the relative vulnerability of cities and areas outside of cities, Nicholls (2011) misses the point-what matters most to our normalization is how the rate of growth of bushfire-prone dwellings compares to that of state level total dwellings. In particular, he overlooks urban encroachment into bushlands on the fringes of many Australian cities (e.g., Fig. 1). Rapid urban encroachment has resulted in an increase in the absolute number of bushfire-prone dwellings in Melbourne (Victoria), Sydney (New South Wales), and Hobart (Tasmania). It also has produced a likely increase in the proportion of bushfire-prone dwellings in some capital cities (e.g., Sydney and Hobart); that is, the rate of growth of bushfire-prone dwellings exceeds that of total dwellings in some capital cities. While it is not possible to quantify this or the number of bushfire-prone dwellings at any resolution throughout our period of study, if this has occurred, then the rate of growth of bushfire-prone dwellings in some capital cities must have also exceeded that of respective state level total dwellings.

We should also note that there is evidence to suggest that for some areas outside of capital cities, the rate of growth of bushfire-prone dwellings has been similar to and, if anything, larger than the contemporaneous

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FIG. 1. Aerial view of northern Sydney showing the highly dissected and complex interface (red line) between bushland (dark green) and urban areas.

growth in statewide total dwellings. This evidence includes the 1983 Ash Wednesday fires case study shown in Table 2 of our original article and two of the most severely affected locations (Kinglake and Marysville) in the 2009 Black Saturday fires (Table 1). There is further evidence in those areas impacted by the 1967 Hobart fires outside of Hobart.

So what is the significance of this discussion?

Where rates of bushfire-prone dwelling growth exceed that of total dwellings across the state, then this will have the opposite effect to that suggested by Nicholls (2011): historic events should have a larger normalization factor applied to them, which would in turn tend to make the trend in normalized damage negative. In other words, if anything, our normalization using state total dwellings is likely conservative.

Nicholls (2011) refers to several factors that may have led to a reduction in building vulnerability to bushfire over time. He also suggests bushfire risk reduction measures undertaken by property owners to be a recent phenomenon. However, preparing a property and active defense to save lives and livelihoods has been a necessity for generations of rural Australians. The "stay and defend, or leave early" policy may have become official Australian Fire Authority Commission policy in 2005, but it has been implemented as a survival strategy in rural areas and country towns since European settlement (Handmer and Tibbits 2005). An examination of many eyewitness accounts of Australian bushfire preparation and survival demonstrates that little has changed over 100 years (Haynes et al. 2010).

Nicholls (2011) further argues that changes in building or planning regulations and autonomous actions by householders (in response to official enquiries into past major bushfire disasters or otherwise) would have led to a decline in damage. While many lessons have been learned from past experience, it is unlikely that any changes implemented would have prevented the impacts of the most extremely damaging bushfires. The most important lesson that should have been learned

TABLE 1. The factor change in dwellings at 10-yr intervals relative to the 2008 bushfire year. The underlying data are from the census of population and housing in the stated years (available from the ABS).

Year	Dwelling factor		
	Victoria	Kinglake UCL	Marysville UCL
1966	2.3	Not available	2.1
1976	1.7	Not available	2.3
1986	1.4	3.5	1.4
1996	1.2	2.6	1.1

from past experience is simply to avoid development in high risk areas. In their analysis of bushfire risk at Melbourne's urban fringe, Buxton et al. (2011) argue that vulnerability has increased because of the failure of land use planning regulations. We agree with this assessment.

An analysis of each of the major bushfires over the past five decades (including the 1967 Hobart fires, the 1983 Ash Wednesday fires, the 1994 Sydney fires, and the 2009 Black Saturday fires) shows that Australia has a history of development in high risk areas. About 80%-90% of destroyed buildings in major bushfires have been consistently located within 100 m of nearby bushland (Chen and McAneney 2004; Crompton et al. 2010). In our analysis of the Black Saturday fires (Crompton et al. 2010), we reported the large proportion of buildings destroyed in Kinglake and Marysville that were located either within bushland or at very small distances from it (<10 m). Our observations suggest that in the early part of last century, lives were lost and homes destroyed where people were living and working in the bush, often in logging camps; more recently, people have chosen to live in bushland for lifestyle reasons (Haynes et al. 2010).

In his mention of changing regulations, Nicholls (2011) does not consider factors that may have *increased* vulnerability over time. A number of lay witnesses who appeared at the 2009 Victorian Bushfires Royal Commission cited stringent and complicated regulations, which *inter alia* restricted the clearing of vegetation around properties, as key factors that increased the vulnerability of their homes to bushfires. Since vulnerability is largely a function of distance from the bushland interface (Chen and McAneney 2004; Crompton et al. 2010), the large proportion of buildings destroyed within bushlands in the Black Saturday fires suggests that building vulnerability has not decreased.

Another possible source of reduced vulnerability cited by Nicholls (2011) was improved emergency preparations and response, such as better firefighting equipment and management. As stated already, the urban fringe in Australia is growing rapidly. While there is a danger in generalizing and we acknowledge that communities are far from homogeneous, many of those residing on the urban–bushland interface have very limited experience and knowledge of bushfires. As demonstrated in 2003 in Canberra and again in 2009 in Bendigo, Horsham, and Narre Warren (Whittaker et al. 2009), many whose homes were destroyed were unaware that they were at *any* risk from bushfires.

What has become clear over the last decade or two is that many bushfires cannot be fully controlled through prescribed burning, clearing, or suppression. Fire services have become increasingly overwhelmed, resulting in a shift of responsibility back onto individuals to prepare their homes and protect themselves. Communities in Victoria are regularly and explicitly told by the Country Fire Authority not to expect an official warning or assistance during a bushfire. While there has been significant emphasis on community self-reliance over the last decade, getting individuals to actually prepare properties, make a bushfire plan, and stick to it has proved challenging (Tibbits and Whittaker 2007; Haynes et al. 2010).

We do not question that improved emergency management has led to a reduction in the lives and property lost in numerous smaller bushfires, as we believe this to be the case. However, in large catastrophic fires such as Black Saturday, firefighting and emergency services have limited capacity to reduce fatalities and property losses. Under the extreme weather conditions prevailing during most of the major loss events that dominate the time history of building damage (see Fig. 1 of our original article), there is little fire services can do to control the spread of fire and protect individual properties.

The final issue raised by Nicholls (2011) is that improvements in weather forecasts over several decades may have reduced vulnerability. This is highly speculative and there is little evidence from anywhere that weather forecasts materially influence property damage from extreme events, even if they do save lives. The weather conditions on Black Saturday were very well forecast and accurate warnings were issued to emergency responders, politicians, and the public prior to February 7. What Black Saturday clearly demonstrated is the reverse: that despite accurate weather forecasts and significant emergency/bushfire planning and response, there is always the potential for large-scale life and property loss.

Providing warnings is only one step in a very complicated chain. The difficulty is achieving adequate preparedness and risk reduction among the community so that people can respond effectively when warnings are given. Survivors of the Black Saturday fires (Whittaker et al. 2009) had a high level of awareness that this was a day of Total Fire Ban (99% of survey respondents). However, the events of Black Saturday suggest little connection between such awareness and individuals taking appropriate actions.

We would like to make it explicitly clear that neither in our original article nor in our discussion here do we dispute that anthropogenic climate change is occurring; rather, we show, as others have also done for other perils in other jurisdictions (Bouwer 2011), that societal changes can explain the increasing trend in Australian bushfire damage.

Our result—that there is no discernable evidence that normalized building damage is being influenced by climate change due to the emission of greenhouse gasesis not surprising, when you consider that bushfire damage is not solely a function of bushfire weather; far from it, in fact. Even given a gradual aggravation of bushfire weather due to anthropogenic climate change or other factors, a bushfire still has to be ignited. Once ignited, a bushfire then has to traverse the landscape and impact a populated area, where outcomes in terms of damage will be a function of the spatial disposition of dwellings with respect to the fire front, and especially distance of properties from the bushland boundary (McAneney et al. 2009). These factors all contribute a large degree of stochasticity to eventual event loss outcomes.

The Nicholls (2011) speculations are worthy of discussion but no evidence is presented to support these contentions. Moreover, the evidence that we are aware of and have presented here in relation to a potential bias in our normalization methodology and to the possible sources of reduced vulnerability does not undermine our findings in any way. Our conclusion holds up well without Nicholls' proposed caveat. Generally speaking, if others are able to improve upon our normalization methodology, then we encourage them to do so.

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