

Urban edge effects in the Blue Mountains, New South Wales: implications for design of buffers to protect significant habitats

PETER SMITH and JUDY SMITH

Urban edge effects can have an adverse impact on native flora and fauna in the adjoining bushland. We surveyed edge effects at sites in the Blue Mountains where the urban area is separated from bushland by a perimeter road. Common edge effects included weed invasion, physical disturbance of the vegetation and soil, incidental rubbish, dumped rubbish, dumped plant material, tree felling/lopping/ringbarking and visits from domestic dogs. Uncommon edge effects included recent hazard reduction burns, bushrock collection, and poor tree health (dieback not associated with fires). The maximum extent of obvious edge effects (all types combined) varied between sites, from 9 m to 60 m from the edge of the road. At most sites (77%), edge effects were restricted to distances of 40 m or less into the bushland, but a significant number of sites (23%) had more extensive edge effects. Sites with extensive weed invasion were associated with older housing, suggesting that weed invasion will increase over time at sites adjacent to younger housing. Weed invasion frequently extended further than 60 m into the bushland along drainage lines and tracks, especially the former, but these were not included in the measurements. Edge effects were more extensive on flatter topography than downslope of housing, apparently because the former is subject to more intensive use by local residents. The actions of local residents have a major influence on edge effects, and are responsible for much of the variability observed between sites. The findings of this study are consistent with previous studies of edge effects around Sydney and elsewhere. Based on the results of the study, we recommend that a buffer of native vegetation at least 60 m wide should be retained around significant flora and fauna habitats to protect them from edge effects. Additional management actions are required to control vegetation degradation along drainage lines.

Key words: Urban edge effects, Buffers, Urban bushland, Significant habitats, Weeds.

INTRODUCTION

NATIVE forest and woodland vegetation (bushland) bordering urban areas is subject to edge effects that can have an adverse impact on the composition and condition of the vegetation. A major example is invasion and degradation of the bushland by exotic weeds (Kirkpatrick 1974; Hester and Hobbs 1992; Fox *et al.* 1997; King and Buckney 2002). Increased physical disturbance of the bushland from human activities on urban fringes (Matlack 1993a), and increased soil nutrient levels from urban runoff (Lambert and Turner 1987; Leishman 1990), provide conditions favourable to weed invasion, with soil nutrient enrichment a particularly important factor on the infertile sandstone soils of Sydney and the Blue Mountains (Leishman *et al.* 2004; Lake and Leishman 2004; Leishman and Thomson 2005). Gardens, lawns and weedy areas adjacent to the bushland provide a source of weed species.

Other edge effects may involve changes in the microclimate on bushland edges adjacent to cleared areas. During the day, the edges typically have higher air temperatures, higher solar radiation, higher wind speeds and lower humidity than the interior of the bushland (Matlack 1993b; Chen *et al.* 1995; Davies-Colley *et al.* 2000; Gelhausen *et al.* 2000; Heithecker and Halpern 2007). At night, by contrast, the edges have lower air temperatures than the

interior (Chen *et al.* 1995). Changes in plant species composition and community structure occur in response to the changes in microclimate (Fraver 1994; Young and Mitchell 1994; Gehlhausen *et al.* 2000). Tree mortality may increase as a result of increased exposure on bushland edges (Williams-Linera 1990; Chen *et al.* 1992).

Changes in plant species composition and community structure may also result from changes in the fire regime (increased fire frequency, reduced fire intensity and a change in fire season from the hotter to the cooler months) due to regular burning of the bushland edges to reduce fire hazard (Benson 1985, Clark 1988, Keith 1996). The overall impact of edge effects on Australian urban bushland can be dramatic (Kirkpatrick 1974, 1975; Clements 1983).

Native fauna are also subject to urban edge effects. Examples are: declining species diversity in urban bushland (Tait *et al.* 2005; Chace and Walsh 2006; Garden *et al.* 2006); invasion or increasing abundance of some species, both native and introduced (Jones 1981; Catterall 2004); predation and disease transmission from domestic cats and dogs (Smith and Smith 1990; Potter 1991; Dickman 1996); increased fauna mortality from collisions with vehicles (Smith and Smith 1990; Harris *et al.* 2008); heavy metal pollution from urban traffic (Quarles *et al.* 1974;

Ieradi *et al.* 1996); and increased predation of bird nests near forest edges (Burkey 1993; Paton 1994; Marini *et al.* 1995).

In the Blue Mountains Local Government Area, west of Sydney, a number of significant flora and fauna habitats have been identified (Smith and Smith 1995, 1998) and have been afforded protection in local environmental plans (Blue Mountains City Council 2005, 2006). Rarity in the Blue Mountains was the primary criterion used to identify significant habitats, but also representation in reserves, threats to survival, importance to significant flora and fauna species, importance in ecosystem processes, and diversity and distinctiveness of the associated flora and fauna. Most of the habitats identified correspond to particular vegetation communities, including threatened ecological communities recognized under state or national legislation, but also other communities of local conservation significance. Long-term conservation of these habitats requires exclusion of development not only from the habitats themselves, but also from a surrounding buffer of less significant native vegetation. The buffer will be affected by edge effects and can be expected to degrade over time, but if it is sufficiently wide it will prevent or minimize edge effects on the habitat that it protects.

In order to determine how wide such buffers need to be if they are to be effective, we measured edge effects in the Blue Mountains. The study was restricted to sites where the urban area was separated from the bushland by a perimeter road, since this will be the standard layout of future urban development. The study was also restricted to sites in eucalypt forest and woodland, since this will be the type of vegetation in the proposed buffers. Impacts along drainage lines were not included in the study, since these pose different planning and management problems.

METHODS

Edge effects were examined at 50 survey sites between Glenbrook and Mount Victoria, including sites at Winmalee and Hawkesbury Heights (Figure 1). The sites were selected from vegetation maps of the Blue Mountains townships (Smith and Smith 1995). All sites supported eucalypt forest or woodland on Triassic sandstone (sites 1–29 on Hawkesbury Sandstone, and sites 30–50 on Narrabeen Group sandstone), and were separated from the urban area by a perimeter road. They encompassed a range of altitudes, topographies, aspects, vegetation communities, housing ages and types of road (Appendix).

Because of the requirement for a perimeter road, the number of potential survey sites was

limited and little choice was involved in their selection. Twenty-five sites were at lower altitudes in the eastern Blue Mountains (Glenbrook to Woodford, 200–600 m, sites 1–25), and 25 sites were at higher altitudes in the western Blue Mountains (Hazelbrook to Mount Victoria, 600–1000 m, sites 26–50). Each site consisted of 50–200 m of sealed or unsealed road, with eucalypt forest or woodland on one side and housing on the other, except for one site (11) that was in an industrial area. At only one site (24) was there a fence restricting access to the bushland.

The 50 sites were surveyed between 18 November and 11 December 1997. At each site we listed all obvious edge effects in the bushland adjacent to the road. We measured the maximum extent (distance from the road edge) of the edge effects (all forms combined), and the maximum extent of weed invasion. “Weed” refers here to all plant species not native to the Blue Mountains. Odd, isolated weeds well beyond the main area of weed invasion were not included in the measurements, since these could give a misleading impression of a continuous zone of weed invasion. This occurred only at three sites (2, 46 and 47).

Edge effects extending from the road into bushland along drainage lines or tracks were not included in the measurements. However, we noted if drainage lines and tracks were present at each site, and if weeds extended further from the road along the drainage line or track than the measured distances at other parts of the site.

To investigate possible influences on the extent of edge effects, comparisons were made between different road ages, housing ages, topographies and types of road. Air photos were examined to determine the age of the housing and the age of the road (which often preceded the houses by many years). Photos were available for various dates between 1931 and 1995, but not for all areas at all dates. Sites were grouped into classes (Appendix) and differences between the classes in extent of combined edge effects and extent of weed invasion were examined by analysis of variance. When a significant difference was found, differences between individual classes were tested by the least significant difference method. Before analysis, tests were carried out to determine whether the data were normally distributed (Kolmogorov-Smirnov test) and whether the classes had equal variances (Bartlett test). In the single instance where the variances were not homogenous (extent of combined edge effects for different road ages), the differences between the classes were examined by the non-parametric Kruskal-Wallis test. The analyses were carried out using the WinSTAT statistics package (R. Fitch Software, Bad Krozingen, Germany).

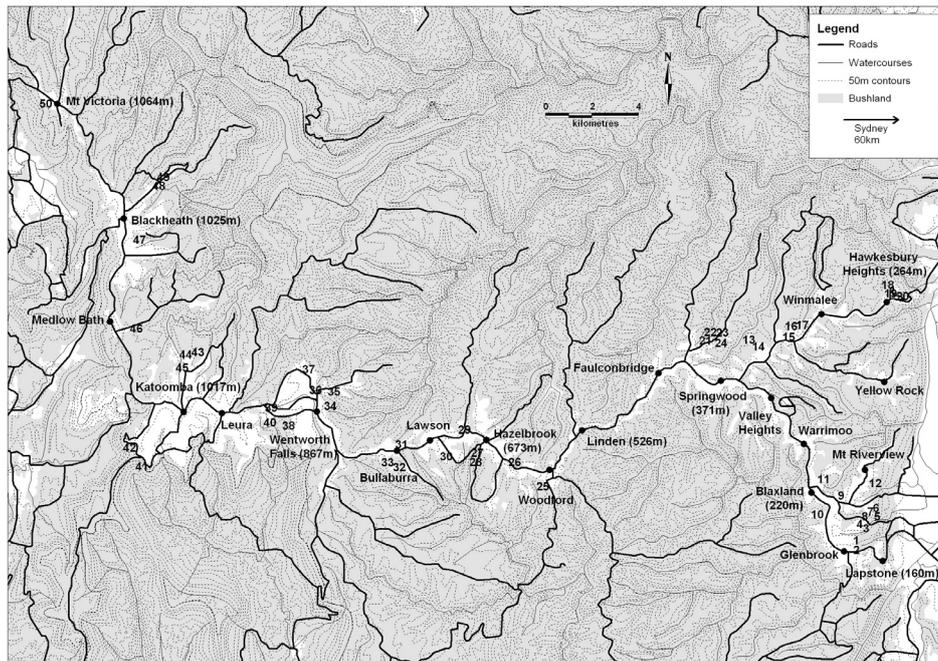


Fig. 1. Location of survey sites 1 to 50 in the Blue Mountains, New South Wales

Three sites (5, 6 and 43) had been subject to hazard reduction burns within the preceding few months and could not be effectively surveyed for other types of disturbance. These sites have been used to indicate the extent of recent hazard reduction burning (i.e., the proportion of survey sites that had been recently burnt), but otherwise have been excluded from the analyses, which are thus based on 47 survey sites.

RESULTS

Edge effects were obvious at all 50 survey sites. Various edge effects were observed (Table 1, Appendix). The bushland at all sites had been invaded by weeds. The most common weeds observed were *Kikuyu Pennisetum clandestinum*, *Coreopsis Coreopsis lanceolata*, African Lovegrass *Eragrostis curvula*, Whisky Grass *Andropogon virginicus* and Catsear *Hypochaeris radicata* in the lower Blue Mountains; and Catsear, *Coreopsis*, Scotch Broom *Cytisus scoparius*, Japanese Honey-suckle *Lonicera japonica*, Prairie Grass *Bromus catharticus*, Lamb's Tongues *Plantago lanceolata*, Montbretia *Crocsmia X crocosmiflora*, Blackberry *Rubus fruticosus* spp. agg. and Yorkshire Fog *Holcus lanatus* in the upper Blue Mountains.

Other common edge effects included physical disturbance of the vegetation and soil, rubbish dumping, incidental rubbish (not deliberately dumped) and dumping of plant material. Tree felling, lopping or ringbarking had occurred at most sites in the distant past, and more recently at more than a third of the sites. Domestic dogs had visited most sites (droppings evident).

Tree health was generally good, with only two sites where there were trees that were obviously in decline, with large dead or dying branches that were not a result of fire damage (trees with dead branches as a result of past fires, but otherwise healthy, are a common feature in the Blue Mountains and were not included in the measurements). Bushrock collecting was evident at only three sites, but may have gone undetected at other sites.

The maximum extent of obvious edge effects (all types combined) varied between sites, from 9 m to 60 m from the edge of the road. The maximum extent was 40 m or less in 77% of sites, while 23% had more extensive edge effects, including 11% with edge effects extending to 52–60 m (Figure 2). The maximum extent of weed invasion ranged from 4 m to 60 m (not including odd, isolated weeds well beyond the main area of weed invasion at sites 2, 46 and 47). The maximum extent was 30 m or less in 81% of sites, while 19% had more extensive weed invasion, including 6% with weed invasion extending to 55–60 m (Figure 3).

Drainage lines were present at 29 (62%) of the 47 sites. At 28 of these (97%), weeds extended further from the road along the drainage lines than the measured distances away from the drainage lines. Tracks were present at 30 (64%) of the 47 sites. At 9 of these (30%), weeds extended further from the road along the tracks than away from the tracks.

Comparisons were made between sites of different road ages (Figure 4), housing ages

Table 1. Edge effects observed at urban/bushland boundaries with perimeter roads in the Blue Mountains. The hazard reduction figure is based on all 50 survey sites; other figures are based on the 47 sites that had not been recently burnt.

Edge effect	Prevalence (% of sites)
Weed invasion	100
Poor tree health (non-fire-related dieback of large branches)	4
Physical disturbance of the vegetation and soil:	100
roadside footpaths/verges	68
retaining walls associated with road	15
sewers	2
vehicle tracks	23
walking tracks	81
BMX bike courses	4
children's cubby/tree houses	15
fireplaces	6
other	26
Tree felling/lopping/ringbarking:	79
recent	36
old	72
Bushrock collecting	6
Hazard reduction burn in last few months	6
Visited by domestic animals (droppings present):	81
dogs	79
horses	2
Dumping of plant material:	96
garden prunings	87
lawn clippings	49
logs/stumps	60
Dumping of rubbish:	98
building rubbish	83
household rubbish	79
oil	6
rubbish from on-site recreation	19
Incidental rubbish	100

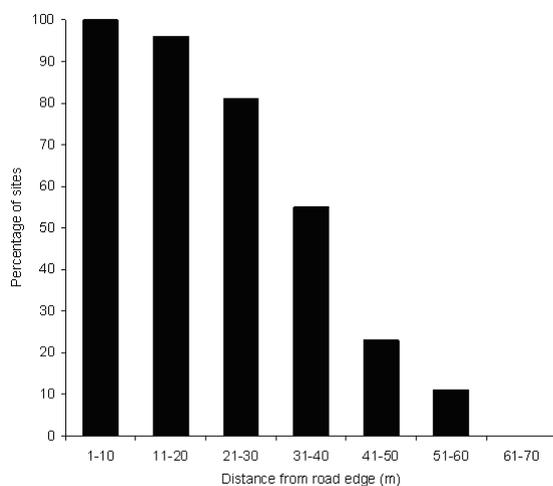


Fig. 2. Extent of obvious edge effects (47 sites)

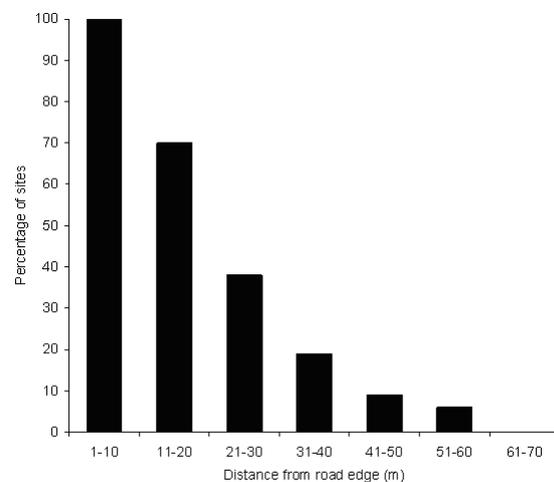


Fig. 3. Extent of weed invasion (47 sites)

(Figure 5), topographies (Figure 6), and types of road (Figure 7), considering both the maximum extent of all obvious edge effects, and the maximum extent of weed invasion alone. The extent of weed invasion varied significantly ($p = 0.03$) with the age of the housing, being greatest on average at sites where there had been houses for over 31 years. In particular, all sites where the extent of weed invasion exceeded 37 m were ones with older housing (Figure 5b). The extent of obvious edge effects varied significantly ($p = 0.03$) with topography, being greater on average at sites where the bushland

was on a similar level to the housing, rather than downslope (Figure 6a). No other statistically significant differences were found.

DISCUSSION

The results of the study show a high but variable level of disturbance of urban bushland interfaces in the Blue Mountains. Degradation of native bushland by weed invasion is a particular concern. Previous studies in sandstone bushland around Sydney have reported a similar concentration of weeds within 30 m of the

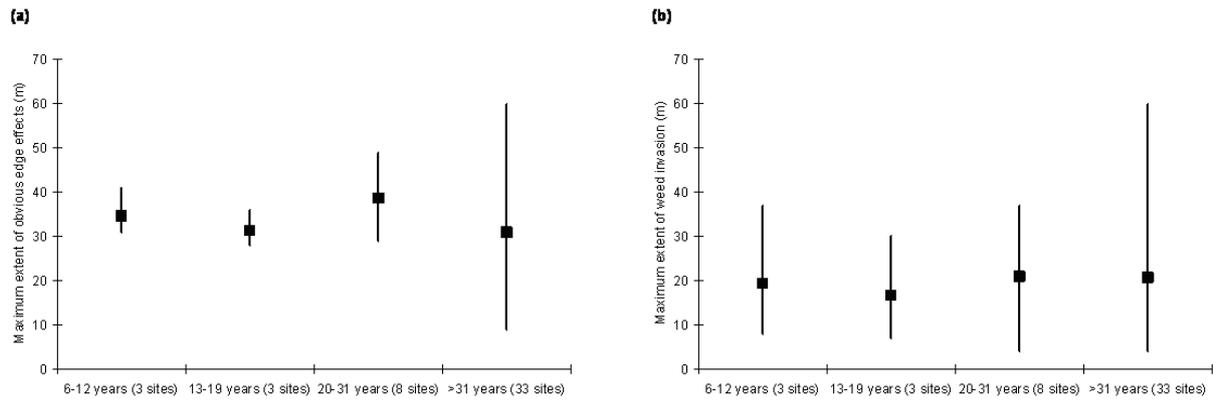


Fig. 4. Extent of obvious edge effects (a) and extent of weed invasion (b) for different road ages (highest, lowest and mean values)

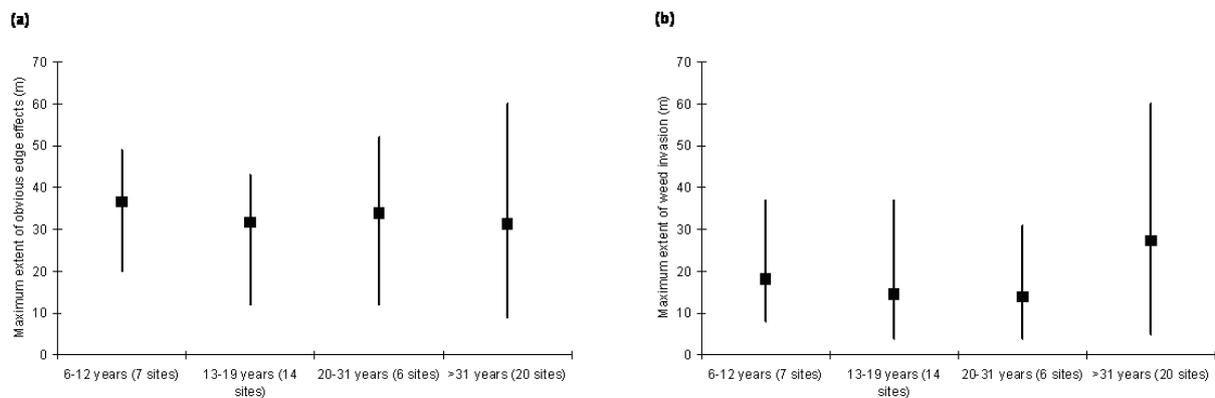


Fig. 5. Extent of obvious edge effects (a) and extent of weed invasion (b) for different housing ages (highest, lowest and mean values)

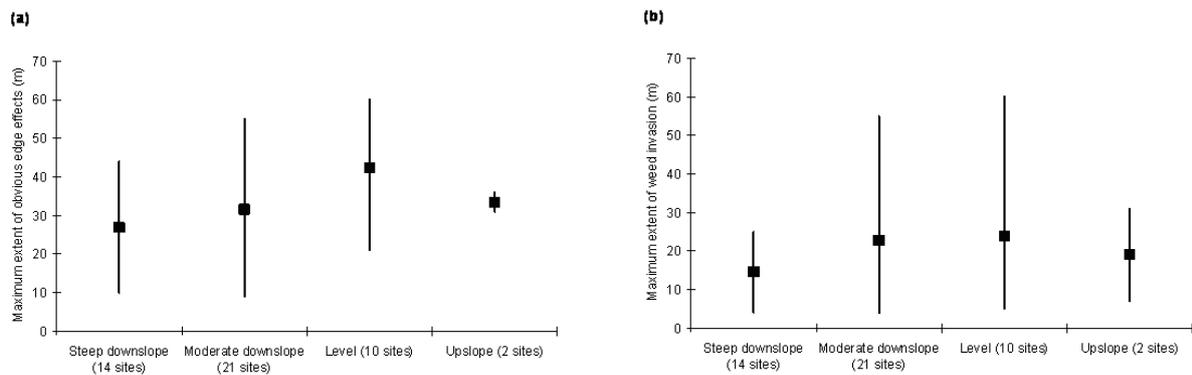


Fig. 6. Extent of obvious edge effects (a) and extent of weed invasion (b) for different topographic relationships of bushland to housing (highest, lowest and mean values), the steep slopes being over 20%.

suburban edge, but have recorded weed invasion extending much further than 60 m (Rose and Fairweather 1997; Dostal 2000). The most extensive weed invasion in the Blue Mountains occurred adjacent to housing that was over 31 years old, suggesting that weed invasion will increase over time adjacent to younger housing. A similar pattern of greater abundance, diversity and extent of weeds on bushland edges adjacent to older suburbs has been reported by both Rose and Fairweather (1997) and Dostal (2000).

Edge effects other than weed invasion have received little attention in previous studies around Sydney. However, on forest edges in the eastern United States, Matlack (1993a) recorded a similar concentration of human-generated damage (such as dumped rubbish, dumped plant material, hacked trees, firewood gathering, treehouses and cubby houses) within 30 m of the forest edge, although some impacts extended much further, and 5% of all records were more than 82 m from the edge.

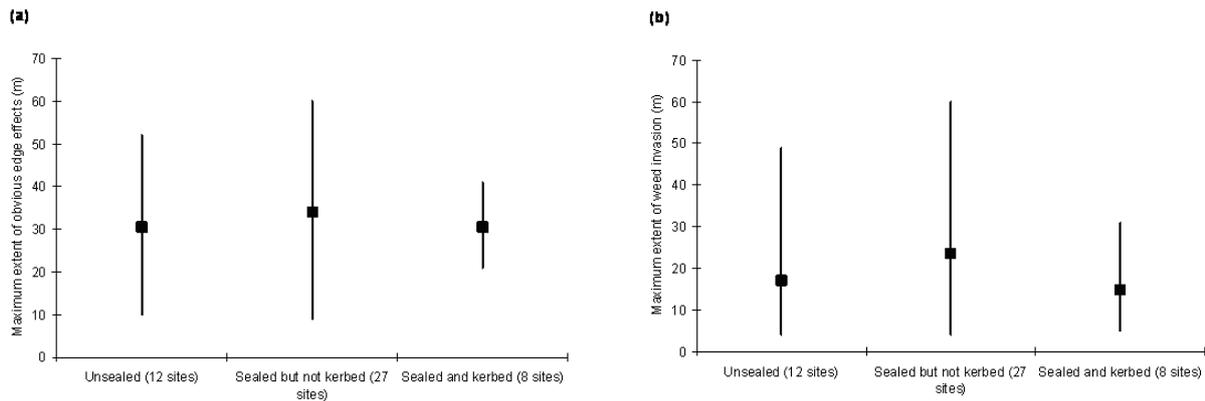


Fig. 7. Extent of obvious edge effects (a) and extent of weed invasion (b) for different types of road (highest, lowest and mean values).

Less obvious edge effects, not considered in the present study, include changes in native plant species composition, changes in microclimate, and increased predation on fauna species. Rose and Fairweather (1997) reported lower native species diversity over a distance of at least 120 m in sandstone bushland on urban edges in northern Sydney when compared with non-urban bushland, with the most pronounced change within 30 m of the bushland edge. Matlack (1993b) reported altered microclimatic variables on forest edges in the eastern United States, in some cases affecting the forest microenvironment up to 50 m from the edge. Young and Mitchell (1994) and Davies-Colley *et al.* (2000), in New Zealand forests, also found that gross microclimatic edge effects penetrated approximately 50 m. Chen *et al.* (1995), however, reported microclimatic edge effects extending from 30 m to over 240 m into forests in the north-western United States. Paton (1994) reviewed the evidence for increased predation and parasitism of bird nests near habitat edges, finding that the most conclusive studies suggest that these adverse impacts usually occur within 50 m of an edge.

The actions of local residents influence the extent of edge effects, and are a major factor in the variability observed between sites in the Blue Mountains. Some residents have a positive impact through activities such as weeding, bush regeneration and rubbish removal. Negative impacts, however, are more typical. Dumping of rubbish and of garden prunings and lawn clippings was evident at most sites. Large piles of plant material were observed frequently and contributed to weed invasion of the bushland. Trees had been felled, lopped or ringbarked at most sites, for firewood, timber, enhancement of views or vandalism. There is an obvious need for greater community awareness of the value of urban bushland, so that it is treated as a valuable resource, not as a rubbish tip.

It might be expected that sites downslope of housing would be weedier than sites upslope or

on a similar level, since soil nutrient enrichment from urban runoff is a major cause of weed invasion in sandstone bushland and has a greater effect downslope of urban areas (Leishman 1990; Leishman *et al.* 2004; King and Buckney 2002). However, edge effects were found to be significantly more extensive in bushland at a similar level to the adjacent housing compared to bushland downslope. It appears that sites on flatter topography are subject to greater use and disturbance by local residents because they are more easily accessible than downslope sites, which tend to be steeply sloping, rocky and densely vegetated. Urban development in the Blue Mountains is concentrated along the ridgetops, so that bushland upslope of development is rare. Only two of our survey sites were upslope ones, but it is noteworthy that weed invasion at one of these sites extended 31 m into the bush, indicating that upslope sites are not necessarily less weedy than downslope ones.

Based on the results of the study, we recommend that a buffer of native vegetation at least 60 m wide should be retained around significant habitats, and that this buffer width should be the same whether the vegetation is downslope, upslope or across slope from urban development. The buffer should consist entirely of native vegetation. A cleared area is not a substitute for a buffer of native vegetation, since it will have microclimatic and other edge effects on the adjoining bushland. Nor is a garden an effective buffer, being a source of nutrient enrichment and weed invasion of the adjoining bushland (Leishman 1990; Randall and Kessal 2004).

The buffer will bear the brunt of the adverse impacts associated with proximity to urban development. Vegetation within the buffer can be expected to degrade, but provided the buffer is wide enough, there should be no degradation of the significant habitat being protected. The effectiveness of the buffer could be enhanced by

fencing, weed control and other measures, but the intention is to provide protection for the significant habitat without the need for continuous active management. Other measures in addition to buffers are needed to control the more extensive vegetation degradation that occurs along drainage lines.

An alternative, often promoted in development applications, is to allow development right to the edge of the significant habitat, or with only a narrow buffer, and to manage edge effects through fencing and a weed control program. This is a poor option. Without an effective buffer, the significant habitat will be subject to continual degradation from invading weeds. The weed control programme would need to be sustained in perpetuity, and this cannot be guaranteed. In any case, fencing and weed control only mitigate some edge effects. The impacts of microclimatic changes and increased nest predation, for example, are not addressed. It is far better to prevent edge effects in significant habitats by retaining adequate buffers, rather than allowing edge effects to occur and then trying to control their impact by perpetual active management of the habitat.

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