APPENDIX 1

Site details including precise locality and altitude for 47 streams sampled between Townsville and Cooktown. P = primary, S = secondary (see methods).

Site number	Location	Longitude and Latitude	Altitude (m)	
1	Mt Spec	146° 10′, 18° 59′	800	P
2	Broadwater Creek	145° 57′, 18° 24′	100	S
3	Kirrama	145° 48′, 18° 13′	720	P
4	Kirrama	145° 51′, 18° 12′	320	S
5	Kirrama	145° 46′, 18° 12′	600	S
6	Tully Valley	145° 38′, 17° 46′	100	P
7	Tully Valley	145° 41′, 17° 48′	60	S
8	Tully Valley	145° 41′ 30″ 17° 48′ 30″	60	S
9	Lacey Creek	146° 04′, 17° 51′	40	P
10	Mulgrave	145° 46′ 30″, 17° 14′ 30″	80	P
11	Mulgrave	145° 46′ 30″, 17° 14′ 30″	80	S
12	Palmerston	145° 46′, 17° 35′	380	P
13	Palmerston	145° 45′, 17° 35′	360	S
14	Bellenden Ker	145° 51′, 17° 16′	1557	P
15	Majuba Creek	145° 51′, 17° 26′	280	S
16	Charmillon Creek	145° 31′, 17° 42′	940	P
17	Danbulla	145° 35′, 17° 06′	940	P
18	Danbulla	145° 38′, 17° 07′	660	P
19	Crystal Cascades	145° 41′, 16° 58′	80	P
20	Crater	145° 29′, 17° 26′	940	P
21	Crater	145° 29′, 17° 26′	960	S
22	Crater	145° 29′, 17° 26′	960	S
23	Crater	145° 29′, 17° 26′	940	S
24	Bobbin Bobbin	145° 46′, 17° 23′	720	P
25	Massey Creek	145° 33′, 17° 37′	1000	S
26	Wright Creek	145° 38′, 17° 17′	740	S
27	Topaz	145° 41′, 17° 25′	640	S
28	Topaz	145° 41′, 17° 25′	660	S
29	Topaz	145° 43′, 17° 23′	820	S
30	Mt Father Clancy	145° 37′, 17° 36′	760	S
31	Mossman Gorge	145° 19′ 30″, 16° 28′ 30″	100	P
32	Mt Lewis (Carbine Tableland)	145° 16′, 16° 34′	900	P
33	Mt Lewis	145° 17′, 16° 32′	980	S
34	Mt Lewis	145° 16′, 16° 31′	1080	S
35	Windsor Tableland	145° 02′, 16° 16′	1080	P
36	Windsor Tableland	145°, 03′, 16° 16′	1080	S
37	Cape Tribulation	145°, 03′, 16° 16′	40	P
38	Cape Tribulation	145°, 03′, 16° 16′	40	S
39	Cape Tribulation	145°, 03′, 16° 16′	40	S
40	Big Tableland	145° 16′, 15° 43′	600	P
41	Big Tableland	145° 15′ 30″, 15° 42′ 30″	400	S
42	Big Tableland	145° 17′, 15° 43′	670	S
43	Mt Finnigan	145° 17′, 15° 49′	1040	P
44	Mt Finnigan (gap)	145° 19′, 15° 49′	160	P
45	Mt Finnigan (gap)	145° 18′, 15° 48′	300	P
46	Mt Finnigan (gap)	145° 18′, 15° 47′	280	P
47	Mt Misery	145° 13′, 15° 54′	600	S

Predictable effects of agricultural development on the long-term availability of hollows for animals: observations from the Western Australian wheatbelt

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AUSTRALIA lacks primary excavators of eucalypts (excluding wood-boring insects), and animals using hollows in trees for shelter or nesting are dependent on hollows created by termites (for processes of termite invasion of eucalypts, and hollow formation, see Mackowski 1984; Perry *et al.* 1985). The abundance of hollows of various sizes has been used to explain why Australia has the largest number of obligate hole-nesting birds, especially the parrots (Saunders *et al.* 1982). The importance of tree hollows to many small mammals is also well documented (e.g., Mackowski 1984; Dickman 1991). Once the hollowed tree has fallen, it represents an important shelter and bolt hole site for small mammals (e.g., Friend 1990; Abensperg-Traun 1991; Dickman 1991). Logs also provide many invertebrates (e.g., cockroaches, beetles, spiders, isopods) and lizards with shelter, breeding and feeding sites. However, the importance of this habitat for these species has not been documented.

European settlement of the Western Australian wheatbelt has resulted in the large-scale clearing of native vegetation. Salmon gum *Eucalyptus salmonophloia* and wandoo *E. capillosa,* which provide the best hollows (Saunders 1979), were cleared in preference to other vegetation types such as heath and shrubland, because they were associated with the best soils, and are now poorly represented in the region (Beard and Sprenger 1984). As a consequence, remaining woodlands represent the last refuges for species depending on them for shelter and breeding sites in the form of hollows.

The limited data suggest that the time from seedling establishment to hollow formation to the availability of hollow logs takes centuries (e.g., Mackowski 1984; Inions *et al.* 1989; Keally 1989). Our observations from the Western Australian wheatbelt predict a long-term decline in these resources; the availability of hollows is known to decline even over relatively short periods of time (Saunders *et al.* 1982). If correct, comparable agricultural regions in other parts of Australia are likely to show similar effects. Our prediction rests on the assumption that continuity of supply of these resources necessitates (a) successful tree regeneration, and (b) growth to maturity and old age. We believe that both of these requirements are compromised due to past and present land-use strategies and related disturbance factors.

First, a large proportion of remnant woodlands have been, and continue to be, grazed by sheep (and rabbits) for many decades and now show significant changes in soil and vegetation characteristics (Arnold and Weeldenburg 1991; Abensperg-Traun 1992). Successful regeneration of eucalypts, and hence the replacement of old trees, is unlikely to occur in the presence of sheep and rabbits (Wilson 1990). Second, the majority of woodland remnants of the wheatbelt have not been burnt for at least 40 years, yet fire may be one factor which is important for the regeneration of woodland eucalypts through its effect on seed-fall and the activities of harvester ants (O'Dowd and Gill 1984; C. Yates, pers. comm.). Also, fire is known to increase seed-predator satiation (Andersen 1988), thus increasing the success of seedling establishment. In addition, fire provides a fertilized ash-bed which is known to enhance regeneration in wandoo (Burrows *et al.* 1990). By killing trees, fire reduces competition for resources such as light, nutrients and moisture among seedlings; it also promotes the cycling of nutrients bound up in litter and mature plants (Christensen *et al.* 1981). Third, changes in hydrology and associated increases in soil salinity due to clearing have had disastrous consequences on native vegetation, including remnant woodlands (Hobbs *et al.* 1992; McFarlane *et al.* 1992). Thus there will be a continuing decline in the availability of hollowed trees and logs as the rate of death and decay exceeds replacement.

To overcome this situation we need more data to identify the factors preventing germination and/or the factors inhibiting the successful establishment, and growth to maturity, of trees. These factors will vary with species, the position of the remnant in the landscape and the factors causing the degradation of the remnant. In the least affected remnant, simple fencing to prevent sheep and rabbit grazing may be all that is needed. However, more degraded remnants may require more intensive management to allow regeneration to take place. The large number of remnants requiring restoration make large-scale rehabilitation economically unlikely in the short to medium-term. Effective modelling techniques will be needed to assist in the selection of the most effective sites for restoration, and for the maintenance of the biota.

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If our prediction of a decline in the availability of hollowed trees and logs is correct, as our observations would indicate, the full consequences of this situation will be slow in making their impact. This is because of variation in the age of woodland blocks and in the rates of the processes leading to the final decay of trees. The slow decline will allow time to start restoration of woodland patches, and the development of new areas of woodland by planting. However, it is essential that these actions start immediately given the time required to form hollows.

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