Impact and Use of Firewood in Australia

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EXECUTIVE SUMMARY

In this commissioned report we provide a national perspective of the extent and impact of firewood collection. The report reviews existing information and provides new survey results from Australian households, firewood merchants, and state government agencies.

Between 4.5 and 5.5 million tonnes of firewood were burned in Australian households over the past 12 months. When industrial firewood use is included, the total amount of firewood used in Australia was between 6 and 7 million tonnes. Although capital cities contain 2/3 of households in Australia, they consume only 1/3 of the firewood.

The four most commonly burned tree categories, in order of popularity, are River Red Gum (*Eucalyptus camaldulensis* 1.1 million tonnes), Jarrah (*E. marginata* 0.61 million tonnes), Red Box and Yellow Box (*E. polyanthemos*, *E. melliodora* 0.54 million tonnes), and Ironbark (*E. sideroxylon* 0.47 million tonnes). Three quarters of the people who collect their own firewood gather fallen timber, but they also take live and standing dead timber.

Approximately half of the firewood burned in households is collected by the residents, and 84% of the timber is obtained from private property.

Established wood merchants who advertise in the Yellow Pages® or have a business premises account for only about one quarter of firewood that is purchased. Merchants obtain the preferred timber species, such as red gum and box, from distant sources and often transport the wood 400 kilometres or more.

Most firewood is purchased from small suppliers (60%), and smaller amounts are bought from friends (10%). These small suppliers represent a completely unregulated part of the market that is worth about $260 million/year.

Inland forests and woodlands in lower rainfall zones appear to be the ecological communities most threatened by firewood collection, because they comprise popular firewood species, have been most extensively cleared for agriculture and have very slow growth rates. However, because of the paucity of research, direct evidence to support this conclusion is available only for River Red Gum forests in the lower Murray-Darling catchment and the Armidale area, NSW. Up to 80% of fallen timber may have been removed from red gum forests. Roadsides and other public land have been badly degraded by firewood collection near Armidale and up to 80% of green timber has been removed.

Inferential evidence suggests that firewood collection has an impact on the whole spectrum of biodiversity. Of particular concern are probable effects on ecosystem processes such as nutrient cycling and plant establishment, because of the potential loss of highly specialised species of invertebrates and fungi.

Few studies test for the effects of firewood removal on wildlife, although there is mounting evidence that at least 20 bird species are threatened by it. This does not imply that birds are more sensitive than other vertebrate groups, only that birds have received more research attention.

Key knowledge gaps

To improve our knowledge about the extent and impact of firewood collection, we need to know:

- the extent to which specific plant communities have been depleted of firewood;
- the extent of possible impacts in Western Australia and Queensland;
- rates of accumulation of fallen timber, and sustainable rates at which to harvest it;
- the amount of wood required to retain particular wildlife species;
- how badly invertebrates and fungi are affected when firewood is removed, and whether ecosystem processes subsequently fail;
- the nature of unregulated firewood businesses, especially small commercial suppliers;
- the role of state forestry agencies in the firewood industry and the effects of firewood harvest in state forests;
- the regional variation in firewood consumption.

Enhancing the knowledge base: Primary Research Strategy

To enhance the knowledge base we need to:

- estimate how much wood can be expected to accumulate in undisturbed woodlands and dry forests;
- assess the extent of wood removal from disturbed areas, stratified by vegetation type, land tenure and distance from population centres;
- relate levels of wood removal to impacts on biodiversity, allowing development of management options.

1. Context and Goals

CSIRO was commissioned by Environment Australia to provide a national perspective on firewood harvesting, particularly in relation to its effects on biodiversity, and knowledge gaps. It is the first step towards improving the information base, which is one of six strategies identified by ANZECC (2000) in its National Approach to Firewood Collection and Use.

The broad objective of this study is to identify the regions in which firewood harvesting is most likely to affect biodiversity at a national scale.

Specifically, the study has used the best available national data to determine

1. the total tonnage of the national firewood harvest;
2. the size and source of the unregulated harvest;
3. the biogeographic concentration of the harvest, including its effects on threatened communities;
4. the species composition, age, size and habitat characteristics of the harvested trees (e.g. as fallen or dead standing timber or live trees);
5. the sustainability of the firewood harvest.

To do this the study has used four broad methods:

- comprehensive review of existing literature (papers, reports, theses);
- canvassing of state agencies involved in natural resources management;
- survey of firewood suppliers;
- national phone survey.

2. AUSTRALIAN FIREWOOD HARVEST SURVEY: RESULTS

In this section we present new and collated information to assess the extent and nature of the firewood industry. In particular we set out to establish the amount of firewood used, its geographical source and the tree species taken. Section 3 presents a full discussion of the results.

2.1 HOUSEHOLDER SURVEY

Introduction

The only previous national examination of firewood use, completed in 1988 (FTSUT 1989), provided extensive new information on household use of firewood for cities in south-eastern Australia. Firewood use was thought to have increased dramatically in the decade preceding the FTSUT study. However, there is evidence that it may have declined by up to 30% since then (Todd 1998). To properly assess the size of the firewood industry, new data were required.

Fuelwood merchants, including state forestry agencies, are a potential source of information about the amount of firewood bought, the tree species sold and the source of the timber. However, they provide, at best, only a glimpse of half or less of the firewood consumed because the other half is collected by the burners themselves (FTSUT 1989). In the present study we found that fuelwood merchants could not supply enough detail to enable us to make firm statements about the present nature of Australia's firewood industry. There was virtually no information about the structure of the wood collected, such as whether it was fallen, standing, dead or alive. As well, there was little information about the proportion of firewood burned that came from the regulated market.

To begin to address these knowledge gaps, we undertook a telephone survey. It specifically aimed to provide a national estimate of firewood consumption, including information on use in each state, use of various tree species, tree structures and the source of the firewood.

Methods

Staff of the consulting firm Australian Marketing and Research Services (AMRS) helped us design a survey form (Appendix 3) and the sampling strategy; and they conducted the telephone interviews. The sample framework was a software listing of year 2000 residential phone numbers in Australia provided by AMRS. This database does not include silent numbers. Interviews were conducted between October 17 and November 2, 2000. Up to three call-backs to phones that were not answered were allowed.

Sampling was conducted in three stages.

Stage One: trial surveys — 19 interviews obtained.

Stage Two: a simple random sample of households Australia-wide, excluding Northern Territory, stratified by state — 306 interviews obtained.

Stage Three: over-sampling in regions where the variance of the quantity of wood contributed most to the uncertainty at a national level (taking into account the number of households and variance in estimate of average firewood use per household, estimated using bootstrap method described below). Sampling was stratified by state and by capital city or 'rest of state', and 92 interviews were obtained.

Capital city post codes and 'the rest of the state' were defined using Australia Post's definitions for the metropolitan and country areas of each state (Customer Contact Centre New South Wales/ACT, pers. comm.). The ACT was treated separately, and the Northern Territory was not sampled because it has such a small population and uses relatively little firewood (Bush *et al*. 1999). The sample was potentially biased by the following factors:

- no mobile phones were called;
- houses without phones or with silent numbers were not sampled;
- people who did not speak English could not be sampled.

Table 2.1.1 Tally of phone calls made during the study, including the number of respondents that said they did not use firewood, the number that said they did, and the number of failed interviews. Estimates of the proportion of households that use firewood using these data are likely to be substantial underestimates (see text).

State	Do not use firewood	Do use firewood	Failed interview	Total no. of calls	Proportion that use firewood, this study	Proportion that use firewood, ABS 1999 (main only)	% main heating (this study)
NSW	519	91	473	1083	14.9%	14.7%	65.9%
VIC	606	103	705	1414	14.5%	13.8%	53.4%
QLD	217	39	251	507	15.2%	9.7%	51.2%
SA	151	37	257	445	19.7%	17.7%	69.4%
WA	148	72	302	522	32.7%	24.7%	84.7%
TAS	71	63	157	291	47.0%	56.2%	84.1%
ACT	67	10	89	166	13.0%	–	–
TOTAL	1779	415	2234	4428	18.9%	15.7%	67.1%

To make maximum use of the data, we estimated average firewood use and confidence intervals separately for three levels of aggregation of the data. For this reason, the sum of the states' usage does not agree with the estimate at national level. For state and national data, we calculated the total amount of firewood burnt by first calculating the average weight of firewood burnt per household and 95% confidence limits, using a bootstrap method, resampling 1000 times (GENSTAT 1997; Efron & Tibshirani 1993). These values were then scaled up to the known number of households in that state, and the proportion of households that use firewood in each state. The Australian Bureau of Statistics (ABS) provided estimates of the proportion of households that use firewood as the main heating source (ABS 1999). To convert these values to an estimate of the proportion of households that use any firewood for heating (main and secondary), we multiplied the ABS proportions by the total number of households using firewood, and divided by the number of households using firewood as the main heating source (data from this study). Using the same approach we estimated the total amount of firewood burned at a national level.

We did not use the ratio of non-users to users that we calculated from the telephone interviews because the latter estimate is almost certainly biased downwards. The percentage of households using firewood, estimated from telephone interviews, is only slightly higher than the ABS estimate; yet a much higher proportion of firewood users burn wood as a secondary heating source (Table 2.1.1). We would therefore expect a substantially higher proportion to burn firewood as main and secondary heating sources than just as the main heating source, as reported by ABS. For example, at the national level, ABS estimates the proportion of households using wood as the main heating source as 15.7%, while this study estimates the proportion of households using firewood for any reason as only 18.9%. This must be a substantial underestimate because, of people who agreed to participate in the interviews, only 67.1% use firewood as the main heating source (Table 2.1.1). The reason for this downward bias was the wording of the questionnaire (Appendix 3) in which we asked people to be involved if they used firewood. To avoid being involved, some people simply replied that they did not use firewood, whether or not they really did. The wording of this question was designed to speed up the screening phase of interviews, allowing a greater number of interviews to be attempted.

No data were collected from the Northern Territory, and so data from Bush *et al*. (1999) have been accepted for that state (25 000 tonnes/year).

Unfortunately no data are available to estimate the proportions of households in each state that use firewood in the capital city compared to the rest of the state, so estimates of total firewood consumption at that level are not possible. Instead, the ABS (unpublished,

Table 2.1.2. Average consumption of firewood per household and total firewood used in capital city and the rest of each state (pooled over states) and for each state separately. 95% confidence intervals are indicated. Northern Territory data are from Bush et al. *(1999).*

Location	*N*	Household firewood use (tonnes per year)	std. error	Lower 95%	Upper 95%	No. of house-holds	Proportion that use firewood	Total firewood used (million tonnes)	Lower 95%	Upper 95%
Cap. city	168	2.25	0.23	1.83	2.75	4 378 700	18.6%	1.82	1.48	2.24
Rest state	250	3.67	0.22	3.28	4.14	2 586 300	34.7%	3.30	2.95	3.71
NSW	91	2.65	0.24	2.21	3.15	2 402 454	22.3%	1.42	1.18	1.68
VIC	103	2.69	0.30	2.13	3.28	1 747 638	25.8%	1.21	0.96	1.48
QLD	41	1.31	0.21	0.92	1.76	1 338 442	18.9%	0.33	0.23	0.45
SA	36	2.64	0.35	2.03	3.39	609 769	25.5%	0.41	0.32	0.53
WA	72	2.70	0.29	2.16	3.29	718 988	29.2%	0.57	0.45	0.69
TAS	63	5.81	0.52	4.87	6.84	186 272	66.8%	0.72	0.61	0.85
ACT	10	1.88	0.34	1.26	2.57	117 290	22.3%	0.05	0.03	0.07
NT						64 687		0.03	0.00	0.00
Australia	418	3.00	0.15	2.71	3.32	7 120 853	23.4%	5.00	4.52	5.54

N is number of respondents

ABS 1999) provides estimates of the proportion of households that use firewood across all capital cites and across the rest (non capital-city areas) of all the states. This permits a national-level assessment of firewood use in capital city versus non-capital city, but does not permit a state-by-state account. The methods described above were used in forming capital city or rest-of-state estimates.

Note that in all estimates of amount of wood used, the error in estimating proportions of households using firewood has not been taken into account.

When respondents did not know what tree species they burned as firewood, we assigned their data to a 'general eucalypt' category. We assume that these households actually use the same species as other responding households, and in the same proportions, and accordingly we have redistributed the tonnage assigned to general eucalypts on a state-by-state basis when calculating the quantity of each species burned. The resulting amount has been added up across states, converted to proportion and multiplied by the total amount of firewood burned.

All other results are reported as percentage of total weight or percentage of number of respondents, including tree species used as firewood, the source of bought and collected wood, the number of permit-holders and the structure of the firewood collected.

Results

Amount of firewood

Australian households burned between 4.5 and 5.5 million tonnes of wood over the past 12 months, over half of which was consumed in New South Wales and Victoria (Table 2.1.2). Although capital cities account for 63% of the households in Australia, only one third of firewood is burned in capital cities. For firewood-using households, average consumption varied from 1.3 tonnes/year in Queensland to 5.8 tonnes/year in Tasmania, with a national average of 3 tonnes/year. Households in capital cities burned significantly less than households in the rest of each State (2.2 vs 3.7 tonnes/year).

Species used

About one third of timber burned falls into the general eucalypt category at the national level (Table 2.1.3). This indicates that a large proportion of the population do not know what sort of wood they burn, highlighting an important issue that an education campaign should address. New estimates of the proportion of firewood in the general eucalypt category can be used as a measure of the success of future education campaigns.

At a national level, more River Red Gum (*Eucalyptus camaldulensis*) is burned than any

Table 2.1.3. Percentage (of total weight) of tree species used as firewood in each capital city, the remainder of the state, each state, and for Australia as a whole. The estimated total mass (megatonnes) of each category after redistribution of the general eucalypt category is also given.

Type	ACT total %	NSW city %	NSW rest %	NSW total %	QLD city %	QLD rest %	QLD total %	SA city %	SA rest %	SA total %	TAS city %	TAS rest %	TAS total %	VIC city %	VIC rest %	VIC total %	WA city %	WA rest %	WA total %	Australia %	Australia (million tonnes)
Red gum		1.9	11.7	9.2		1.8	1.0	31.4	49.4	46.8		1.7	1.3	33.2	42.8	39.4		0.8	0.5	15.4	1.08
Jarrah														1.3		0.4	89.7	65.6	74.8	11.3	0.61
Box, red or yellow	75.7	8.3	18.2	15.6		1.8	1.0	5.7		0.8				12.9	13.5	13.8				7.4	0.54
Ironbark		23.3	8.9	12.7		3.1	28.8					4.2	3.2	1.5	5.6	5.0				5.7	0.47
Local eucalypts		1.5	2.7	2.3		4.6	4.4		5.9	5.4		7.6	5.8	8.4	4.0	5.5	0.2	9.3	5.8	4.8	0.39
Stringybark		0.3	7.8	5.8							5.0	8.2	7.2		3.3	2.1				3.7	0.34
Peppermint			1.2	0.9				2.3	1.1	1.2	19.9	1.9	6.1							2.0	0.20
Callitris or Casuarina			1.8	1.3	3.8	1.6	1.7	11.4		1.7		6.5	5.0	1.3	0.1	0.5				1.9	0.19
Blue Gum								3.4	6.5	6.7	19.7		4.7							1.8	0.18
Other box species			6.7	4.9		0.3	0.2							2.3	1.7	1.9				1.5	0.11
Mallee roots								2.9	2.2	2.3				2.6		0.9		14.5	8.9	1.8	0.10
Recycled		4.6	3.0	3.4					4.3	3.7				1.3		0.4	2.7		1.4	1.3	0.09
Pine or softwood			0.6	0.4		1.6	1.5					1.0	0.7	1.4	0.3	0.7				0.5	0.04
Myrtle											3.4	0.8	1.3							0.4	0.04
Mallee stems								2.9	3.9	3.7				0.4		0.1	1.8	0.7		0.5	0.03
Wattle			0.1	0.2								1.2	0.9							0.3	0.03
Silky Oak						6.9	6.6													0.3	0.02
General eucalypts	24.3	52.2	3.9	36.5	96.9	4.9	42.5	38.6	16.4	19.6	53.5	54.5	54.2	33.5	26.9	29.2	3.3	8.7	6.6	33.7	0
Other		7.8	6.4	6.8		13.0	12.3	1.4	1.4	10.0		12.5	9.5	1.7	2.0	1.9	4.8		1.6	6.2	0.53

Table 2.1.4. Percentage (of total weight) of firewood burned that was purchased or collected and the source of the firewood for each state

	NSW %	VIC %	QLD %	SA %	WA %	TAS %	ACT %	Australia %
% bought	39.4	44.1	14.4	34.5	65.6	60.8	51.3	49.6
Small collector or Supplier	67.9	41.1	92.6	70.8	63.3	62.5	51.4	59.9
Wood yards	11.0	39.4	5.2	9.2	26.2	22.5	10.3	23.7
Friends/Relatives	13.6	9.6	2.3	1.5	1.6	15.0	17.6	10.1
Sawmill/Joinery	7.4	9.8	0.0	6.1	4.3	0.0	20.6	4.6
Other	0.2	0.0	0.0	12.3	4.7	0.0	0.0	1.7
% collected	60.6	55.9	85.6	65.5	34.4	39.2	48.7	50.4
Own land	60.9	38.5	63.6	44.4	59.1	55.9	2.2	51.8
Other private land	35.4	31.6	23.4	44.0	29.4	26.3	59.8	32.1
Roadside	3.0	3.9	0.0	8.3	4.1	0.0	0.0	2.9
State forest	0.0	20.9	0.0	0.0	2.2	17.8	0.0	9.5
Other Crown land	0.0	0.6	0.0	0.0	1.5	0.0	0.0	0.3
Other	0.7	4.4	13.1	3.2	3.7	0.0	38.0	3.5

other species; we estimate that about 1.1 million tonnes are burned annually. Red gum is the most popular species to burn in Victoria and South Australia. Substantial amounts are also burned in New South Wales, although some of the red gum burned in that state is probably Blakely's Red Gum (*E. blakelyi*), which occurs in similar environments to Yellow Box. The amount of Jarrah (*E. marginata*) that is burned is second only to red gum, even though it is virtually only burned in Western Australia where it makes up three quarters of the market. Also high on the national pyre are Red Box and Yellow Box (*E. polyanthemos, E. melliodora*), and Ironbark (*E. sideroxylon*). In New South Wales, box species account for over 20% of firewood used and are the most popular species to burn. In Victoria, Red Box and Yellow Box are the second most common species burned. In ACT, box species account for three quarters of the firewood market. Ironbark is popular in New South Wales and Queensland.

Tasmanians burn a wide range of species, including stringybarks, peppermints and *Callitris* or *Casuarina* species. Tasmania had the highest percentage of general eucalypts, probably because of the broad range of species that the Tasmanian market accommodates.

Sources of firewood

The telephone interviewers were asked to try and differentiate between merchants with an established premises — including wood yards, fuel stations and garden supplies — and the smaller supplier selling from the back of a truck. Surprisingly, the vast majority (60%) of bought firewood is purchased from small collectors or suppliers, while less than one quarter of the firewood is bought from firewood merchants with established premises (Table 2.1.4). Approximately half of the firewood that is burned is purchased, and half is collected by the burner.

Of timber that is collected, most (84%) is obtained from private property. The proportion coming from state forests varies substantially among states, perhaps because of small sample sizes rather than real variation. The estimate of 9.5% coming from state forests at a national level is in concordance with the state forestry agencies' own figures (Section 2.4), and indicates that only a small proportion of the firewood burned is obtained from state forests. Very little firewood is collected from roadsides or other public land, according to the people who were interviewed (Table 2.1.4).

Permits and type of timber

We included a question about permits and type of timber, in the hope that people would answer honestly and we could generate a better indication of the proportion of people who collect firewood illegally. Unfortunately, this appears to have been optimistic. A large number of respondents said they held permits for collecting domestic firewood from their own land or other private land (Table 2.1.5). To our knowledge, no state issues permits for the

Table 2.1.5. Number of respondents indicating they hold a permit to collect firewood, and the source from which they collect (some people collected from more than one site, and the site for which a permit was held was not indicated)

Source	Permit held?	ACT	NSW	QLD	SA	TAS	VIC	WA	Australia
Own land	No	1	21	19	6	12	30	12	101
	Yes		18	3		4	9	7	41
Other private land	No	2	18	8	10	10	15	2	65
	Yes		9	4	1		4	6	24
Roadside	No		6		4		4	5	19
	Yes				1		2		3
State forest	No					1	1	1	3
	Yes					2	5		7
Other Crown land	No						1	3	4
	Yes								
Other	No	1	1		2		3	1	8
	Yes							1	1

Table 2.1.6. Number of respondents who collect fallen, standing dead or standing live timber

Type	ACT	NSW	QLD	SA	TAS	VIC	WA	Australia
Fallen	100%	76%	81%	80%	58%	75%	88%	76%
Standing alive	0%	5%	5%	8%	9%	9%	0%	6%
Standing dead	0%	19%	14%	12%	33%	16%	12%	18%

collection of domestic firewood from private property. Interestingly, most respondents who collect firewood from roadsides indicated they did not have a permit and seven additional respondents admitted to collecting from state forests or Crown land without a permit.

Three quarters of respondents who collected firewood said they collected fallen timber, while almost one fifth said they collected standing dead trees (Table 2.1.6).

2.2 Firewood Merchant Survey

Introduction

Approximately half of the firewood burned in households in Australia is purchased (FTSUT 1989), and so firewood merchants can potentially give information about the amount of firewood sold, the type of wood and its source.

Methods

Firewood retailers advertising in Telstra Yellow Pages® OnLine were phoned during business hours in September and October, 2000. Potential respondents were chosen randomly using pseudo-random numbers generated in Microsoft® Excel. If respondents were unable to be contacted or did not wish to participate, another random selection was made. Approximately 10% of retailers were chosen from each state (Table 2.2.1). Sixty five percent of respondents were within 50 kilometres of the state's capital city. Locations given were checked in the AUSLIG Place Name Search or Australia Post Postcode listings. If merchants agreed to participate they were asked a series of open questions to facilitate discussion (Appendix 4).

The responses were given as number of trailer or truck loads sold. To assess the results, we converted loads to tonnes, as nearly as possible, based on the carrying capacity of the vehicle. We used a common conversion for firewood from volume to weight, namely two cubic metres to the tonne (pers. comm. various wood merchants). For analysis we have taken the mid-point of the given weight range.

We have estimated the total amount of firewood sold by merchants in Australia by scaling up the total estimates for the sample

Table 2.2.1. Number of firewood retailers listed in the Yellow Pages® in each State and Territory and the number surveyed in each

	ACT	NSW	VIC	SA	WA	NT	QLD	TAS	Total
No. of retailers	14	157	158	59	56	2	76	33	555
Sampled	3	16	16	7	7	2	9	5	65
%	21.4	10.2	10.1	11.9	12.5	100	11.8	15.2	11.7

Table 2.2.2. Numbers of firewood retailers of various sizes based on weight (tonnes) of firewood sold.

	ACT	NSW	VIC	SA	WA	NT	QLD	TAS	Total %
Tonnes				*Number of retailers*					
1–500	-	10	8	4	1	2	7	3	58.7
501–1000	-	4	3	1	1	-	2	1	19.6
1001–2000	-	-	3	-	4	-	-	-	6.5
2001–3000	1	-	1	1	-	-	-	-	4.3
3001–4000	-	2	-	-	1	-	-	1	6.5
>4000	2	-	1	1	-	-	-	-	4.3
				Weight of wood sold					
Total tonnes (all)	14 500	12 806	22 482	8480	10 370	85	2255	5400	76 378
Range/merchant	3000 –7000	3–10 000	10–4500	6–3500	20–3500	35–50	25–700	100–4000	

(65 merchants) to the total number advertising in the Yellow Pages®. Confidence intervals have been estimated using a bootstrap method, resampling 10 000 times (GENSTAT 1997; Efron & Tibshirani 1993).

Results

Amount of firewood sold, and sizes of firewood businesses

Many respondents found it difficult to estimate the quantity of firewood they sold, partly because firewood is a sideline to the main business. Some could not give any measure or gave a very wide estimate.

The 65 respondents sold 76 738 tonnes during the last year or season. Just over half of the respondents sold less than 500 tonnes each and accounted for 7% of the wood sold. In contrast, 28% of businesses sold more than 1000 tonnes each and accounted for 79% of the wood sold (Table 2.2.2).

The estimated total amount of firewood sold by merchants who advertise in the Yellow Pages® was 0.65 million tonnes, with 95% confidence intervals spanning 0.43 to 0.91 million tonnes. This represents approximately 26% (confidence intervals 17–36%) of the total amount of firewood that is purchased by households in Australia (cf. Section 2.1). This result corresponds well with the estimated proportion of firewood purchased from wood yards or other sellers with business premises in Section 2.1 (23.7%). Although wood merchants who advertise in the Yellow Pages® may not all have business premises, the result lends confidence to the conclusion that sales by established wood merchants account for only about one quarter of firewood that is sold.

Species sold

The species sold largely reflect the species available locally and the preference of consumers in each state for a particular species as fuel: ironbark in Queensland, red gum in Victoria, red gum/box mixtures in New South Wales, Jarrah in Western Australia and peppermint in Tasmania (Table 2.2.3).

Most respondents were able to give common names for the types of wood they sell. Some respondents were only able to give the colour of the wood (e.g. ‘I only sell red wood’). Terms used by the respondents to describe the wood, such as ‘stringybark’ and ‘mahogany’, refer to a range of species with common wood colour or bark characteristics rather than particular species. The ‘stringybark’ and ‘mahogony’

Table 2.2.3. Categories of wood named by retailers and the percent sold in each state or territory

	ACT	NSW	VIC	SA	WA	QLD	NT	TAS
Mixed hardwood	1.55	32.18	-	-	-	26.97	-	-
Red gum	-	28.31	79.96	24.88	-	-	-	-
Red gum mix	-	8.23	-	-	-	-	-	-
Red gum/Box mix	68.28	-	-	-	-	-	-	-
Box only mix	23.28	-	11.88	-	-	-	-	-
Box/Ironbark	-	27.70		-	-	-	-	-
Ironbark	-	0.70	0.46	-	-	49.28	-	-
Jarrah	-	-	-	-	89.11	-	-	-
Salmon Gum	-	-	-	-	8.86	-	-	-
Mallee — cut stems	-	-		12.69	-	-	-	-
Mallee — root	-	-	5.28	5.84	0.19	-	-	-
Mulga	-	-	-	-	-	-	87.06	-
Ironwood	-	-	-	-	-	-	12.94	-
Brown peppermint	-	-	-	-	-	-	-	59.30
Peppermint/Gum mix	-	-	-	-	-	-	-	22.20
Other Eucalyptus	-	2.34	2.32	2.40	1.73	1.34	-	18.50
Black Oak	-	0.55	-	-	-	-	-	-
Pine	6.90	-	0.09	-	-	-	-	-
Railway sleepers	-	-	-	54.07	-	22.40	-	-
Recycled timber	-	-	0.5	0.12	0.10	-	-	-
Eco-Brix	-	-	0.01	-	-	-	-	-

Table 2.2.4. Number of locations in major vegetation types given as a source of firewood. Some respondents gave several locations.

	ACT	NSW	VIC	SA	WA	NT	QLD	TAS	Total
Coastal forest	1	5	2	-	8	-	2	3	13
Inland forest	-	6	4	3	-	-	3	3	19
Riverine forest	3	3	12	5	-	-	-	-	23
Woodland	4	9	4	-	2	-	2	-	21
Mallee	-	-	3	4	1	-	-	-	8
Other	-	1	-	-	-	2	-	-	3
Metropolitan area	1	3	2	-	-	-	4	-	10
Plantation	1	-	1	-	-	-	-	-	2

groups are a minor firewood source — about 1% of the total sold. The composition of 'mixed hardwood' varies from state to state; the term refers to a mixture of the preferred firewood types: box and ironbark mixed with red gum and wood of poorer burning quality.

Sources of firewood

Most of the source locations can be broadly summarised as occurring in coastal or inland forests, riverine forests or woodlands (Table 2.2.4 and Figure 2.2.1). Coastal and inland forests are the most common sources of firewood, but these areas contribute to only a small part of the amount sold except in Western Australia and Tasmania. In Western Australia, 90% of the wood sold comes from the Jarrah forests, and in Tasmania all the timber is obtained from forest regions. Riverine forests are the most common sources in Victoria and South Australia where red gum is the main type sold. Woodlands are a major source for the ACT and New South Wales where box species are the preferred fuel. Nationally, 72% of locations from which merchants obtain firewood are in low rainfall plant communities, including inland and riverine forests, woodland and mallee.

Tree lopping or removal in urban areas and clearing for developing suburbs contributes small amounts and has been the main source for a few of the respondents.

Figure 2.2.1. Map of Australia showing sources of firewood. The coloured dots indicate the states in which the firewood from each source is sold. The Murray and Murrumbidgee rivers and southern areas of eucalyptus forest, woodland and mallee (after Bridgewater 1987) are indicated.

Table 2.2.5. Distance of firewood source from the retailer. Values in distance categories indicate number of retailers.

Max. distance travelled (km)	ACT	NSW	VIC	SA	WA	NT	QLD	TAS
				Number of retailers				
0–100	-	6	2	2	4	2	4	4
101–200	-	2	-	1	3	-	3	1
201–300	1	2	1	-	-	-	1	-
301–400	1	1	6	1	-	-	-	-
401–500	-	3	4	1	-	-	-	-
>500	1	1	1	-	-	-	1	-
				Distances travelled				
Mean max. distance	433.3	253.6	332.1	220.0	121.4	75.0	194.4	70.0
Mean min. distance	116.7	171.4	178.6	140.0	114.3	75.0	121.4	70.0
Range	50–450	50–650	50–450	50–450	50–200	50–100	50–750	50–150

Over half of the respondents obtain their firewood within 200 km of the point of sale (Table 2.2.5). Larger retailers in Victoria, New South Wales and the ACT acquire preferred firewood species from greater distances than in the other states. Red gum and box species are generally transported the largest distances, frequently more than 400 kilometres, to supply the major urban centres.

When asked to give the source of the wood they sell, the respondents were often unable to state the locality, sometimes because they were unsure or considered it to be of a commercial or confidential nature. Respondents buy in wood and also obtain it for themselves, but often did not differentiate between the two when giving the source of the firewood. The locations given for the source of the wood might reflect the location of their supplier's business or the nearest sawmill rather than the source of the wood. Generally the respondents were able to give the approximate region or the region in which the supplier was located, but we could not find all the locations in the AUSLIG Place Name Search or Australia Post Postcode listings. Some respondents did not differentiate the species and gave broad locations as a source for all the species they sold (Appendix 5).

Number of suppliers to retail merchants

The responding merchants have a varying number of suppliers from year to year, depending on the availability of firewood to the supplier. Fifteen merchants cut their own firewood and had no other suppliers. Of merchants who had at least one supplier, nine had one major supplier, eleven had two to four suppliers and ten respondents had five or more main suppliers. Seven respondents were unable to give an estimate of the number of suppliers and thirteen were only able to give a general indication of number.

2.3 New South Wales Rural Lands Protection Board Survey

The New South Wales Rural Lands Protection Boards (RLPB) manage stock routes and are able to issue permits to the public for firewood collection. We sent a fax survey, on 19 September 2000, to all 55 boards to discover their role in regulating firewood collection in that State.

Questions asked

1. Does your board issue permits for firewood collection?
2. How many permits are issued annually?
3. How much timber is taken under the permits?
4. What restrictions are placed on the permits (e.g. location restrictions, type of timber or species to be removed, etc.)?
5. How effective is your permit system? Can you estimate the proportion of firewood cut from lands under RLPB control that is illegal?
6. Are there any other comments you wish to make about firewood collection in your area?

Results

Twenty nine of the 32 respondents (90%) do not issue permits for firewood collection. Of the three boards that issue permits, two issue 50 permits per year to collect fallen timber, with an estimated 100 tonnes collected in one wheatbelt RLPB area. A third RLPB issues only one permit each year.

Thirteen respondents commented on the prevalence of illegal firewood collection. Firewood collection is recognised as a major problem by the Central Tablelands RLPB (Bathurst), which reported that all mature Yellow Box trees on two reserves have been poisoned or ringbarked for future use as firewood. The staff estimated that hundreds of tonnes have been removed illegally. Two other respondent RLPBs thought that illegal firewood collection occurs at a high rate in their area. All three RLPBs are in wheat–sheep areas formerly occupied by eucalypt woodlands.

Five respondent RLPBs thought that illegal collection occurs but at a very low rate. Four of the five RLPBs are in coastal areas, while the fifth, Narrabri, is on the western slopes in the wheat belt.

Five other RLPBs — the Riverina, three boards in sheep–wheat producing areas and one on the north coast — indicated that illegal collection occurs, without implying whether the rate is low or high. Two of these respondents suggested that 20–30 tonnes per year are taken from their area.

Discussion

Two key points arise from this survey. First, if we assume that the Rural Lands Protection Boards that do issue firewood permits were just

as likely to respond to this survey as those that do not issue permits, then it appears that very little firewood collection is administered by these organisations. It may be rewarding to send the RLPBs educational material about the possible ecosystem impacts of firewood collection, especially in the highly cleared landscapes of the wheatbelt, because the RLPBs retain the option of selling timber for firewood; also our assumption above may be incorrect.

The second issue arises from comments about the prevalence of illegal firewood collecting. The respondents report high levels of illegal collection from the New South Wales wheatbelt, where the preferred firewood timbers, such as box species, occur. However, the opinions are varied, and two-thirds of respondents did not give an opinion. Therefore, it appears that the organisations responsible for managing travelling-stock routes do not know how much timber is taken illegally. There is a clear need for research.

2.4 State Forestry Survey

Introduction

State forestry agencies in all states issue permits for the commercial or private collection of firewood. These agencies are an immediate potential source of information about the regulated firewood market, and so we approached them on this basis during September and October 2000.

Methods

We contacted state forestry agencies in all states and the ACT and asked for information about volumes of firewood taken, tree species taken and the location of firewood collection, preferably on a bioregional basis. No state agencies were willing to provide such detailed information because of the effort involved and because they considered the information too sensitive. The information that was provided is summarised below.

Results

Tasmania

Forestry Tasmania would provide only an overview of the firewood they sold. Permits are issued for about 50 000 tonnes annually, and about 40% of that is sold to commercial firewood operators (Michael Wood, Manager Customer Services, Forestry Tasmania, pers. comm.).

Table 2.4.1. Firewood sold (amounts >100 tonnes only) from private property in Tasmania over 12 months 1999–2000 (Graham Wilkinson, Tasmanian Forestry Practices Board, pers. comm.)

IBRA Region	Firewood (tonnes)
Ben Lomond	5600
Central Highlands	3900
D'Entrecasteaux	2650
Freycinet	3000
Midlands	25 625
Woolnorth	10 300
TOTAL	51 075

The Tasmanian Forest Practices Board regulates timber removal from private property for amounts greater than 100 tonnes. Data for 1999–2000 are presented in Table 2.4.1 (Graham Wilkinson, Chief Forest Practices Officer, Forest Practices Board, pers. comm.). While these data account for only about 10% of the total firewood used in Tasmania, they indicate that about half of the firewood collected comes from the Midlands bioregion (the central lowland valley), and one fifth from the Woolnorth bioregion (the north-coastal extension of that land system). These areas include the most populous parts of Tasmania.

South Australia

Very little firewood is harvested from South Australian forestry reserves, and what is taken is either pine waste products or eucalypt waste from track maintenance operations (Table 2.4.2). The Native Vegetation Council and Secretariat issue permits for the clearing of native vegetation and may have records of wood sold for firewood (Bob Inns, Manager, Biodiversity Policy & Planning, Department for Environment and Heritage South Australia, pers. comm.), but we have not obtained them.

Victoria

In 1997–98, 137 000 cubic meters (approx. 82 200 tonnes) of firewood was extracted from Victoria's state forests (Table 2.4.3), accounting for approximately 6% of the firewood used in that state (cf. FTSUT 1989). Almost one third of the harvest came from the box–ironbark forests of the Bendigo Forest Management Area (FMA) and one sixth from the box–ironbark forests of the Midlands FMA. In 1998–99 approximately 74 000 licences for domestic firewood were issued, representing about 65%

Table 2.4.2. Summary of timber sold for firewood from South Australian forestry reserves over 12 months

Location	type of wood	approx. tonnes p.a.
Kuitpo Forest	pine	150
Mt Crawford	pine 50% of sales	
	stringybark 50% of sales	280
Northern (Wirrabra, Bundaleer)	Sydney Blue Gum, red gum, Spotted Gum	360
South East	red gum	830
TOTAL		1620

of the firewood sold by the Dept of Natural Resources and Environment (DNRE 1999).

Western Australia

Under Ministerial Condition no.10, CALM (1998) reports the quantities of 'other logs' taken from state forests. In the period 1994–97, an annual average of approximately 45 000 cubic metres of Jarrah (or tonnes: dry Jarrah has a conversion factor of approximately 1; Geoff Stoneman, CALM Western Australia, pers. comm.) (*Eucalyptus marginata*) was sold as domestic firewood, and 80 000 tonnes as charcoal logs. The report says that 300 000 tonnes are available annually, indicating that only 34.7% of the resource is exploited.

More recent information (Wally Cox, Executive Director CALM, reply to Robert Butterworth, Acting Head Biodiversity Group, following request for firewood information, 22 May 2000) suggests that about 40 contract buyers are supplied with 60 000 tonnes of

Table 2.4.3. Firewood harvested in state forests, Victoria, 1997–98 (from report to ANZECC firewood working group)

Forest Management Area	Firewood harvested (cubic metres)	Proportion of total	Species
East Gippsland	5000	4%	Durable species, e.g. Gippsland Grey Box, Red Ironbark. Others include stringybark species, Silver-top Ash, Southern Mahogany
Tambo	6000	4%	Durable species, e.g. Gippsland Grey Box and Red Ironbark. Others include stringybark species, Silver-top Ash, Southern Mahogany
Central Gippsland	9000	7%	Red Ironbark, Red Box, Gippsland Grey Box, Yellow and White Stringy bark
Dandenong	2000	1%	Durable timbers are preferred although Messmate may be used
Central	4000	3%	Durable timbers are preferred although Messmate may be used
Benalla/Mansfield	1000	1%	River Red Gum, Ironbark and Box species, stringybark species
North East	5000	4%	River Red Gum, Ironbark and Box species, stringybark species
Mid Murray	13 000	9%	River Red Gum
Bendigo	41 000	30%	Box–ironbark species
Midlands	22 000	16%	Box–ironbark species
Otways	5000	4%	Messmate, Brown Stringybark, Scentbark, Manna Gum
Portland	16 000	12%	Messmate, Brown Stringybark, Scentbark, Manna Gum
Horsham	6000	4%	River Red Gum, Yellow Gum
Mildura	2000	1%	River Red Gum
Total	137 000	100%	

firewood logs annually, while annual domestic firewood collection from state forests is estimated to be more than 50 000 tonnes. This suggests that CALM regulates approximately one quarter of the firewood used in Western Australia (cf. FTSUT 1989, Section 2.1).

New South Wales

In 1997–98, 65 578 tonnes of firewood were extracted from NSW State Forests (State Forests Web Site). About 40–45 000 tonnes of red gum are sold as firewood annually from the Riverina region, half of which goes to the Melbourne market. An additional 5000 tonnes of mallee are sold annually from western land leases (Mike Thompson, NSW State Forests, pers. comm.). In the New South Wales south coast region, there is a commercial firewood operation that specialises in ironbark, grey box and woolly butt. Approximately 10 000 tonnes are sold annually. Domestic permits are issued, but no estimate of amounts sold is available (Steve Dodds, NSW State Forests, pers. comm.). NSW State Forests chose not to provide more detailed information about the source and volumes of firewood sold (Mark Watt, NSW State Forests, pers. comm.).

Queensland

Queensland's Department of Primary Industries (QDPI) Forestry issues permits for firewood collection, but does not make electronic records. Approximately 2900 tonnes were sold by QDPI in 1999–2000 (Table 2.4.4), representing less than 1% of the firewood burned in Queensland (cf. FTSUT 1989, Section 2.1).

ACT

No native forests are harvested in the ACT, but ACT Forestry sells 4–5000 tonnes of pine waste as firewood. This is sold as 'mixed loads' by ACT firewood merchants as part of the ACT's firewood strategy (David Power, Environment ACT, pers. comm.).

Table 2.4.4. Firewood permits and amount of firewood issued by QDPI Forestry in 1999–2000. The amount of firewood is not specified on domestic permits, so the amount collected has been estimated using FTSUT (1989) estimates of average household use in Queensland (2.7 tonnes/year). (Source: Bill Gordon, Senior Planning Officer (Marketing), Market Development and Sales, DPI Forestry, Qld.)

Forestry District	No. of domestic permits	Tonnes, domestic	No. of commercial permits	Tonnes, commercial
Atherton	140	378	19	200
Dalby	135	364.5	13	200
Imbil	50	135	10	100
Monto	1	2.7		
Maryborough	30	81	20	200
Rockhampton	25	67.5		
Ingham	2	5.4		
Roma	3	8.1		
Yarraman	40	108	1	150
Beerburrum	105	283.5	35	600
TOTAL		1433.7		1450

3. Updating the knowledge base. Appraisal of the Australian firewood harvest

In this section, we answer and make critical appraisal of the five key objectives defined in Section 1, using data presented in Section 2 and existing reports that examine the firewood industry.

3.1 Total tonnage of the national firewood harvest

Households burned between 4.5 and 5.5 million tonnes of firewood in the past year. Household use of firewood is slightly higher than estimates from 1988, which is consistent with projections made at that time. Average household consumption of firewood appears to have declined in Victoria, Queensland, and the ACT but has increased slightly in Tasmania. There is substantial regional variation in the amount of firewood consumed. A more extensive survey effort will be needed to define regions of high firewood use within states.

Discussion

The FTSUT report (1989) estimated that total firewood consumption by Australian households in 1988 was 4.38 million tonnes (Table 3.1.1). Projections for 2000 were between 4.25 and 6.61 million tonnes/year, depending on population growth. Actual population growth averaged 1.16% over 1992–96 (ABS 2000), indicating growth rates closer to the low than high estimates in FTSUT (1989). FTSUT (1989) estimated the amount of fuelwood used by industry was 1.73 million tonnes of green wood per year, based on ABS national survey data from 1986–87. Industrial firewood includes any wood burned by industries, approximately half of which is waste wood from timber-based industries.

The FTSUT (1989) figures compare favourably with estimates made by the Australian Bureau of Agriculture and Resource Economics (ABARE; Bush *et al.* 1999), which include industrial firewood use (Table 3.1.1). However, the ABARE estimates were based on a 1976 census question, and adjusted on the basis of changes in stock of wood burning equipment with data provided in 1980, 1983, and 1988, and so the values should be regarded with caution (Andrew Dickson, ABARE pers. comm.). Nevertheless, both the ABARE forecasts and the FTSUT forecasts compare favourably with our estimate (Section 2.1), which placed firewood use at between 4.5 and 5.5 million tonnes, excluding industrial firewood.

Table 3.1.1. Estimates of firewood use in 1988 and 2000 based on FTSUT (1989), ABARE (Bush et al. *1999) and the current study. The range of estimates for 2000 by FTSUT (1989) are based on high and low population forecasts from ABS. The ABARE data include industrial firewood use; other estimates do not. All figures are in millions of tonnes.*

State	FTSUT 1988 estimate	ABARE 1987–88 estimate	FTSUT 2000 forecast	ABARE 2000–01 forecast	This study
New South Wales	1.25	1.66	1.22–2.01	1.96	1.18–1.68
Victoria	1.41	1.83	1.35–1.88	2.11	0.96–1.48
Queensland	0.37	0.39	0.36–0.66	0.50	0.23–0.45
South Australia	0.32	0.62	0.31–0.53	0.86	0.32–0.53
Western Australia	0.43	0.54	0.41–0.73	0.72	0.45–0.69
Tasmania	0.53	0.69	0.53–0.66	0.68	0.61–0.85
ACT	0.07		0.07–0.12		0.03–0.06
Northern Territory	0.009	0.02	0.009	0.03	
Total	4.38	5.75	4.25–6.61	6.85	4.52–5.54

Table 3.1.2. Comparison of average consumption of firewood per household in 1988 (FTSUT 1989) and 1999–2000 (this study)

State	Average consumption per household (tonnes/year) *FTSUT 1989*	Average consumption per household (tonnes/year) *This study*
NSW	3	2.2–3.2
VIC	4	2.1–3.3
QLD	2.8	0.9–1.8
SA	2.3	2.0–3.4
WA	2.4	2.2–3.3
TAS	4.7	4.9–6.8
NT	6.2	-
ACT	3	1.3–2.6
Total	3.2	2.7–3.3

If industrial firewood use is assumed to be about the same as estimated in 1988 (FTSUT 1989), then the current total amount of firewood consumed in Australia is of the order of six to seven million tonnes/year.

Using some additional ABS information from 1996 on the proportion of Canberra households using firewood as the main heating source, Todd (1998) estimated that the amount of firewood consumed in Canberra had dropped from 68 000 tonnes in 1988 to approx. 45 000 tonnes, and predicted that the amount used up to 2007 would remain steady at just over 40 000 tonnes per year. The results imply a 32% decrease in firewood use over the past decade. While our results (Section 2.1) support a value for the ACT of approximately 40 000 tonnes/year, there has not been a general decline in firewood use nationwide. Total firewood consumption estimated in this study is higher than both estimates for the late 1980s (Table 3.1.1).

Average household consumption of firewood appears to have declined in Victoria, Queensland, and the ACT but has increased slightly in Tasmania (Table 3.1.2). Rogers (1990) reported substantial variation in the amount of firewood consumed by households in different areas of South Australia (Table 3.1.3). The smallest amounts were used by homes in Adelaide (2.02 tonnes/year) and the highest volumes were used by homes in the south east (6.27 tonnes/year).

Rogers' (1990) study included interviews from 3600 homes, and indicates that to develop a very accurate estimate of firewood use, extensive sampling and stratification is needed. Australian Marketing and Research Services estimate that at least 1500 completed calls would be needed to obtain a reasonably accurate breakdown by state (costing approximately $20 000 to collect), and even larger samples would be needed to assess the type of regional variation identified by Rogers.

3.2 Size and source of unregulated harvest

Of the firewood that is bought, up to 70% is purchased from small operators who do not have a business premises or do not advertise in the Yellow Pages®. This entirely unregulated market may be worth approximately $260 million per year.

Table 3.1.3. Other estimates of average firewood consumption per household and estimates of total firewood use for particular regions of Australia

Location	Year	Average consumption (tonnes/year)	Total firewood use (tonnes)	Sample / type	Reference
SA / Adelaide / south east	1989	2.96 / 2.02 / 6.27	415 300 / 70 600 / 83 300	3600 / personal interview with census	Rogers (1990)
Country town / farm Victoria	1994	3.3 / 4.5–5	All Victoria: 1.2–2.5 million	520 / school student-householder	Read Sturgess & Associates (1995)
Canberra	1982	3		400 / phone	McArthur (1983)
ACT	1983	3.17	61 200	720 / postal	Morse (1985)
Armidale NSW	1991	1.25	19 480	502 / personal interview	Wall & Reid (1993) Wall (1997)

Half of the total firewood harvest is collected rather than bought. State forest department permit sales account for less than 10% of the firewood market; therefore the majority of collected firewood is unregulated, and over 80% of it is obtained from private land. It is difficult to find out how much is collected illegally. Survey results show that illegal collection is less than 5% of the total harvest, but there are indications that this may be an underestimate.

Table 3.2.1. Percentage of firewood bought from merchants, bought from other suppliers, and collected by the householder (FTSUT 1989)

	% merchant	% other	% collected
Canberra	50.2	8.4	41.4
Hobart	53.6	12.0	34.4
Melbourne	31.3	9.4	59.3
Ballarat	27.9	6.7	65.4
Adelaide	38.5	4.7	56.8
Mean	40.3	8.2	51.5

Discussion

Anecdotal evidence suggests that illegal harvesting of trees for firewood occurs and can occur extensively in some areas (Section 2.3). McArthur (1989) stated there had been a rapid escalation in the number of attacks on roadside trees by firewood collectors in the Mornington Shire, Victoria. This caused the council to erect signs and instigate penalties for illegal firewood collection. Considerable illegal collection is believed to occur in the Midlands Forest Management Area (RFA 2000b), a region of Victoria where the preferred box and ironbark species occur. Illegal collection is rife in the Holbrook and Hume (Albury) shires and the problem is becoming more widespread (David Costello, Holbrook Landcare, pers. comm.). Commercial cutters who advertise in local newspapers take timber from roadsides illegally, including White Box and Yellow Box (*E. albens*, *E. melliodora*). Grassy White Box communities are listed as endangered under the *Environment Protection and Biodiversity Conservation ACT 1999*. Firewood is very scarce around campsites on the River Murray and campers have killed mature River Red Gum trees to ensure a firewood supply (David Costello, Holbrook Landcare, pers. comm.).

While it is relatively simple to establish that illegal and unregulated harvesting occurs, it is more difficult to quantify. However, we take a first step towards quantifying the unregulated firewood market by considering the way people acquire their firewood. Previous research found that about half of all firewood burned in households in south-eastern Australia was collected by the householder and a further 8% was purchased through sources other than merchants (Table 3.2.1, FTSUT 1989). While city and farm households represent extremes in the proportion of households that collect their own firewood (Victorian farms (89%) against the ACT (33%), Table 3.2.2), it is reasonable to assume that about half of the firewood-using population collects its own fuel (Section 2.1).

Table 3.2.2. The proportion of households that buy or collect their own firewood and the source of firewood collected

Location	% buy	% collect	% private property	% state forest	% roadsides or other public land	Reference
SA	30.7	61.8	41 (friends), 30 (own home), 22 (own property)	4.1	9.5	Rogers (1990)
Armidale,NSW	64.5	35.5	30.7	0.4	4.4	Wall & Reid (1993)
Victoria country town / farm (2 estimates)	38 / 11–19	62 / 81–89	41 / 66–77	14 / 7–9	4	Read Sturgess & Associates (1995)
NSW city / country	40 / 40	43 / 52				Young (1995)
ACT	33 (23% buy and collect)	33				Morse (1985)
ACT		41	80		16	FTSUT (1989)

Most of the collected firewood comes from private property, and only small proportions come from state forest (0.4–14%), or from roadsides and other public land (4–9.5%, Table 3.2.2; also this study, Section 2.1). Wall & Reid (1993) suggested that their householder survey under-reported the amount of collecting from public land. In addition, Read Sturgess & Associates (1995) reported that some licensed collectors took more than stated on their permits, so estimates of timber removed from state forests are likely to be underestimates, even for permit holders.

It is likely that illegally collected firewood makes up a much larger proportion of the total amount of firewood consumed than Table 3.2.2 suggests. After considering the distance that collectors travelled in the ACT and the number of permits to collect that were issued, FTSUT (1989) concluded that approx. 20 000 tonnes of firewood must be collected illegally in the ACT each year — approximately one third of the total amount consumed. The telephone survey (Section 2.1) suggested that only a small proportion of firewood is illegally collected from roadsides or other public land, which seemingly contradicts other evidence that roadsides can be badly degraded by firewood collection (Dickson 1999). Telephone respondents may have under-reported the amount of firewood they collect from public land. However, it is also possible that even low levels of collection could have a large impact on roadsides because roadside vegetation occupies only a very small proportion of the landscape.

Our results indicate that a very high proportion of firewood is bought from small merchants who do not have established premises, or from friends or relatives (Section 2.1). We have no information about this group of sellers. However, they represent a very large part of the market, much greater than is accounted for by state forest department sales (Section 2.3), so they must essentially be operating outside of any regulated system. If that assumption is correct, up to 70% of firewood that is purchased is collected by unregulated means, including legal collection from private property and illegal collection from state forests, nature reserves, roadsides and other public land. The actual proportion may be even higher because firewood merchants with premises can be supplied by small, unregulated operators (Section 2.2). Assuming that 70% is a reasonable estimate, and that firewood costs $120/tonne, the unregulated commercial firewood market is worth approximately $260 million per year.

3.3 Species composition, age, size and habitat characteristics of the harvested trees

River Red Gum, box and ironbark species are the most popular firewood types in south-eastern mainland Australia; Jarrah dominates the market in Western Australia; and a range of dry forest and woodland species is preferred in Tasmania. In South Australia, the amount of mallee burned has declined substantially over the past decade, being replaced by River Red Gum. A broader range of local tree species is taken by people who collect their own wood.

There is very little evidence from which to assess the habitat characteristics of harvested trees, but localised studies indicate that live, dead standing and fallen trees are taken. Nationally, three quarters of the people who collect their own firewood target fallen timber. Limited evidence suggests commercial harvesters may target standing dead trees.

Discussion: Species

Purchasers of firewood in most states show clear species preferences, but information from Victoria and South Australia suggests that people who collect their own wood take a larger range of species (Table 3.3.1). In Victoria a high proportion of firewood purchases are River Red Gum and box species, while people who collect their own firewood gather Messmate, stringybark, peppermints and ironbark; hence the different species emphasis in local state forest department sales reported in Regional Forest Agreements (Table 3.3.1). Presumably this highlights the difference in distance that collectors are prepared to travel (short distances) compared with commercial suppliers who transport red gum from the Riverina to Melbourne. Previous studies found that River Red Gum and mallee dominated the commercial market in South Australia, while local eucalypt species were predominant in the non-commercial arena (Table 3.3.1).

There is little information about New South Wales firewood use, although a thorough study in Armidale indicated preference for local woodland species. The ACT market strongly prefers box or ironbark species. Tasmania does

not have access to the box or red gum species favoured in Victoria or New South Wales, and so a broader range of species is used, including peppermints and stringybarks. The Western Australian market is flooded with Jarrah firewood, predominantly logging residue. No published information is available for Queensland or the Northern Territory.

These findings (Table 3.1.1) are relatively consistent with our results (Sections 2.1 and 2.2). Our surveys also report substantial use of red gum in Victoria, Jarrah in Western Australia, and a broad range of species in Tasmania, including peppermints and stringybarks. The preference for ironbark in Queensland and red gum/box in New South Wales reported in Sections 2.1

Table 3.3.1. Summary of studies identifying preferred firewood species in each state

Location	Species	Proportion or preference	Source	Reference
VICTORIA				
Melbourne	Red Gum (*E. camaldulensis*)	High	34 firewood merchants	Read Sturgess & Associates (1995)
	Box species	2nd to red gum	34 firewood merchants	Read Sturgess & Associates (1995)
	Stringybark and mallee	Small amounts	34 firewood merchants	Read Sturgess & Associates (1995)
Melbourne	Red gum (*E. camaldulensis*)	Bought 50%, collected 21%	Phone survey of householders	FTSUT (1989)
	Box species (*E. melliodora, E. polyanthemos*)	Bought 15%, collected 7%	Phone survey of householders	FTSUT (1989)
	Mallee roots	7%	Phone survey of householders	FTSUT (1989)
Ballarat	Box species (*E. melliodora, E. polyanthemos*)	Bought 61%, collected 19%	Phone survey of householders	FTSUT (1989)
	Red gum (*E. camaldulensis*)	Bought 12%	Phone survey of householders	FTSUT (1989)
	Stringybark (mainly *E. obliqua*)	Collected 30%	Phone survey of householders	FTSUT (1989)
Otway Forest Management Area, near Colac Victoria	Peppermint *E. radiata,* Messmate stringy bark *E. obliqua*	Preferred	not given	RFA (2000a)
Wimmera, Victoria	Red gum (*E. camaldulensis*)	Preferred	not given	RFA (2000a)
Portland, Victoria	*E. camaldulensis* and *E. obliqua*	Preferred	not given	RFA (2000a)
Midlands Forest Management Area	*E. camaldulensis* and *E. obliqua*	Preferred	not given	RFA (2000a)
North East Forest Region, Victoria	Box and red gum *E. melliodora, E. polyanthemos, E. camaldulensis*	50–80%	not given	RFA (1998)
Gippsland Forest Region	Red Box (*E. polyanthemos*), Ironbark (*E. sideroxylon*), stringybark species	Commonly used	not given	RFA (1999)

Table 3.3.1. continued

SOUTH AUSTRALIA				
South Australia	Mallee stems	Bought 27%, collected 17%	3600 household survey	Rogers (1990)
	Mallee roots	Bought 49.6%, collected 38.9%	3600 household survey	Rogers (1990)
	Red gum (*E. camaldulensis*)	Bought 41.2%, collected 46%	3600 household survey	Rogers (1990)
	Other local eucalypts	Bought 18.3%, collected 50.5%	3600 household survey	Rogers (1990)
Adelaide	Mallee stems	Bought 32%	Phone survey households	FTSUT (1989)
	Mallee roots	Bought 47%	Phone survey households	FTSUT (1989)
	Red gum (*E. camaldulensis*)	Bought 32%, collected 17%	Phone survey households	FTSUT (1989)
	Eucalypts general	Collected 28%	Phone survey households	FTSUT (1989)
Adelaide	Mallee stems	20%	Informal phone survey of merchants	Neagle (1994)
	Mallee roots	20%	Informal phone survey of merchants	Neagle (1994)
	Red gum (*E. camaldulensis*)	60%	Informal phone survey of merchants	Neagle (1994)
NEW SOUTH WALES				
Armidale	Stringybark (*E. calignosa*)	29.6%	716 household survey	Wall & Reid (1993)
	Box (*E. melliodora*)	29.4%	716 household survey	Wall & Reid (1993)
	Blakely's Red Gum (*E. blakelyi*)	22.3%	716 household survey	Wall & Reid (1993)
Sydney	Coastal eucalypts, box and ironbark species	Preferred	Phone 2 firewood merchants	FTSUT (1989)
AUSTRALIAN CAPITAL TERRITORY				
Canberra	Box species (*E. melliodora, E. polyanthemos*)	Preferred	Phone survey households	FTSUT (1989)
Canberra region	Box species (*E. melliodora, E. polyanthemos, E. albens, E. microcarpa*); Ironbark (*E. sideroxylon*)	Major species transported for sale	Timber merchant interviews	Alison Treweek (pers. comm.)
TASMANIA				
Hobart	Eucalypts general	Most common	Phone survey households	FTSUT (1989)
	Peppermints, stringybarks	Popular	Phone survey households	FTSUT (1989)
WESTERN AUSTRALIA				
Perth	Jarrah (*E. marginata*)	Most common	Phone survey households	FTSUT (1989)
	Mallee	Supplemental	Phone survey households	FTSUT (1989)

and 2.2 is new information. The high use of red gum is especially evident in our study, with an estimated 1.1 million tonnes of red gum burned annually, representing more than one fifth of the total amount of firewood burned in Australia.

Interestingly, merchants in South Australia claim to sell a high proportion of railway sleepers (Section 2.2), which has not been reported previously, and was not picked up in the telephone surveys of Section 2.1. Possibly people are sold sleeper timber as red gum, and so sleepers are not identified as distinct from unprocessed red gum (Section 2.1). Also, there appears to be much less mallee burned in South Australia now than has been reported previously. A study by Neagle (1994) reported mallee root and mallee stem use at about 20% each, much less than reported five years earlier (Rogers 1990). Our study estimates that mallee root and stem use in South Australia is only about 6% now, suggesting that the mallee firewood market has collapsed.

This change in the mallee market in South Australia offers a good opportunity to understand how firewood markets can be shifted from one resource to another. It could be valuable to study that shift to understand the types of changes that might be expected in markets when particular resources are regulated.

Habitat characteristics of harvested trees

Forestry residue makes up a large proportion of firewood taken from state forests. For example, Read Sturgess & Associates (1995) noted that of approximately 73 000 cubic metres of timber made available for firewood by Victoria's Dept of Conservation and Natural Resources, 64% was the product of forestry or silviculture. Approximately 30% of firewood collected by householders in Hobart is forestry residue (FTSUT 1989), as is much of the firewood collected from state forests in the Riverina in New South Wales (Mike Thompson, Regional Manager Riverina, NSW State Forests, pers. comm.). However, in Victoria where most evidence is available, 27% of firewood available is fallen timber, 5% is designated for felling and 4% is mining salvage (Read Sturgess & Associates 1995; RFA 1998, 1999, 2000a). Sizable amounts of fallen timber may be collected from state forests that are not being logged.

In Hobart the bulk of firewood collected (60%) is standing or fallen dead trees (FTSUT 1989), and in general more than 80% of timber collected for burning is dead wood (FTSUT 1989; Read Sturgess & Associates 1995). From interviews with firewood merchants in Melbourne, Read Sturgess & Associates (1995) report that more than half of firewood suppliers work on private land to collect dead red gum. MacNally *et al*. (2000b) estimate that on average 81% of fallen timber has been removed from River Red Gum communities in the southern Murray-Darling basin, indicating that firewood collectors have targeted wood on the ground. Ford *et al*. (2001) contend that large mature trees are gathered for firewood, which also removes tree hollows — a situation contributing to observed bird declines. This contradicts Bennett *et al.* (1994b) who suggested that large trees were not taken, and indeed were common across private property in northern Victoria. Traill (2000) argues, without producing direct evidence, that fallen, standing dead and standing live timber is targeted by firewood collectors, and emphasises that loss of hollow-bearing trees, dead or alive is a major problem. Dickson (1999) has recently shown that live, dead standing and fallen timber are removed from public land near Armidale, New South Wales. In Section 2.1 we reported that all three components are taken for timber, but that 75% of people who collect their own firewood look for fallen timber. Any research into the impacts of firewood collection should assess all potential firewood sources, including fallen and standing dead timber, and live trees.

3.4 Biogeographic concentration of the harvest, including impacts on threatened communities

Through the Regional Forest Agreement process, Victoria is most advanced among the states in recognising communities threatened by firewood collection. In Victoria, 49 plant communties are potentially threatened and these are predominantly woodlands and dry forests, often with a grassy understorey. The little information available from New South Wales, South Australia and Tasmania supports the contention that dry forests and woodlands, especially in cleared landscapes, are most threatened. There have been no assessments in

Western Australia or Queensland, and very little thought has been given to communities that may be threatened by firewood collection there. Studies are warranted in both states.

Discussion

The geographic distributions of the key species used for firewood (Section 3.3) provide some indication of where commercial harvesting is concentrated. To supply the strong demand for red gum, box and ironbark species in south-eastern Australia, extensive timber harvesting must occur throughout the western slopes and plains of New South Wales, the Riverina area of Victoria and New South Wales, and box–ironbark forests of Victoria and New South Wales. The results of MacNally *et al*. (2000b) attest to impacts in River Red Gum forests. It is also apparent from the species preferences that extensive firewood collection also occurs near to population centres where many local eucalypt species are gathered, including species that would not normally be sold.

The state forestry survey has produced information about other prime firewood regions (Section 2.4), although the amount of firewood sold by state agencies is only a small proportion of the total consumed. In Tasmania, most firewood sold from private property is obtained in the Midlands and Woolnorth bioregions, suggesting that the central lowlands are the preferred firewood hunting grounds. A similar analysis for Victoria (Table 2.4.3) shows that box–ironbark forests near Bendigo and in the Midlands Forest Management Area provide almost half of the firewood sold by the Dept of Natural Resources and Environment (DNRE). River Red Gum from throughout northern Victoria also accounts for a substantial proportion of firewood sold by the DNRE.

Firewood merchants also provide a broad perspective on areas targeted for firewood collection (Section 2.2). Figure 2.2.1 supports the generalisations made above, with most firewood coming from drier forests and woodlands west of the Great Dividing Range. However, the map also highlights the number of coastal forests that are currently providing firewood to the commercial market.

Threatened communities

Victoria

The most detailed and valuable information about the plant communities threatened by firewood appears in the Victorian Regional Forest Agreement Biodiversity reports for the North East, West and Gippsland Forest Regions (RFA 1998, 1999, 2000a). These reports describe threatening processes affecting Ecological Vegetation Classes. Ecological Vegetation Classes are detailed classifications of plant communities; see Appendix 2. The data sets of these reports could be used to map communities threatened by firewood collection, serving as an initial basis for further research, as well as helping to focus local education campaigns.

Forty nine plant communities are recognised as potentially being threatened by firewood collection. Among them are 30 woodland communities, 23 forest communities and one mallee community. Nineteen of the communities have a grassy understorey. Most of the forest communities, including box–ironbark forests and foothill forests, are in lower rainfall areas.

The West Region biodiversity report (RFA 2000a) explicitly recognises that Plains Grassy Woodland communities dominated by River Red Gum (*Eucalyptus camaldulensis*) and Yellow Gum (*E. leucoxylon* var. *leucoxylon*) are threatened by firewood collection. The report recommends that managers of the communities aim to retain fallen timber and standing trees with hollows.

Table 3.4.1. Summary of the proportion of Ecological Vegetation Classes in Victorian Regional Forest Agreements that are classified as woodland, and the proportion of those that have less than 30% of their pre-1750 extent remaining. The percentage of what remains of those communities that is in the CAR reserve system is also indicated (percentage for woodland communities only in parentheses)

Region	No. of plant communities	% woodland	No. <30%	% <30% woodland	Average % of remaining area in CAR
North East	62	50%	34	70%	14.4 (4.9)
West Region	259	59.1%	110	63.6%	47 (39.7)
Central Highlands	70	22.5%	17	29.4%	1.9 (5.34)
Gippsland	120	20.8%	24	33.3%	32.9 (34.4)

The Victorian RFA reports also assess the conservation status of Ecological Vegetation Classes. In woodland communities, often the target of firewood collectors (e.g. Traill 2000), less than 30% of the original vegetation remains, particularly in the North East Region (Table 3.4.1). In the North East and Central Highlands regions, only a small percentage of the remaining area is within the Comprehensive, Adequate and Representative (CAR) reserve system. This means that most of the few remaining woodland and ironbark forest communities are available for firewood collecting (RFA 2000b). Greater attention to the conservation of woodland is warranted, especially in the North Eastern Region.

New South Wales

Compared to Victoria, the Regional Forest Agreements in New South Wales do not provide the same detail, and they do not include areas of the state where important firewood species occur. Several plant communities are probably threatened by firewood collection, and a wide-ranging assessment like that done in Victoria would be valuable. For example, River Red Gum forests around main population centres, particularly Albury, are being badly degraded by firewood collection (Mike Thompson, NSW State Forests, pers. comm.). Forest Red Gum (*E. tereticornis*) has been extensively cleared on the New South Wales south coast and now occurs mainly on private property. It could be further degraded by timber removal for firewood (Steve Dodds, NSW State Forests, pers. comm.).

There is also evidence that plant communities in the wheat–sheep belt of New South Wales are under extreme pressure. A NSW State Forests report (Andrew Deane, NSW State Forests, pers. comm.) indicates that Jindalee and Combaning State Forests near Cootamundra have been extensively cleared of firewood. There are also signs of firewood removal in the nearby Inglebar Nature Reserve where firewood collection is illegal. Ironbark (*Eucalyptus sideroxylon*) is the dominant tree species in Jindalee and Combaning State Forests, and it is associated with Scribbly Gum (*E. rossii*), Grey Box (*E. microcarpa*), Red Stringybark (*E. macrorhyncha*), Black Cypress (*Callitris endlicheri*), and Cootamundra Wattle (*Acacia baileyana*). There was a large illegal operation removing firewood from Jindalee State Forest in 1994; the offenders were prosecuted. Firewood was so scarce that high limbs were taken, including one from a Squirrel Glider den-tree; Squirrel Gliders are classified as vulnerable in New South Wales. Firewood collection has been banned in Jindalee State Forest.

In view of this extreme pressure on the firewood resource, NSW State Forests is considering initiating a co-operative project to establish and manage woodlots of local species. The woodlots may act as 'stepping stones', allowing fauna to move between larger patches of vegetation, as well as providing a sustainable source of firewood (Warwick Bratby, Dubbo Region, NSW State Forests, pers. comm.).

Tasmania

In Tasmania, dry forest and woodland within 50 km of Hobart and Launceston are potentially suffering from firewood collection. The Tasmanian Regional Forest Agreement identifies many plant communities as being of conservation concern (Jamie Bayly-Stark pers. comm.), and it notes several species that are potentially threatened (see Table 3.6.1), but it does not list communities threatened by firewood collection (RFA 1997b).

South Australia

There has been no formal appraisal of threats to ecological communities in South Australia, although there is a list of prioritised vegetation communities which could be used as a basis for making such an assessment (Neagle 1995). Bob Inns (Dept of Environment and Heritage, South Australia, pers. comm.) suggests that *Eucalyptus microcarpa* woodlands near Adelaide may be threatened by firewood collection and have been extensively cleared. Although River Red Gum woodlands have been depleted in the south-east of the state and the species makes prime firewood, the main threat is clearance for vineyards and other agricultural developments (Bob Inns, pers. comm.).

Queensland

In Queensland, firewood collection is generally regarded as a southern states' problem. It has not been identified as a serious threatening process in Queensland, especially in comparison to the major threats of overgrazing and land clearing (Jeremy Thompson pers. comm.; Wendy Drury pers. comm.).

Nevertheless, extensive land clearing in the southern Brigalow belt, and indications (Section 2.2) that firewood is collected from that region

imply that the resource could be depleted. Further research is warranted.

Western Australia

In south-west Western Australia, extensive forestry operations surround all major population centres, effectively flooding the firewood market with Jarrah. Firewood collection does not directly threaten any of the plant communities on the Swan Coastal plain, although several are threatened in other ways (Neil Gibson, Wildlife Research Centre, Dept Conservation and Land Management Western Australia, pers. comm.). However, firewood collectors can spread the soil fungus *Phytophthora cinnamomi*, which is a serious threat to Western Australian plant communities (Gibson pers. comm.).

While CALM has global figures that show that the Jarrah firewood resource is being harvested sustainably, some independent research is warranted to specifically examine retention of wood in logged and unlogged forests, because 610 000 tonnes of Jarrah are burned annually, the second largest amount of any tree group in the country.

In the wheatbelt of Western Australia, where only 10% of native vegetation remains (Saunders *et al*. 1993), it is thought that firewood collection is not a serious threat (Denis Saunders, Robert Lambeck, CSIRO Sustainable Ecosystems, pers. comm.), although some woodland remnants appear a bit 'cleaner' than others (Steven Sarre, Massey University, pers. comm.). However, the illegal taking of woody plants in general, for firewood, posts and didgeridoos, contributes to degradation of wheatbelt woodland remnants, and the impact appears to have increased over the past decade (Ken Wallace, Wheatbelt Regional Manager, Department of Conservation and Land Management, pers. comm.).

To collect firm information, FTSUT (1989) recommended that the extent of firewood harvest in the wheatbelt of Western Australia be examined, but there have been no studies completed in the interim. We can only reiterate the need for specific research to assess the extent and possible impacts in the Western Australian wheatbelt.

3.5 Sustainability of the firewood harvest

Preferred firewood species have very low rates of growth compared with coastal and mountain species; however, no studies have assessed the rate of production or decay of key firewood resources. The expected amount of fallen timber has been reported only for River Red Gum communities (125 tonnes/hectare). However, that report found that 95% of sites in the lower Murray-Darling basin had less than 50 tonnes/hectare, indicating substantial resource depletion due to firewood harvesting. A similar level of over-exploitation has been reported for public land near Armidale: 80% of standing green timber has been removed from roadsides, state forests and travelling-stock routes. Firewood collected after logging operations may cause few additional effects, but the sustainability of collection from unlogged state forests has not been assessed. Limited evidence indicates that firewood harvesting in dry forests and woodlands occurs at rates well above a sustainable level.

Discussion

The preferred firewood species such as box, ironbark, and red gum accumulate biomass extremely slowly. Grierson *et al*. 1992 reported that biomass accumulation in box–ironbark forests of Victoria declines from less than 2 tonnes/hectare in young forest to virtually no net biomass production in 60 year old forest. Mallee biomass production remains stable as the trees age, at less than 1 tonne/hectare/year. In contrast to these low rainfall forests, mean annual biomass increment in 60 year old mountain, coastal and foothill forests varies from 6 to 10 tonnes/hectare. Mike Thompson (NSW State Forests, pers. comm.) has indicated that River Red Gum grows at 1.8–2 cubic metres/year, a growth rate similar to that in box–ironbark forests.

The rate of biomass accumulation may not be relevant if fallen timber is the main firewood resource collected.

We need to consider the rate at which fallen timber enters the ecosystem. Harmon *et al*. (1986) report that the input of coarse woody debris (including fallen timber, dead branches

on live trees and standing dead trees) for a range of northern hemisphere forests varies from 0.12 tonnes/hectare/year in the dry oak scrub (*Quercus nigra*), to 30 tonnes/hectare/year in north American coniferous forest. The rate of accumulation depends on forest type and on the age of the stand: rates of input increase with stand age. Coarse woody debris accumulates over the long term (decades) and most studies are done in the short term, so Harmon *et al*. (1986) warn that the estimates should be regarded with caution. We are not aware of any similar studies conducted in Australia.

On the other side of the equation is the decay of coarse woody debris. Very little is known about decomposition rates in Australian forests (but see Brown *et al*. 1996). Until studies of rates of input and decay are conducted in Australian forests, a sustainable yield of fallen timber cannot be firmly established.

We are aware of only two calculations of a sustainable yield of firewood and both are for harvesting green standing timber. For the 'fuelwood' catchment of Armidale, New South Wales, Wall (1997) has estimated that 2.39 million tonnes of standing tree biomass is available for firewood production from the 31.7 million tonnes in the region, after considering access, stream buffers and exclusions intended to prevent further degradation of already extensively cleared landscapes. These forests occur on 15 700 hectares of private land, and 1500 hectares of State Forest. With a growth increment of 2.5 tonnes/hectare/year, Wall estimates a sustainable yield of 43 000 tonnes/year, which exceeds the estimated 31 000 tonnes consumed in the Armidale region. However, the actual yield could be lower if only trees that are 15–60 centimetres in diameter at breast height were harvested, and if some trees in this age class were retained to grow into larger trees, as Wall (1997) recommends. Wall concludes that the Armidale firewood industry could operate sustainably if it shifted its focus from the declining box and Blakely's Red Gum species, towards the more abundant stringybark forests. Wall also points out that tree plantations grow at up to 10 tonnes/hectare/year, and that they also have the potential to supply Armidale's firewood needs, using only 2500 hectares of farmland.

Neagle (1994) provides a second calculation of green firewood yield. Neagle's report delineates the main Adelaide supply area for mallee as the Murray mallee and mid north, to the north-west of Adelaide. Within this area there are 127 000 hectares of mallee, and with a cutting interval of 50 years and production of 24 tonnes/hectare an economically sustainable harvest is 61 000 tonnes/year. Neagle points out that a further 25% of the area must remain uncut for the yield to be ecologically sustainable, leaving a possible yield of 23 000 tonnes/year. Uncut areas are necessary so that trees can develop hollows. Adelaide's use of mallee when that report was prepared was 25 500–45 000 tonnes/year, 17–30% of the total fuelwood used, and exceeding the estimated sustainable yield by between 10 and 96%.

Given the general absence of studies like Wall (1997) or Neagle (1994) for indicating sustainable harvests, an alternative way of considering the sustainability of firewood collection is to examine levels of firewood depletion. We can determine how much coarse woody debris should be present in an undisturbed woodland or forest, and compare that with what is actually present. In the northern hemisphere, Harmon *et al*. (1986) report 5–38 tonnes/hectare of log biomass for deciduous forest, and 1–490 tonnes/hectare for coniferous forest, making the point that the expected amount of coarse woody debris depends on species and climate. In Australia, Lindenmayer *et al*. (1999) report 309–393 cubic metres/hectare for Mountain Ash forests (*E. regnans*) in Victoria, and Meggs (1996) reports 174–455 cubic metres/hectare for young Messmate (*E. obliqua*) in Tasmania. The expected amount of coarse woody debris needs to be established for each ecosystem, particularly the drier forests which have not been studied.

After exhaustively searching historic records, MacNally *et al*. (2000b) conclude that records are inadequate to estimate the amount of coarse woody debris in River Red Gum (*E. camaldulensis*) communities. Therefore they have used an estimate of coarse woody debris from undisturbed forest (125 tonnes/hectare) as the best indication of natural quantities of coarse woody debris (Robinson 1997; MacNally *et al*. 2000b). Having measured fallen timber along 516 transects in the southern Murray-Darling Basin, MacNally *et al*. (2000b) found that 11% of transects had no coarse woody debris, 24% had <2 tonnes/hectare, 47% had <10 tonnes/hectare, and only 5% had >50 tonnes/hectare. These authors attribute the huge loss of coarse woody debris to firewood harvesting and logging. Their study provides

the clearest evidence to date that firewood harvesting in River Red Gum communities is unsustainable, and that the resource is being depleted to levels which adversely affect some fauna species (see Section 4).

Dickson (1999) compared firewood loads in forest remnants on six paired private/public sites in the Armidale region of New South Wales, and found that on public land there was significantly less green wood, an average of five times less standing dead timber, many more cut stumps, and about 30% less fallen timber, although the trend varied from pair to pair. Dickson attributes this variation in the amount of fallen timber to increases in fallen timber on some public sites where trees had been felled for firewood, leaving tree heads, twisted, and difficult-to-manage timber on the site. Dickson estimates that about 80% of green timber has been removed from public land, indicating an extreme rate of resource depletion.

Several state forestry representatives who were interviewed (Section 2.4) emphasised that the firewood taken from their forests is collected on a sustainable basis. For example, after logging in the New South Wales south coast region, there might be 2–300 tonnes of wood per hectare on the ground, but firewood harvesters take only 2–3 tonnes/hectare (Steve Dodds, NSW State Forests, pers. comm.). So firewood collection in state forests after logging or thinning may not have substantial additional impacts on the ecosystem, although that is not demonstrated in any formal studies that we know of.

In unlogged forests where firewood collection is permitted, it is unlikely that the amount of fallen timber on the ground will have been measured or monitored. In view of this lack of data, and because it is likely that illegal collection in state forests places additional pressure on the resource (Sections 3.4, 3.2), the sustainability of harvesting must be determined. This applies especially to firewood harvesting that is not associated with logging in state forests. State forests should be included in any research examining the sustainability of firewood harvesting.

While it is likely that the firewood industry can be sustainable if it shifts its resource focus (Wall 1997, 1999; Grey 2000), the evidence to date indicates that firewood is generally not being managed sustainably (Wall & Reid 1993, for Armidale; Morse 1985, for ACT; Allender 1988). Having reviewed current literature, Wall (1999) concludes that the Australian firewood industry is not on a sustainable footing, and that a shift in attitude is needed, towards properly managing remnant stands and producing firewood from plantations. We have found nothing to contradict this conclusion.

4. IMPACTS OF FIREWOOD COLLECTION ON WILDLIFE

Large amounts of firewood are burned in Australia, obtained from a broad range of plant communities, and current collection practices appear to be unsustainable. Therefore, we now turn our attention to the consequences for wildlife. We review information that links wildlife to the habitat elements that firewood collectors remove, including fallen timber, and standing trees with hollows. We also outline the few studies that directly assess the impact of firewood removal. Throughout this section we refer to fallen timber, dead branches on live trees and standing dead trees as coarse woody debris.

4.1 INVERTEBRATES

A diverse range of invertebrate species specialise in exploiting dead wood, and depend on dead wood for their survival. Research, mainly from the northern hemisphere, has demonstrated reduced invertebrate diversity in areas with less fallen timber or standing dead trees. Invertebrate species can be part of co-adapted systems with fungi or plants, and so declines of one group could have indirect impacts on a range of other species and ecosystem processes. The limited research done in Australia demonstrates that the principles established overseas are likely to be true in this country also, with many species threatened by firewood collection.

There is very strong evidence suggesting that coarse woody debris maintains a diverse fauna that is, to some extent, distinct from the fauna associated with other habitat elements, and that loss of coarse woody debris reduces species diversity.

Extensive research in the northern hemisphere shows the importance of coarse woody debris for maintaining saproxylic biodiversity (Niemela 1996). (Gunning (2000) defines saproxylic invertebrates as those which are dependent on dead wood, either directly or indirectly for survival.) For example, in a Norwegian spruce forest, Okland *et al*. (1996) has found that the most important explanatory factors for saproxylic beetle diversity are the variety of dead tree parts, the number of dead trees of large diameter and the number of fungi. Okland *et al*. (1996) notes that three threatened beetle species did not occur in areas where there were fewer than 4–7 standing dead trees per hectare. In the same environment, Okland (1996) shows that coarse woody debris is positively correlated with species richness of Mycetophilid flies. Siitonen & Martikainen (1994) argue that rare beetle species are less abundant in Finland's forests than in Russian forests because of the loss of coarse woody debris in Finland. In beech–spruce forests of Switzerland, Schiegg (2000) has found that the more the ground is covered by dead wood, the greater the diversity of saproxylic beetles and flies. Saproxylic beetles make up approximately half of the beetle species captured by Martikainen *et al*. (2000) in their study of old-growth and logged spruce forest in Finland. Most (78%) of the saproxylic species are more abundant in old growth forest, whereas non-saproxylic species are just as abundant in logged forest as old-growth forest. These authors conclude that the maintenance of coarse woody debris in managed forests would improve their biodiversity amenity.

Apart from relying on coarse woody debris for survival, saproxylic invertebrates can be highly specialised, using only particular parts of a decaying tree or log, or particular fungal species (Speight 1989), or logs with a particular exposure to the sun (Key & Ball 1993). Species that depend on dead wood may have specialised dispersal abilities linked to the longevity of their dead-wood resource, which in turn may influence their ability to recover after disturbance (Nilsson & Baranowski 1997). In an agricultural area in Norway, Rukke (2000) has found that different beetle species have a significant preference for fungi on either fallen or standing trees. With such a degree of specialisation, invertebrates that need one type of dead wood, such as fallen timber, cannot be compensated by another type, such as standing

tree hollows; the full range of habitats is required. In view of this, Speight (1989) recognised firewood collection as a significant threat to saproxylic invertebrates in European forest remnants.

Saproxylic invertebrates are entwined in complex ecological webs; therefore declines in particular invertebrate species can have substantial consequences. Some fungi have specially adapted spores that can be transported by saproxylic invertebrates, while some beetle species have special organs for storing and transporting spores of symbiotic fungi (Speight 1989). A breakdown in that transport system would have profound effects for the species concerned and for other species dependent on the fungus, and would disturb the rate of decay and recycling in the forest ecosystem. In a review of the ecological role of the Nearctic earthworm fauna, Hendrix (1996) notes that earthworms shelter beneath and help in the decay of fallen timber, and suggests that fallen wood is needed for maintaining the biodiversity of soil fauna. Invertebrates that depend on dead wood can also have important roles in adjacent ecosystems. In a detailed study of saproxylic invertebrates in living trees near Oxford, Paviour-Smith & Elbourn (1993) have found that wetland species hibernate in dead wood, and that species which pollinate Hawthorn flowers depend on dead wood during their larval stages.

With this strong evidence emerging from the northern hemisphere, Grove (2000) asks if the same principles apply in Australia. He has examined saproxylic beetles in nine sites in the Daintree lowland rainforests in Queensland. Regrowth areas in these sites have little coarse woody debris and the trees have small basal areas, whereas old growth forest sites have large but variable amounts of coarse woody debris and the standing trees have large basal areas. As in Europe, invertebrate species richness in Grove's study is strongly correlated with amount of coarse woody debris.

In eucalypt forest of north-eastern New South Wales, Andrew *et al*. (2000) report that ant species richness is higher in leaf litter associated with large logs (>1 metre diameter) than in leaf litter away from logs. They suggest that logs are important for maintaining ant biodiversity in areas subject to frequent fuel reduction burning. In a report to the New South Wales Scientific Committee, Gunning (2000) points out that there are saproxylic species in almost every terrestrial insect order in Australia, although saproxylic beetles are most diverse. Gunning mentions several examples, including the endangered Ant Blue butterfly (*Acrodipsas myrmecophila*), which is dependent on a symbiotic ant *Papyrius* sp., which in turn is dependent on dead wood and is threatened by firewood collecting near Broadford, Victoria. In MacNally *et al*. (2000b), preliminary results of a study of invertebrates in River Red Gum communities show that the fauna near coarse woody debris is different from the fauna away from coarse woody debris. Contrasting results have been generated from a Western Australian woodland study; Abensperg-Traun *et al*. (1996) found that invertebrate orders varied in abundance among sites, but the variation appeared to have little to do with dead wood. Possibly Abensperg-Traun *et al*. (1996) did not include sites spanning a large enough range of dead wood; more firewood-focused research might pick up the sort of effects indicated by other research in Australia and overseas.

Apart from concerns about loss of habitat for particular species when dead timber is collected from a site, there is the potential for firewood collection and transport to alter the natural distributions of native invertebrates, potentially introducing species into new areas. Todd & Horwitz (1990) captured 56 species of invertebrates in firewood from Hobart wood yards, including many forest species, highlighting the potential for inadvertent introduction of alien species.

4.2 Fungi

Fungi are highly specialised and many species contribute to a functioning ecosystem. Fallen timber can provide a refuge for mycorrhizal fungi during disturbance. Retention of fallen timber may therefore allow the symbiotic plant–fungi relationships to re-establish quickly, and the community to recover from disturbance more effectively. Ecosystem resilience may be reduced by over-exploitation of firewood.

Like invertebrates, fungi exhibit a high degree of diversification, with particular species specialising on dead wood in different situations, of different sizes, or in different stages of decay. For example in Norwegian Spruce forest, Kruys *et al*. (1999) have found that threatened species of fungi occur only on relatively large logs in relatively advanced stages of decay, features which are rare in

logged forests. Sippola & Renvall (1999) have shown that the diversity of wood-rotting fungi in Finnish boreal forest is dependent on the amount and stage of decomposition of coarse woody debris. Amaranthus *et al.* (1994) have found that mature Douglas fir forest has 20 times more biomass of truffles than the surrounding plantation, and much of the difference is attributable to the abundant coarse woody debris found in the mature forest. Eight of 21 truffle species are confined to coarse woody debris and do not occur in the soil (Amaranthus *et al*. 1994). Sites with large amounts of coarse woody debris have highly diverse and abundant fungi. The fungi are a food resource for invertebrates and vertebrates, and also enhance the ecosystem's resilience to disturbance by providing a reservoir of mycorrhizal fungi for re-establishing plants (Vogt *et al.* 1995). In Australia, fungi are at least as diverse as in the northern hemisphere; they are equally important components of the ecosystem, and face similar threats (Scott *et al.* 1997).

4.3 Birds

There is mounting opinion that more than 20 bird species are declining due to the effects of firewood collection. Although the few studies that directly examine the impact of firewood collection on bird communities are contradictory, there are compelling arguments and some correlational evidence that link bird declines to loss of coarse woody debris.

The few studies that directly examine the relationship between birds and coarse woody debris have not produced consistent results. Unpublished analyses arising from the nationwide Birds-On-Farms project of Birds Australia indicate that for every 10 fallen trees in a farm site, the number of species of ground-foraging birds increases by 30% and the number of species of bark-foraging birds increases by 70% (Barrett *et al.* in prep). Also from the Birds-On-Farms project, Barrett & Davidson (1999) report that half hectare woodland plots with six or more fallen trees have significantly more bird species, more ground foragers and more ground nesters than sites with five or fewer fallen trees. In a study of bird faunas in Victoria, Laven & MacNally (1998) have surveyed box–ironbark forests where there is little fallen timber (2.6 cubic metres/hectare) in comparison to forest that has plentiful fallen timber (9.6 cubic metres/hectare, 'high'), including sites near to fallen timber, and away from fallen timber. Within the 'high' forest areas, sites that have coarse woody debris have significantly more individual birds and species, possibly related to resources for food or shelter. Cam & Cam (unpublished, quoted in Neagle 1994) have found that parrots leave an area of mallee that has been cut for firewood, and any birds that remain in isolated trees with hollows are subject to higher rates of predation. They recommend that no cutting be permitted in areas where trees contain hollows. In South Africa, Du Plessis (1995) has provided evidence that at least two hollow-dependent bird species have declined from a woodland remnant that was heavily harvested for firewood, whereas they are still present in an unharvested area. Du Plessis (1995) also argues that lower densities of several species are due to the reduced availability of suitable tree cavities.

Contrasting with the above studies, which all demonstrate an adverse impact of firewood collecting, MacNally *et al*. (2000b) report that the bird species in River Red Gum forests in the lower Murray-Darling catchment seem to be unaffected by the quantity of coarse woody debris present, although there seems to be a peak in species richness at 20 tonnes/hectare. In remnant buloke *Allocasuarina luehmanni* woodland in north-western Victoria, Watson *et al*. (2000) have found that the presence of standing dead trees or fallen logs is not an important factor in a model distinguishing bird communities. Grazing by sheep is the major deleterious factor in that environment.

While firm evidence of a relationship between coarse woody debris and birds is thin and contradictory, several authors have implicated firewood removal, directly or indirectly, as influencing bird abundance, based on observation and inference rather than experimental or explicit analytical approaches (e.g. Er *et al*. (1998), in ACT red gum/Yellow Box woodlands; Barrett *et al*. (1994), New England Tablelands; Reid (1999), sheep–wheat belt New South Wales; MacNally *et al*. (2000a) Victorian box-ironbark forest; Bennett *et al*. (1998), Victorian Riverina; Robinson (1992), Southern Tablelands of New South Wales; Ford *et al*. (2001), southern Australia; Traill (1993) box–ironbark forest, Victoria). In northern Victoria, Bennett & Ford (1997) have observed a strong relationship between the number of woodland bird species and tree cover at a landscape scale. They predict that gradually

decreasing numbers of trees would have a disproportionate effect in landscapes that are already extensively cleared. In this context, the gradual depletion or loss of individual trees to firewood harvesters may severely disadvantage bird species in areas that have less than 10% cover of native woody vegetation.

Regional Forest Agreements between the Federal and state governments were introduced in an attempt to stabilise the native timber harvesting industry. The RFA process included a series of workshops that brought biologists together to consider threatening processes for native wildlife. Firewood harvesting was explicitly considered in Victoria and New South Wales threatening-process workshops. Wildlife species identified as threatened by firewood collecting in eastern Australia are listed in Appendix 1, derived from various workshops. The list includes twenty-two bird species.

The recent Action Plan for Australian Birds (Garnett & Crowley 2000) also identifies 21 species that are threatened by firewood collection at a national level (Table 4.3.1). Twenty of these species have large parts of their geographical distributions in woodland or mallee ecosystems (Blakers *et al*. 1984). It is interesting to note that a Western Australian species (Crested Shrike Tit) is listed as threatened by firewood collection, because this is one of only two pieces of evidence that we have encountered to show that firewood collection may be a threatening process in Western Australia.

4.4 Mammals

The international database of case studies that explicitly investigate the relationship between coarse woody debris and mammals is weak. It consists of a handful of correlational studies, apparently no definitive experimental research, and contrasting results. However, these few studies show that some species are influenced by the existing range of woody debris, but that responses are specific to species and habitats.

Very few studies have examined the relationship between mammals and coarse woody debris. Bennett (1993) trapped small mammals in coastal forest remnants of south-eastern Victoria and found weak positive relationships between the number of logs and two bandicoot species, a weak negative relationship for female Long-nosed Potoroos, and no relationship for four other small mammal species. Understorey vegetation was the most important element of the habitats of all the species studied, implying that livestock grazing of the understorey would be a major threat to them. In a broad survey of vertebrate

Table 4.3.1. Bird species threatened by firewood collection (Garnett & Crowley 2000) and their habitats (Blakers et al. *1984)*

Species threatened by firewood collection	Conservation status	Habitat
Red-tailed Black-Cockatoo (south-eastern)	Endangered	Woodland
Superb Parrot	Vulnerable	Woodland
Regent Parrot (eastern)	Endangered	Woodland and Mallee
Swift Parrot	Endangered	Woodland and Forest
Barking Owl (southern)	Near Threatened	Woodland
Masked Owl (Tasmanian)	Endangered	Woodland and Forest
Australian Owlet-nightjar (Tasmanian)	Vulnerable	Woodland and Forest
White-browed Treecreeper (eastern)	Near Threatened	Arid
Brown Treecreeper (south-eastern)	Near Threatened	Woodland and Forest
Forty-spotted Pardalote	Endangered	Woodland and Forest
Shy Heathwren (Riverina)	Near Threatened	Mallee
Speckled Warbler	Near Threatened	Woodland
Regent Honeyeater	Endangered	Woodland and Forest
Black-chinned Honeyeater (eastern)	Near Threatened	Woodland and Arid
Painted Honeyeater	Near Threatened	Woodland and Forest
Hooded Robin (south-eastern)	Near Threatened	Woodland, Mallee and Arid
Grey-crowned Babbler (eastern)	Near Threatened	Woodland
Chestnut Quail-thrush (eastern)	Near Threatened	Mallee
Crested Shrike-tit (western)	Near Threatened	Woodland and Forest
Crested Bellbird (southern)	Near Threatened	Woodland and Arid
Diamond Firetail	Near Threatened	Woodland, Mallee and Forest

fauna in relation to the density of coarse woody debris on River Red Gum plains, MacNally *et al*. (2000b) found that the only native species they captured, *Antechinus flavipes* (Yellow Footed Antechinus), was present in significantly greater numbers when coarse woody debris exceeded 45 tonnes/hectare (MacNally *et al*. 2000b).

In overseas examples, Bowman *et al*. (2000) has shown that the abundance of Red-backed Voles is positively influenced by the abundance of highly decayed logs, when comparing logged and relatively undisturbed forests in New Hampshire. Highly decayed logs are an essential component of vole habitat (Tallmon & Mills 1994), but they are only one of the factors that affect vole distribution. Mills (1995) has observed higher densities of voles further from forest edges and has found that this is correlated with their fungal food and not with the amount of coarse woody debris.

Bennett *et al*. (1994a) measured a range of environmental attributes, including logs, in comparison to chipmunk abundance in an agricultural landscape in Canada and found that the number of logs was not a significant determinant of chipmunk abundance. In an Appalachian mixed hardwood forest, Menzel *et al*. (1999) have found that only one of seven small mammal species depends on the presence of coarse woody debris (>1cm diameter) along a gradient from open to deep forest habitat.

Traill (1993) has recommended total bans on removal of standing dead trees and on the random removal of fallen timber for firewood, because this clearance may contribute to an observed decline of hollow-dependent mammal species in box–ironbark forests. Additional anecdotal evidence that the taking of firewood has an impact on mammals was collected in the Regional Forest Agreements (Appendix 1). In south-eastern Australia, there was opinion that firewood collection may adversely affect nine mammal species. Also, the endangered Red-tailed Phascogale from south-west Western Australia in the mid-rainfall zone is found in association with hollow-forming trees (Maxwell *et al.* 1996) and so may be threatened by loss of that habitat element.

4.5 Reptiles and Amphibians

Limited evidence suggests fallen timber may be more important for reptiles in dry forests and woodlands than in high rainfall areas, because shelter is abundant and factors other than logs are more limiting in high rainfall environments. While inferences that reptiles will be adversely affected by firewood collection are sound, there has been inadequate corroborating research. It is not known how frogs are affected by the loss of coarse woody debris.

There is some published evidence showing reptiles are heavy users of coarse woody debris. In remnant woodland of the Western Australian wheatbelt, Sarre (1998) has observed 58% of geckos *Gehyra variegata* on logs and 9% on dead standing trees. Webb & Shine (1997) note that tree hollows are a critical habitat element for the threatened Broad-headed Snake *Hoplocephalus bungaroides* in the Sydney sandstone region. Broad-headed Snakes move between rocky outcrops and tree hollows in adjacent forest. If there are fewer tree hollows the snakes' home ranges must increase because they have to travel further to reach the hollows, with resultant increased mortality during dispersal (e.g. Bonnet *et al*. 1999).

The importance of coarse woody debris for reptiles may differ in wet and dry forest habitats. In recent work, having radio-tracked carpet pythons (*Morelia spilota*) in River Red Gum (*Eucalyptus camaldulensis*), and Black Box (*Eucalyptus largiflorens*) communities, Robertson (in prep.) reports that of 88 rest sites for four pythons 55% were in tree hollows, 34% in logs on the ground and 5% in shrubs. This contrasts with a study in a higher rainfall zone, where pythons preferred to use dense clumps of vegetation for shelter, and only 7% of records were under heavy cover, including rocks and logs (Shine & Fitzgerald 1996). In another study from a high rainfall forest, Brown & Nelson (1993) found there was no relationship between the number of logs in Mountain Ash forests in Victoria and the abundance of the skink *Eulamprus tympanum*, possibly because logs are not a limiting factor in that environment (approx 300–400 tonnes/hectare; Lindenmayer *et al*. 1999). Brown & Nelson (1993) also reported a negative relationship between *Niveoscincus conventryi* and the number of logs, but suggested this could be because of the little sunlight available in older forests which also have a large number of logs. Coarse woody debris may therefore be particularly important as habitat in dry forests and woodlands, and may play a less crucial role in wetter forests.

Given the generally recognised relationship between reptiles and logs, it is not surprising

that authors have speculated that loss of coarse woody debris will have a negative effect (see, e.g., Robertson *et al*. (1989), *Morethia spilota variegata*; Brown & Bennett (1995), reptiles in northern Victoria; Sadlier (1994), reptiles in riverine habitats). Anecdotal evidence collected through the Regional Forest Agreement process has identified 25 reptile species that are likely to be adversely affected by firewood collection (Appendix 1). However, the few correlational studies that have been published do not show overwhelming support for supposed impacts. Smith *et al*. (1996) have reported that the amount of woody litter (>5 cm diameter) is positively correlated with the number of species of gecko and skink and total reptiles, but these effects are not significant when biogeographic factors are considered. In a study of nine reptile and four frog species in remnant buloke woodlands in Victoria, Hadden & Westbrooke (1996) have found that log cover is not correlated with abundance of the species. The reptiles' numbers appear to depend more on the understorey structure and grazing history, while the frogs are influenced by soil type. MacNally *et al*. (2000b) find that reptiles and amphibians appear to be unaffected by the amount of coarse woody debris in River Red Gum communities. However these authors note that few reptile species were present at these sites and suggest that this may be due to the broad loss of coarse woody debris, or it may be a natural state on the floodplains. Nevertheless, the potential for tree removal to influence species abundance was demonstrated by Brown & Nicholls (1993), who found a positive correlation between abundance of the disturbance-favouring skink *Morethia boulengeri* and stump density. There is virtually nothing known about possible effects of firewood removal on frogs.

As a means of summarising the state of knowledge we consider one additional example. Brown & Bennett (1995) have argued that many reptile species are dependent on fallen or standing dead timber, including 11 species from their own surveys of woodland remnants in northern Victoria. Therefore, they contend that firewood collecting is likely to contribute substantially to habitat degradation, and may have contributed to the very low abundance and species diversity they observed at most sites during their study. This logic is impeccable, and is used extensively throughout the literature. However, their forward stepwise analyses fail to identify the number of logs as a significant factor explaining either the abundance and diversity of reptiles, or the abundance of four common individual species. So despite Brown and Bennett's extensive survey and despite the intuitive argument that there should be an impact, there is still no firm evidence of impacts. This, and the preceding examples highlight the weakness of approaches to date which only address loss of coarse woody debris or firewood collection incidentally and do not specifically design surveys or experiments around the question of firewood removal.

4.6 Plants

Firewood collection may threaten plants by directly removing them, by altering their micro-

Table 4.6.1. Plant species potentially threatened by firewood collection in Tasmania (RFA 1997b)

Species	Habitat
Caladenia aff. venusta	Eucalyptus viminalis *sedgey woodland*
Caladenia caudata	*Eucalyptus amygdalina* and *E. sieberi* heathy open forests, *E. viminalis* heathy woodland, *E. viminalis* grassy woodland with *Allocasuarina littoralis* and heathland
Caladenia lindleyana	*Eucalyptus amygdalina* shrubby open forest; grassy *Eucalyptus viminalis* forest
Colobanthus curtisiae	Grassland/grassy woodland
Danthonia procera	Dry sclerophyll forest
Eucalyptus morrisbyi	Dry sclerophyll forest
Eucalyptus risdonii	Dry sclerophyll forest
Glycine latrobeana	Dry sclerophyll forest
Prasophyllum robustum	*Eucalyptus amygdalina* grassy dry sclerophyll forest
Pultenaea hibbertioides	Heathland/mooreland
Scleranthus fasciculatus	Grassland/grassy woodland
Stenanthemum pimeleoides	Dry sclerophyll forest
Tetratheca gunnii	Dry sclerophyll forest

habitat, and by introducing competitors and disease, notably Phytophthora cinnamomi. There is virtually no research to document the extent of the problem.

Although we have found virtually no peer-reviewed literature that examines whether firewood collection has any effect on plants, there is some ground for concern. The Regional Forest Agreement reports in Tasmania and Victoria (e.g. RFA 1997b; RFA 2000b) proposed a number of ways in which firewood collection could threaten plants, by causing:

- damage or loss of individual plants during timber collection,
- alteration of microclimate and loss of micro-habitat,
- weed invasion,
- spread of pathogens, notably *Phytophthora cinnamomi* (also a problem in Western Australia; Neil Gibson pers. comm.),
- increased erosion and sedimentation,
- disturbance to the understorey by vehicles.

In addition to these potential problems, McKenny & Kirkpatrick (1999) have reported that fallen logs are particularly important for plant germination in two high rainfall forests, at 1000 and 1400 millimetres rainfall, in Tasmania. Removal of logs by firewood collectors therefore has the potential to alter plant community dynamics.

The Tasmanian RFA (RFA 1997b) includes a list of plant species that are threatened by firewood collection (Table 4.6.1). Many of these species have very restricted distributions, which means that firewood collectors could inadvertently damage a large proportion of the remaining populations of these plants. Interestingly, the list includes a species from grassland/moorland habitat — not a habitat that would normally be associated with firewood collection — in which the threat is the spread of *Phytophthora cinnamomi.*

5. Knowledge gaps and Research framework

From our review of the scientific literature (Section 4), and our analyses presented in Sections 2 and 3, we now define the major gaps in knowledge about the extent and impacts of firewood harvesting in Australia.

5.1 Key Knowledge Gaps: Impacts

1. **Depleted areas.** There is scarce evidence to demonstrate that firewood has been depleted from specific plant communities. While there is strong circumstantial and anecdotal evidence of widespread effects of removing timber from a broad range of plant communities in south-eastern Australia, formal assessments have not been completed. The general lack of information limits our ability to draw firm conclusions about the spatial variation of firewood-collecting. Remediation work cannot be decided on until more is known. For example, to reduce the impacts of past or ongoing over-collecting, we need to know where over-collecting has occurred, and where the impacts are likely to be greatest, on threatened species and communities, and the amount of wood that is required to restore key sites.
2. **Western Australia and Queensland.** There are no assessments of firewood depletion in Western Australia or Queensland. However, areas have been extensively cleared in both states, so firewood collection is likely to be concentrated into very small remnants. For Western Australia there is anecdotal and published evidence (Garnett & Crowley 2000) that firewood collection may be a problem. In addition, because of the relatively large amounts of Jarrah used as firewood, it would seem sensible to make independent assessment of the effects of its removal.
3. **Sustainable yield.** There are currently no data from which to calculate sustainable yields of fallen timber for dry forest and woodland communities, or estimates of expected loads of dead timber in un-harvested communities. If existing remnant vegetation is expected to remain an important firewood source into the future (that is, if future firewood is not expected to come completely from plantations), then estimates of the production rates of potential firewood and standing loads are required.
4. **Impact on vertebrates.** There are very few direct data that test whether vertebrate wildlife groups are affected by firewood collection, and even less information that could indicate optimal management strategies. Although evidence is mounting that bird species are disadvantaged by firewood removal, a conclusive study would substantially strengthen our knowledge base, as well as being timely with the recent release of the Bird Action Plan. Impacts on other vertebrate groups are very poorly understood. They are in urgent need of research so that management plans can accommodate the requirements of a broad range of wildlife groups.
5. **Impact on invertebrates and fungi.** While many invertebrate and fungal species are expected to be adversely affected by firewood collection, there have been no studies on the subject in the dry forests and woodlands, the main sources of firewood in Australia. Invertebrates and fungi can be very specialised, and can have much smaller geographic distributions than vertebrates, making them especially vulnerable to firewood collection.
6. **Ecosystem processes.** The potential for failure of ecosystem processes through the loss of fungal and invertebrate species is possibly the most serious expected consequence of the depletion of coarse woody debris. The extent to which this occurs is completely unknown. Research in this area should be of high priority so the information can assist in the effective reconstruction of degraded landscapes.

5.2 Key Knowledge Gaps: industry

7. **Small suppliers.** There is essentially no information about the small suppliers of retail firewood. Merchants with business premises represent only one quarter of the market; the rest are essentially unregulated, consisting of small operators. Where do these suppliers get their wood? Can they be regulated? Will regulation of the rest of the industry favour the small supplier? Would an education campaign leading to reduced demand for box or ironbark destroy the market for small suppliers?
8. **State forests.** A full appraisal of the role that state forests play in the firewood industry is yet to be made. Some state forest agencies do not keep electronic records, so resources need to be devoted to collating paper records to complete an initial appraisal. There are few or no data about the amount of coarse woody debris in state forests, but without these data it is not possible to assess if state forests are being managed sustainably.
9. **Merchant suppliers.** Firewood merchants who advertise in the Yellow Pages® are supplied from a range of sources, but our telephone survey was unable to pinpoint the nature of supply arrangements. We have speculated that some proportion of their firewood is from small suppliers who operate without regulations. The questions asked for issue 7 also apply here.
10. **Regional Differences.** We do not know how firewood use varies from region to region. Our study lists use state by state and indicates differences between capital cities and the rest of the states, but there is evidence of substantial variation in firewood use at regional level. It would take a more detailed survey to better define the areas in which large amounts of firewood are burned, as a target for research and education campaigns.

5.3 Recommended Research Framework

1. **Extent of depletion.** Future research should estimate expected loads of standing dead and live trees and fallen timber in undisturbed woodlands and dry forests, and assess how much has already been taken from disturbed areas. Sampling should be stratified by vegetation type, land tenure and distance from population centres. The results and review here in our study provide a good indication of plant communities that could be the focus of research, especially in south-eastern Australia (Section 3.4).

   Land tenure stratification should specifically include state forests. Read Sturgess & Associates (1995) have questioned whether the habitat log/tree retention regulations in Victoria are adequate, and they suggest that all fauna requirements should be considered more thoroughly, especially where habitat needs are based on just one species (e.g. Leadbeaters Possum). It is necessary to know how much coarse woody debris is retained in state forests because there is evidence of over-harvesting, especially in lower rainfall areas. Cooperation between agencies will need to be arranged at a high, preferably ministerial, level, to ensure that thorough and detailed information can be collated and shared, and to expedite the independent research that will be needed to properly assess coarse woody debris loads in state forests.

   Other land tenure categories include National Parks and other conservation reserves, travelling-stock routes, roadsides and private property. Studies in all states are warranted, including south-west Western Australia and south-east Queensland.

2. **Impacts on Wildlife.** Loss of coarse woody debris and live trees may disturb the spectrum of biodiversity, from specialised fungi and invertebrate species through to more generalist vertebrate species. Research should attempt to span that spectrum, with the aim of establishing relationships between the amount of coarse woody debris remaining and the proportion of biodiversity that is retained.

   A key weakness of previous correlational studies, from the point of view of understanding the effects of firewood collection, is they were not designed to test specifically for variation in loads of coarse woody debris. After a broad-ranging census of coarse woody debris, research studies with a more powerful, balanced design could be implemented to examine a full range of

coarse woody debris loads. Study sites in woodland remnants would need to be matched as far as possible for other variables, including size and isolation of the remnant. Correlational studies that do not take this approach may not include an adequate range of loads of coarse woody debris in the sites that are chosen for fauna or flora surveys, and so may be unable to detect an impact, even when an impact exists.

This stratified correlational approach would be strengthened by a manipulative experimental study. An experimental study could irrefutably demonstrate any cause–effect relationship between removal of firewood and loss of biodiversity. A suitable study region has been identified in the threatened grassy box woodlands of the Southwestern Slopes bioregion of New South Wales. A study like this would balance similar research underway in the Victorian River Red Gum open forest ecosystem. Inevitably, existing habitat remnants will continue to be the focus for firewood harvesting in the short to medium term, until policy initiatives such as the move to plantation firewood start to take effect. Sound knowledge of how to manage remnants in the interim will be essential.

3. **Ecosystem processes.** The research described above can be tailored to address knowledge gaps 1–5 (above; section 5.1). To fill knowledge gap 6, a distinct study should measure rates of ecosystem processes when particular elements are missing from those ecosystems. For example, how successfully do seedlings re-establish when there are more or fewer mycorrhizal fungal species in the soil; or how fast does woody material decay at sites with different complements of decomposer invertebrates and fungi?
4. **Changing firewood resource: retrospective case study.** The firewood market in South Australia has shifted substantially over the past ten years, with mallee use declining to only about 6% of all firewood consumed. This is consistent with a decline in applications to harvest mallee (Liz Byzard, Department for Environment, Heritage and Aboriginal Affairs, South Australia, pers. comm.). If we can investigate the political context of this decline and what happened to the suppliers (did they go out of business or shift to collecting red gum?), the information may be valuable in planning regulation for other firewood markets.
5. **Home owner surveys.** Periodic surveys are needed to guage the effectiveness of firewood education campaigns. A thorough national survey allowing for reasonable estimates of firewood use at a sub-state scale may also be valuable. It is difficult to obtain honest answers for some questions, especially those aimed at assessing the amount of illegal firewood collection. Face to face interviews by experienced interviewers may have greater success than our telephone survey.
6. **Unregulated firewood sellers.** It is beyond our area of expertise to investigate this category of firewood sellers, but because they are the largest category of suppliers, some effort should be put into trying to understand how they operate.

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APPENDIXES

Appendix 1. ***Species listed as threatened by firewood collection in Regional Forest Agreements*** *(RFA 1997; 1998; 1999; 1999c; 2000a; Environment Australia 1999; 1999b; Eyre* et al. *1997). Includes all records for NSW RFAs, and records with impact level 2 or 3 from Victorian RFAs (levels likely to impact on the population). RFA codes: NE Victoria = 1; Upper and Lower NE NSW =5; West Victoria = 2; Southern NSW = 6; Gippsland Victoria=3; Eden NSW = 7; Central Highlands Victoria = 4; SE Qld = 8*

Common Name	Scientific Name	Impact level	RFA
MAMMALS			
Spot-tailed Quoll	*Dasyurus maculatus*	2	1, 2, 3, 8
Brush-tailed Phascogale	*Phascogale tapoatafa*	2	1, 2, 6
Common Dunnart	*Sminthopsis murina*	3	2
Yellow-footed Antechinus	*Antechinus flavipes*	2	1, 2
Red-necked Wallaby	*Macropus rufogriseus*	2	3
Greater Glider		4	6
Squirrel Glider	*Petaurus norfolcensis*	2	1, 2, 5, 8
Yellow-bellied Glider	*Petaurus australis*	2	2, 6
Inland Broad-nosed Bat	*Scotorepens balstoni*	2	2
BIRDS			
Square-tailed Kite	*Lophoictinia isura*	3	5
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	2	3
Bush Stone-curlew	*Burhinus grallarius*	3	1, 2
Red-tailed Black-Cockatoo	*Calyptorhynchus banksii graptogyne*	3	2
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	3	5, 6, 7
Musk Lorikeet	*Glossopsitta concinna*	2	5
Superb Parrot	*Polytelis swainsonii*	1	6
Swift Parrot	*Lathamus discolor*	2	1, 2, 3, 5, 6
Turquoise Parrot	*Neophema pulchella*	2	1, 5, 6
Black-eared Cuckoo	*Chrysococcyx osculans*	2	2
Barking Owl	*Ninox connivens*	2	1, 2, 6
Masked Owl	*Tyto novaehollandiae*	2	1, 2, 3, 8
Dollarbird	*Eurystomus orientalis*	2	1, 6
Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	2	1, 2, 3
Speckled Warbler	*Chthonicola sagittata*	2	1, 2
Regent Honeyeater	*Xanthomyza phrygia*	2	1, 2, 3, 4, 5, 6
Painted Honeyeater	*Grantiella picta*	2	1, 2, 5, 6
Pink Robin	*Petroica rodinogaster*		7
Hooded Robin	*Melanodryas cucullata*	2	2, 3, 5, 6
Grey-crowned Babbler	*Pomatostomus temporalis*	2	1, 2, 5
Spotted Quail-thrush	*Cinclosoma punctatum*	3	6
Gilbert's Whistler	*Pachycephala inornata*	2	2

(Reptiles on next page)

Appendix 1. continued

Common Name	Scientific Name	Impact level	RFA
REPTILES			
Common Scaly-foot	*Pygopus lepidopodus*	2	2
Striped Worm-lizard	*Aprasia striolata*	3	2
Woodland Blind Snake	*Ramphotyphlops proximus*	2	2
Gray's Blind Snake	*Ramphotyphlops nigrescen*s	2	1
Woodland Blind Snake	*Ramphotyphlops proximus*	2	1
White naped Snake	*Cacophis harriettae*	2	5
Bandy Bandy	*Vermicella annulata*	2	1
Crowned Snake	*Drysdalia coronoides*	2	5
Pale headed snake	*Hoplocephalus bitorquatus*	2	5, 8
Common death adder	*Acanthophis antarcticus*		7
Carpet python	*Morelia spilota*	2	1, 6, 7
Heath monitor	*Varanus rosenbergi* – southern population	3	6
Lace Monitor	*Varanus varius*	2	1, 2,3
Gecko	*Underwoodisaurus sphyrurus*	2	5
Leaf tailed gecko	*Saltuarius wyberba*	3	5
Maccoy's skink	*Nannoscincus maccoyi*	3	6
Red calyptotis	*Calyptotis ruficauda*	2	5
Red-throated Skink	*Pseudemoia platynota*	2	1
Skink	*Eulamprus kosciuskoi*	2	5
skink	*Lampropholis caligula*	2	5
skink	*Lampropholis elongata*	2	5
skink	*Ophioscincus truncatus*	2	5
Spencer's Skink	*Pseudemoia spenceri*	2	3
Tree Skink	*Egernia striolata*	2	1

Appendix 2. ***Ecological Vegetation Classes threatened by firewood collection, Victoria***
From the North-Eastern, West and Gippsland Forest Regions in Victoria, as identified in the biodiversity component of the Regional Forest Assessment (RFA 1998, 1999, 2000a). Firewood appears not to have been considered in the Central Highlands or East Gippsland RFA (RFA 1997, 1999d), so it is uncertain how important firewood collection is in those regions.

EVC no.	Ecological Vegetation Class	Threatening Processes	RFA Region
67	Alluvial Terraces Herb-rich Woodland	Grazing, weed invasion, clearing for agriculture, minor forest produce	West, NE
	Alluvial Terraces Herb-rich Woodland/Plains Grassy Woodland Complex	Habitat loss, clearing, agriculture, fragmentation, grazing, weed invasion, road construction and maintenance, firewood collection and post and pole production	NE
	Alluvial Terraces Herb-rich Woodland/Valley Grassy Forest Complex	Firewood collection and post and pole production, grazing, clearing, habitat loss, fragmentation, weed invasion	NE
61	Box Ironbark Forest	Timber harvesting, minor forest produce, mining, fragmentation, weed invasion, clearing, inappropriate fire regimes, recreation	West, Gippsland, NE
	Box Ironbark Forest/Spring Soak Herbland Mosaic	Grazing, timber harvesting, altered water regimes, weed invasion, agriculture, firewood collection and post and pole production, mining, habitat loss, fragmentation, clearing	NE
93	Broombush Mallee	Minor forest produce, pest animals, inappropriate fire regimes	West
640	Creekline Sedgy Woodland	Clearing for agriculture, grazing, weed invasion, minor forest produce	West
167	Depauperate Heathy Dry Forest	Inappropriate fire regimes, mining/ quarrying, minor forest produce, recreation, weed invasion	West
332	Depauperate Herb-rich Foothill Forest	Timber harvesting, clearing for agriculture, grazing, weed invasion, minor forest produce	West
285	Dry Creekline Woodland	Grazing, minor forest produce, weed invasion	West
673	Dune Soak Woodland	Clearing for agriculture, grazing, minor forest produce	West
56	Floodplain Riparian Woodland	Clearing for agriculture, fragmentation, minor forest produce, alteration of drainage patterns and flooding regimes, grazing, weed invasion, dieback	West, Gippsland
690	Floodplain Riparian Woodland/ Billabong Wetland Mosaic	Clearing for agriculture, fragmentation, minor forest produce, alteration of drainage patterns and flooding regimes, grazing, weed invasion, dieback	West
689	Gippsland Plains Grassy Woodland/Gilgai Wetland Mosaic	Altered drainage patterns and flooding regimes, weed invasion, clearing, agriculture, grazing, minor forest produce, fragmentation, habitat loss, road construction and maintenance	Gippsland
22	Grassy Dry Forest	Clearing, weed invasion, grazing, minor forest produce, recreation, inappropriate fire regimes, pest animals	West

Appendix 2. continued

EVC no.	Ecological Vegetation Class	Threatening Processes	RFA Region
128	Grassy Forest	Weed invasion, grazing, clearing, minor forest produce, agriculture, fire	West, Gippsland
175	Grassy Woodland	Grazing, weed invasion, habitat loss, fragmentation, clearing for agriculture, minor forest produce, mining	West, Gippsland
20	Heathy Dry Forest	Inappropriate fire regimes, mining/ quarrying, minor forest produce, recreation, weed invasion	West
179	Heathy Herb-rich Woodland	Clearing for agriculture and pine plantations, minor forest produce	West
23	Herb-rich Foothill Forest	Timber harvesting, clearing for agriculture, grazing, weed invasion, minor forest produce	West
71	Hills Herb-rich Woodland	Clearing for agriculture, weed invasion, pest animals, minor forest produce	West
704	Lateritic Woodland	Gravel extraction, clearing for agriculture, weed invasion, grazing, minor forest produce	West
15	Limestone Box Forest	Grazing, clearing, minor forest produce, weed invasion, habitat loss, timber harvesting, fragmentation, inappropriate fire regimes	Gippsland
16	Lowland Forest	Timber harvesting, clearing, weed invasion, inappropriate fire regimes, minor forest produce, dieback	West
652	Lunette Woodland	Agriculture, grazing, weed invasion, minor forest produce	West
151	Plains Grassy Forest	Grazing, minor forest produce, agriculture, clearing, weed invasion, timber harvesting	Gippsland
55	Plains Grassy Woodland	Clearing for agriculture, fragmentation, grazing, weed invasion, road construction and maintenance, minor forest produce, timber harvesting, inappropriate fire regimes, dieback	West, Gippsland
	Plains Grassy Woodland/ Creekline Grassy Woodland/ Floodplain Riparian Woodland Mosaic	Habitat loss, clearing, agriculture, fragmentation, grazing, weed invasion, road construction and maintenance, firewood collection and post and pole production, alteration of flooding regimes	NE
	Plains Grassy Woodland/ Creekline Grassy Woodland/ Wetland Mosaic	Habitat loss, clearing, agriculture, fragmentation, grazing, weed invasion, road construction and maintenance, firewood collection and post and pole production, altered water /drainage regimes, salination	NE
	Plains Grassy Woodland/ Valley Grassy Forest Complex	Habitat loss, clearing, agriculture, fragmentation, grazing, weed invasion, road construction and maintenance, firewood collection and post and pole production	NE
	Plains Grassy Woodland/ Valley Grassy Forest/Rainshadow Grassy Woodland Complex	Habitat loss, clearing, agriculture, fragmentation, grazing, weed invasion, road construction and maintenance, firewood collection, post and pole production, habitat loss, fragmentation, clearing, agriculture, lack of fire	NE
659	Plains Riparian Shrubby Woodland	Weed invasion, uncontrolled access, minor forest produce	West

Appendix 2. continued

EVC no	Ecological Vegetation Class	Threatening Processes	RFA Region
283	Plains Sedgy Woodland	Minor forest produce, drainage for agriculture, grazing, weed invasion	West
	Rainshadow Grassy Woodland/ Valley Grassy Forest Mosaic	Weed invasion, grazing, firewood collection and post and pole production, habitat loss, fragmentation, clearing, agriculture, lack of fire	NE
641	Riparian Woodland	Clearing for agriculture, grazing, weed invasion, recreation, hydrological alteration, minor forest produce	West
103	Riverine Grassy Chenopod Woodland	Clearing for agriculture, salinity, minor forest produce, grazing, pest animals	West
295	Riverine Grassy Woodland	Clearing for agriculture, grazing, weed invasion, minor forest produce	West
264	Sand Ridge Woodland	Minor forest produce, inappropriate fire regimes, clearing, weed invasion, pest animals	West
195	Seasonally Inundated Shrubby Woodland	Weed invasion, alteration of drainage patterns and flooding regimes, grazing, clearing, minor forest produce	West
65	Sedge-rich Woodland	Clearing for agriculture, grazing, weed invasion, minor forest produce	West
882	Shallow Sands Woodland	Clearing for agriculture, grazing, minor forest produce, weed invasion	West
21	Shrubby Dry Forest	Inappropriate fire regimes, minor forest produce, weed invasion, pest animals	West
45	Shrubby Foothill Forest	Minor forest produce, timber harvesting, inappropriate fire regimes, weed invasion	West, Gippsland
	Shrubby Granitic-outwash Grassy Woodland/Valley Grassy Forest Mosaic	Weed invasion, grazing, firewood collection and post and pole production, habitat loss, fragmentation, clearing, agriculture, lack of fire	NE
47	Valley Grassy Forest	Weed invasion, grazing, clearing, minor forest produce, agriculture, fire	West, Gippsland, NE
	Valley Grassy Forest/Box Ironbark Forest Complex	Weed invasion, grazing, firewood collection and post and pole production, mining, fragmentation, habitat loss	NE
	Valley Grassy Forest/Grassy Dry Forest Mosaic	Weed invasion, grazing, firewood collection and post and pole production	NE
	Valley Grassy Forest/Plains Grassy Woodland Mosaic	Weed invasion, grazing, firewood collection and post and pole production, habitat loss, clearing, agriculture, fragmentation, road construction and maintenance	NE
127	Valley Heathy Forest	Weed invasion, grazing, clearing, minor forest produce, agriculture, fire	West

Appendix 3. SCRIPT — CSIRO National Firewood Use Telephone Survey

Contact Name	Interview initials	Record No.
Contact Number	Date of IV	
Location	Call Back	
(Code later) City or Country/Rural	Data Entry done	

Record first and any subsequent call date and results:
Call 1: **Call 2:** **Call 3:** **Call 4:** **Call 5:**

1. Not Applicable — Not firewood users
2. Calls Completed — Interview obtained with firewood user
3. Need to Call Back — call made to answering machine, person not there
4. Need to Call Back — engaged, no answer
5. No interview — 5 call backs made and no contact made
6. Refusal

Introduction
"Good evening. My name is _____, calling from AMRS in Canberra. I'm doing a very brief survey for CSIRO on firewood use in Australia. If your household uses firewood I'd like to ask you to be involved in the survey. Do you use firewood?
(**Check if they are best person to talk to?)**

YES (go to Q1)
REFUSAL?/ DON'T USE FIREWOOD? *End and close with thanks*

1. During the last 12 months has your household used any firewood — for heating, cooking or hot water?

YES
NO *(If No then thank and end survey, else Q2.)*

2. Does your household use firewood as the main source of heating?

YES Go to next question
NO Comments……..

3. Approximately how much firewood has this household used in the last 12 months (from all sources)? *Enter amounts in numbers, e.g. 2.5 for each that applies*

Tonnes/year
Cubic metres/year
No. trailer loads
No. ute loads
No. truck loads
No. car boot loads
Other load (estimate size) and no. loads …….
Don't Know (probe and write comments)……..

4. What type of firewood did your household use in the last twelve months?

Code answers in proportional use of each wood type if possible, in e.g. half, otherwise, just the main type, e.g.

Box (Red or Yellow)
Red gum
Ironbark
Mixed hardwood/Eucalypts (general)
Local eucalypts
Stringy Bark
Pine — softwood
Pine — hardwood
Mallee stems
Mallee roots
Jarrah (WA only)
Myrtle (TAS)
Peppermint (TAS)
Other (please specify)……..

The next questions are about where you get your wood …

5. In the last 12 months, did your household buy any wood?

YES
NO If No go to Q 8

6. Approximately what proportion of wood did you buy

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%

7. Where does your household buy wood from? *(if more than one, report carefully)*

Woodyard/seller with business premises (main business, incl petrol station)
Sawmill/joinery
Small local collector/supplier (sideline for bloke with chainsaw and truck)
Friends/relatives
Other (specify)…….

8. In the last 12 months, did your household collect any wood?

YES
NO go to Q 15

9. Approximately what proportion of wood did you collect (in the last 12 months?)

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%

10. Where did you get the wood from, was it

(allocate proportions if possible)

Side of the road
State Forest
Other Crown Land
Your own land
Other private land
Other sources – Please specify…….
Don't know/Comments……...

11. Did you collect any fallen timber (trees, branches)?

YES
NO

12. Did you collect any standing timber (trees not fallen over)?

YES
NO

13. Was it dead or alive?

DEAD
LIVE
BOTH

14 . Do you have a permit for the firewood you collect?

YES
NO

15. Did you get any wood from any other source? e.g. given wood

YES
NO Record answers if yes……

Any other comments?

CLOSE: Thank you very much for your assistance. The results of this survey will be used by the CSIRO to help to ensure a sustainable firewood supply.

Appendix 4. *Firewood Merchant Survey Questions*

Comments in italics are used as prompts or reminders.

How long have you been selling firewood?
Give the number of years.

Can you give an estimate of how much wood you supplied during the last year?
Give the amount in tonnes per year.
If you are unsure, use an other way of estimating, for example: number and size of loads sold, number and size of bags sold.

What type of wood do you supply?

Can you tell me the species?

How much of each do you sell?
Give tonnes, percentage or any other form of estimate.

How much softwood do you supply?
Give tonnes, percentage or any other form of estimate.

What proportion of your wood do you or does your company directly collect?
Estimate the percentage.

If supplied by others: How many suppliers do you have?

Who are your main suppliers?
Give the names of your main supliers if possible.

What percentage would the main suppliers account for?

What percentage comes from small suppliers?

What locality does your wood come from?
Name the closest towns or localities. If you cannot give the locality, give the distance from you.

What is the tenure of the land most of your wood is collected from?
For example, is it: Private land, State forest, Crown land, Other: Give details, Do not know.

Why is the timber available for firewood?
For example, is it: Dead timber left from past land clearing, Residue from forestry operations, Plantation timber for firewood, Other: Give details, Do not know.

Were the trees dead and standing, fallen, or live?

Appendix 5. *Locations given by firewood retailers as the source of firewood species*

Numbers in square brackets indicate the number of respondents giving the source; all others, one respondent.

Type of wood	Source
	ACT
Red Box	Condobolin [2], Parkes, Griffith, Nyngan.
Yellow Box	Condobolin [2], Parkes, Griffith, Nyngan.
Grey Box	Condobolin.
Red Gum	Swan Hill, Darlington Pt., Griffith, Nyngan.
Pine	Canberra plantations.
Eucalyptus mix	Canberra suburban.
Bloodwood	Ulladulla.
	NSW
Mixed Hardwood	Lismore suburban, Wyong to Bulahdelah.
Flooded gum	Coffs Harbour.
Black butt	Coffs Harbour.
Yellow Box	Coffs Harbour, Coonabarabran, Mittagong, Inverell area.
Red Gum	Darlington Point [2], Broken Hill area, One Tree to Narrandera, Cumnock, Warren.
Recycled	Kellyville.
Ironbark	Cuttabri, Gloucester, Tamworth, Barraba, Wee Waa, Coonabarabran (within 200 km W -NW), Wyong to Bulahdelah, Suburban Wyong-Pearl Bend, Barraba, Bingara, Kurindi, Baradine, Warwick Qld [2], Inverell area.
Western Red Gum	Mandurah, Gadoo SF.
Black Oak (Casuarina)	Broken Hill area.
"Whatever"	Corryong, Temora, Bombala.
Box	Gloucester to Coast, Tamworth, Barraba, Wee Waa, Wyong to Bulahdelah, Barraba, Bingara, Kurindi, Baradine, Warwick Qld.
Blue Gum	Gloucester, Tamworth, Barraba, Wee Waa, Coonabarabran, Suburban Wyong to Pearl Bend.
Mahogany	Gloucester, Tamworth, Barraba, Wee Waa.
Anything dead	Gloucester, Tamworth, Barraba, Wee Waa.
Stringybark	Gloucester, Tamworth, Barraba, Wee Waa, Coonabarabran, Wyong to Bulahdelah, Mittagong, North Coast NSW, Inverell area.
Red Box	Coonabarabran.
Blood wood	Coffs Harbour.
Peppermint	Cooma.
White Gum	Cooma.
Spotted Gum	Wyong to Bulahdelah.
Grey Gum	Wyong to Bulahdelah, Suburban Wyong to Pearl Bend.
Snappy Gum	Mittagong.
E. scoparia	Suburban Wyong to Pearl Bend.
Red Box	Cumnock.
Mahogany	North Coast NSW.
Tree Loppings	Sydney suburban.
White Box	Inverell area.
Brown Box	Inverell area.
	VIC
Red Gum	Swan Hill, Narrandera, Deniliquin [2], Darlington Point [2], Quoondrop, near SA border, Casterton, Merbein, South NSW, "Murray sawmills", Echuca [2], Moama, Balranald [2], Wagga Wagga.

"Red wood"	Moama, Gilgandra, Darlington Pt., Riverina, Balranald.
Mallee root	Mildura, Close by (Cribb Pt), Ouyen, Boundary Bend.
Messmate	not stated.
Stringybark	not stated, Local (50 km Morwell).
Box	Close by (Cribb Pt), Merbein, Rutherglen, Barn water, Wangaratta, NE Vic. Dunolly, Bendigo, Maryborough.
Ash	Local (50 km Morwell).
Blue Gum	Local (50 km Morwell).
Eco-Brix	Morwell – Healesville – Geelong pine mill residue.
Mountain Ash	Dandenong.
Peppermint	Bright.
Ironbark	Not stated.
Pine	Recycled from manufacturing in Melbourne district.
	SA
Red Gum	Adelaide Hills area, Naracoorte [2], Woodside, Blanchetown, Williams, Southeast of SA, Keith, Balranald.
Pink Gum	Naracoorte.
SA Blue Gum	Local (Modbury North).
Cut mallee	Berry, Udanda, Woodside, Blanchetown, Williams, Riverland, Lincoln.
Mallee root	Meningea area.
White Box	Naracoorte
Unspecified	Edenhope NSW, (note: Edenhope SA is near the border).
Recycled timber	Local (Tea Tree Gully) .
Railway sleepers	Salvage [2].
	WA
Jarrah	Manjimup, Pemberton, Boyup brook, Sth of Bunbury, Boddington, Mundijong, Jarrahdale, Byford, Perth metropolitan area mills, Mundaring, Picton, Not given [2].
Mallee root	Salmon Gums, Esperance.
Salmon Gum	Salmon Gums.
Black Butt	Salmon Gums.
Gimlet	Salmon Gums.
Recycled timber	Perth metropolitan area.
	NT
Mulga	Less than 100 km West of Alice Springs [2].
Ironwood	Less than 100 km West of Alice Springs [2].
	QLD
Ironbark	3hrs W. of Kingaroy, North Brisbane & outlying suburbs [2], Goomeri, Warwick, Goolabah, Gymnut, Maroochydore district, Hattonvale, Inglewood area.
Mixed Hardwood	Brisbane metropolitan area [2], up to 200k Nth Brisbane Gundowl, Sydney.
Bloodwood	Maroochydore district.
Grey Gum	Maroochydore district.
Blue Gum	Maroochydore district.
Yellow Box	Inglewood area.
Stringybark	North Brisbane & outlying suburbs.
Gum	North Brisbane & outlying suburbs.
	TAS
Brown Peppermint	Swansea, Buckland, East coast of Tasmania.
Peppermint	East coast of Tasmania, Royal George.
Stringybark	East coast of Tasmania.
Browntop	North-west coast of Tasmania.
White Gum	East coast of Tasmania.
Gum	East coast of Tasmania, Avoca.
Eucalyptus mix	Bridgewater.