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PARROT DAMAGE TO BLUEGUM TREE CROPS

A review of the problem and possible solutions

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Agriculture Western Australia

Resource Management

Technical Report No. 150

PARROT DAMAGE TO BLUEGUM TREE CROPS

A REVIEW OF THE PROBLEM AND POSSIBLE SOLUTIONS

By

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SUMMARY

Damage to Bluegum (*Eucalyptus globulus*) tree crops by the Twenty-eight Parrot (*Barnardius zonarius*) is an emerging problem which could threaten the viability of the infant Bluegum industry in south-western Australia. The parrots strip bark from the lead shoot of the Bluegums causing the shoots to break off. Consequently lateral shoots develop resulting in deformed (bent or multi-stem) trees unsuited to harvest and utilisation.

Indications that the reason Twenty-eight Parrots strip bark from Bluegums is to obtain food include:

1. A literature review showed various other birds and mammals from around the world also debark trees in search of food, often at times of food shortage. The food may be wood- and bark-boring insects (not found in Bluegum shoots) or, more commonly, starches and sugars in the sap, cambium or bark exudates.
2. Monitoring of parrot damage to Bluegums at several sites showed that 'attack rates' consistently decreased when other preferred food (Marri nectar) became available and increased when a food supply (oat from grain silos) was withdrawn.

However, it is not yet known if the parrots obtain any substantial nutrition from the Bluegums.

Studies of the diet of Twenty-eight Parrots show they are very versatile at using whatever foods are available and quickly adapt to any new foods including introduced crops. Parrot adaptation to Bluegums may be 'learned behaviour' and hence the damage may also develop in areas where it is absent or uncommon now. Currently the zone of worst damage includes around 20% of the total area suitable for Bluegum planting in south-west Australia.

There is a 'critical period' for controlling parrot damage. At monitoring sites this was found to start in March of the first year after planting and end around July of the second year after planting, i.e. from the time of earliest parrot damage to the time when most trees had sufficient height that any new damage to the lead shoot would not spoil the base log of (assumed) minimum length 3 m. This gave a critical period of around 16 months in a 10 year rotation. Variation in specifications for minimum log length or other criteria for determining the critical period will vary the length of the critical period at any site.

There is no currently established practical method ('best practice') for managing parrot damage to Bluegums. One possibility would be to develop means of predicting which sites will be prone to severe parrot damage and avoid planting those sites, at least until possible control techniques are investigated.

Studies of related problems of vertebrate pest damage to trees show the following techniques have been applied and are worth investigating as potentially suitable techniques for managing parrot damage to Bluegums.

- **Reduce pest population:** Achieved by shooting, trapping, poisoning, encouraging natural predators.
- **Divert pest from crop:** Repellents, diversionary feeding, barriers, and tree breeding for pest resistance have all been used with success in particular situations.
- **Rectify damage after it occurs:** Thinning to cull out damaged trees has been applied. Other possible techniques to correct parrot damage to Bluegums are pruning and coppicing.

CONTENTS

1. INTRODUCTION

Parrot damage to Bluegum (*Eucalyptus globulus*) tree crops is an emerging problem which could threaten the viability of the infant Bluegum industry in south-western Australia.

This review was undertaken as a first step in developing a strategy for dealing with the problem. The objective was to collate all existing information which may help in developing such a strategy. It includes information gleaned from surveys and monitoring of parrot damage, and general observations of the problem. A literature search indicated lessons from research and management of related pest problems, including various control techniques attempted.

An Action Plan (Part II of this report) has also been prepared. This outlines activities to gain further information relevant to finding a suitable way of alleviating parrot damage to Bluegum tree crops.

1.1 The Bluegum industry in south-western Australia

The production of wood fibre from Bluegums is a new and rapidly developing industry in south-western Australia. Bluegums grow rapidly and can be harvested on a rotation of around 10 years. They are an excellent source of wood fibre for production of pulp used to make high quality paper.

An estimated 40 000 hectares of Bluegums has now been planted on farmland in south-western Australia, mostly in the last five years. The projected planting area is in excess of 100 000 hectares. This resource would be for export of wood fibre (as woodchips) and to support a proposed pulp and paper mill in the south-west.

Gross revenue to growers on a resource of 100 000 hectares is estimated at $40M / year. Processed as chips and loaded for export the resource would be worth around $140M / year.

As well as direct economic benefits to the growers and support industries there is considerable scope for secondary benefits from Bluegum tree crops by complementing other agricultural production (Shea and Bartle, 1988; Shea *et al.*, 1992). Potential secondary benefits include:

- improvements to sustainable agriculture through provision of shelterbelts (protection of soils, crops and livestock) and amelioration of land degradation due to salinity and waterlogging.
- protection of water resources, e.g. around 6500 hectares of eucalypts planted in the Wellington Reservoir Catchment by the Water Authority for stream salinity control.
- conservation and environment benefits include scope to provide wildlife corridors, greenhouse benefits and reduced reliance on native forest sources of wood fibre for paper production.

1.2 The Bluegum crop

Site preparation for Bluegum planting usually includes ripping, mounding and weed control followed by fertilisation at or soon after planting. Typically the trees are planted at 2.5 metre spacing in rows 4 metres apart (1000 trees/hectare) though this is varied slightly according to rainfall, soils and other considerations. At such spacing the trees normally grow as single-stem straight trees. This form is important for efficient harvesting and transport operations.

Most Bluegum crops in south-west Australia are intended for harvest at around 10 years age. At this age a typical tree would be around 25 metres tall. Stem diameter is customarily measured at 1.3 metres above ground level (breast height) and the diameter at breast height (DBH) would be around 25 cm.

1.3 Damage caused by parrots

Many observations indicate that most pest damage to Bluegums is the work of Twenty-eight Parrots, also known as Port Lincoln Ringnecks or Port Lincoln Parrots (*Barnardius zonarius*). There is a gradual change (geocline) in this species from *B. zonarius zonarius,* a form inhabiting central and southern Australia through into Western Australia, to *B. zonarius semitorquartus,* a larger form with a green rather than yellow belly found in the coastal forests of south-western Australia (Forshaw, 1964). Both forms and intermediate forms are commonly known in Western Australia as the Twenty-eight Parrot (Forshaw, 1969) and this name is used throughout this document to refer to all *B. zonarius* in Western Australia.

Twenty-eight Parrots strip bark from the branches and lead shoot of Bluegums (and many other planted trees in WA). On Bluegums the section of the shoot affected is typically "as thick as a little finger" (0.5-2.0 cm diameter) and 0.5-1.5 m from the growing tip. Often the shoot is ringbarked (girdled) but incomplete stripping will also destroy the shoot if the damaged section becomes brittle and breaks before the wound can heal over.

Destruction of the lead shoot has a detrimental effect on tree form. It causes lateral shoots from below the wound to develop. If only one of these shoots becomes dominant the tree will retain its single-stem form. However, there will be a bend (deformity) in the stem which, if it can be included in a pulp log, may reduce its suitability for debarking and other processing operations. Often two or more lateral shoots grow from below the ringbarking to form double- or multi-stem trees. Severe bends and the forks of double- and multi-stem trees are unacceptable in pulp logs. If such "unacceptable deformities" occur at a height less than the minimum acceptable log length then all of the stem below the deformity will be lost. Also, if the distance between two unacceptable deformities in a stem is less than the minimum log length, then that section of the stem will be wasted. Refer to Fig. 1 for an example.

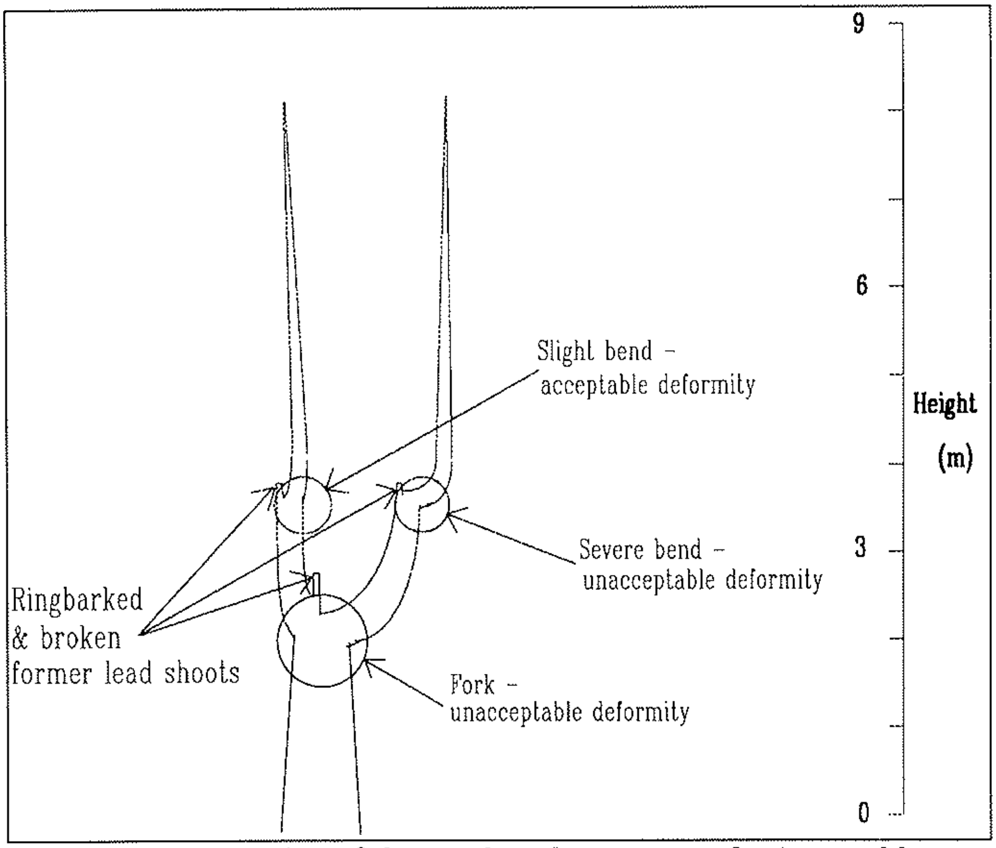

Fig. 1. Representation of the trunk and two stems of a 4 year old Bluegum tree damaged by parrots. Only the left stem and the upper section of the right stem can be used for pulp logs. The trunk and lower section of the right stem do not make pulp logs (assuming minimum log length is 3 m).

Thus parrot damage to Bluegums is of concern on at least three counts:

1. **Loss of volume** - from deformities and sections of the tree too short to harvest.
2. **Loss of quality.** although some deformities can be included in pulp logs they will increase handling and processing (debarking) costs.
3. **Increase in harvesting costs** - e.g. for a harvester to deal with a forked tree, the fork crutch must be removed and the trunk and each stem handled separately.

If damage is frequent there will also be a 'loss of volume' due to reduced growth rates of the trees.

1.4 Extent of damage

The zone of greatest damage includes some 20% of the total area suitable for Bluegum planting in the south-west (Fig. 2). There is also the risk that parrot damage to Bluegums, like parrot damage to other introduced crops, is 'learned behaviour' that will also develop in other zones where Bluegums are planted.

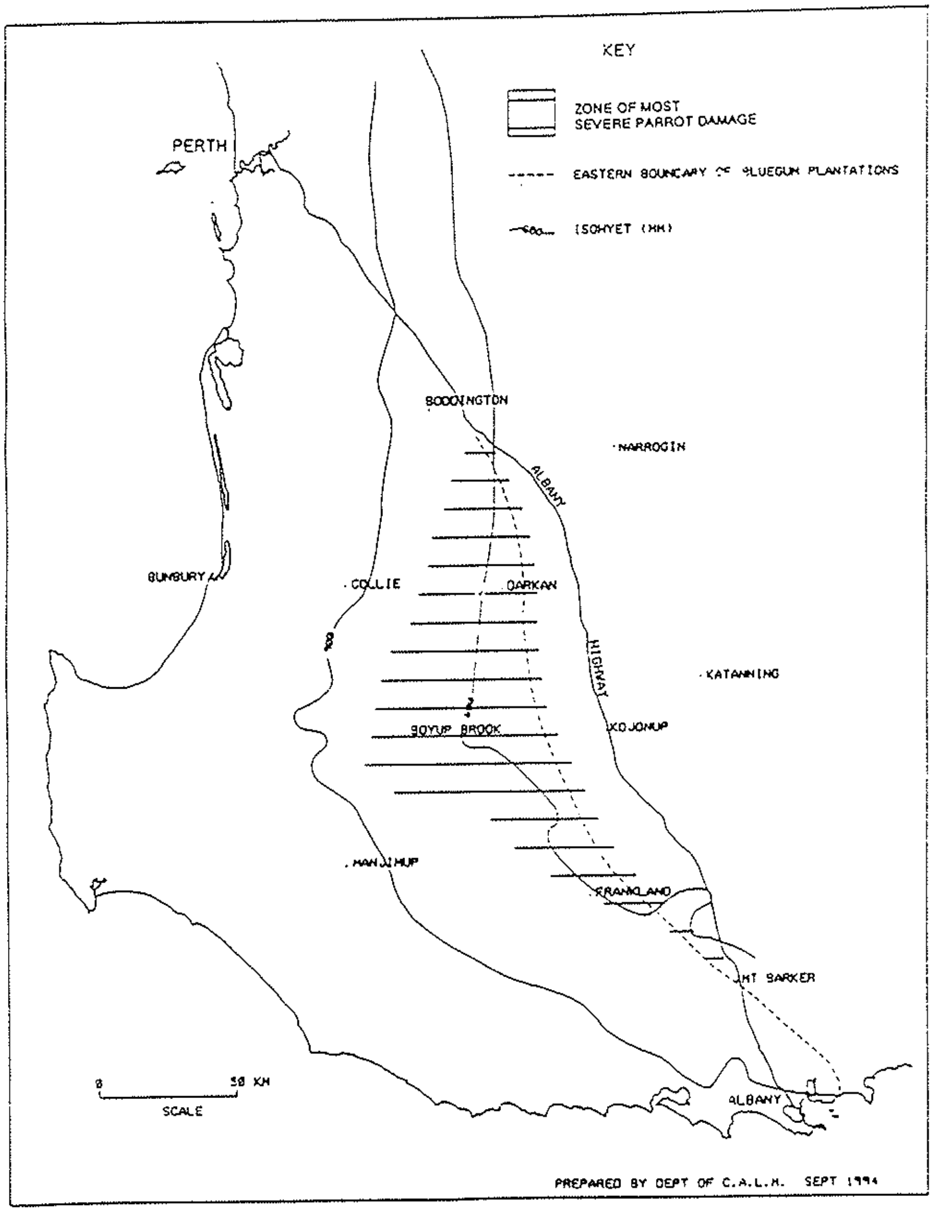

Fig. 2. Parrot damage to Bluegum plantings in south-west Western Australia.

Surveys of 12 CALM sharefarm plantations in the zone of greatest damage were carried out in July-September 1993. The results (summarised in Tables 1 & 2) show that damage levels were highly variable, e.g. they varied from the Giles site where 4% of trees were damaged by parrots (96% undamaged) to the Wunnenberg site where 98% of trees were damaged by parrots. Of the 12 sites, 6 had > 50% trees damaged while another 3 of the sites had 30%-50% trees damaged. Damage also varied between trees from only 'Minor Damage' where any degrade could still be included in a pulp log to 'Extreme Damage', in which case there would be considerable loss of volume from the tree, if it was worth harvesting at all. It is expected that parrot damage will continue at all sites so, particularly amongst the younger plantations, the extent of the damage will increase with age.

Table 1. Parrot damage surveys in the Williams/Darkan and Boyup Brook areas - percentage of trees in each 'tree form' class

	1 y.o			2 y.o						3 y.o.	4 y.o.	
Farm	South	Ritson	Stene	"Kievi"	South	Hilder	White	Bradford	Giles	South	Wunnen-berg	Stene
No. sample trees	25	162	16	38	96	292	73	48	23	32	251	65
Tree form class												
0	4	54	88	8	30	48	56	92	96	12	2	69
1	24	26	6	23	8	13	8	4	0	19	6	0
2	0	2	0	42	14	11	8	0	0	9	12	14
3	0	0	0	0	3	5	2	0	0	6	10	6
4	0	0	0	11	12	9	14	2	0	35	41	8
5	0	0	0	5	3	5	4	0	0	19	29	3
X	72	18	6	11	30	9	8	2	4	0	0	0
Total	100	100	100	100	100	100	100	100	100	100	100	100

Tree form classes:

- **0** = no damage by parrots;
- **1** = bark stripped on the main stem by parrots, but no change to form;
- **2** = single stem tree, but parrot damage causing deformity which could be included in a pulp log;
- **3** = single stem tree with parrot damage causing deformity which could not be included in a pulp log;
- **4** = double stem tree (the fork resulting from parrot damage), neither stem dominant;
- **5** = multi-stem tree - same as 4, but >2 stems.
- **X** = Only damage is that the lead shoot is ringbarked, but it is not clear what form the tree will take as a result of the damage.

Table 2. Parrot damage surveys in the Williams/Darkan and Boyup Brook areas - percentage of trees in each 'log degrade' class

Plantation age	1 y.o			2 y.o						3 y.o.	4 y.o.	
Farm	South	Ritson	Stene	"Kievi"	South	Hilder	White	Bradford	Giles	South	Wunnen-berg	Stene
No. sample trees	25	161	16	38	96	292	73	48	23	32	251	65
Log degrade class												
None	4	54	88	8	30	48	56	92	96	12	2	69
Minor	24	28	6	65	22	24	22	4	0	28	18	14
Major	0	0	0	8	10	7	13	0	0	38	11	11
Extreme	0	0	0	8	8	12	0	2	0	22	69	6
X	72	18	6	11	30	9	9	2	4	0	0	0
Total	100	100	100	100	100	100	100	100	100	100	100	100

Log degrade classes:

None: No damage, i.e. Tree Form = 0.

Minor: No loss of volume, possibly, some loss of quality. Any degrade could be included in a pulp log, i.e. Tree Form = 1 or 2.

Major: Loss of volume. Single, double or multi-stem tree (Tree Form = 3, 4 or 5) with **one only** "unacceptable deformity" at either < 1 m height or > 3 m height. (i.e. can recover a pulp log from the lower trunk of the tree). The lead shoot(s) may be ringbarked.

Extreme: Single-, double- or multi-stem tree with an "unacceptable deformity" between 1 and 3 m height and/or with >1 "unacceptable deformity" in the tree.

X: Only damage is that the lead shoot is ringbarked, but it is not yet clear what form the tree will take as a result of the damage.

The sample trees in each of the 12 sites in the survey were located on a rectangular grid basis. This was to check if there were any regular patterns to the distribution of damage but none were detected. In particular there was no evidence of an 'edge effect'. Thus Table 3 shows there was no evidence that parrots were more likely, or less likely, to damage trees at the end of rows than the midst of rows. Of the seven sites where comparison between 'end trees' and 'not end trees' was possible, damage to the end trees was greater in three cases and less in four cases.

Table 3. Parrot damage surveys in the Williams/Darkan and Boyup Brook areas - proportion of trees with either 'Major', 'Extreme' or 'X' degrade.

Site	'End' trees	'Not End' Trees
1 y.o. plantings		
South	69%	75%
Ritson	14%	19%
Stene	N/A*	6%
2 y.o. plantings		
South	50%	47%
Hilder 1	37%	29%
Hilder 2	18%	28%
Hilder 3	29%	22%
"Kievi"	N/A**	N/A**
Giles	N/A***	4%
3 & 4 y.o. plantings		
South	50%	61%
Wunnenberg	N/A**	N/A**
Stene	N/A*	17%

* no 'end' trees at Stenes - ends of rows bordered by native forest
** end trees not identified at the "Kievi" and Wunnenberg sites
*** end trees at the Giles site were eucalypt species other than Bluegum

2. DAMAGE TO TREES BY BIRDS AND OTHER ANIMALS

Other birds and mammals also damage trees in similar ways to parrot damage to Bluegums. The purpose of reviewing these problems here is to help understand why Twenty-eight Parrots damage Bluegums and indicate possible control strategies.

2.1 Primary damage and the reasons for it

A large array of vertebrate and invertebrate animals damage tree crops. Damage by vertebrates ranges from seed eating and browsing of seedlings to damage to all parts of mature trees.

Table 3 summarises reports of bird damage to the stem or tops of trees. Primary damage tended to fall into one of two categories, i.e. either:
1. birds feeding on and so destroying the lead shoot/buds or;
2. bark removal from the stem, often including the cambium and outer sapwood.

Only one report (Tanton (1968), Table 3) was found of birds ringbarking shoots as Twenty-eight Parrots do on Bluegums and other trees. The species involved is another Australian parrot, the White Cockatoo. Sapsuckers in North America were found to sometimes ringbark the stem of a favourite trees by repeated feeding - they drill a ring of holes through the bark around the stem and may eventually remove the bark between the holes (Oliver, 1968).

Rowley (1990) reported that Galahs in Australia will bite through sprays (small shoots with several leaves attached) of eucalypts. This is usually done by nesting pairs of Galahs to gather material to line their nest hollows . At least half the sprays are dropped before they reach the nest. There are also occasions when resting flocks of Galahs nibble extensively at the sprays near where they are perched. Rowley found there appeared to be no purpose (nutritional or reproductive) to this behaviour other than to keep their bills in good order and prevent them from overgrowing.

There have been some reports of spay-cutting by Twenty-eights on Bluegums and other eucalypts (Rick Mitchell, Rojer Underwood and others, *pers. comm.*, 1994). Generally the top around 10-20 cm of the tree is nipped off. Usually it is done in a period of just a few weeks in July/August (just prior to egg laying) though it has not been established that the purpose is for breeding. Spray-cutting is different from the ringbarking activity and does not appear to damage tree form, i.e. the shoots apparently recover without forming bends or forks.

Another behaviour of the Galah described by Rowley (1990) is what he called 'scarring'. Galahs usually nest in smooth-barked eucalypts and they commonly chew and strip bark from an area on the trunk. This activity was attributed to bill-maintenance, the Galahs interspersing bark chewing with bouts of rubbing either side of the bill on the exposed wood as if stropping a razor. Since the bill-stropping was so noisy Rowley felt it could also serve to let the bird on the nest know that it mate was on the nest tree, not other Galahs.

Table 3. Summary of reports of bird damage to the stem or tops of forest trees

Bird Pest(s)	Tree(s)	Location	Damage caused*	Assumed reason**	Source
Blackgame	Scots Pine; Lodgepole Pine; Larch.	Britain	Destroy lead shoots and buds	Feeding on shoots/buds	Palmar, 1968
" "	Sitka Spruce; Lodgepole Pine.	Scotland	Destroy terminal buds		Thompson, 1984
Capercaillie	Scots Pine	Sweden	Destroy tops		Andersson *et al*, 1970
" "	European Larch	Siberia	Destroy terminal shoots		Mezennyj, 1957
Cockatoos, Red-tailed-Black & Yellow-tailed-Black	Eucalypts	E. Australia	Bark removal	Feeding on wood- and bark-boring insects	Brown, 1968.
Cockatoo, Black; Cockatoo, White	Eucalypts; Radiata Pine.	Australia	1. Strip bark and wood (eucalypts); 2. Ringbark upper branches (eucalypts); 3. Break/bend lead shoot (Pines)	1. Feeding on insects; 2. Clean beaks; 3. Perching	Tanton, 1968
Cockatoo, Sulphur Crested	Hoop Pine.	SE Queensland	Chew out tops		Bomford, 1992
Cockatoo,Sulphur Crested; Corella, Little; Galah	River Redgum & other tree spp	South Australia & Victoria	Pruning, defoliation & ringbark limbs.		Bomford, 1992
Galah	Eucalypts	Australia	1. Remove sprays (small shoots). 2. Scarring (bark removal from trunk)	1. Mainly nest lining. 2. Bill-maintenance and possibly communication with nesting mate.	Rowley, 1990
Grouse, Black	Scots Pine, Black Pine	Belgium	Destroy terminal shoots		Nef, 1959
Grouse, Blue	Ponderosa Pine	Idaho, USA	Destroy buds and young leaders of seedlings	Feeding on buds/leaders	Curtis & Elder, 1965
Grosbeak	Scots Pine	NE of USA	Destroys terminal shoots	Feeding on shoots	Cook & Littlefield, 1945
" "	White Pine	Maine, USA	Destroys apical buds	Feeding on buds	Stark, 1964
Kaka	Rimu; Silver Beech	Western Southland, New Zealand	Remove bark	Feeding on bark or sapwood exudates (Rimu); Feeding on insects (Silver Beech).	Holloway, 1948
" "	Silver Beech	New Zealand	Remove bark	Feeding on insect larvae	Beggs & Wison, 1987

" "	Southern Rata	New Zealand	Remove bark	Feeding on sap	O'Donnell & Dilks, 1989
Sapsuckers	Norway Spruce	Quebec, Canada	Remove bark		Ouellette, 1967
Sapsuckers, Red-naped & Natalie's; Woodpeckers	Quaking Aspen	Colorado, USA	Remove bark	None given (Sapsuckers); Feeding on insects (Woodpeckers)	Packard 1942
Sapsuckers, Red-breasted & Williamson	Ponderosa Pine	California, USA	Bark & cambium removal	Feeding on cambium, bark & sap	Oliver, 1968
Sapsucker, Yellow-bellied	Birchs; Blue Spruce; Scots Pine; Siberian Elm	Great Plains region, USA	Bark & sapwood removal	Feeding on sap (most pronounced when sap pressure greatest)	Hildahl, 1978 in Timm, 1988
Woodpeckers (other than Sapsuckers)	Silver Fir	Europe	Remove bark	Feeding on sap and cambium	Turcek, 1954

* 'Damage caused' is the primary damage only. For discussion of secondary effects see Section 2.2 of text.
** 'Assumed reason' is that given in the source. Blank cells indicate that no reason was given.

Scientific names for bird pests in Table 3

Blackgame	*Lyrurus tetrix*
Capercaillie (Capercailzie)	*Tetrao urogallus*
Cockatoo, Red-tailed Black	*Calyptorhynchus magnificus*
Cockatoo, Sulphur Crested	*Cacatua galerita*
Cockatoo, White	*Cacatua galerita*
Cockatoo, Yellow-tailed Black	*Calyptorhynchus funerus*
Corella, Little	*Cacatua sanguinea*
Galah	*Eolophus roseicapillus*
Grouse, Black	*Lyrurus tetrix*
Grouse, Blue	*Dendragrapus obscurus*
Grosbeak	*Pinicola enucleator*
Kaka	*Nestor meridionalis,*
" "	*Nestor occidentalis*
Sapsucker, Natalie's	*Sphyrapicus thyroideus nataliae*
Sapsucker, Williamson	*Sphyrapicus thyroideus thyroideus*
Sapsucker, Red-breasted	*Sphyrapicus varius daggetti*
Sapsucker, Red-naped	*Sphyrapicus varius nuchalis*
Sapsucker, Yellow-bellied	*Sphyrapicus varius*
Woodpeckers	several genera included

Scientific names for tree species in Table 3

Birchs	*Betula* spp
Birch, Silver	*Betula pendula*
Black Pine	*Pinus nigra*
Eucalypts	*Eucalyptus* spp
European Larch	*Larix decidua*
Hoop Pine	*Araucaria cunninghamii*
Lodgepole Pine	*Pinus contorta*
Norway Spruce	*Picea abies*
Pacific Silver Fir	*Abies amabilis*
Ponderosa Pine	*Pinus ponderosa*
Quaking Aspen	*Populus tremuloides*
Radiata Pine	*Pinus radiata*
Rimu	*Dacrydium cupressinum*
Scots Pine	*Pinus sylvestris*
Siberian Elm	*Ulmus pulmia*
Silver Beech	*Nothofagus menziesii*
Silver Fir	*Abies alba*
Sitka Spruce	*Picea (?) sitchensis*
Southern Rata	*Metrosideros umbellata*
Spruce, Blue	*Picea pungens*
Southern Beech spp.	*Nothofagus* spp
White Pine	*Pinus stobus*

Mammals will also damage the stem or top of trees. Most similar damage to that caused by Twenty-eight Parrots is caused by possums. Both the Mountain Possum (*Trichosurus caninus*) and the Brush-tailed Possum (*T. vulpecula*) have been reported to cause extensive damage to some pine (*Pinus radiata, P. taeda,* etc.) plantations in Victoria and New South Wales. These possums will gnaw and tear off bark from the upper stem and lead shoot of pine trees, often ringbarking the tree and causing the top to break off. The bark itself is not eaten but the cambial layer is scraped from the wood (McNally 1955; Barnett, 1977).

Brush-tailed Possums, introduced from Australia into New Zealand, also cause extensive damage to planted poplar and willow trees. As well as eating buds and young shoots and breaking branches the possums are reported to eat the bark of some species in winter. The damage is so severe in some regions that planting programs (to control soil erosion on hill-country farmland) have been abandoned (FRI, 1980).

Other mammals responsible for stripping or gouging bark from trees include:

- many types of rodents such as rats, mice, voles, beavers, porcupines and squirrels (Davis, 1942; Brand, 1951; Pudden, 1959; Gessel and Orians, 1966; Tanton, 1968; Timm, 1988);
- rabbits and hares (Prakash, 1964; Tanton, 1968)
- marsupials including quokkas, wallabies and gliders (Stewart, 1936; McNally, 1955; Smith, 1982; Smith and Russell, 1982; Craig, 1985);
- deer (Packard, 1942; Timchenko, 1987)
- primates, particularly marmosets (Columbra-Filho and Mittermeir, 1976; Kinzey *et al.* 1975) and
- livestock such as cattle, sheep and horses (Timm, 1988).

Generally the assumed reason for the damage by birds or mammals was feeding. Thus herbivorous animals eat buds and shoots as part of their diet. Birds that remove bark from trees do so either in search of wood- and bark-boring insects or to feed on sap and cambial tissue (Table 3). The sap could come from the outer sapwood (xylem) or inner bark (phloem) vessels.

An interesting case is that of a New Zealand parrot, the Kaka (*Nestor meridionalis*), that strips bark from branches or the trunk of trees. On some species the purpose is to feed on insect larvae, while on other species the purpose is sap-feeding (Table 3). Detailed observations of feeding by Kaka showed that sap-feeding is concentrated in late winter and spring when few of the of the nectar sources that the Kaka also feeds on are available (O'Donnell and Dilks, 1989).

Where mammals were reported to have debarked trees the assumed reason was generally to obtain food at times of food shortage, e.g. according to McNally (1955) native possums, rats and wallabies that he recorded debarking pine trees in Victoria did so for the concentrated source of starches and sugars in the cambial tissues. Often the bark is not eaten. Squirrels have been observed to strip bark from trees only to lick its inner surface (Norstedt, 1945).

Smith (1992) found the Marsupial Sugar Glider in eastern Australia fed predominantly on plant exudates (*Acacia* gum and *Eucalyptus* sap obtained by bark stripping) and *Eucalyptus* nectar in autumn and winter. However, insects were preferred in spring and summer (possibly to meet protein requirements for reproduction) even though exudates were more common then. Smith concluded that *Eucalyptus* saps would provide an excellent energy source at times of other food shortage for any vertebrate that could succeed in tapping them. Phloem and cambial saps of *Eucalyptus* have been found to be rich in soluble sugars but low in protein (Basden, 1965; Stewart *et al.*, 1973).

Some alternative explanations for birds' and mammals' behaviour in debarking trees were also found:

1. Hares in Pakistan debark trees in summer for sap to maintain their water balance (Prakash, 1964);
2. Elk in North America debark certain trees in winter in search of some substance not present in other plants which they need for physiological reasons (Packard, 1942);
3. Galahs and other cockatoos debark eucalypts for bill-maintenance (Tanton, 1968; Rowley, 1990).

2.2 Secondary damage

2.2.1 Response to topping

Even frequent destruction of the lead shoot (topping) is unlikely to affect tree survival (Curtis and Elder, 1965) though, depending on the species, it can have some effect on height growth (Neilsen, 1981; Thompson, 1984). The major concern expressed over topping is that it is likely to result in the development of multiple replacement leaders (Mezennyj, 1957; Barnett *et al.*, 1977; Timm, 1988).

The response to topping will vary with species. For example, Cook and Littlefield (1945) recorded this on conifers used for reforestation in New York state as follows. Where Grosbeaks destroyed the terminal buds of spruces only one replacement leader tended to form from the highest uninjured bud. This would cause only a slight crook, quickly outgrown, with little loss of height. Grosbeak feeding on other conifers (White Pine, Red Pine) was more serious, but worst of all on Scots Pine. Where the terminal bud cluster of Scots Pine was attacked the result would be the development of one crooked leader, or two or more leaders depending on the number of buds left. Repeated damage to Scots Pine resulted in a bushy, irregular crown, spoiling the timber value of the tree. Damage was of most consequence if it occurred in what would have been the first log length.

2.2.2. Effect of stem barking

Ringbarking of a stem will cause the death of the stem above that level or, if the trunk is ringbarked, the whole tree will die, e.g. Timm (1988) discusses some of the many animals that can kill trees, especially young trees, this way.

Removal of sections of bark can allow entry of decay-causing organisms and subsequent timber degradation. Thus, discs cut from 35 year old Norway Spruce in Quebec showed that while lesions from sapsucker attack healed over fairly quickly they still allowed entry of decay organisms (Ouellette, 1967). In an extreme case, Packard (1942) felt that the existence of Quaking Aspen in a National Park in Colorado was threatened by a dieback fungus that entered through bark wounds, especially those caused by Elk.

2.3 Susceptible trees

While productivity from plantations is generally much greater than from a comparable area of native forest one of the risks of plantations is that they may be more susceptible to pests and diseases. Thus, in the simplified ecosystem (monoculture) of plantations the affected plant is concentrated in one location and there may be less predators to keep any pest in check (Horn, 1988).

Fertilisation of plantation trees may also make them more prone to damage by pests, e.g. increased nitrogen supply to trees has been shown to increase insect herbivory (Mattson, 1980 and Landsberg, 1990) and browsing by various mammals (Brockley, 1988). Abundant nitrogen tends to make foliage more succulent and palatable. Also herbivores may have difficulty getting sufficient nitrogen (required for protein formation) in their diet and so will favour high nitrogen sources of plant food.

In fertiliser trials in Sweden, Anderson *et al.* (1970) found a link between fertiliser treatment and feeding by Capercaille (*Tetrao urogullus*) on the tops of Scots Pine. Trees treated with calcium and nitrogen were damaged more frequently and severely by these birds than trees given other fertiliser (potassium, phosphorus) treatments.

Capercaille have also been reported to prefer the shoots and buds of nursery and plantation grown conifers to those of naturally regenerated trees (Fitter, 1960). Fertilisation of planted trees may account for such differences.

Gessels and Orions (1966) found that rodents caused greater damage to the terminal shoots and buds of Pacific Silver Fir (*Abies amabilis*) in USA than adjacent untreated trees. About 36% of trees receiving some nitrogen were damaged compared to 6% of unfertilised trees. There was a 20% increase in the nitrogen content in the needles of fertilised trees.

Literature on non-tree crops was not generally sought for this review but one study noted (Halse and Trevenen, 1985) showed a clear link between grazing by Skylarks (*Alauda arvensis*) on wheat in Iraq and rate of phosphorus application. Grazing damage increased with increased phosphorus supply until a level several times the threshold phosphorus level for increased phosphorus response.

3. ECOLOGY OF TWENTY-EIGHT PARROTS

An important step in devising possible solutions to a bird pest problem is to understand the ecology of the species. The three elements 'pest', 'crop' and 'environment' will all interact as indicated in Fig 3.

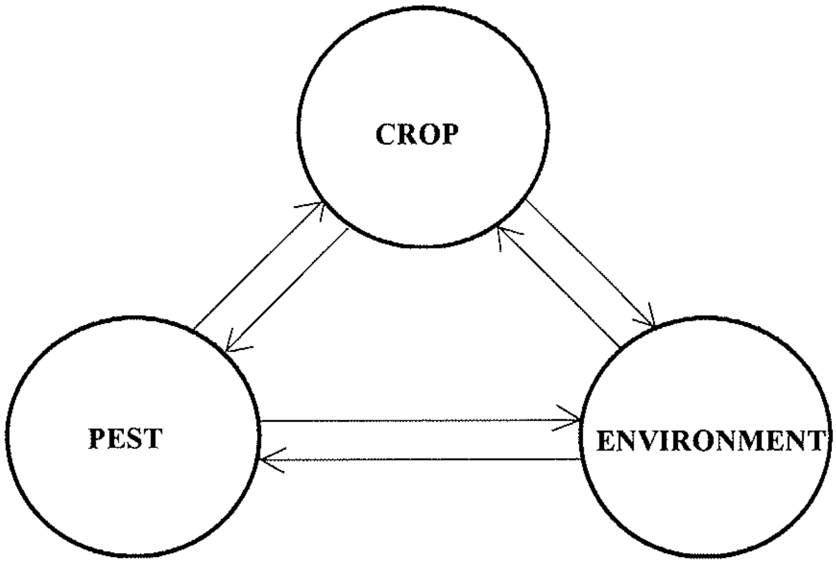

Fig. 3. The crop-pest-environment triangle showing interactions between the three elements

Understanding these relationships will help in devising possible ways to modify any element of the triangle to shift the balance and so reduce crop damage. The remainder of this section reviews what is known of the relationships between the pest (Twenty-eight Parrots), their environment and the crop (Bluegums).

3.1 Twenty-eight Parrots and their environment

3.1.1 Diet

Long (1984a) reported a detailed study of the diet of three parrots in Western Australia. This included the Twenty-eight Parrot (Port Lincoln Parrot) studied for two years at two locations:

1. Wickepin, 230 km south-east of Perth, average rainfall ~ 500 mm/yr, predominantly pasture land, and Salmon Gum (*E. salmonophloia*) woodland; and
2. Balingup, 240 km south of Perth, average rainfall ~ 1000 mm/yr, predominantly pasture land, orchards and jarrah (*E. marginata*) forest.

At Wickepin the parrots ate the seeds of 52 species (including 17 introduced plants) and 6 orders of insects. At Balingup seed from 51 species (25 introduced) and 6 orders of insects were consumed. Bark and woodchips, 'vegetable material' and, to a lesser extent, blossom were also commonly recorded but these materials were not further identified. Nectar taken by parrots in Long's study could not be recorded as it was lost in the formalin treatment of the crops and gizzards of collected parrots.

At Wickepin grains ('wild' oats, cultivated oats and wheat) made up a major part of the diet of Twenty-eight Parrots in Long's study. Together these grains made up around 80% of the material recovered from the parrots in summer, around 60% in autumn and winter, and 13% in spring. The parrots obtained oats and wheat from old stubble, around sheds and haystacks, along roadsides, where sheep were being fed, and from the edges of growing crops. In spring seeds of the introduced weed Long Stork's-bill (Wild Geranium or Corkscrew, *Erodium botrys*) were very important (56% of material recovered). At this time it was noted that the crops of many nestlings were crammed with these seeds.

At Balingup grains were not so important, the highest seasonal record being 23% oats recovered in winter. Other items of seasonal importance were the seeds of thistles (52% of material recovered from parrots in summer), seeds of *Rumex* and *Banksia* (33% and 29% respectively in autumn), *Eucalyptus rudis* seeds (61% in winter), and an unidentified legume (34% in spring).

Other authors have noted the importance of Marri (*Eucalyptus calophylla*) in the diet of Twenty-eight Parrots. This tree is common in south-western Australia in areas of mean annual rainfall > 650 mm (Boland *et al.* 1984). Thus, although abundant around Balingup, Marri is replaced by other eucalypts as far inland as Wickepin, the other of Long's study sites. From studies around orchards at Bridgetown and Manjimup, Halse (1986) found that, as well as feeding on apples and pears, Twenty-eight Parrots fed extensively on the immature seed capsules and nectar of Marri. Three out of four Twenty-eight Parrots collected in Jarrah forest had also been feeding on immature Marri seed capsules. At all sites the Marri capsules were infested with cyclorrhaphid larvae but their importance to the parrots was not evaluated.

Sedgwick (1938), Robinson (1960)and Wykes (1985) also recorded observations of Twenty-eight Parrots feeding on Marri (*E. calophylla*) capsules. The fleshy outer parts of capsules that are still green and fairly succulent are eaten. Twenty-eight parrots will also eat seed from mature Marri capsules, either once it has fallen to the ground (Robinson, 1960) or by rotating the capsule with the upper part of the bill inserted and the head raised so the seed falls into the mouth (Long, 1984).

Besides Marri, Twenty-eight Parrots feed on the fruit and nectar of various eucalypts and other native and introduced trees (Forshaw 1964, 1969; Wykes, 1985; personal observations). Forshaw (1964) recorded that Twenty-eight Parrots crush flowers in the bill to obtain nectar and that they rival lorikeets in quantity of nectar consumed while eucalypts are in flower. He found one specimen, collected from a flock of Twenty-eight Parrots feeding on the flowers of Karri (*Eucalyptus diversicolor*) gave a flow of nectar from the bill when held up by the feet. As Forshaw (1964) wrote of Twenty-eight Parrots "These noisy large green birds with their black heads and brilliant yellow collars present an unforgettable sight when observed feeding in numbers in a large flowering tree".

Hussey and Wallace (1993) noted an apparently increasing practice of Twenty-eight Parrots feeding on the soft bases of Blackboy (*Xanthorrhoea* spp) leaves, killing some Blackboys in the process. Widespread loss of Blackboys damaged by Twenty-eight Parrots is a major concern in some rural communities in south-west Australia.

Considering all observations of the diet of Twenty-eight Parrots, it is clear they consume a wide variety of foods and are very versatile at utilising whatever food is available. The propensity of the Twenty-eight Parrot to adapt to introduced plants including cultivated crops has often been noted (Robinson, 1960; Forshaw, 1964; Long, 1984a, 1984b & 1985; Halse, 1986).

The importance of Marri flowering in relation to damage by Twenty-eight Parrots to cultivated crops has also often been noted. Marri generally flowers over 4-6 weeks in February/March but occasional trees produce two lots of flowers in a year and some flowering can extend as late as July or August (Robinson, 1960; Halse, 1986; personal observations). It is generally accepted amongst fruit growers that a heavy Marri flowering in February/ March will cause a dramatic reduction in damage to their crops at that time by Twenty-eight Parrots and other bird pests (Robinson, 1960; Halse, 1986; Rooke, 1983).

3.1.2 Breeding biology

Most detailed information comes from a study of the breeding biology of a population of Twenty-eight Parrots (Port Lincoln Parrots) in a remnant of wandoo/morrel (*E. wandoo/E. longicornis*) near Dudinin, 270 km south-east of Perth (Long, 1990). Over 4 years (1971-74) the remnant of about 1 ha supported between 6 and 9 breeding pairs. Female Twenty-eight parrots first entered nest hollows in June of each year. Other dates recorded over the four years were:

- Laying - around mid-August to late-September;
- Hatching - around early-September to mid-October; and
- Fledging - around mid-October to late-November.

Incubation of eggs took 3 weeks, with the young leaving the nest (fledging) around 5 weeks after hatching.

Observations of parrot fledging in the Boyup Brook district in 1994 were in agreement with Long's dates. Around the Evanlee Bluegum plantation Twenty-eight Parrots began fledging in the first week in November indicating that they would have begun laying eggs in the first week in September (Dean Wainwright, Agriculture Protection Board, WA, *pers. comm.*, 1994).

There was no 'double-clutching' at the Dudinin study site. Measurements of testicular weight from parrots collected in the diet study previously discussed (Long, 1984) also indicated the parrots only bred once a year. However, Forshaw (1964) records that *Barnardius zonarius zonarius* (the central and southern Australian form) will breed from August (June in northern desert areas) up until February and, if conditions are favourable, two broods will be reared.

The mean clutch size in Long's study was around 5 eggs of which an average 75% hatched, i.e. average 3.8 fledglings/breeding pair/year. No information on how many times a bird will breed was given but, obviously, such breeding rates will produce a "doomed surplus". There must be high juvenile mortality rates in most years to compensate.

Long found that just under 1 in 3 of the available suitable nesting hollows at the Dudinin site were used by Twenty-eight Parrots. Thus the availability of nesting hollows did not appear to be a limiting factor on population size.

3.1.3 Movement and Population dynamics

The movement and population dynamics of Twenty-eight Parrots do not appear to have been studied systematically and documented. According to Forshaw (1964, 1969) they are sedentary though Tingay and Tingay (1982) say they are nomadic. The Twenty-eight Parrots studied by Long (1990) at Wickepin and Balingup remained close to their breeding sites throughout the year, either roosting or foraging in the same or adjacent areas.

It is possible that Twenty-eight Parrots are similar to the Eastern Rosella (*Platycercus eximius*) in northern New South Wales. Brereton (1971) described the Eastern Rosella as having core groups and subsidiary populations. The core groups, made up of high status adult pairs were entirely sedentary. Subsidiary groups, which may be loose flocks of juvenile and young adults, intersperse through the area of sedentary adult pairs.

There is only a little information relating to regulatory mechanisms for populations of Twenty-eight Parrots. Long (1984a) found Twenty-eight Parrots had lowest mean body weight in January-March, suggesting food may be short then. From the breeding study at Dudinin, Long (1990) concluded that, at that site at least, the availability of nest hollows did not appear to limit population size. No information on natural predators or other possible limits to population growth of Twenty-eight Parrots was found.

3.2 Twenty-eight Parrots and Bluegums

3.2.1 Evidence that Twenty-eight Parrots 'attack' Bluegums for food

Given that reports of vertebrate animals debarking trees for food are common (Section 2.1) it seems likely that Twenty-eight Parrots are doing the same, i.e. Twenty-eight Parrots debark Bluegum shoots to feed on cambial tissue, sap and, possibly, bark exudates. It is unlikely that the parrots are searching for insects as the shoots they 'attack' are generally less than 2 cm diameter and do not contain bark- or wood-boring insects. The belief that Twenty-eight Parrots attack Bluegums out of 'pure mischief' is commonly expressed but this seems unlikely.

Evidence to support the hypothesis that Twenty-eight Parrots attack Bluegums for food was also obtained from parrot damage monitoring in Bluegum plantations. The results indicate that attack rates on Bluegums decrease when other preferred foods are available and increase immediately if a preferred food source is withdrawn. Thus, Fig. 4 shows a a clear reduction in attack rates during February and early March. This coincides neatly with the main period of a generally very heavy Marri flowering in 1994. Fruit growers in the South-west also report that a heavy Marri flowering will divert Twenty-eight Parrots from feeding on their crop while they feed on the Marri nectar (Halse, 1986). Presumably, at other times of the year when attack rates on Bluegums are low, Twenty-eight Parrots have available alternative food supplies (natural or introduced) that they prefer to Bluegums.

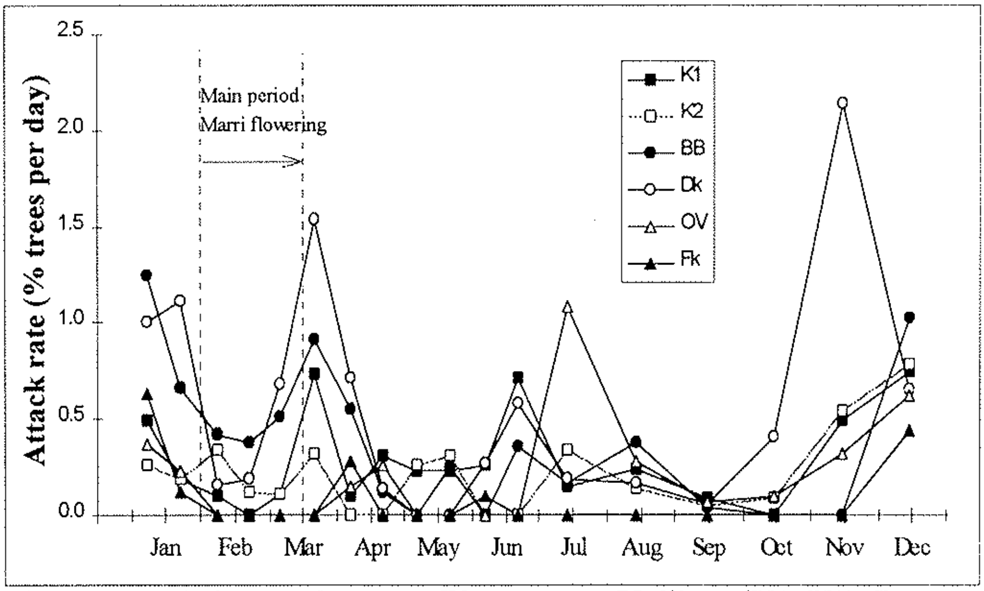

Fig. 4. Trends in attack rate to Bluegums at Kulikup (K1, K2), Boyup Brook (BB), Darkan (Dk), Orchid Valley (OV) and Frankland (Fk).

Notes:

1. 'Attack' defined as debarking (bark removal to expose wood) of the leader(s).
2. 'Attack rate' defined as '% trees with leader(s) attacked per day', any tree with a broken top (no leader due to parrot damage) not included in calculations.
3. Data points calculated as means from 2 or 3 plots of 25 trees each.
4. Trees planted in winter 1992, observations of parrot damage Jan.-Dec. 1994.

The increase in attack rate at Orchid Valley in July (Fig. 4) appears to be in response to a food source being withdrawn. That increase was observed at only one of the two Orchid Valley plots. This plot was around 100 m from a grain silo. The farmer noted large flocks of parrots gathering at the silo to feed on oats spilt whilst feeding sheep. This supply of oats was stopped in early July when sheep feeding ceased.

The lesser peaks in attack rate in June at the Kulikup (K1), Darkan and Boyup Brook sites (Fig. 4) may also have been related to cessation of sheep feeding with oats in paddocks nearby the Bluegums. (Fig. 4 also shows a large peak in November at the Darkan site. While no explanation for this was found, possiblities are that it relates to the fledging of Twenty-eights at the time, i.e. sudden increase in parrot population, and/or some particular food shortage at the Darkan site at the time.)

Another peak in 'attack rate', out of character to other sites, occured in August in the P93 plots at Frankland (Fig. 5c). These plots were approximately 400 m from an open bin used to store oats in winter. Large flocks of parrots fed on the oats. The supply of oats ran out in early August, corresponding with the sudden increase in attack rate that month in the nearby plots.

Other indications that Twenty-eight Parrots attack Bluegums for food includes:

- Examination of shoots of Bluegums where the bark has been freshly removed show marks consistent with scrapping of the cambial layer by Twenty-eight Parrot beaks.
- Twenty-eight Parrots shot in Bluegum plantations often give off a strong smell of eucalyptus on opening up of the crops (Dean Wainwright and Marion Massam, Agriculture Protection Board, WA, *pers comm., 1994*).
- Twenty-eight Parrots in captivity will readily consume eucalypt branches placed in the avairy (Wilson, 1990).

While none of the above points prove that Twenty-eight Parrots debark Bluegums for food together they do provide a strong indication that this is the case. However, until further studies are done it is not possible to say if the parrots obtain any substantial nutrition from the Bluegums.

3.2.2 Hypotheses for the increase in parrot damage

There are at least three hypotheses to explain the apparent increase in parrot damage to Bluegums over the last 5 years:

1. An increase in numbers of Twenty-eight Parrots, at least in some parts of their habitat, has put increased pressure on their traditional food sources forcing them to develop new food sources such as new crops;
2. The traditional food sources for Twenty-eight Parrots have declined and this has forced them to develop new food sources.
3. Feeding on Bluegums by Twenty-eight Parrots is 'learned behaviour' and the parrots are only just learning of a new food source.

Verification of either or both the first two hypotheses could also explain the apparent increase in Twenty-eight Parrots killing native Blackboys (*Xanthorrhoea* spp). Hussey and Wallace (1993) attribute an apparent increase in numbers of Twenty-eight Parrots in recent years to the parrot's response to agricultural development which has provided them with ideal conditions of open areas, patches of remnant vegetation and plentiful water. Traditional food sources of Twenty-eight Parrots in undisturbed native forest and woodland environments have been little studied but it may be that, for example, they relied on understorey species now mostly absent from remnant vegetation on farms.

The third hypothesis (also suggested by Hussey and Wallace in relation to parrot damage to Blackboys) could explain other aspects of parrot damage to Bluegums, i.e:

- why parrot abundance is a poor indicator of susceptibility of Bluegums to parrot damage. (Twenty-eight Parrots were common in all 12 sites included in Table 1, yet damage rates varied from 4% - 98% of trees);
- why parrot damage has not been recorded in early (pre-1989) plantings even in the zone of (currently) worst damage.

While other factors may be involved it may simply be that where Twenty-eight Parrots have been abundant yet caused little or no damage to Bluegum plantings that they had not yet discovered a new food source. If the 'learned behaviour' hypothesis applies then parrot damage to Bluegums may also develop in areas where it is not common now.

Although there is insufficient knowledge to confirm or reject any of the three hypotheses it seems likely that all three are correct, i.e. at times both population increases and declines in traditional food resources have forced Twenty-eight Parrots to explore new food sources such as Bluegums. Once the parrots learn of these new food sources they continue to feed on them.

The provision, then sudden withdrawal of artificial foods (feast, then famine), could also cause Twenty-eight Parrots to explore new food sources. For example, the evidence that sudden withdrawal of oat supplies can result in an increase in parrot attacks to nearby Bluegums has been discussed (Section 3.2.1). Other examples may be the harvesting of a crop (oats, canola, etc.) that the parrots have been feeding on or the introduction of grazing by farm animals into an area kept free of grazing for an extended period. Thus sheep are generally kept out of Bluegum planting areas for the first year. This allows a build up of pastures and weeds (food for Twenty-eight Parrots) between the rows of trees until sheep are re-introduced. Alternatively, if weed control in the first year after planting is applied (pastures/weeds between rows 1 y.o. trees sprayed) as is becoming common practice, then this could also cause a sudden loss of food. The provision of artificial foods may allow Twenty-eight Parrots to build up in numbers (reduced mortality), exacerbating food shortage when the food is suddenly withdrawn.

4. MANAGING PARROT DAMAGE TO BLUEGUMS

There are at least two possibilities for managing parrot damage to Bluegums to consider:
1. Identify and avoid planting susceptible sites;
2. Develop practical method(s) for controlling parrot damage.

4.1 Avoid planting susceptible sites

Avoiding susceptible sites could involve stopping all planting in any region(s) of greatest risk. Thus, as previously discussed, programs to control hill-country erosion in New Zealand by planting poplars and willows were abandoned in regions of very severe possum damage, at least until control techniques were developed.

Stopping planting of Bluegums in the zone of worst damage in south-western Australia would exclude some 20% of the area that would be suitable for planting but for the risk of parrot damage (Fig. 2). This zone generally coincides with the area where secondary benefits from planting Bluegums (salinity amelioration, shelterbelts, conservation values) are greatest. Losing scope to plant such an large area on any long term basis is clearly undesirable. It is also possible that, if parrot damage to Bluegums is 'learned behaviour' that it will develop in areas where it is uncommon or absent now.

It may also be possible to identify sites within regions that are at greatest risk of parrot damage and avoid planting only those sites, at least until possible control techniques are evaluated. For example, it may be that 'black spots' for parrot damage are sites near a particular remnant vegetation type that supports populations of Twenty-eight Parrots.

4.2 Control parrot damage

It is important to consider both 'when' and 'how' to control parrot damage and these questions are considered separately.

4.2.1 The 'critical period' for controlling parrot damage

Even if it were possible to control parrot damage to a Bluegum crop for the entire rotation (about 10 years) this would probably be very expensive. A better strategy may be to *concentrate control efforts on the period when damage is most likely and of most consequence*. Thus, the concept of a 'critical period' can be developed.

Start of the 'critical period'

Fig. 5a indicates the start of the critical period for P93 Bluegums at the Darkan site was the second half of March 1994. Before that (the first 8-9 months after planting)

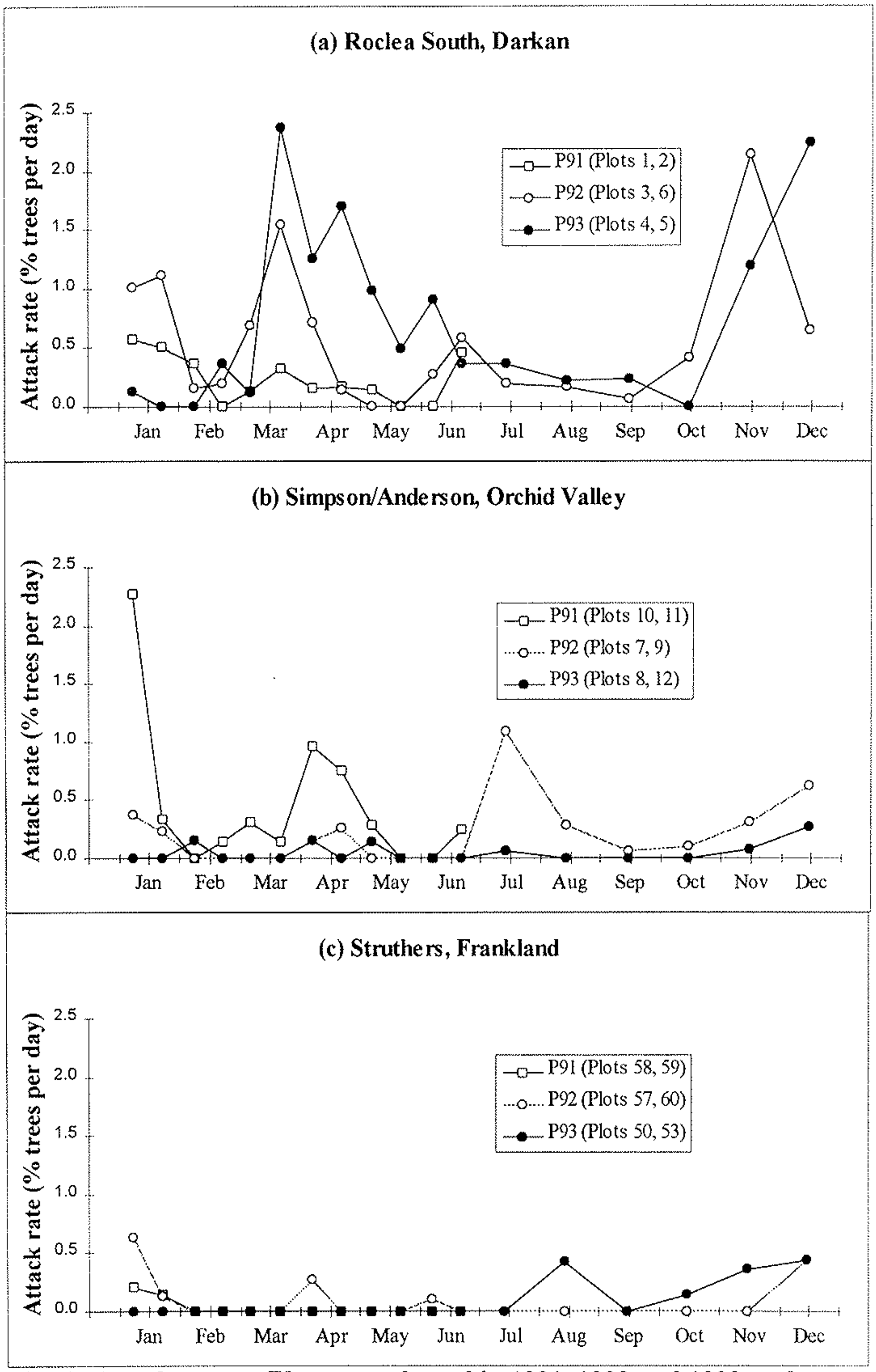

Fig. 5. Attack rate on Bluegums planted in 1991, 1992 and 1993 at three sites.

Notes:

1. P91 trees too tall to reliably assess after June (Darkan & Orchid Valley sites) and July (Frankland sites).
2. Observations of parrot damage Jan.-Dec. 1994.

there was very little damage. At the other two sites where P93 trees were monitored (Orchid Valley and Frankland) the start of the critical period for P93 Bluegums appeared to come later in 1994.

Fig. 5b shows that at the Orchid Valley sites there was little damage to P93 trees until the end of 1994 (around 17 months after planting). At the Frankland site the first damage to P93 trees was in August 1994 (Fig. 5c) though, as discussed in Sect. 3.2.1, that may have been an effect of the nearby oat supply being stopped. Thus, over the three sites, the earliest date for a start to a critical period for parrot damage was March of the first year after planting.

'Critical height' and the end of the 'critical period'

To define the end of the 'critical period' it is first necessary to introduce the concept of 'critical height'.

One definition is that *the 'critical height' for parrot damage is that where it would be just possible at harvest time to cut out any resulting 'unacceptable deformity' and still harvest a base log equal to the minimum log length.* Refer to Fig. 6 for illustration.

Note that a parrot attack causing an 'unacceptable deformity' (fork or severe bend) is likely to be of most consequence if it occurs below the critical height for 2 reasons:
(i) Base logs have the most value per metre length because trees are widest at the base, e.g. base logs of 2, 3 and 6 metres would comprise around 17%, 25% and 47% respectively of the merchantable volume of a typical 25 m tall Bluegum at harvest age.
(ii) If parrot damage causing an unacceptable deformity occurs just below the critical height the base log will not meet minimum log length specifications and will be wasted. Compare waste in 'left' and 'centre' trees in Fig 6.

Other important points about critical height to note are:
1. Defining 'critical height' is not to say that damage above this height is of no consequence. There will still be an impact of damage above the critical height, e.g. loss of quality and greater harvesting costs, but loss of harvestable volume is *likely* to be less. If two 'unacceptable deformities' occur in a stem less than the minimum log length apart (e.g. 'right tree' in Fig 6) then that section of the stem will be wasted.
2. Standards for minimum log length have not generally been set. They will depend on harvesting and processing considerations. In general terms, logs that are too short (< min. log length) will be uneconomic to harvest due to greater handling costs. Bunnings Forest Products specify a minimum 2 metre log length for chipping. However, most trucks are not equipped to carry logs that short and logs are normally delivered to the mill in 6 m lengths (preferred length for logging operations). For mill operations, an even longer log length is preferred.
3. It may be desirable to re-define 'critical height' so that it includes more than the minimum log length. A critical height that would provide for a base log of the preferred 6 m length has been suggested.

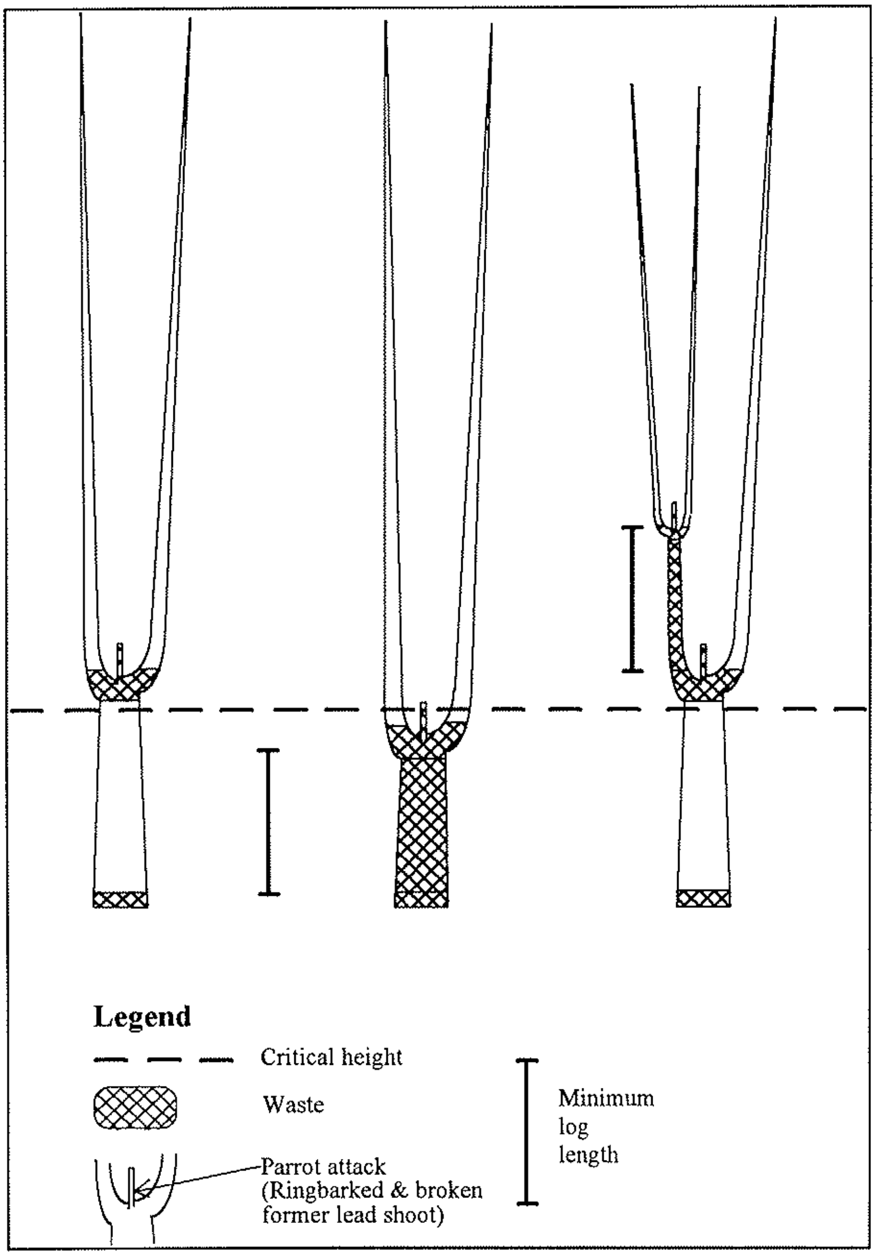

Fig. 6. 'Critical height' for parrot damage.
Left tree: Parrot attack above the critical height, i.e. after allowances made for a stump and removal of the fork crutch it is still possible to harvest a base log of acceptable length. *Minor volume loss only.*
Centre tree: Parrot attack just below the critical height. Base of tree wasted. *Major volume loss.*
Right tree: Two 'unacceptable deformities', both above the critical height but less than the minimum log length apart. *Moderate volume loss.*

Once critical height is specified it is possible to calculate the end of the critical period. *The end of the critical period occurs when trees are sufficiently tall that parrot damage to lead shoots is unlikely to occur below the critical height.*

Fig. 7 is an attempt to define the end of the critical period for controlling parrot damage at the Darkan site. Specifying a critical height of 3.3 m based on a minimum log length of 3 m were judged to be reasonable assumptions.

Thus, Fig. 7 indicates the end of the 'critical period' for P92 trees at the Darkan site was around July 1994, i.e. approximately 2 years after planting. Clearly the younger trees (P93) had not passed the critical period while the older trees (P91) had.

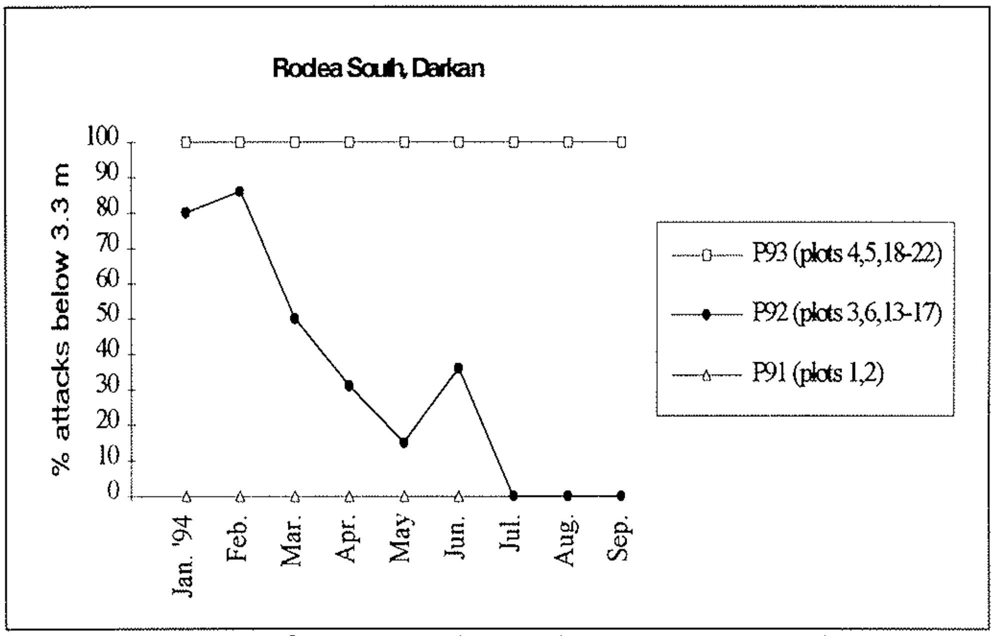

Fig. 7. Percentage of stems attacked each month where the lower extent of the attack was below the critical height.

Note:
Critical height assumed to be 3.3 m, i.e:
3.0 m = minimum log length
+ 0.1 m = stump allowance
+ 0.2 m = allowance assuming any bend or fork will form some distance below the lower extent of any parrot attack
An 'unacceptable deformity' (fork or severe bend) occurring below 3.1 m would mean the base log would be wasted. An unacceptable deformity above 3.1 m could be cut from the tree and a base log of at least 3.0 m harvested together with any stem(s).

Fig. 8 shows an assumed maximum critical period at the Darkan site extending for 16 months. The word 'maximum' is used because, if it turns out there is little likelihood of parrot attack during any or all of the months from May-November, then these would not be 'critical months' for protection of Bluegums from parrot damage.

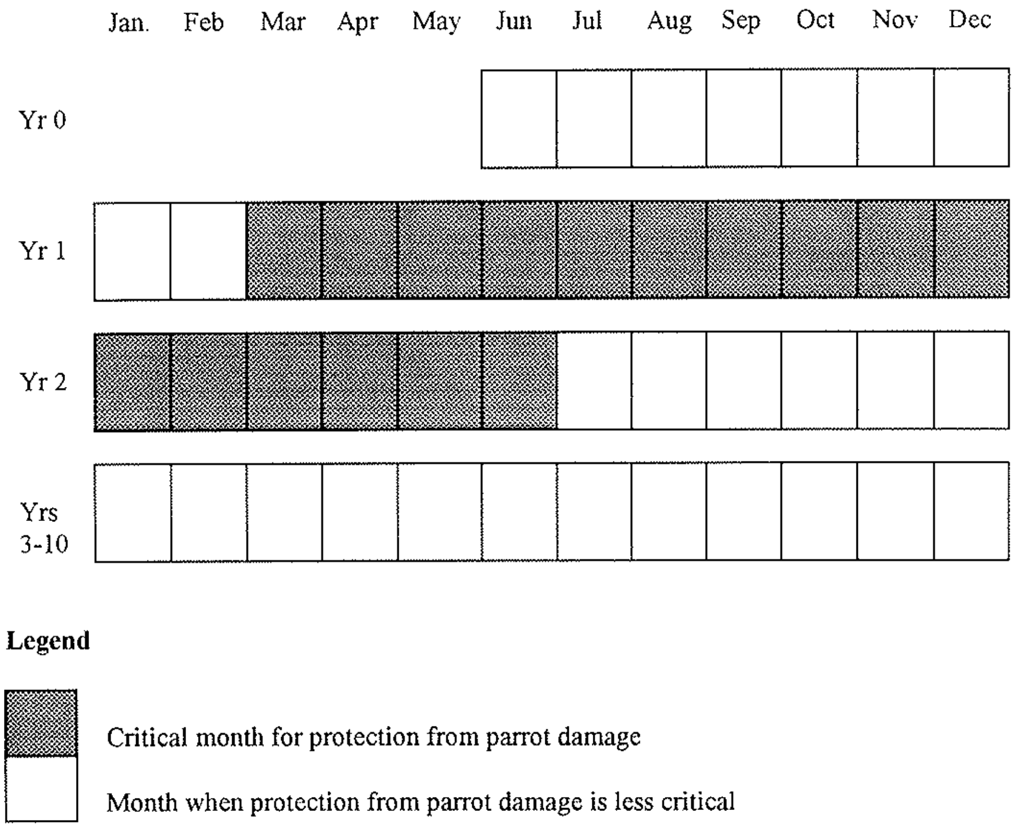

Fig. 8. Maximum 'critical period' for protection of Bluegums at Roclea South site, Darkan.

Note:

1. Trees planted around July of Year 0.
2. Before March of Year 1 have low incidence of parrot attacks.
3. After June of Year 2 assume most attacks will be above 'critical height'.

The length of the critical period is dependent on specifications for minimum log length. If minimum log length is decreased then this will shorten the critical period. Conversely, if the minimum log length is increased (or critical height re-defined to provide for more than the minimum log length) then this will extend the critical period.

In the event that more than one age of Bluegums is planted in an area affected by a population of Twenty-eight Parrots and population reduction is the strategy relied on for controlling parrot damage then the critical period *for that area* would also be extended. This situation is discussed further in Section 5.

4.2.2 Possible control techniques

To control damage to Bluegums (the crop) by Twenty-eight Parrots (the pest) at least one of the elements in the crop-pest-environment triangle (Fig. 3) must be changed. There are many potential ways of doing this and it may be convenient to group the techniques as follows. (The groups are listed in logical sequence, not intended to imply order of importance).

1. **Reduce parrot populations -**
   This could be achieved by targeting the *pest* element directly, e.g. shooting campaigns. Otherwise, techniques such as modifying the *environment* to encourage predators may effectively reduce pest numbers.
2. **Divert parrots from damaging the crop -**
   The *environment* could be changed, e.g. provision of alternative food supplies or use of scaring devices. Another possibility would be to change the *crop* to a less susceptible species or genotype of the same species.
3. **Rectify the damage if it occurs -**
   The advantage of this approach that it is possible to wait and see if the pest actually damages the crop before taking action. Silvicultural techniques to manipulate the *crop* such as pruning to correct forking or culling to remove deformed trees from the stand may be worth investigating.

The various control techniques, which could be applied singularly or in combination, are discussed in more detail in the following Sections 5, 6 and 7

5. TECHNIQUES TO REDUCE PARROT POPULATIONS

It is generally recognised now, e.g. Brasher (1993), that management of pest impacts should focus on reducing damage not just pest numbers. Concentrating on pest population control can divert attention from other more cost-effective means of reducing damage.

Another issue relevant to parrot damage to Bluegums is that Twenty-eight Parrots are a native species and, as such, worthy of conservation. This is reflected in community attitudes expressed in legislation. Under the West Australian *Wildlife Conservation Act 1950* Twenty-eight Parrots are protected except where an 'open season' has been declared. An open season currently applies in most shires in the south-west of Western Australia. This permits the destruction of Twenty-eight Parrots where they are impacting on land production or could reasonably be expected to do so. Shooting is the only means by which the parrots may be taken, unless a licence to take Twenty-eight Parrots by other means is obtained from the Department of Conservation and Land Management.

Any attempt to permanently reduce Twenty-eight Parrot numbers throughout their range by imposing artificial mortality would seem to be impractical for at least two reasons:

1. Unless control is extended to all areas pest animals will only increase and spread from unprotected areas, e.g. see discussion by Whitehouse (1976). This may especially apply to Twenty-eight Parrots which are widespread throughout the south-west of WA and have probably become more abundant as a result of agricultural development (Halse, 1986).
2. 'Compensatory mortality' - i.e. imposing artificial mortality would cause a reduction in the high natural mortality rates amongst parrots (Halse, 1986 and Bomford, 1992).

However, as discussed in Section 4.1, the critical period for controlling parrot damage may be not more than 16 months of a 10 year rotation. Therefore a temporary reduction in the parrot population affecting an area of Bluegums may be sufficient. This could apply if the Bluegums affected by the parrots were all the one age. But, if several ages of Bluegums are affected, the critical period for each age would not coincide and population control would be necessary for more than the critical period for any one age of trees. The situation could arise where a permanent reduction in a population of Twenty-eight Parrots would be necessary, i.e. if small areas of Bluegums were planted regularly every 1-2 years in a compact area such as a single farm. (The classical sustained yield model for a tree crop managed on a 10 year rotation would involve harvesting and regenerating one tenth of the area each year.) In this situation the concept of a critical period, although still applicable to any age unit, would not apply to the farm as a whole.

Studies by the Agriculture Protection Board have shown that temporary reductions in parrot populations on a local scale are achievable. By intensive shooting over a period of weeks, it was possible to temporarily eliminate parrots from two isolated orchards in south-west WA. However, by the same time next year (when the next year's apple crop was vulnerable) parrot populations had returned to normal. (Peter Mawson, Agriculture Protection Board, WA, *pers. comm.* 1993).

Whether local reductions in parrot numbers would be effective in reducing damage to Bluegums is another question. It may be that much reduced populations of parrots could still cause unacceptable damage. This appears to be the case with the Long-billed Corella in South Australia. Despite numbers of Long-billed Corellas declining by 74% over 10 years in SA (shooting, illegal poisoning, drought), there was still widespread concern among farmers over the level of damage caused to crops by Long-billed Corellas (Bomford, 1992).

Anecdotal evidence from rural communities in south-west WA indicates that local control of parrot populations can reduce damage to crops. Some farmers say they were only able to pick fruit from their few fruit trees or grow roses in their garden with a concerted shooting or (illegal) trapping program. Others have apparently used poisoning (also illegal) with success.

In south-east Australia poisoning with 1080 (sodium monofluoroacetate), although controversial for various reasons, has been widely relied on for temporary reductions in populations of browsing animals in reforestation areas. Rabbit and wallaby populations have been controlled to allow establishment of seedlings and other pests, e.g. possums, controlled over the crucial stage when they would otherwise have inflicted damage on young trees (Statham, 1983; DCE, 1991).

Some possible means of reducing parrot populations are discussed below.

5.1 Shooting

Shooting, both for frightening and killing, has been widely used in attempts to control bird pests in WA (Long, 1962). In his review of parrot damage to apple orchards Halse (1986) concluded it was the most effective method of controlling the number of birds in orchards, functioning more by scaring the birds out of orchards than by reducing population sizes.

Shooting may be less cost-effective in Bluegum plantations than in orchards for at least three reasons:

1. The capital value of the crop per hectare would generally be much lower in Bluegums;
2. Visibility in Bluegums would be less as they tend to be more dense than orchards so the effort required to implement shooting (per hectare) would be greater
3. Human activity in Bluegum plantation is much less. The potential for workers to scare away birds made shy of humans by shooting would therefore be less.

5.2 Trapping

According to Long (1962) trapping of some bird pests in WA, including Twenty-eight Parrots, has been used with some success. He comments that a trap similar to 'The Australian Crow Trap' (Woodbury, 1961) is suitable for Twenty-eight Parrots. The Australian Crow Trap is a cage type trap with funnel entrances in a depression at the top. Farmers have also reported successes in trapping parrots with cage type traps with entrances at ground level.

5.3 Poisoning

Poisoning has been used for bird pest control in WA, e.g. Long and Vagg (1962). However, no poisons are currently registered for use on Twenty-eight Parrots. Therefore none can be used or even trialled legally without a permit to do so.

One poison registered for use on Sulphur-crested Cockatoos in WA is alpha-chloralose. Its acts as an anaesthetic, causing the birds to go into a coma. Advantages are that it is regarded as a humane poison and only target species need be killed. Non-target species can be held in a safe place for 12-24 hours and allowed to recover.

Twenty-eights (along with many other animals native to SW Australia) are moderately tolerant of 1080 (King, 1990). Therefore 1080 is unlikely to be a suitable poison for the control of Twenty-eight Parrots.

A recent development from New Zealand with scope for reducing the impact of poisoning on non-target wildlife and domestic animals is the use of gel carriers. Poisons can be mixed in gels such as Petrolatum grease and applied to the affected part of crop plants. In this way only animals that consume that part of the crop plant will directly consume the poison. (Warburton, 1990).

Putting a suitable poison on the lead shoots of Bluegums may be a way of increasing target specificity. It seems unlikely that any animal other than Twenty-eight Parrots would chew on the lead shoots and therefore ingest the poison directly. From monitoring of parrot damage it is clear that the leads shoots of Bluegums are frequently chewed, e.g. around 0.5%-1.0% of lead shoots affected *per day* at times of high damage (Fig. 4). Therefore it would not be necessary to treat every tree. Applying the poison to the lead shoots of a few 'bait trees', e.g. 5% of trees in a stand, may be all that is required.

Another possible advantage of applying a poison to the lead shoots of Bluegums is that, if not all Twenty-eights are causing the damage, then the poison would work selectively on those that are. Thus, one theory for the apparent recent increases to parrot damage (to Blackboys and other crops besides Bluegums) in south-western Australia is that the wheatbelt (eastern) form of Twenty-eights (*B. z. zonarius)* is encroaching on the traditional range of the forest (south-western) form (*B. z. semitorquatus*). If this is the case, i.e. *B. z. zonarius* more likely to cause damage, then poisoning lead shoots of Bluegums would work selectively against *B. z. zonarius* and favour retention of the *B. z. semitorquatus* in populations. In other words, there may be potential for genetic selection of parrots that will cause little or no damage to the crop.

However, care would be required in developing any poisoning approach even if permits to do so were obtained. Putting the poison only on the affected part of the crop plant appears to offer many advantages over approaches such as putting poison in food (grain) likely to be consumed by many different animals. But there is still the risk of secondary poisoning whereby an animal that eats a poisoned parrot is in turn poisoned. If predators of Twenty-eight parrots, such as birds-of-prey, are affected then the end result may be the opposite of that intended.

5.4 Encouraging Predators

No instances of successful control of bird pests by encouraging predators were found. However, reports of this approach working on rodent pests were noted.

From Switzerland two cases were quoted where mouse damage to the buds of Silver Fir stopped abruptly when nesting boxes were put up and taken over by owls (Reudi, 1945).

In a *Pinus radiata* stand in Chile owls and foxes were successfully encouraged to prey on small mammal pests (rodents and rabbits). This was achieved by clearing 4 m wide strips to provide access for predators while reducing cover for pests and by putting up perches for the owls. (Munoz and Murua, 1990.)

In New South Wales Kay *et al.* (1994) found the placement of artificial perches around the perimeter of irrigated soybean crops significantly increased the numbers of birds of prey visiting and hunting over these crops during the day compared with untreated crops. This increased hunting pressure reduced (a) the rate at which the mouse population increased in the crops and (b) the maximum mouse population density. However, no significant reductions in mouse damage were detected as mice failed to reach the threshold densities for crop damage on the untreated plots.

5.5 Reduce food supplies

As discussed (Sections 3) oats and other grains can be a large part of the diet of Twenty-eights and sudden withdrawal of supply can lead to extensive damage to nearby Bluegums. Therefore it seems likely farmers could avoid this problem and, in the long-term, reduce Twenty-eight Parrot populations on their land through careful grain management. This would involve taking care not to spill grain, e.g. around silos. Also, where oats or oat hay are being fed to sheep to supplement pastures, supplies could be cut back as soon as the sheep start leaving some grain. It is common to see flocks of parrots feeding on oats left over by sheep. Also, lines of oat germination across paddocks where sheep have been fed show that the sheep do not always consume all the oats. At least one farmer (Ray Harrington, Darkan district) has observed a considerable reduction in parrot numbers once he took care to avoid providing grain food for the parrots.

5.6 Fertility control

Various fertility control techniques are also possibilities for bird pest population control but have not yet attracted research attention in Australia (Bomford, 1992).

6 TECHNIQUES TO DIVERT PARROTS FROM DAMAGING BLUEGUMS

6.1 Crop selection

An obvious response to risk of severe damage is to consider growing a different crop. For example, in areas of south-eastern and eastern Australia where damage to sunflower crops by cockatoos is high, the economic return from sorghum, cotton or soybeans is competitive and bird damage is minimal (Bomford, 1992).

However, it seems unlikely that a competitive alternative to Bluegum could be found. Of all the species tested for pulpwood productivity in the south-west Bluegum is clearly superior. It is also clear that most, if not all, other species of *Eucalyptus* and *Acacia* (the most likely genera for pulpwood production) are damaged by parrots.

It is possible that there is variation between genotypes of Bluegum in susceptibility to parrot damage or that Bluegums could be bred for resistance to parrot attack. In New Zealand there have been some successes in reducing possum damage by breeding less palatable ('bitter') willows and poplars (Markham, 1971; FRI, 1980). Another desirable trait to select and breed for would be a tendency to develop only one replacement leader in response to destruction of the original lead shoot.

6.2 Nutrient manipulation

If fertiliser treatments are a factor in determining parrot damage to Bluegums (Section 2.3) then this should be taken into account when planning fertiliser regimes. Some trade off between growth response and susceptibility to parrot damage may be necessary.

6.3 Repellents

Repellents have long been used in attempts to deter pest animals from trees (Armour, 1963). They are substances applied to crops to deter pests and are generally non-lethal. Most bird repellents work by making the crop distasteful. However others, called aversive conditioning repellents, work by making birds ill after they have eaten treated crop, causing them to avoid it thereafter (Conover, 1984; Mason and Clark, 1992).

Finding a suitable repellent to protect Bluegums may be easier than for food crops for the following reasons:

1. Substances which may affect the taste or toxicity of foods for humans can be used.
2. It is only necessary to protect the lead shoot (top 2 m) of Bluegums to maintain the single-stem growth form important for wood production. Any attacks on side branches would be of little consequence. If side branches are left unprotected there may not be the problem of the bird pest not having anything else to eat once the entire crop is protected.

However, there may also be factors which make it difficult to find a suitable repellent to protect Bluegums:

1. Repellents may need to be applied more than once during a rotation. Whether more than one application a year is necessary would depend on the length of the damage season (or seasons if there is more than one in a year) and the length of time repellents could be made to stick.
2. The fast growth rate of Bluegums may mean that new growth of the lead shoot quickly extends beyond that protected by any repellent. Again the extent to which this is a problem will depend on the time and length of any damage season(s). Obviously parrots can only attack shoots which have had time to grow strong enough to bear their weight. Data are being gathered on the nature of shoots attacked (diameter and distance to tip).

Information on some promising repellents is presented below.

Mesurol

One commonly used bird repellent which is available in WA is Mesurol, a Bayer product containing the active ingredient methiocarb. Mesurol is a dual property repellent, combining a noxious taste with an ability to produce illness (Conover 1984). However, advice from Bayer (Geoff Summers, *pers comm.*, 1994) is that, on fruit at least, it is only effective against smaller birds such as Silvereyes. Twenty-eights will spit out treated fruit without ingesting enough to make them sick.

Methyl anthranilate

Recent studies in USA show that methyl anthranilate and dimethyl anthranilate have promise as bird repellents (Mason *et al,* 1989; Dolbeer, *et al.*, 1992; Peter Vogt, PMC Speciality Group, USA, *pers comm.*, 1994). These chemicals have also been used in Australia with some success on cherries and sunflowers (Ron Sinclair, SA Animal & Plant Control Commission, *pers comm.*, 1993). In USA, methyl anthranilate is available in ReJeX-iT brand formulations sold by PMC. Anthranilates are used as food additives and therefore generally regarded as safe (Dolbeer, *et al.*, 1992).

D-ter

D-ter is the trade name of a bird and mammal repellent used since the 1960s and more commonly marketed outside Australia as Curb. It is reported to act on the taste and smell receptors and be effective for protecting seeds and crop plants. D-ter is recommended for preventing ringbarking of trees and shrubs by wildlife. The main ingredient is aluminium ammonium sulphate. (M.E. Forster, Erica Vale Australia Pty Ltd, *pers comm.*, 1994).

Lime

Only one case (Nef, 1959) was found in the literature of a bird repellent used to protect growing trees. A moderately thick lime-wash, applied with a hand brush reduced attacks (Black Grouse eating terminal shoots of young pines) to only 2% of trees, compared with 83% for control trees. The lime did not harm the trees and one man could treat 4000 trees/day. However, according to Palmar (1968) the treatment was too costly for general application. This was because the treatment had to be repeated annually for up to 4 years before the crop had grown above the vulnerable height.

If a lime solution was an effective repellent on Bluegums, the economics may be more favourable than for the pines in Belgium, particularly if fewer applications are required (critical period < 2 years) and application could be mechanised. Phytotoxicity of the lime to the Bluegums is a possibility that would have to be checked.

Two recipes for a lime-based repellent, apparently effective against rodent attack to young pines in South Africa are given by Willan (1984):

A.	Whitewash (lime)	45 kg	B.	Whitewash	40 kg
	Water	50 L		Liquid manure	45 L
	Petroleum	5 L		Cow dung	15 kg
	Adhesive (glue paste)	600 g		Adhesive	600 g

Seed coatings

Various bird repellents have been developed to protect seeds and some of these may also have application for the protection of growing shoots of trees. Amongst the possibilities are cinnamic acid derivatives, Thiram and anthraquinone (Crocker and Reid, 1993) and copper oxalate and lithium chloride (Conover, 1984).

Jacksonia

As well as the repellents discussed above an interesting possibility is the use of a Western Australian native shrub *Jacksonia furcellata*. Margaret Benn, who grows Protea flowers commercially near Kojonup, has found a novel way of preventing the normally severe losses of Protea flowers to Twenty-eight Parrots. Placing a piece (around 30-50 cm long) of *Jacksonia furcellata* in each Protea bush gives complete protection against parrot attack until the bush grows above the level of the *Jacksonia* branch. *Jacksonia furcellata* branchlets have many spines and it is not known whether it is the spines or something else in the plant which repels the parrots. (Margaret Benn, *pers. comm.* 1994).

6.4 Barriers

Individual tree guards (e.g. netting, plastic sheet) may be used to control either browsing of planted seedlings or bark stripping from the stems of trees. However, the cost is high. Coleman (1991) found the cost of tree guards to protect newly planted seedlings varied upwards from $90 per 1000 and required a two to three fold increase in planting time. Presumably, fitting tree guards to protect the lead shoot of trees would take longer and would therefore be unlikely to have practical application for Bluegum crops.

One reference to tree guards (top nets) being used to control damage to the lead shoots of trees was found (Thompson, 1984). However, that was an experiment to investigate other factors (shelter from wind, weeding) where bird damage threatened to compromise the results. The use of top nets, though successful in reducing bird damage in the experiment, was not recommended for general application.

For high value crops, such as some fruits, throw over nets or the erection of a permanent structure and nets may have application. However, the cost of such systems is likely to be greater than $1000/ha/yr (Sinclair, 1990; Ron Sinclair, SA Animal & Plant Control Commission, *pers comm.*, 1994). Such costs would clearly make Bluegum production uneconomic.

6.5 Scaring

Bomford and O'Brien (1990) reviewed literature on devices that use sound to control animal damage. They found devices that produce communication signals (recorded alarm or distress calls) showed the most promise but these were usually species-specific and birds tend to adjust and ignore the sound if calls are played frequently or over a long time. Devices producing other sounds (bangers, crackers, clangers, poppers, bombers, sirens and electronic noises) were found to be, at best, useful for short-term damage reduction with no persistent effects.

Field trials of various scaring devices for prevention of parrot damage to cultivated fruit in south-west WA indicated none had any promise of preventing damage by parrots, other than possibly White-tailed Black Cockatoos (Long *et al.*, 1989). Equipment tested included three types of electronic scaring devices, one type of gas cannon, imitation hawks, balloons and "eye patterns".

6.6 Diversionary feeding

Providing pests with a more attractive food supply to the crop they are damaging can be a simple solution. Thus, Dorwood (1965) reported that growing a crop of soy bean and sorghum alongside pine nursery beds solved the problem of birds feeding on sown seed and seedlings. He felt it was a better solution than their traditional approach of shotgun patrols.

Another success story comes from the Leeuwin Estate Winery near Margaret River in south-west Australia. They have grown a sunflower crop near the vineyard each year for the last 10 years to provide an alternative food source for Twenty-eight Parrots at the time when the grapes are vulnerable to severe parrot damage. This is a 6-8 week period in late summer/ autumn. The Vineyard Manager is happy with the results. (John Brocksopp, Leeuwin Estate Winery, *pers. comm.*, 1994).

Based on studies of the biology of the Silvereye (*Zosterops lateralis*) in vineyard areas near Margaret River, Rooke (1983, 1984) suggested growing alternative food crops for the Silvereye on the edge of vineyards. The alternative crops suggested included figs, Nightshade, *Banksia* and Seaberry Saltbush. Rooke found the Silvereye (like Twenty-eight Parrots in orchards) causes most damage to grapes when Marri flowering and nectar production are light.

Timm (1988) suggests that supplementary feeding at times when pests are under food stress may reduce damage to planted trees. However, he also raises the possibility that the long-term effect of the technique may be to increase survival of potential pest animals, increasing the problem in subsequent years.

The growing of crops specifically as food for bird pests to divert them from oilseed and cereal crops in south-eastern Australia is discussed by Bomford (1992). Some studies have shown this to be a more effective and economical solution than shooting or scaring. However, growing crops for pest animals may be hard for landholders to accept and may require regional co-ordination for maximum effect.

7. TECHNIQUES TO RECTIFY DAMAGE IF IT OCCURS

7.1 Pruning

A fairly obvious approach would be to prune trees attacked by parrots to re-establish their single-stem form important for wood production. Thus, where multiple replacement leaders have formed in response to destruction of the original lead shoot, these could be thinned to just one per tree (Fig. 9). This would leave only slight bends in logs.

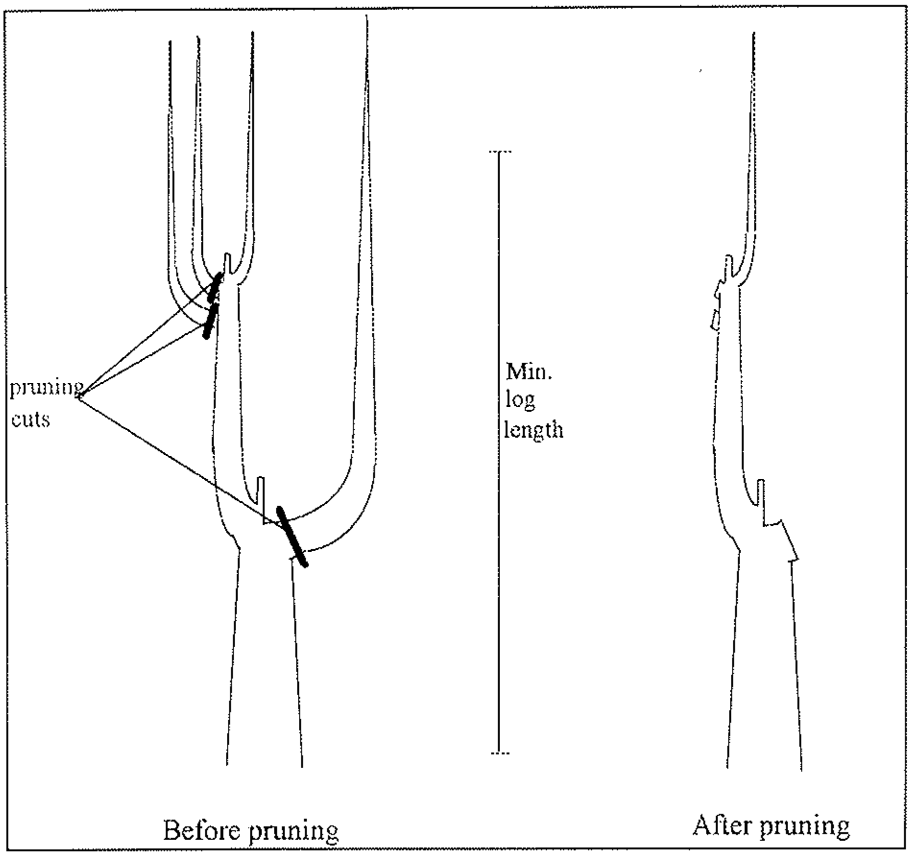

Fig. 9. Representation of the trunk and stem(s) of a tree before and after pruning to correct parrot damage.

Note:

1. The right hand stem above the first fork unacceptable for retention because of severe sweep above the fork.
2. Any further damage to the tree after pruning is likely to occur above what would be the first (base) log length.
3. The tree as illustrated 'after pruning' may still appear to have fairly severe deformities but the tree will tend to 'grow over' those deformities. If pruning is done at age 2 years then by harvest age (around 10 years) the tree should be nearly 5 times as tall and 5 times the diameter.

7.3 Culling (thinning)

This technique would involve removing deformed trees from the stand giving the remaining (better form) trees more room to grow (Fig. 10). If a tree is not going to be harvestable it is probably best removed from the stand. Volume losses from culling some trees would be made up for, at least partly, by increased growth rates of the retained trees.

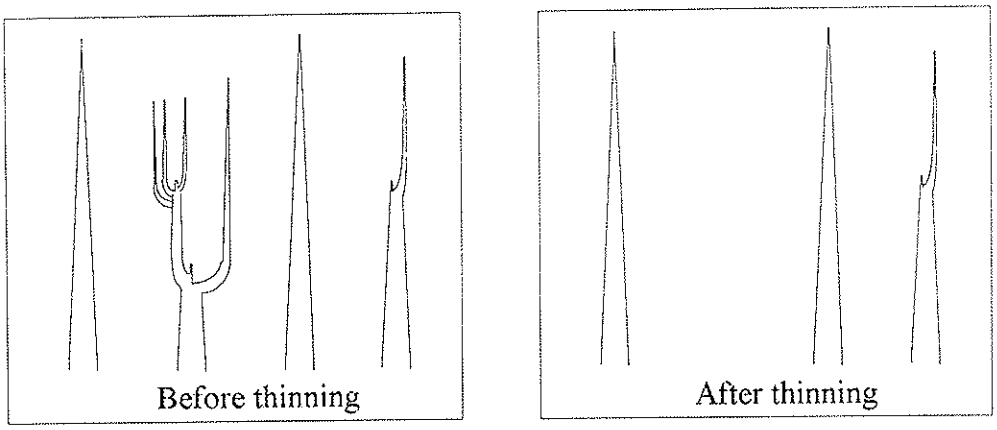

Fig. 10. Illustration of thinning. In this simplified example one badly deformed tree is removed. In a heavier thinning operation the tree on the right (slightly deformed) would also be removed concentrating all growth on the two remaining undamaged single-stem trees.

Oliver (1968) recommends the thinning approach to managing Sapsucker damage in Ponderosa Pine in California. He suggested foresters, through their normal thinning operations, could reduce possible losses by removing trees peppered with sapsucker drill holes.

7.3 Pruning and culling combined

Possibly a better approach than relying on either pruning or culling individually would be to apply the techniques together. Thus, badly deformed trees could be removed and moderately deformed trees pruned. The pruning could involve correction of all forks as described in Section 7.1 or pruning only up to a set height. To protect a 3 m base log individual stems of double- and multi-stem trees could be removed up to 3.1 m (allows 0.1 m stump). As another example, to protect a 6 m base log, "extra" stems up to 6.1 m could be removed.

Timing of pruning and culling operations may be important, particularly to achieve the desired result with just one round of treatment. Delaying treatment longer than necessary would only increase the cost (larger trees/limbs to treat) and may reduce returns (less time for retained trees to respond to thinning). The best time may be:

1. At the start of a long lull in the attack rate to allow the trees maximum growth before being vulnerable to repeat attack; and
2. When the trees have sufficient height so that once the parrots start attacking the trees again most attacks will be above the 'critical height'.

Thus, the data presented for the Darkan site (Figs 5-7) indicates that, if the minimum log length is 3 m, then the best time to apply pruning and culling there would be around July of the second year after planting.

7.4 Coppicing

Coppicing is a common means of regenerating eucalypt plantations after harvesting which may be advantageous where parrot damage is prevalent. Variations on the technique were trialed in an 8 y.o. Bluegum stand in the Wellington Reservoir Catchment (Ritson and Pettit, 1991). Typically, around 4-8 coppice shoots from each stump grew on to form stems. These were mostly 4-6 m tall at the time of thinning (21 months after harvest of the first rotation). Thus, under a coppice system, the shoots could be grown on to a height greater than the critical height for controlling parrot damage before thinning out. If 1 or 2 stems were required for retention then those with no parrot damage, or least parrot damage, could be selected (Fig. 11). This may be a reason for favouring coppicing to the alternative of replanting for regenerating harvested stands where parrot damage is expected.

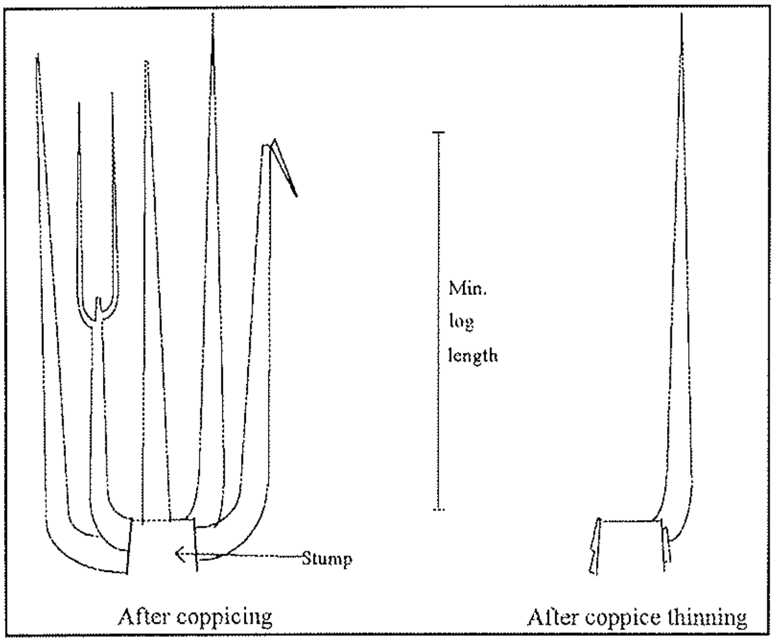

Fig. 11. Representation of the stump and stems (coppice shoots) of a tree after coppicing and after coppice thinning.

Another strategy worth investigating is to treat badly damaged young plantations by clearfelling and coppicing. This may apply to stands so badly damaged that harvesting would be uneconomic. It would mean writing off the growth to that time for the option of having several stems/stump to select from at the time of coppice thinning.

There are many questions relating to coppicing which could only be answered in field experiments, e.g:

1. What are the coppicing characteristics of young (1-5 y.o.) trees?
2. If parrots attacked one coppice shoot would they tend to attack the other shoots on the stump at the same time? This behaviour has been observed of parrots feeding on multiple replacement shoots (following initial parrot damage), all attacks being at the same height.
3. Would the competition between coppice shoots on a stump force them to grow straight and develop only one replacement shoot if damaged?
4. If there were no undamaged stems left at the time of thinning would it be practical to prune forks from the stem(s) selected for retention as part of the thinning operation?
5. How much growth would be lost by coppicing? Since coppice would be growing on an established root system it should grow more quickly than the seedling initially planted.

8. CONCLUSIONS AND RECOMMENDATIONS

All available information judged useful in developing a strategy for managing damage by Twenty-eight Parrots to Bluegum tree crops has been reviewed. The following conclusions are drawn.

1. There are strong indications that the parrots damage the trees by ringbarking the lead shoot to obtain food (cambial tissue, sap and possibly bark exudates) when other foods are lacking.

2. Parrot adaptation to Bluegums may be 'learned behaviour' and hence the damage may also develop in areas where it is absent or uncommon now. Currently the zone of worst damage includes around 20% of the total area suitable for Bluegum planting in south-west Australia.

3. The diet and breeding biology of Twenty-eight Parrots have been studied though not in areas where Bluegums have been planted. Ecological knowledge is lacking in some important areas, particularly:
   - Information on the nutrition Twenty-eight Parrots obtain from Bluegums;
   - Information on food preferences of Twenty-eight Parrots in relation Bluegums as a food source;
   - Evaluation of environmental factors that determine site susceptibility to parrot damage of planted Bluegums;
   - Understanding population dynamics and social organisation in Twenty-eight Parrots.

4. There is a 'critical period' for controlling parrot damage. Based on the assumption that the minimum log length is 3 m this was calculated to extend from around March in the first year after planting to around July in the second year after planting, i.e. around 16 months in a 10 year rotation.

5. There is no currently established practical method ('best practice') for managing parrot damage to Bluegums.

6. One possibility would be to develop means of predicting which sites will be prone to severe parrot damage and avoid planting those sites, at least until possible control techniques are investigated.

7. Studies of related problems of vertebrate pest damage to trees show the following techniques have been applied and are worth investigating as potentially suitable techniques for managing parrot damage to Bluegums.
   - **Reduce pest population:** Achieved by shooting, trapping, poisoning, encouraging natural predators.
   - **Divert pest from crop:** Repellents, diversionary feeding, barriers, and tree breeding for pest resistance have all been used with success in particular situations.

- **Rectify damage after it occurs:** Thinning to cull out damaged trees has been applied. Other possible techniques to correct parrot damage to Bluegums are pruning and coppicing.

8. The above techniques, if successful, may best be applied singularly or in combination.

Recommendations

1. The only recommendation for management that can be made at this stage is that farmers take care to minimise grain supply to parrots. This should help reduce the build up of parrot populations and avert possible damage to crops such as Bluegums on sudden withdrawal of grain supply.

2. It is recommended that an active program of research and development, involving all stakeholders, be undertaken to develop a 'best practise' solution to managing parrot damage to Bluegums. Suggested activities are described in Part II (*Action Plan*) of this report. The *Action Plan* is available on request from:
   - Farm Forestry Unit, Department of Conservation and Land Management, 50 Hayman Road, Como, WA, 6152. Phone 097 334 0322; Fax 097 344 0327.
   - Bunnings Treefarms Pty Ltd, PO Box 444, Manjimup, WA, 6258. Phone 097 717 222; Fax 097 771 377.

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