

Effects of Logging, Fire and Drought on Possums and Gliders in the Coastal Forests near Bega, N.S.W.

Daniel Lunney

National Parks and Wildlife Service, P.O. Box N189, Grosvenor St, Sydney, N.S.W. 2000.

Abstract

Seven species of possums and gliders were found during a survey in logged coastal forests near Bega on the south coast of New South Wales. A study of the preferences for the various tree species shows that both commercial and non-commercial species must be retained to support the full range of possum-glider species. Spotlight searches were carried out in six adjacent coupes each autumn from 1981 to 1983. Four species (*Petaurus breviceps*, *P. australis*, *Petauroides volans*, and *Pseudocheirus peregrinus*) were seen frequently enough to determine their habitat preferences. There were significantly fewer possums and gliders in logged coupes, with a greater impact on some species, such as *Pd. volans*, than others, such as *P. breviceps*. Fire rendered the logged areas even less habitable, and drought compounded the effect of logging and fire by further reducing numbers. Deep unlogged gullies were found to be crucial refuges from logging, fire and drought. The primary conclusion is that the current logging operation is causing a significant reduction in numbers; if logging continues under the present Eden Native Forest Management Plan populations will continue to fall. The primary recommendation is that gullies need to be redefined to include all drainage lines, and to remain unlogged.

Introduction

As possums and gliders are dependent upon forests, they are susceptible to changes brought about by logging (Tyndale-Biscoe and Smith 1969; Green 1982; Heislors 1974; Tyndale-Biscoe and Calaby 1975; Australian Parliament 1977; McIlroy 1978; Recher *et al.* 1980; Suckling 1980; Braithwaite 1983, 1984; Braithwaite *et al.* 1983, 1984; Mackowski 1984). Their recognised sensitivity to changes in forest habitat makes possums and gliders an important group to consider when the impact of logging for woodchips and sawlogs is assessed. Recher *et al.* (1980), Braithwaite (1983, 1984) and Braithwaite *et al.* (1983, 1984) considered aspects of the problem in the Eden woodchip area of south-eastern New South Wales. The study reported in this paper is complementary to the foregoing. The first part of the study was a survey of the possums and gliders in Tanja and Mumbulla State Forests near Bega on the south coast of New South Wales; the second part was a 3-year study in the western part of Tanja State Forest to determine the cumulative impact of logging, fire and drought on possums and gliders. Fire is recognised as having a major impact on them (Fleay 1947; Green 1982; Fox 1978), but has not been the subject of detailed study. The only study on the impact of drought on this group of animals found no effect (Henry 1985). The combination of logging, fire and drought is sufficiently common in south-eastern Australia for their cumulative impact to be taken into account in the planning of conservation of possums and gliders.

Survey Area and Logging Practices

The survey was carried out from 1979 to 1983 in both Mumbulla and Tanja State Forests, which are coastal forests to the north-east and east, respectively, of Bega on the south coast of New South Wales (Fig. 1). In 1982 most of Tanja State Forest was re-dedicated as an extension to Mimosa Rocks National Park (in this study it is referred to as Tanja State

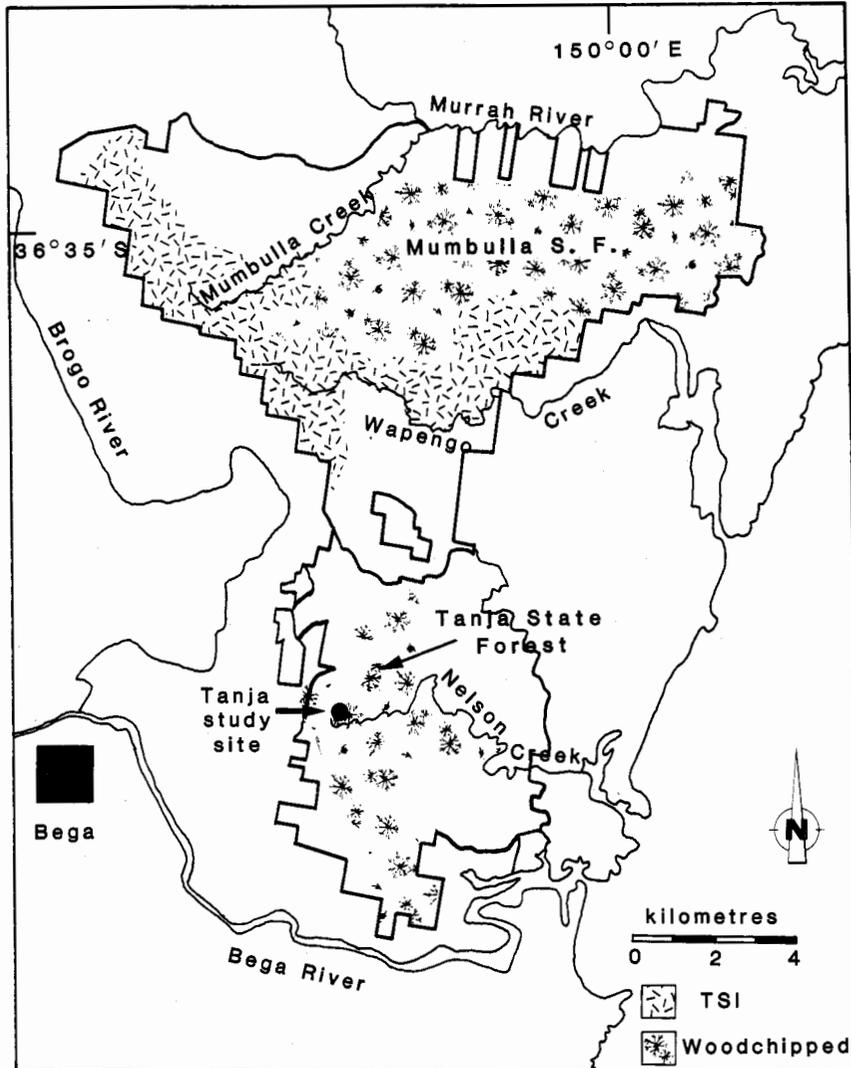


Fig. 1. The Mumbulla and Tanja State Forests, showing the two habitats where the survey was carried out: 10–15-year regeneration of TSI (timber stand improvement) forest, and forest logged principally for woodchips in alternately logged coupes of 10–20 ha. The blank areas were not searched. Mumbulla State Forest is bounded by Mumbulla Creek and Wapengo Creek. Nelson Creek is the main creek of Tanja State Forest (now incorporated into Mimosa Rocks National Park). Most of the area outside the forest is cleared farmland.

Forest). The terrain in both study areas is hilly, with altitudes ranging from sea level to 774 m on Mumbulla Mountain. The dry open eucalypt forest is dominated by silvertop ash *Eucalyptus sieberi*, and three species of stringybark: yellow stringybark *E. muellerana*, white

stringybark *E. globoidea*, and blue-leaved stringybark *E. agglomerata*. Other species present include monkey gum *E. cypellocarpa*, woollybutt *E. longifolia*, coast grey box *E. bosistoana*, red ironbark *E. sideroxylon*, rough-barked apple *Angophora floribunda*, and black she-oak *Allocasuarina littoralis*.

Mumbulla and Tanja State Forests have a history of selective logging since the district was first settled in 1830. In the 9084-ha Mumbulla State Forest, about 13% was virtually clear-felled during a TSI, or Timber Stand Improvement, operation between 1964 and 1972. This practice ceased with the advent of integrated logging (logging for both woodchips and sawlogs) in 1976. Integrated logging commenced in Tanja State Forest in November 1976 and ceased in March 1977. Logging in both forests has been conducted under the procedure described in the Eden Native Forest Management Plan (Forestry Commission of New South Wales 1982). A feature of the plan is to log in small alternate coupes, or cutting areas, which differ in size, but typically are of 10–20 ha. The first set of alternate coupes was logged in the first cutting cycle (1976–83), and the unlogged coupes are scheduled to be logged 20 years later, in the second cycle. After the first cutting cycle the forest took on a chess-board appearance of adjacent logged and unlogged coupes. The amount of timber removed, and the proportion used as sawlogs, varied between areas. For the years 1976–82, the Forestry Commission (1982) figures show that between 79 and 112 tonnes per hectare were taken during the integrated logging operations in the State Forests of the Bega district, with the proportion of sawlogs varying from 17–27%. Another feature of the plan is to leave buffer strips along major gullies, creeks and rivers that have a catchment area of at least 60 ha, or 40 ha in steep country, or where there are highly erodible soils. Buffer strips are left principally for hydrological reasons, but they are also recognised as containing valuable wildlife habitat. Buffer strips under the present management plan are 20 m wide on each side of the gully or creek, and even though trees may be felled from the outer 10 m of the buffer strip, no heavy equipment, such as snigging tractors, may enter it.

From February 1980 to May 1983, south-eastern New South Wales was subject to the most severe drought on record (Bureau of Meteorology 1983), with relief from February to June 1982, those being the only months not drought-declared by the Pastures Protection Board in the Bega District during the study period. A fire on 18 November 1980 burnt half of Mumbulla State Forest, and another on 3 October 1981 burnt the western part of Tanja State Forest.

The Tanja Study Site

The site used in the 3-year study of the effects of logging, fire and drought comprised six adjacent alternately logged coupes in the western part of Tanja State forest, which had been logged in 1977. The dominant tree species were *E. muellerana*, *E. agglomerata* and *E. sieberi*; these occurred in association with *E. bosistoana*, *E. sideroxylon*, *E. cypellocarpa*, *A. floribunda*, and the understorey species, *Al. littoralis* and wattles *Acacia* spp. The ridge line divided each coupe into north-western and south-eastern aspects. The gully on the south-eastern side was one of the most substantial in the forest, being part of the headwaters of Nelson Creek, and contained rainforest trees, particularly lilli pilli *Acmena smithii*. The gully on the north-western side was shallow, characterised by *Al. littoralis*, and did not support rainforest vegetation. Adjacent to the gullies was a 40-m buffer strip, the outer half of which had been logged. Of the timber taken, the greater proportion (0.76) went to the woodchip mill.

The site was burnt by the fire of 3 October 1981, which came from the north-west. The north-western ridge and gully were intensely burnt, with extensive crown scorch. The south-easterly aspect was only lightly burnt, the ridge being more heavily burnt than the midslope, and the gully remaining unburnt.

Methods

Survey Methods

The survey in Mumbulla and Tanja State Forests was carried out by spotlight searches and analysis of the scats of predators (dogs and foxes). Spotlight searches were made with hand-held portable spotlights in 134 logged coupes (total 1680 ha) and 86 unlogged coupes (total 1009 ha), and along the roads and tracks through the TSI area in Mumbulla State Forest. Total spotlighting effort was 214 nights, between August 1979 and May 1983. Spotlight surveys were also carried out from the roofs of vehicles along 65 km of roads in Mumbulla and Tanja State Forests in January 1981. The scats, or faecal droppings, of dogs and foxes were collected from July 1981 to August 1982 along the roads and logging tracks through both State Forests, including the TSI area. The hair contents were analysed by the methods of Brunner and Coman (1974) and Triggs *et al.* (1984).

Estimate of Changes in Number of Trees and in Timber Volume due to Logging

To determine the numbers of trees and timber volume in the major habitats, and hence assess changes due to logging, trees were counted in Mumbulla State Forest in November 1982. Six randomly chosen quadrats (10 by 50 m) were located in each of six habitats: both ridge and gully in unlogged, logged and TSI forest. The number of trees of each species was recorded, together with the DBHOB (diameter at breast height over bark) and height of each tree (any single-stemmed plant over 5 m tall). Timber volume (m³) was obtained by a formula which used both these values (personal communication from R. Bridges, Forestry Commission, Eden).

Preferences for Different Species of Trees

The species and sizes of trees in which possums and gliders were seen during the spotlight searches were recorded, so that their preferences could be determined.

Census Procedures in the Tanja Study Site

Censuses were taken in April 1981, April 1982 and May 1983, during the dark phase of the moon in fine weather with little or no wind. The census procedure was to search, by listening for calls and by scanning with a spotlight, each aspect of each coupe. The sequence in which the coupes were searched was randomly selected. The animals were recorded as being on the slopes (including the ridges) or the gullies, in logged or unlogged coupes, and in a north-western or south-eastern aspect. The DBHOB of the trees in which possums and gliders were seen was also recorded.

In April, 1981, each aspect of each coupe was searched by a team of two people at four times a day: 1800 h (dusk)–1930 h; 1930–2100 h; 2100–2230 h; and 2230–2400 h. It thus took two teams six days to search each aspect of each coupe. In April 1982 the census was scaled down because the forest had been burnt and searching was easier; each aspect of each coupe was searched once by one person. In May 1983 the census procedures of April 1981 were repeated, so that the two years could be compared.

Results

Survey Results

The 214 nights of spotlighting yielded 347 records of six species: greater glider *Petauroides volans* (45), sugar glider *Petaurus breviceps* (166), yellow-bellied glider *P. australis* (78), brushtail possum *Trichosurus vulpecula* (26), ring-tailed possum *Pseudocheirus peregrinus* (23), and feathertail glider *Acrobates pygmaeus* (nine). All species were seen in both logged and unlogged coupes.

Analysis of the 1645 scats collected from Mumbulla and Tanja State Forests found 183 records of possums and gliders. All species found by the spotlight searches were found in the scats, but a comparison of the two survey methods showed clear differences: *T. vulpecula* (95) and *Ps. peregrinus* (43) were more common in the scat analysis than the spotlighting, but the converse applied to *Pd. volans* (4), *P. breviceps* (10), *P. australis* (26) and *A. pygmaeus* (two); scat analysis also yielded three records of the pygmy possum *Cercartetus nanus*.

A feature of the spotlight survey was that possums and gliders of all species were most frequently sighted in the unlogged gullies, such as the unlogged edge of Nelson Creek in Tanja State Forest. This was the most substantial creek searched, and it contained all species except *C. nanus*. The spotlighting records show that *Pd. volans* had a highly restricted distribution, being recorded, except for one instance in Mumbulla, only in the gullies leading along, or into, Nelson Creek. *P. australis* had a less confined distribution, although most spotlight records were along major gullies. *P. breviceps*, *T. vulpecula* and *Ps. peregrinus* were comparatively widespread. *A. pygmaeus* was rarely seen, and *C. nanus* was not seen by spotlight. In the TSI the only species found by spotlighting was *P. breviceps*, and this was only sighted in old seed trees in the unburnt TSI of the western part of Mumbulla. No possums or gliders were seen from the roofs of vehicles in January 1981.

Timber Volume and Numbers of Trees

Timber volumes varied greatly between ridge and gully sites, unlogged areas carrying $134 \text{ m}^3 \text{ ha}^{-1}$ on ridges and $258 \text{ m}^3 \text{ ha}^{-1}$ in gullies. Logged areas carried $41 \text{ m}^3 \text{ ha}^{-1}$ on ridges and $24 \text{ m}^3 \text{ ha}^{-1}$ in gullies, and the TSI carried $8 \text{ m}^3 \text{ ha}^{-1}$ on ridges and $118 \text{ m}^3 \text{ ha}^{-1}$ in gullies. Table 1 shows the number of trees, all species combined, arranged in size classes, per 3000 m^2 . Unlogged gullies carried a greater total number of trees than unlogged ridges, and twice the timber volume. In the TSI area the ridges carried, almost exclusively, a large number of very small trees, hence the low timber volume. The number of trees in the TSI gullies was similar to that in unlogged gullies, although the timber volume was less than half.

Table 1. Comparison of the number of trees (all species combined) in 3000 m^2 in four size classes in each of six major habitats in Mumbulla State Forest in November 1982

DBHOB, diameter at breast height over bark

Size class (DBHOB, cm)	Ridge or gully	Number of trees		
		Unlogged	Logged	TSI
0-20	Ridge	54	31	155
	Gully	112	16	142
21-40	Ridge	38	17	14
	Gully	23	5	10
41-60	Ridge	15	4	0
	Gully	8	4	7
60+	Ridge	3	0	1
	Gully	15	0	5
Total	Ridge	110	52	170
	Gully	158	25	164

The woodchip-sawlog operations had a greater impact in the gullies than on the ridges. On the ridges timber volume was reduced to one-third of the original amount, whereas in the gullies it was reduced to one-eleventh.

Preferences for Different Species of Trees

The tree species in which each possum or glider was seen was identified for 200 of the spotlight records (Table 2). The three species of stringybark were used by all species of possums and gliders, and accounted for the highest number of sightings; stringybarks are abundant and widespread throughout the forests. In contrast, *E. sieberi*, also abundant and widespread, was only once found to contain an animal. *Al. littoralis*, a common and widespread species, had the second highest total number of records, and was the preferred tree

species of *Ps. peregrinus*, but *Pd. volans*, *P. australis* and *T. vulpecula* were not seen in it. *E. longifolia* was widespread through the forests, occasionally in dense stands, and was the tree species favoured by *T. vulpecula*. *E. bosistoana*, was not common, but occasionally occurred in dense stands and was preferred by *P. australis*; along with the stringybarks, it was the only tree species to be used by all the species of possums and gliders. *E. cypellocarpa* is principally a gully species and, although not as common as silvertop ash or the stringybarks, it occurs throughout the forests and was used by *P. breviceps*, *Pd. volans*, and *P. australis*. Spotted gum *E. maculata* is highly restricted in its distribution, occurring only in the eastern parts of Tanja State Forest, and was used by *Pd. volans* and *P. australis*. Wattles *Acacia* spp., although widespread and common, contained only two species of possum and gliders, principally *P. breviceps* in *A. falciformes*, a tall, open wattle. The other species of trees were uncommon, restricted in distribution, and carried few possums or gliders. Stags, or dead eucalypts, although reasonably common, contained no possums or gliders.

Table 2. The trees in which possums and gliders were found by spotlighting in Mumbulla and Tanja State Forests

Tree species	<i>P. brev.</i>	<i>Pd. vol.</i>	<i>P. aust.</i>	<i>T. vul.</i>	<i>Ps. per.</i>	Total
Stringybarks ^A	24	15	2	4	2	47
Black she-oak, <i>Allocasuarina littoralis</i>	29	0	0	0	13	42
Woollybutt, <i>Eucalyptus longifolia</i>	11	9	1	8	0	29
Coast grey box, <i>E. bosistoana</i>	3	4	12	1	1	21
Monkey gum, <i>E. cypellocarpa</i>	3	7	6	0	0	16
Spotted gum, <i>E. maculata</i>	0	7	7	0	0	14
Wattles, <i>Acacia</i> spp.	9	0	0	2	0	11
Red ironbark, <i>E. sideroxylon</i>	3	0	0	4	0	7
Rough-barked apple, <i>Angophora floribunda</i>	2	1	0	2	0	5
River peppermint, <i>E. elata</i>	1	0	3	0	0	4
Sassafras, <i>Doryphora sassafras</i>	2	0	0	0	0	2
Silvertop ash, <i>E. sieberi</i>	1	0	0	0	0	1
Bangalay, <i>E. botryoides</i>	1	0	0	0	0	1
Stag, or dead eucalypt	0	0	0	0	0	0

^A *Eucalyptus globoidea*, *E. muellerana* and *E. agglomerata*.

Some species of possums and gliders were catholic in their preferences for the various tree species, and others were discriminatory, as can be seen from Table 2. *P. breviceps* was seen in all but one species of tree, whereas *Ps. peregrinus* was highly selective, occurring in only three species. The preferences of *Pd. volans* show that, although selecting the stringybarks, it frequently occupied other species of trees. *P. australis* showed, besides a marked preference for *E. bosistoana*, a strong preference for the gums *E. cypellocarpa* and *E. maculata*. *T. vulpecula*, although not often sighted, was seen in six species of tree, and showed a preference for *E. longifolia*.

Tanja Study Site: Census Results Pre-fire

In 1981, *P. breviceps*, *Pd. volans*, *P. australis* and *Ps. peregrinus* were recorded sufficiently often to determine habitat preferences (Table 3). One species (*A. pygmaeus*) was seen only once in a logged south-eastern gully, and *T. vulpecula* was not seen. The consistent finding among the species was that the gullies carried higher numbers of possums and gliders than did the ridges.

P. breviceps was the commonest species, was the only one to occur in all habitats, and showed a marked preference for gullies. Its preference for unlogged coupes (35 records to 23) was not significant. The only significant difference in relation to logging was in the north-western gullies, where *P. breviceps* was recorded significantly more often in unlogged than logged coupes ($\chi^2=4.3$, $P<0.05$) (Yates' correction for continuity being used on all χ^2).

Table 3. Numbers of possums and gliders of five species recorded in the Tanja study site in April 1981 + April 1982

Values are not directly comparable between years, because the search effort was reduced in 1982, but they do reveal a shift in distribution

Species	Coupes	Slopes			Gullies		
		NW.	SE.	Total	NW.	SE.	Total
<i>P. breviceps</i>	Unlogged	6+3	4+5	10+8	12+4	13+3	25+7
	Logged	4+1	2+1	6+2	3+1	14+0	17+1
<i>Pd. volans</i>	Unlogged	0+0	5+4	5+4	7+0	2+4	9+4
	Logged	0+0	0+0	0+0	0+0	0+0	0+0
<i>P. australis</i>	Unlogged	0+0	2+0	2+0	0+0	8+3	8+3
	Logged	0+0	2+0	2+0	0+0	8+0	8+0
<i>Ps. peregrinus</i>	Unlogged	0+0	0+0	0+0	3+2	1+0	4+2
	Logged	0+0	0+0	0+0	2+0	1+0	3+0
<i>T. vulpecula</i>	Unlogged	0+0	0+0	0+0	0+0	0+2	0+2
	Logged	0+0	0+0	0+0	0+0	0+0	0+0

P. australis was the next most common species; a striking feature of its distribution was its absence from the north-western slopes and gullies. On the south-eastern aspect it was found in both logged and unlogged slopes and gullies.

Pd. volans was not present on north-western slopes and none of the 14 sightings was in a logged coupe.

Ps. peregrinus was seen exclusively in the gullies.

Table 4. Total numbers of possums and gliders recorded in the Tanja study site in 1981, 1982 and 1983

Year and month	Coupe	Slopes			Gullies		
		NW.	SE.	Total	NW.	SE.	Total
April 1981	Unlogged	6	11	17	22	24	46
	Logged	4	4	8	5	21	26
April 1982	Unlogged	3	11	14	6	10	16
	Logged	1	1	2	1	0	1
May 1983	Unlogged	2	3	5	1	3	4
	Logged	1	3	4	0	5	5

When the records for all species in 1981 were combined, as shown in Table 4, some differences between habitats emerged. Whereas there were similar numbers of animals in logged and unlogged south-eastern gullies and unlogged north-western gullies (21, 24 and 22 records respectively), the numbers in unlogged north-western gullies were significantly greater than in logged north-western gullies (22 and five respectively) ($\chi^2=10.7$, $P<0.001$). There were significantly more records in logged south-eastern gullies than in logged north-western gullies (21 and five respectively) ($\chi^2=9.85$, $P<0.01$). Thus the impact of logging in gullies was heavy only in the north-western ones, although the impact on all gullies combined was also significant ($\chi^2=5.01$, $P<0.05$). On the slopes there were twice as

many records in unlogged coupes as logged coupes (17 and eight records), the impact of logging falling more heavily on the south-eastern slopes (11 records in unlogged and four in logged coupes); however, none of the differences on the slopes were significant. When records of both aspects for slopes and gullies were combined (63 records in unlogged coupes, 34 in logged coupes) the difference was significant ($\chi^2=8.76$, $P<0.01$).

The sizes of trees in which the possums and gliders were seen in 1981 are given in Table 5. *Ps. peregrinus* was predominantly seen in the black she-oak *Al. littoralis*, which was smaller than the other tree species present. *Pd. volans* was not seen in small trees, and *P. breviceps* was seen in trees of all sizes.

Table 5. Numbers of three species of possums and gliders recorded in 1981 in various size-classes of trees in the Tanja study site

	Number in trees of DBHOB:					
	0-20 cm	21-40 cm	41-60 cm	61-80 cm	81-100 cm	100+ cm
<i>P. breviceps</i>	5	5	3	6	0	1
<i>Pd. volans</i>	0	0	5	2	1	2
<i>Ps. peregrinus</i>	5	1	1	0	0	0

Tanja Study Site: Census Results Post-fire

Except for *A. pygmaeus*, all species seen in 1981 were again recorded in 1982. *T. vulpecula*, not seen before the fire, was seen in both post-fire years. The 1982 post-fire census results show that *P. breviceps* was the only species to be found in logged coupes (Table 3). Whereas before the fire *Pd. volans* had been found equally on the north-western and south-eastern aspects in unlogged forest, after the fire it was seen only on the unlogged south-eastern aspect. Before the fire *P. australis* occurred on both slopes and gullies, but after the fire it was confined to the south-eastern gullies.

Comparison of the records for 1981 and 1982 show that the fire rendered all coupes less habitable (Table 4). In 1981 there were significantly more animals in unlogged than logged coupes. In 1982 the difference was even greater (30 records in unlogged and three in logged coupes; $\chi^2=20.5$, $P<0.001$). It was significant both on the slopes, with 14 records in unlogged and two in logged coupes ($\chi^2=7.6$, $P<0.01$), and in the gullies, with 16 records in unlogged and one in logged coupes ($\chi^2=11.5$, $P<0.001$). By 1983 this difference had disappeared, there being nine records each in unlogged and logged coupes.

In 1983 there was a significant ($\chi^2=3.84$, $P<0.05$) drop in total records compared with 1982 (18 v. 33 records) (Table 4).

Discussion

Survey Results and Comparison of Methods

The seven species of possums and gliders found during the study period were the full complement expected in these coastal forests (Recher *et al.* 1980; Braithwaite 1983, 1984), and the two survey methods produced different indices of relative abundance. The spotlight searches readily found the larger gliders *P. breviceps*, *Pd. volans* and *P. australis*. In contrast, scat analysis found that the large possums, *Ps. peregrinus* and *T. vulpecula*, were more common than the spotlight searches had indicated.

During studies of other animal groups in these forests, incidental observations of possums and gliders added a second species, *Ps. peregrinus*, to the number living in the TSI. This was shown by the presence of dreys, a fact not recorded during the spotlight searches (Lunney and Barker 1986, 1987).

The use of spotlights on vehicles yielded no sightings, the principal reason being that the roads followed the ridges, and all species of possums and gliders preferred the gullies.

Furthermore, a principal tree species of the ridges and slopes, *E. sieberi*, was found to be almost entirely devoid of possums and gliders. Recher *et al.* (1980) also found spotlight survey along roads in coastal forests near Eden to be unrewarding, which suggests this technique is inefficient in coastal forests of south-eastern New South Wales.

Scat analysis was demonstrated to be the single most effective technique for compiling a species list of possums and gliders. It also showed that dogs and foxes are predators of these arboreal animals. That the majority of records in the scats were of the two large possums (*Ps. peregrinus* and *T. vulpecula*) is a reflection of the fact that possums spend more time on the ground than gliders and are therefore more vulnerable to predators. MacLennan (1984), for example, recorded *T. vulpecula* as spending 8.9% of its time on the ground. Also, the finding by Triggs *et al.* (1984) that *Ps. peregrinus* was found in a greater percentage of dog and fox scats than was any other species supports the view that these predators are efficient at taking it.

Braithwaite (1983) surveyed possums and gliders by asking logging contractors to record all animals seen when the trees were felled. His records from 43 coupes, totalling 486 ha, in Mumbulla and Tanja State Forests show 64 *A. pygmaeus*, 23 *P. breviceps*, seven *T. vulpecula*, four *P. australis* and one *Ps. peregrinus*. The high number of *A. pygmaeus* he recorded shows that both spotlighting and scat analysis underestimated the presence of this species. Conversely, Braithwaite's records of the other species, particularly *P. australis* and *Ps. peregrinus*, were lower than the spotlight and scat records. The preference of *Ps. peregrinus* for gullies and *Al. littoralis* (a tree not felled for either woodchips or sawlogs) may explain the low number found by Braithwaite. That he did not record *Pd. volans* may reflect its dependence on the largest trees of the major gullies, which were not logged. The absence of *C. nanus* from both Braithwaite's records and the present spotlight records indicates that this species is either cryptic or rare.

Preferences for Different Species of Trees

The preferences for different species of tree suggest that it is necessary to retain trees of almost all the species originally present, if a full complement of possums and gliders is to be carried. It is possible that, since the different tree species flower at different times, the original composition of tree species provides a variety of sources of food within a season, between seasons, and between years. Several of the species found to be important to possums and gliders are of little current commercial importance; these include *E. longifolia*, *E. bosistoana* and *Al. littoralis*.

Habitat Preferences and Potential Conflict

The finding of low overall densities does not indicate that these coastal forests are uniformly poor possum-glider habitat. During the three years of survey it was found that the gully forests, with a higher number of large trees and a greater timber volume than the unlogged ridges, was richest in possums and gliders. The richest gullies were those that bordered the largest creeks, such as Nelson Creek. As current logging is most intense in the most preferred possum-glider habitat, this points to a potential conflict between logging and conservation of these arboreal marsupials. The paucity of possums and gliders in the TSI, both in number of individuals and number of species, suggests that there is a threshold of tree size for possum-glider species. The presence of only two species (*P. breviceps* and *Ps. peregrinus*) indicates that 10–15 years after a high-intensity logging operation the regrowth forest is unsuitable for most species of possums and gliders.

Effect of Logging

The 1981 (pre-fire) results show that the differences in habitat preferences among *P. breviceps*, *Pd. volans*, *P. australis*, and *Ps. peregrinus* were striking. The only common feature was the preference for gullies.

The ability of *P. breviceps* to utilise logged coupes was attributed to its capacity to use trees of all sizes. In contrast, the absence of *P. volans* from logged coupes was attributed to its dependence on large trees, which were not present in logged coupes (Table 3). This is consistent with the findings of Suckling (1980), who found that *P. breviceps* successfully used small forest isolates, whereas *Pd. volans* had declined in abundance since European colonisation, was now rare, occurred only in large forested reserves, and needed corridors of gullies for its conservation. The conclusion drawn here is that logging the forest at the intensity planned (Forestry Commission of New South Wales 1982) will make *Pd. volans* rare in these forests.

When the records of all species in 1981 were combined there were significantly fewer in logged coupes. Two points are worthy of note. Firstly, in unlogged coupes the north-western and south-eastern gullies had equal numbers of possums and gliders, but in logged coupes only the shallow north-western gully showed a significant loss of animals. Secondly, even though the coupes were intensively logged, the remaining trees were used, which shows that the retention of even a small proportion of the original trees contributes to the conservation of these animals.

Effect of Fire

In 1982, the first post-fire census, there was a marked shift in the distribution of possums and gliders away from the burnt, logged coupes. The unburnt south-eastern gully provided a critical refuge. The fact that it supported rainforest species suggests that it had not burnt in previous fires. This leads to the conclusion that gullies which serve as refuges during natural calamities are the best for refuges during logging operations. The results also show that unlogged areas assume greater importance following a fire. The equal distribution of possums and gliders between logged and unlogged coupes in the 1983 census suggests that the effect of fire had eased following regrowth.

Information on the effect of fire is scarce, but what is available is consistent with current findings. Fleay (1947) attributed the survival of *Pd. volans*, and its subsequent recolonisation of burnt areas following the 1939 Victorian bushfires, to the remnant patches of forest, such as in the deep valleys, that were not devastated by fire. Fox's (1978) study of the intense fire, in 1972, in Nadgee Nature Reserve (60 km to the south) identified unburnt creeks as oases for wildlife, with *Ps. peregrinus* in the *Acacia* canopy, and *Pd. volans* in *E. cypellocarpa*. He noted that severe famine prevailed throughout the reserve after the fire, and that in the following months both *Ps. peregrinus* and *Pd. volans* survived in unburnt, or lightly burnt, regenerating trees. *Pd. volans* for example, was seen in *E. longifolia* in wet gullies and steep slopes.

Effect of Drought

The 1983 census figures show the significant impact of the intensifying drought. Despite the effect of regrowth of the vegetation from 1982 to 1983, which is reflected in equal numbers of records in logged and unlogged coupes, the total numbers of possums and gliders were significantly lower in 1983 than 1982. This decline was attributed to the effect of drought. Henry (1985) studied the effect of this drought on *Pd. volans*, *P. breviceps* and *P. australis* in Gippsland, Victoria, but found that the abundance remained similar to pre-drought levels and reproduction was not curtailed. Henry concluded that gliding possums appear resilient to the effects of the most severe drought recorded in his area. This conclusion suggests that the drop in numbers in the Tanja study site during the drought was due to the additional impact of logging and fire.

Conservation of Possums and Gliders

The primary conclusion from this study is that the current operation of logging for woodchips and sawlogs is causing a significant reduction in the numbers of possums and

gliders, and that if logging continues under the present Eden Native Forest Management Plan (Forestry Commission of New South Wales 1982) the reductions in populations will continue. It is also clear that the recurrent natural hazards of fire and drought compound the effects of the intensive logging operation.

If the decline of possum and glider populations is to be arrested and the species adequately conserved in areas where the impact of logging is intensified by periodic fire and drought, it is recommended that:

(1) gullies, being the richest areas of the forest and providing essential refuge, need to be redefined to include all drainage lines and not simply those of major creeks and rivers or areas with large catchments, and remain unlogged;

(2) the practice of retaining buffer-filter strips should be expanded to include the above redefined gullies;

(3) logging, as well as heavy equipment, should be excluded from this protected zone;

(4) the buffer strips should be wider than in the current plan and be proportional to the catchment size;

(5) the practice of cull-felling tree species currently regarded as not commercially important, such as *E. longifolia*, *E. bosistoana*, *A. floribunda*, *E. sideroxylon* and *Al. littoralis*, should cease because they are extensively utilised by possums and gliders.

Braithwaite's (1983, 1984) studies throughout the south-east forestry region demonstrated that a small proportion of the forest held most of the possums and gliders. The study period in this paper yielded similar results: namely, that small areas of the coastal forests carry most of the possums and gliders. The implications for conservation are the same. Prime possum-glider habitat, which in the coastal forests near Bega consists of the unlogged gullies with large trees, is worthy of special attention and should not be logged in the misconception that any type of unlogged forest is adequate for conserving all species of possums and gliders.

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