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DISTRIBUTION, HABITAT AND CONSERVATION STATUS OF THE LAND SNAIL *MISELAOMA WELDII* (PULMONATA:PUNCTIDAE)

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Abstract. The land snail *Miselaoma weldii* (Tenison-Woods, 1876) is currently listed as vulnerable under the Tasmanian Threatened Species Act. The species was surveyed on the Circular Head peninsula to investigate the status of populations on The Nut and to determine if it occurred elsewhere on the peninsula. On The Nut, it was found to occupy about four hectares of habitat in three discrete subpopulations. It occupied a wide range of native vegetation types and sometimes occurred in introduced vegetation. However, it had been eliminated by massive weed invasion and other past disturbances. *M. weldii* was not found away from The Nut. The population is estimated to be approximately 20 000. The Tasmanian population of this species warrants a classification of endangered.

INTRODUCTION

Miselaoma weldii is a small punctid land snail most readily distinguished by its reversed (sinistral) shell. It was discovered in the early 1870s by W.F. Petterd. Tenison-Woods (1876) described the species and gave the following quote from Petterd:

"This small and reversed *Helix* I have only observed at the foot of the high rocks about Stanley, Circular Head, where I collected it with a few other species of Helices on the surface of blocks of rocks that are overgrown with a thick mass of entangled vegetation. It is extremely abundant and generally in clusters. I have collected some hundreds of specimens." (p.161)

Petterd (1879) further commented that *M. weldii* was found in company with *H. coesus* (*Pedicamista coesa*) and *H. stanleyensis* (*Pernagera officeri*) and that "it appears to be strictly confined to the habitat given, where it is anything but rare."

The southern Victorian name *Laoma sinistra* (Gabriel 1930) is presently a synonym of *M. weldii*, but further work on this is desirable as the similar South Australian *Miselaoma reevesbyi* Cotton 1938 is definitely distinct from *M. weldii.*

Recent records of *M. weldii* are few. Smith and Kershaw (1981) show the species as present in the 10km grid square below The Nut, but this record does not seem to be matched to any museum specimen and may be a case of filling in all possible dots for a vague locality description. I recorded the species in good numbers in a small dogwood gully perched above the Stanley quarry in December 1988 and again in October 1991. Many sites near Circular Head (including around Smithton, Rocky Cape, Table Cape, the Hunter Islands and areas on the Black River) have been searched by various collectors without finding the species (Petterd 1879; author's records; collections by Bill Mollison held in the Tasmanian Museum and Art Gallery).

In the absence of any records away from The Nut, the species was listed as vulnerable under the *Threatened Species Act 1995*. In April 1998 a more detailed survey of the species was commissioned by the Threatened Species Unit to enable management recommendations to be formulated and to more accurately determine the status of the species.

METHODS

Previous species-specific surveys conducted by the author (eg for *Tasmaphena lamproides* and *Anoglypta launcestonensis*) have used 15 metre radius (0.07 hectare) sites, which were searched for about 75 minutes. This was not considered appropriate for *M. weldii*, a tiny snail which requires much closer searching and which is known, where present, to occur in much greater densities. Instead, each site was an area of 0.01 hectares (typically a 10x10 metre square) which was searched for one hour. At some sites discrete small areas of searchable habitat occurring near each other were combined to make up the total 0.01 hectare area.

Any available and accessible shelter was searched. Numbers of all snail species (native or introduced) seen during this time were counted, and subdivided into live and, in the case of *Miselaoma weldii*, dead specimens. Adults and juveniles were not differentiated as the proportion of clear juveniles in this species is very small. Microhabitats of live *M. weldii* seen were classified and recorded.

Fieldwork was conducted between 12 and 17 May, 1998. On The Nut 17 sites were searched. Some additional informal searching was also undertaken near selected sites to verify the extent of populations and the species' ability to occur under weeds. As most of The Nut is either cleared, massively weed-infested or dangerously steep, no attempt was made to proportionally sample the available habitat. Instead, sites were selected deliberately to obtain as much information about the species as possible. The largest areas of searchable habitat were found on the south and south-west slopes (eight sites), and the north and north-east slopes (eight sites). A site was also searched on top of The Nut, an area that has been almost entirely cleared.

The peninsula away from the Nut was explored for the occurrence of habitat and suitable sites searched. Details of all sites, including site numbers, Australian Map Grid references, altitudes, descriptions of vegetation and tenure are given in Table

Table 1. Details of the sites where searching for *Miselaoma weldii* was undertaken on the Circular Head peninsula.

Site	Grid Reference	Altitude	Vegetation	Tenure
The Nut				
1	35644859	60	Dogwood with gorse and ivy at cliff base	State Res.
2	35654856	30	Introduced wattle, gorse and fireweed	State Res.
3	35654857	60	Blackwood/dogwood scrub with creepers	State Res.
4	35674856	80	Blackwood/*Melaleuca/Dicksonia* scrub with nettles and weeds	State Res.
5	35664856	90	Dogwood/*Bursaria/Banksia/Goodenia* scrub	State Res.
6	35674856	110	Dogwood scrub with gorse, *Melalueca* and tea-tree	Quarry Res.
7	35644859	110	*Banksia/Bursaria* scrub with dogwood and *Cyathodes*	State Res.
8	35714860	10	Foreshore shrubbery and rockfields	State Res.
9	35704860	30	Dry tea-tree scrub with grass and *Cyathodes*	State Res.
10	35694862	70	Eucalypt woodland with wattle, sedges and sclerophyll shrubs	State Res.
11	35684862	110	Blackwood scrub with *Bursaria* and *Correa*	State Res.
12	35674863	10	Boxthorn and succulents	State Res.
13	35664858	130	Open sedgeland with *Banksia*	State Res.
14	35674856	50	Blackwood/Dogwood scrub with *Blechnum* on rocks	State Res.
15	35704860	40	Dry tea-tree scrub with *Banksia* and bracken	State Res.
16	35704861	10	Foreshore shrubbery on rocks	State Res.
17	35694863	10	Wattle and thick foreshore scrub	State Res.
Away from the nut				
A1	35544854	5	Coast wattle scrub with creepers	Council?
A2	35504849	10	Wet coast wattle scrub with tea-tree and various sedges	Coast Res.
A3	35464839	10	Blackwood/Melaleuca regrowth forest	Coast Res.
A4	35174804	5	Wet eucalypt/blackwood/*Melaleuca/Dicksonia* swamp forest	Private?
A5	35614874	5	Foreshore shrubbery on rocky tidal islands	Council?
A6	35524879	50	Blackwood forest with fireweed	Private
Abandoned Sites				
	35774845		Rockpile, railway line behind Tatnells Beach	
	35314815		Foreshore scrub, West Inlet Coastal Reserve	
	35254807		Degraded swamp scrub, West Inlet	
	35594876		Road cutting with fern regrowth near Godfreys Beach	
	35394855		Tea-tree scrub near West Beach	

1.

Size of the *M. weldii* population was estimated using the following formula:

$$P = H*D*S*A/C$$

where P = population estimate, H = area of habitat present in searched sites, D = mean density of live specimens per successful site, S = proportion of sites that were successful in this area, A= proportion of live specimens seen which were adult, C = proportion of specimens estimated to be found (rather than missed through undercounting) at each site.

RESULTS

Miselaoma weldii was found to be locally very common on The Nut. It occurred at 10 of the 17 sites searched there, and had the highest specimen count of any of the nine native and eight introduced species recorded, except for the abundant *Pernagera officeri* (Table 2). 157 live and 249 dead *M. weldii* were found. The 157 live specimens were found in the following microhabitats: leaf litter, 36%; in detritus between shrubbery and rocks 30%; in moss and detritus on rocks 12%; in detritus between rocks, 9%; under rocks, 6%; in small grasses, 4%; and in soil under small rock overhangs, 3%. There was no evidence of arboreality, even in low shrubs.

Of the successful sites, some were far more successful than others. The best four sites (10, 6, 16 and 8) contributed 78% of the total number of specimens, and 88% of the live specimens. Specimens were often clustered to a large degree. At site 10, nine specimens were found, all alive, on the underside of a single leaf. At site 16, 39 of the 57 specimens found were under one pigface plant in an area of about 30 x 100 cm. At site 1, the five live specimens found in native vegetation were within the same very small patch of litter.

Nearly all specimens found, live or dead, were around the same size. It was estimated that only 10% of specimens seen were sub-adult, although this cannot be confirmed without knowledge of the reproductive anatomy of the species.

The northern sites were much more successful (7 successes out of 8) than the southern sites (3 successes out of 8). Two failed sites (2 and 12) had been almost entirely over-run with introduced vegetation, although other native snails still occurred there. Another (site 13) had been almost entirely cleared. The remaining four failed (sites 3, 4, 5, 14) retained vegetation cover similar to that found in successful sites, and in some cases had a better or purer native vegetation cover than successful sites.

The species was found in a range of native vegetation types including remnant low *Eucalyptus viminalis* scrub (site 10), blackwood scrub (site 11), rocky damp coastal shrubbery (sites 8, 16), dogwood gullies (sites 1, 6, 7), and dry scrub (sites 9, 15 and 17). It was much scarcer at the dry scrub sites, with a high proportion of dead shells. Three live specimens were found in a large ivy plant (clearly visible

Table 2. Numbers of each native snail species found at each site.

Key to species: Mw, *Miselaoma weldii* (number in brackets is the percentage of individuals found alive); Pac, *Paralaoma caputspinulae;* Pec, *Pedicamista coesa*; Lc, *Laomavix collisi;* Mp, *Magilaoma penolensis;* Pl, *Planilaoma luckmanii;* Po, *Pernagera officeri;* Tl, *Tasmaphena lamproides;* Pd, *Prolesophanta dyeri.*

Site	Mw	Pac	Pec	Lc	Mp	Pl	Po	Tl	Pd	No of species	No. of individuals
The Nut											
1	26(31)	1	-	53	3	-	-	-	-	4	83
2	-	-	-	11	2	-	109	-	-	3	122
3	-	3	-	94	2	-	2	-	-	4	101
4	-	4	-	-	2	-	33	-	-	4	40
5	83(39)	1	-	24	2	1	29	-	-	4	56
6	12(42)	1	-	34	7	-	-	-	1	5	126
7	46(41)	15	-	-	-	-	3	-	-	3	30
8	22(5)	5	140	2	6	-	273	5	-	7	477
9	132(40)	-	-	-	4	-	197	-	-	3	223
10	19(16)	58	-	-	1	-	74	6	-	5	271
11	-	5	-	-	-	-	54	-	-	3	78
12	-	-	-	-	-	-	34	-	-	1	34
13	-	-	-	15	9	-	54	-	-	3	78
14	-	-	-	-	4	-	49	-	-	3	64
15	4(25)	2	-	-	-	-	13	-	-	3	19
16	57(60)	-	45	-	12	-	152	-	-	4	266
17	5(20)	-	163	-	-	-	79	1	-	4	248
No. of sites	10	10	3	8	12	1	15	3	1	9	
No. of individuals	406(39)	95	348	244	54	1	1155	12	1		2316
Away from The Nut											
A1	-	4	-	434	202	-		-	-	3	640
A2	-	-	-	69	39	-	32	-	-	3	140
A3	-	-	-	94	43	-	2	-	-	3	139
A4	-	-	-	30	3	-		-	-	2	33
A5	-	22	-	-	5	-	12	-	-	3	39
A6	-	-	-	-	1	-	-	-	-	1	1
No of sites	-	2	-	4	6	-	3	-	-	4	-
No. of individuals	-	26	-	627	293	-	46	-	-		992
Overall											
No. of sites	10	12	3	12	18	1	18	3	1	9	
No. of individuals	406	121	348	871	347	1	1201	12	1	-	3308

from the Stanley township) at site 1, and the presence of gorse in the litter did not prevent a few specimens from being found at sites 1 and 6. However, specimens found in purer dogwood litter at these sites were much more often alive than those found in gorse litter.

The population of *M. weldii* on The Nut was estimated at 18840 using the following values in the formula used to calculate population size: H = 400, D = 15.7,

Table 3. Numbers of each introduced snail species found at each site.

Key to species: Ai, *Arion intermedius;* Dr, *Deroceras reticulatum;* Dc, *Deroceras caraunae;* Ln, *Lehmannia nyctelia;* Ha, *Helix aspersa;* Cb, *Cochlicella barbara;* Oc, *Oxychilus cellarius;* Od, *Oxychilus draparnaldi.*

Site	Ai	Dr	Dc	Ln	Ha	Cb	Oc	Od	No. of species	No. of individuals
The Nut										
1	1	-	-	-	4	-	17	2	3	24
2	1	7	-	-	-	-	-	-	2	8
3	-	5	-	-	-	-	2	-	2	7
4	-	3	-	-	-	-	-	-	1	3
5	-	5	-	-	-	-	6	-	2	11
6	-	-	-	-	1	-	4	-	2	5
7	-	-	-	-	-	-	7	2	2	9
8	-	2	-	-	-	-	-	-	1	2
9	-	-	-	1	-	-	-	-	1	1
10	-	1	-	-	-	-	-	-	1	1
11	2	2	-	-	-	-	-	-	2	4
12	-	-	-	-	9	8	-	-	2	17
13	-	4	-	-	1	-	9	-	3	14
14	-	-	-	-	-	-	-	-	0	0
15	-	-	-	-	-	3	-	-	1	3
16	-	-	-	-	-	-	-	-	0	0
17	1	-	-	-	-	-	-	-	1	1
No. of sites	4	8	0	1	4	2	7	2	7	
No. of individuals	5	29	0	1	15	11	50	4		115
Away from The Nut										
A1	-	-	-	1	-	-	-	-	1	1
A2	-	-	-	-	-	1	-	-	1	1
A3	-	-	-	1	-	-	-	-	1	1
A4	1	-	2	2	-	-	1	-	4	6
A5	-	-	-	-	-	-	2	-	1	2
A6	-	-	-	-	-	-	-	-	0	0
No of sites	1	-	1	3	-	1	2	-	5	
No. of individuals	1	-	2	4	-	1	3	-		11
Overall										
No. of sites	5	8	1	4	4	3	9	2	8	
No. of individuals	6	29	2	5	15	12	53	4		126

S = 1, A = 0.9 and C = 0.3.

Habitat quality for land snails was found to be generally very poor on the peninsula away from The Nut. Worthwhile search sites were scarce. Only six sites were fully searched. A further five potential sites were commenced but abandoned after ten minutes because no native snails at all had been found and there appeared no realistic chance of finding any. It was hoped to cover about 30 sites rather than the 23 actually searched, but there simply was not sufficient worthwhile and accessible habitat to do so. The six sites actually searched were located between Tatnells Beach and the highway (A1, A2, A3), at West Inlet (A4), at the far end of Godfreys Beach (A5) and on the slopes of the Green Hills (A6). The species did not occur at any of these six sites away from The Nut, although one of these yielded more native snail specimens than any site on the Nut.

Other land snails

This survey yielded a number of interesting finds of other snail species (Table 2). Petterd (1879) recorded the following species from the Nut: *Tasmaphena lamproides, Paralaoma caputspinulae, Pedicamista coesa, Laomavix collisi, Magilaoma penolensis, Miselaoma weldii, Allocharopa legrandi, Elsothera limula, Pernagera officeri, Stenacapha hamiltoni.* Many other species were recorded from the "vicinity of Circular Head" but do not seem to have been found on The Nut. The abundance of *Stenacapha* is suggested by the variety of now synonymised species names under which Petterd lists it. The Nut was formerly forested, and the lack of *Stenacapha hamiltoni* along with *Allocharopa legrandi* and *Elsothera limula* indicates the extent of environmental impact upon the Nut - an impact which *Miselaoma weldii* has survived.

Introduced snails have become a significant part of the Nut's fauna, with 15 of the 17 sites surveyed yielding introduced species, as did 5 of the 6 non-Nut sites. Populations of introduced species were modest, but their biomass per specimen is much larger than most of the native species present. There was no evidence of elimination of native species by introduced snails.

Of the native species found, four form an abundant coastal assemblage throughout Tasmania and on parts of the mainland as well. These were *Pernagera officeri, Laomavix collisi, Paralaoma caputspinulae* and *Magilaoma penolensis*. The last two did not occur in large numbers on The Nut. It is normal for *P. caputspinulae* to be less numerous than the other three in shared habitats, and *M. penolensis* was outcompeted by *Pedicamista coesa* at the most apparently favourable sites. *L. collisi* was surprisingly scarce on the north side of The Nut.

Pedicamista coesa is a coastal species that is seldom reliably recorded but, where found, occurs in extremely dense localised colonies. The Nut is its type locality and it is still abundant at some sites.

Tasmaphena lamproides (nominated for listing as a rare species) was also first described from The Nut, but has not been seen there for a long time and was presumed locally extinct. However, three live juveniles and several dead shells were found during this survey. The dead shells found (even the adults) were all small, suggesting that the local variety is stunted. The likely population on The Nut must be very small, a few hundred specimens at most.

Prolesophanta dyeri is a carnivore/scavenger previously unrecorded from The Nut, although the range extension is minor (20 km). It usually occurs in extremely low population densities. The sole specimen found was alive and feeding on *Miselaoma weldii*.

The presence of *Planilaoma luckmanii* is surprising as it is 140 km outside the previously confirmed range of the species (best described as the eastern half of the state). Johnston's distributional table (in Petterd 1879) gives a record from the Burnie/Table Cape area but no specimen is known. A single dead shell was found under shrubs on a rock in blackwood forest.

DISCUSSION

Ecology and susceptibility

Miselaoma weldii is a detritivore, that appears to feed on fine dirt and leaf/moss particles that accumulate between litter, soil and rocks. It was not found in open rocky areas, indicating that it has a moisture or cooling requirement which necessitates vegetative protection (not necessarily native) or deep rockpiles. Early paintings of The Nut suggest that much of the area now covered by the failed sites 3, 4, 5 and 14 was formerly a cleared sheep farm. It is suspected that sheep either overgrazed these areas (which have subsequently regrown) or degraded and over-disturbed the leaf litter (a process which may be continuing) and hence eliminated the species from these areas. A small and semi-gregarious snail like *M. weldii* is quite incapable of rapid recolonisation and its confinement to such a small area further indicates a poor dispersal ability.

The snail was found in areas where gorse was a significant contributor to the litter layer. It seems that the species is continuing to use the native vegetative remnants that exist in these areas, but can still use gorse litter as a shelter. Similarly, at site 1, it appeared that the species was using an ivy plant that had trapped detritus-rich soil and moss litter. This suggests that the species might be adversely affected by the removal of large gorse plants (which still act as habitat, however inferior) from the two dogwood gullies, and would certainly be adversely affected by the removal of the large ivy. Poisoning gorse plants and planting native species amongst the dead vegetation would not pose such problems.

Distribution

The survey results suggest that it is extremely unlikely that *M. weldii* occurs anywhere on the Circular Head peninsula other than the Nut. Habitats away from the Nut were either too degraded for native snails, or else revealed a fauna comprised only of the extremely hardy "coastal snail" assemblage *Pernagera officeri, Laomavix collisi, Magilaoma penolensis* and *Paralaoma caputspinulae*.

It is also unlikely, given the amount of searching, that *M. weldii* occurs anywhere in Tasmania other than The Nut. Habitats surveyed along Tatnells Beach and

Godfreys Beach were definitely capable of yielding the species if it occurred on substrates other than the basalt of the Nut. This suggests that the species is not capable of inhabiting generic coastal environments, and that accidental dispersal to a distant suitable site would have been required for it to become established there; something which is unlikely given its small population. Unsurveyed Bass Strait islands such as Black Pyramid are plausible sites for relict populations.

Occupancy on the Nut

The successful searches on the north-east side of The Nut suggest a continuous population, occurring from just above sea level to about 120 m ASL (where not disrupted by cliffs) and covering an area about 70 metres wide on average and about 500 metres along, i.e. a total of 3.5 hectares. This area is considered to start at the easternmost point of the Nut (Australian Map Grid reference 3571 4859) and extend around to about AMG 3567 4863.

The two areas in which *M. weldii* occurred on the south-west side of The Nut were separated by a large area of apparently suitable habitat in which the species did not occur. It is likely therefore that these two small dogwood gullies comprise the only significant habitat of the species away from the north-east side of The Nut. The population closest to the township is located at about AMG 3564 4859 and follows a small gully which starts just below a communications hut and extends curving southwards down the side of the cliff face towards a large ivy plant which is clearly visible from the Stanley township. Some specimens may extend into gorse-infested dogwood remnants further to the west of this ivy plant. The area of this population is estimated at 0.3 hectares.

The population above the Stanley quarry is located at about AMG 3567 4856 and can be seen to the left as one follows the track on top of the Nut down from the fence above the quarry towards the large grove of pines. The top of this gully is extensively gorse-infested, but the lower slopes contain low dogwood scrub in good condition. This gully ends abruptly at the face of the Stanley quarry and habitat at the base of the quarry is in very poor condition. The area of the population is estimated at 0.2 hectares.

Population Estimate

The estimate of a live adult population for *Miselaoma weldii* is more difficult than for other large snails for the following reasons:

- The small size of specimens increases the risk of them being missed in sorting through the leaf litter, or hiding in inaccessible niches, or not found in the available time. Undercounting is inevitably massive compared with other snail surveys, and is estimated at 70%.
- The nature of habitat on The Nut prevents truly representative surveying and the survey was deliberately aimed at the greatest possible range of sites.
- The density of populations is extremely variable.

- The extent of undercounting is not uniform, generally being worse at sites where the snail is more abundant.
- At some sites, some areas of microhabitat were inaccessible (usually due to thick weeds or steep rocks).
- It is unclear whether to treat failed search sites on the south side as representing a block of non-utilised habitat or just coincidence that individuals were not located. I have assumed the former although it makes little difference to the estimate.

The population estimate of around 20 000 live adults seems reasonable on this basis, but this could conceivably be incorrect by a factor of two either way given the uncertainties involved. Thus the true population could be between 10 000 and 40 000. This is an impressive population for a small area but an extremely low population for a land snail on a statewide basis.

Conservation Status.

Miselaoma weldii is classified as vulnerable under the Tasmanian Threatened Species Act. The guidelines that were recently issued for the listing of species (Scientific Advisory Committee 1998) suggest it should be reclassified as endangered. It meets the preamble for Criterion B (Extent of occurrence estimated to be less than 5000 km^2 or area of occupancy estimated to be less than 500 km^2). It also meets criterion B2 (Continuing decline, inferred, observed or projected in various categories), and therefore needs only to meet criterion B1 (Severely fragmented or known to exist at no more than five locations). A "location" (according to IUCN 1994) is an area in which all organisms present could be subject to a single threatening event. This can certainly be said of the populations on The Nut.

While it cannot be proven that the species occurs nowhere else, IUCN (1994) allows for the use of the lowest credible estimate in cases of uncertainty. It is credible that the species may be confined to The Nut given the amount of searching elsewhere. The species should therefore be considered as endangered in Tasmania and should remain so until surveys demonstrate that numbers are stable or until further populations are found.

MANAGEMENT RECOMMENDATIONS

Remedial action is required to help ensure that numbers of *Miselaoma weldii* do not decline further. The following are recommended:

- To slow the rate of weed invasion, isolated smaller patches and seedlings of gorse and boxthorn should be removed where practical from the north-eastern part of The Nut, in accessible areas below the cliffs and above the shoreline roughly between the points AMG 3571 4859 and AMG 3567 4863.
- Any invading gorse seedlings near the top part of the gully near the telecommunications hut (AMG 3564 4859) should be removed regularly. Gorse

should not be removed from the bottom part of the gully or from the gully at AMG 3567 4856 as this may cause excessive surface disturbance or lead to drying out of the area. Instead, if possible, gorse could be poisoned and natives planted around and between the gorse thickets.

- The large ivy plant growing on the cliff-face and clearly visible from Stanley should be retained. The snail does not generally utilise ivy, so other ivy plants apart from this one are not important.
- Fires should not be lit or permitted in any area where there is risk of escape onto the slopes of The Nut.
- The status of the species should be monitored by surveying populations every five years.
- Existing revegetation programs on The Nut should be encouraged and reintroductions of *M. weldii* attempted in well established revegetated areas.

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I wish to thank Sally Bryant (Threatened Species Unit, Department of Primary Industries, Water and Environment) for organising this survey, and Greg Taylor, Perry de Rooy and Lalani Hyatt (Stanley Peninsula Landcare) for local knowledge and habitat information. Voucher live specimens of *Miselaoma weldii* were collected under permit FA 98052 and live specimens of *Paralaoma caputspinulae*, *Laomavix collisi*, *Pernagera officeri*, *Pedicamista coesa* and *Magilaoma penolensis* were collected under permit FA 98047. All material collected was deposited at the Queen Victoria Museum in Launceston.

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A REVIEW OF FACTORS IMPLICATED IN TREE DECLINE IN TASMANIA

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Abstract. Trees in the rural landscape of Tasmania are dying at an unprecedented rate. Evidence indicates that a combination of drought, possum browsing, insect attack and changes in the environment is causing the rapid decline and death of rural eucalypts. Between 1975 and 1994 there weren't two consecutive years of significantly above average rainfall in the low rainfall districts of the State. In effect there has been a drought lasting over twenty years. Possum numbers in the low rainfall districts of Tasmania are at record levels. The collapse of the fur trade has resulted in a dramatic decline in the numbers of possums harvested each year and this has coincided with the drought. The browsing pressure of possums is, in some areas, pushing the trees 'over the edge'. Control of possum numbers will assist the health of trees. Land clearance and management practices have altered the environment dramatically. Eucalypts in the agricultural environment are subject to a wide range of pressures: soil compaction, nutrient enrichment, isolation, increased soil temperatures, decreased infiltration of water, grazing of regeneration and increased browsing levels by both possums and insects. With no regeneration to replace the existing trees the rural landscape is changing quickly, and the manifold benefits of trees are being lost. In order to preserve the last fragments of native vegetation in the low rainfall districts of the State, a change in management practices is required. Control of herbivores (stock, natives and ferals) needs to be combined with tree planting and protection of remnant stands of native forest.

INTRODUCTION

Rural tree decline is the accelerated death of rural trees, principally eucalypts. It is not confined to paddock trees, which have been dying out for at least the last thirty years, but also extends to the forests and woodlands of the low rainfall districts of Tasmania.

All the forests of the low rainfall districts of Tasmania are affected by 'dieback' to some extent. Locally, the extent of dieback varies according to site conditions, such as the soil type and depth, the species of eucalypt present, the site history (past land management practices) and the size of the remnant (where a forest is isolated from other forested areas).

Previous studies (Wilson 1993; Grice 1995) have shown that tree decline is closely related to annual rainfall. Tree decline is moderate (10 to 40% of canopy branches dead) where the annual average rainfall is between 625 and 1000 mm per annum. Tree decline is severe (40 to 80% of canopy branches dead) where the annual average rainfall is below 625 mm per annum (Grice 1995).

Eucalyptus viminalis or white gum is the tree that is affected to the greatest extent by dieback. *Eucalyptus amygdalina* (black peppermint), *E. ovata* (black gum), *E. rodwayi* (swamp peppermint), *E. tenuiramis* (silver peppermint), *E. dalrympleana* (mountain gum), *E. pauciflora* (cabbage gum), *E. delegatensis* (white-topped stringybark), *E. globulus* (blue gum) and *E. rubida* (candlebark) are also affected but the impact on these species is less than it is on white gum.

Eucalyptus viminalis was the dominant tree in the Midlands, and is still widely distributed throughout the region. *Eucalyptus viminalis* has a wide ecological range. It has the most nutritious and most palatable foliage of the eucalypts in the Midlands and hence is targeted by browsing animals and insects. The other species of eucalypt listed above have foliage that is not as attractive to browsers, although all eucalypts, particularly when young, are subject to browsing. Dieback as a phenomenon is not restricted to Tasmania but has long been recognised from the mainland as well (Landsberg and Wylie 1991).

This paper reviews the likely causes of tree decline in Tasmania and recommends management techniques to help combat the problem.

CLIMATE

Rainfall data were examined from six Bureau of Meteorology stations (Avoca, Longford, Oatlands, Ouse, Swansea and Kempton) representing an even spread of sites from throughout the low rainfall districts of the state. For each station, the rainfall over the period of recording was plotted using a ten year running average. That is, each point on the charts represents an average of the rainfall over the decade leading up to that point. This has the advantage of smoothing the variation which is inherent in a plot of annual rainfall.

The data from all stations indicate that there has been a sustained dry period in Tasmania since the mid 1970's. Data from two of the stations are shown in Fig. 1. Local droughts were recognised in 1967-1969, 1972-1973, 1979-1983, 1987-8 and 1991-1993, but effectively there has been a sustained dry period from the mid 1970's up to the present. Potential evaporation in the Midlands and the Derwent Valley is in the order of 1500 mm per annum (Tasmanian Year Book 1994), which far exceeds the annual rainfall, even in good years. After twenty years of average and sub-average rains, and with no years of significantly above average rainfall, there is very little subsoil moisture.

To see what impact this rainfall pattern has had on tree growth five trees were felled on Clyde Run, a property to the north of Bothwell. Annual growth rings on these trees were measured and averaged over the five trees. The data indicate that the drought was having an impact on the trees by the early eighties (Fig. 2). It also shows that periods of rainfall deficit are reflected in the relative growth rates of the trees. After the 1982-1984 drought, despite moderate rainfall in 1984-1985 and 1985-1986, the trees failed to recover.

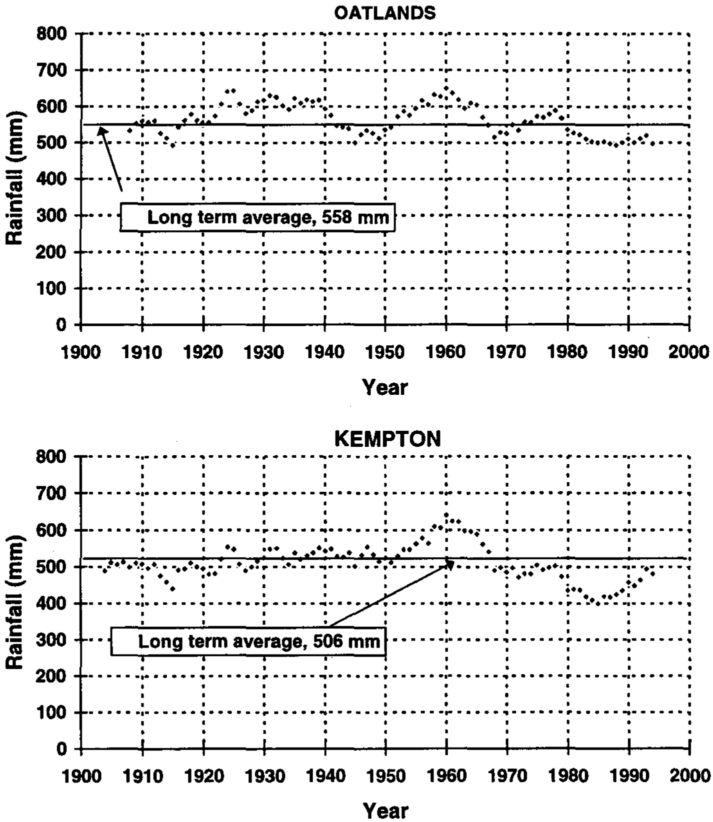

Fig. 1. Long term 10 year running averages for two climate stations from the low rainfall districts of the State.

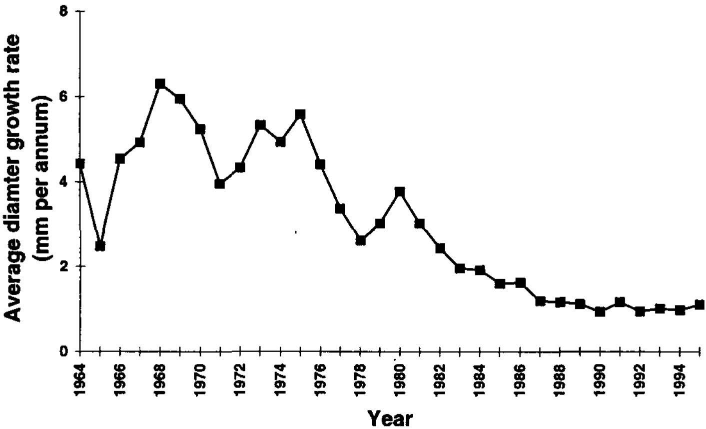

Fig. 2. Average diameter growth rate (mm per annum) for five trees from Clyde Run.

Temperature trends in the southern hemisphere also support the idea that the Tasmanian climate is changing. Stable carbon isotopes in tree rings from King Billy pines indicate that since about 1940 there has been an average increase in temperature in the order of 1 to 1.5°C (Pearman *et al.* 1976). Pittock (1983) also found considerable support for a rise in temperature in Tasmania from 1945 to 1978 of about 1.1°C. More recent work on tree rings from Huon pines on the west coast also points to a temperature increase of the same order (Cook *et al.* 1991).

In a number of locations around the state (e.g. Meadowbank and the Tamar Valley) it is evident that trees on the usually moist south to south-east facing slopes are the worst affected. Trees on these slopes experience drought only rarely whereas trees on drier north facing slopes have experienced drought stress every season throughout their lives, and so have been selected for their ability to survive dry spells. Intense drought episodes, sufficient to cause the death of trees on the normally moister south facing slopes only occur rarely, but when they do, they usually result in the death of many trees. Such an event occurred in the north-east of Tasmania in 1967, when over a five month period only 47 mm of rain fell on an area centred on Mathinna. Throughout the area, *E. obliqua* in the gullies died while the *E. sieberi* of the slopes survived.

Evidence thus indicates that drought stress is a major factor in rural tree decline. Classical symptoms of drought stress, such as splitting of the bark and consequent exudation of gum, have been noted over the last fifteen years. Most of the rural trees at present have much reduced foliage as a consequence of the drought and this in turn is thought to increase the impact of browsing on the trees.

BROWSING BY POSSUMS

The common brushtail possum (*Trichosurus vulpecula*) is most abundant in eucalypt forest or woodland (Rounsevell *et al.* 1991). Spotlight surveys conducted by the Parks and Wildlife Service indicate that possum densities are highest in the eastern Midlands and that numbers throughout the low rainfall districts are higher than elsewhere in the State (Fig. 3).

Through the 1970's and early 1980's large numbers of possums were shot commercially for the fur trade. However, after this time there was a rapid decline in the price of skins and the number of animals taken by commercial hunters dropped dramatically (28,667 in 1993 compared with over 400,000 in 1979). The spotlight survey data also suggests that possum numbers have been increasing steadily in the low rainfall districts since the collapse of the fur trade in the early eighties (Fig 4).

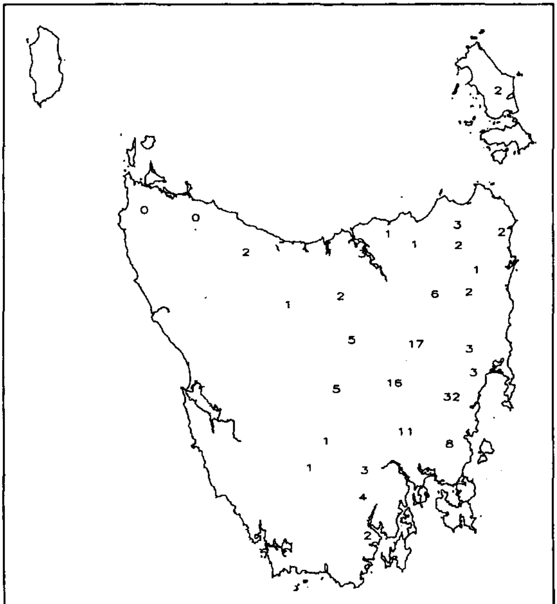

Fig. 3. Relative abundance of brushtail possum by district. The numbers represent the average counts of five to seven transects per district averaged over 1986 to 1990.

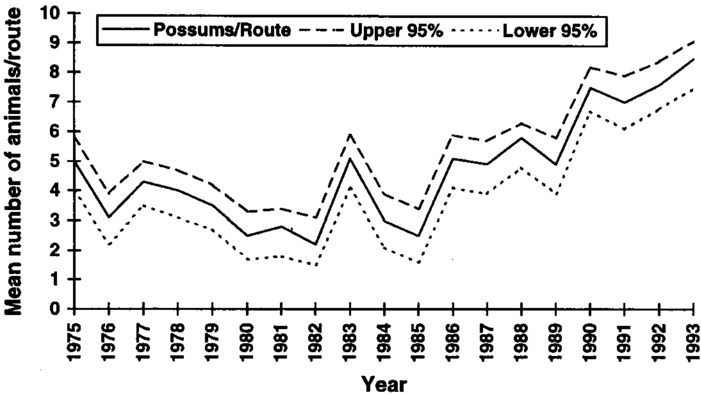

Fig. 4. Trend in brushtail possum abundancebetween 1975 and 1993 with 95% confidence limits (after Driessen and Hocking 1992).

Possums feed both on eucalypts and on herbs, notably clover (Statham 1992). The landscape that has been created by European settlement of Tasmania has thus in many areas created an environment that is ideal for possums. The mixture of improved pasture and remnant bush areas provides the possums with nutritious feed and den sites. Whilst the actual impact of possums is impossible to quantify, there is ample field evidence to suggest that possums are a factor in the decline of rural eucalypts. Scratch marks, a common feature on trees, can be quite extensive. Browsing damage to the foliage is common. At one property in the Midlands, just to the north of Oatlands, 13,500 possums were shot over a three month period. Trees which had been significantly defoliated have since begun to recover.

When possums defoliate a tree the tree responds by producing epicormic foliage, the characteristically tufty shoots which arise from the trunk and branches of the tree. It has been shown that this foliage is more nutritious and more palatable than the older foliage on the tree (Journet 1980). The possums target the new foliage and thus a vicious cycle develops whereby a tree once browsed produces foliage which is more attractive to the possums than the original foliage, so the possums prefer to browse the epicormic shoots. As fast as the tree produces new shoots, the possums browse them.

DEFOLIATION BY INSECTS

In general terms, outbreaks of insects are local and cyclic. They may persist for two or even three seasons but as the insect numbers build so do the numbers of their predators. One notable recent event was the outbreak of the peppermint looper (*Stathmorrhopa aphotista*) around Hobart in the late 1970's (Elliott *et al.* 1981), where over 1000 ha of dry eucalypt forest was severely defoliated. The insect population declined naturally and there has not been a similar outbreak since.

The gum leaf skeletoniser *Uraba lugens* is perhaps the most common and widespread defoliator of eucalypts. Widespread and severe damage caused by this insect occurred most recently in the Midlands in the summer of 1990-1991 (Wardlaw 1993). Previous outbreaks of similar intensity occurred in 1962 and 1975 but recovery following these outbreaks was generally good (Wardlaw 1993). However, the outbreak of 1990-1991 occurred at a time when the eucalypts were also under extreme drought stress. Foliage recovery following the outbreak was poor and mortality of trees was high (Wardlaw 1993).

Periodic sampling has also found the eucalypt weevil *Gonipterus scutellatus* to be a major insect defoliator of *E. viminalis*. Other insects which may periodically cause defoliation include sawflies *Perga affinis*, chrysomelids *Chrysophtharta bimaculata* and the peppermint looper (occasionally severe on *E. amygdalina*). Trials outside the Midlands have shown that insect defoliation can cause severe reductions in growth and insects have undoubtedly played a major role in accelerating decline of rural trees in some areas (Wardlaw 1993).

LAND MANAGEMENT PRACTICES

Land Clearing

Over 85% of the native vegetation of the tree decline areas of Tasmania has been cleared (Duncan 1993). During the period 1980-1988, clearing in Tasmania continued at a rate of around 6000 ha per annum following a rate of around 15,000 ha per annum through the seventies (Fig. 5)(Kirkpatrick 1991a). Much of this clearing took place in the tree decline areas. Land is still being cleared, although the rate of clearing is slowing, presumably as the area of land suitable for agricultural development declines.

Clearing results in changed microclimates around remaining trees. Soil temperatures are increased, particularly in summer (Stoneman *et al.* 1994). Frost effects are greater and ground water movement is affected. Wind speeds at ground level are increased. Evaporation and transpiration rates are increased. These microclimatic changes around the trees result in a considerably increased stress on the trees, particularly during times of drought.

It is apparent that one factor which determines tree health in the tree decline area is the size of the remnant forest. The largest remnants are relatively unaffected, except on their margins, whilst the smallest patches are often in very poor condition. Over 75% of isolated paddock trees have died over the last 40 years (McMurray 1983).

Grazing

Stock camping beneath trees causes soil compaction (Willat and Pullar 1983), loss of soil microfauna and microflora, and increased nutrient levels caused by the accumulation of droppings. There is evidence to suggest that increased nutrient levels beneath the trees results in increased nutrient levels in the foliage of the trees which increases their palatability. This in turn results in increased browsing damage, by both possums and insects (Landsberg 1987, 1990; Landsberg and Wylie 1983; Marsh and Adams 1995). Soil compaction damages the fine feeder roots of the trees and causes reduced water infiltration rates (Proffitt *et al.* 1995).

Stock grazing of remnants prevents natural regeneration of the trees and of the understorey, except where the grazing levels are carefully managed. Natural regeneration has been recorded where remnants are lightly grazed in winter and spelled for the rest of the year (Duncan 1994). Where remnants are grazed all year round there is no regeneration. As the understorey is simplified, the fauna is also simplified. In a study in Victoria, Loyn (1987) showed that as remnant size decreased and as the understorey of remnants was simplified by grazing, the smaller insectivorous

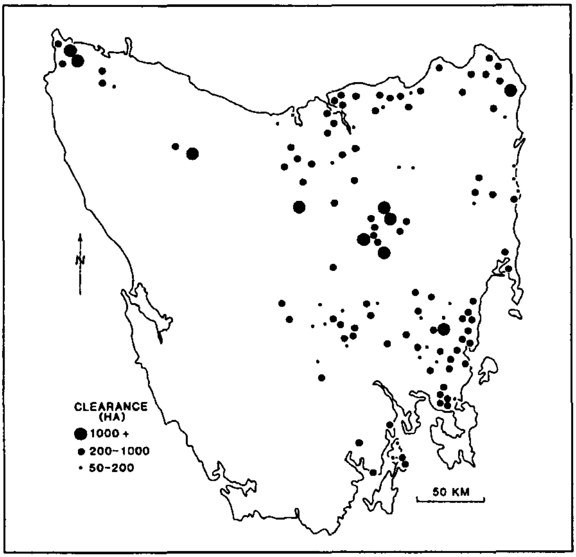

Fig. 5. Pattern of land clearance between 1980 and 1988 (from Kirkpatrick 1991a).

birds were displaced by noisy miners *Manorina melanocephala*. Noisy miners are aggressively territorial and by displacing the smaller insectivores they reduce the amount of insect predation that occurs in the remnants, resulting in an acceleration of tree decline. Other studies (eg Ford and Bell 1982; Arnold *et al* 1987) have also shown that the diversity of woodland birds decreases following partial clearing and grazing of woodland.

Gilfedder and Kirkpatrick (1993) looked at the general health and condition of 100 remnants in the tree decline area. Overall they found that those remnants which were ungrazed or grazed for only part of the year were in better health than those which were grazed all year round. Only six remnants showed no evidence of dieback.

Subterranean clover and superphosphate

The introduction of subterranean clover and the addition of superphosphate to pastures has also altered the ecological balance. In some cases superphosphate has been applied directly to remnants, in other cases it drifts in from adjacent pasture areas. The impact of fertilisers on remnant trees is manifold. Increased nutrient levels (just as caused by stock camping beneath trees) can result in increased foliage nutrient levels and hence increased foliage browsing by insects and possums. High nutrient levels in the soil can interfere with osmotic water absorption. The combination of superphosphate and clover is also related to the increasing acidification of much of Australia's rural soil (Russell and Isbell 1986; Borough 1990). This is the result of the increased nitrogen levels brought about by the nitrogen fixing abilities of the clover. Acidification is less of a problem in Tasmania than on the mainland (Leigh Sparrow pers. comm.)

Clover and superphosphate are also implicated in the dramatic increase in possum numbers. Clover is highly desired by possums and on a nutritious diet of clover possums are now breeding twice a year where traditionally they only bred once (Statham 1992). Increased browsing damage by possums is a major factor in tree decline.

MANAGEMENT RECOMMENDATIONS FOR RURAL AREAS WITH TREE DECLINE

The term remnant vegetation is used here to define any areas of natural vegetation, whether they are grasslands, woodlands or forests. Management of remnant vegetation aims to maintain the health and diversity of native species of the remnant and the periodic regeneration of the trees whilst at the same time providing for the supply of products such as posts and firewood, feed and shelter for stock. The three key tools of management are fencing, grazing and fire.

Light winter grazing can reduce fuel loads and maintain species diversity by controlling tussock growth. Ungrazed tussocks can grow to the point where they smother the smaller herbs and shrubs. Set stocking (uncontrolled grazing) of remnants also reduces fuel loads but at the same time it prevents tree and shrub regeneration, depletes the ground layer and increases the potential for weed invasion. Set stocking is not recommended for remnants. Periodic light grazing, preferably in winter, will increase the probability that the health of the remnant is maintained.

Regular (whether set stocking or periodic) grazing of native forest areas by sheep and/or cattle prevents regeneration of the trees. In order to ensure regeneration of tree species it is necessary to spell the remnant, so the remnant must be fenced. It is often possible to get regeneration simply by spelling the remnant following light winter grazing. The grazing will often create sufficient germination sites and seed fall from the trees usually occurs in spring and summer. Seed production in the low rainfall districts is erratic, and hence so is seed fall. If no seed is present in the overstorey trees it may be necessary to direct sow part of the site.

If tree regeneration is successful after spelling of the remnant, then the remnant will need to be left ungrazed until the trees are tall and strong enough to withstand stock. This can mean no grazing for five to six years, depending on the site and the growth rates of the trees. However once regeneration is established the remnant will not need to be spelled again for some time. The overall aim is to ensure that there is sufficient regeneration on the site to replace the trees that die.

In management of remnant vegetation fire is an important tool for reducing fuels, stimulating germination, removing grass cover and providing a receptive seed bed. Many native species will only regenerate following fire, which stimulates germination of seed stored in the soil, and induces seed to fall from capsules in the crowns of trees such as the eucalypts. In some vegetation types, too long an interval between fires will result in the loss of some species. In grassy vegetation a closed sward of grass can swamp the smaller plants.

The timing and intensity of fire is important. Many weed species flower and set seed early in spring, whilst native species flower and set seed across summer. Fires in late spring can therefore stimulate germination of weed species whilst destroying natives before they have had a chance to set seed. It is important not to burn during very dry spells as seeds which germinate following the fire will have little hope of establishing. It is also important not to burn remnants which have young eucalypt regrowth present as the fire will destroy the regrowth. Once young trees are about eight metres tall they can survive a low intensity fire.

The best time to burn is in early spring or late autumn. Fires in early spring will destroy many weeds whilst stimulating germination of native species. Fires at this time are rarely very hot and the moisture remaining in the soil from winter usually means that the fire will go out overnight. Burning in late autumn is considered safer than spring burning. The soil moisture is higher and the risk of a fire smouldering overnight is reduced. The weather is more stable than in spring and the chance of extreme fire weather developing is much less. Autumn burning also allows young trees a period to establish before the summer drought.

It is important that fires in any particular remnant are widely distributed in time and space. In other words, only burn part of a remnant each year, not the whole lot, and some years don't burn at all. By burning different parts of a remnant in different years a wide range of different ages of regeneration can be present in the one remnant.

Because of the impact of their browsing, control of feral (deer, goats, rabbits and hares) or native herbivores, if present, is essential for successful tree establishment.

It is important to minimise fertiliser drift into remnant bush areas. Increased soil fertility encourages the spread of weeds, which respond more quickly to the added nutrients, and is detrimental to many native species that are adapted to low nutrient environments. The addition of fertiliser to pasture also leads to greater browsing pressure on the trees from possums whose populations increase due to the more nutritious and palatable pasture plants present.

One of the responses of remnant bush to fencing can be the proliferation of weeds. Gorse is a particular problem in the agricultural districts of Tasmania and where it is obviously invading remnants it should be controlled. However, gorse can be valuable shelter for stock and it can sometimes allow eucalypt regeneration to establish through providing protection against stock.

Dead trees in remnant bush can provide a source of firewood for the owner. However it is important that some dead trees are left. Dead trees with nesting hollows may provide den sites for possums. However, such trees also provide a rich and unique habitat for other organisms such as fungi and invertebrates. This is particularly the case after they fall to the ground when they are also used as basking sites and shelter for smaller vertebrates such as skinks.

Further information on management of remnant vegetation is provided in Orr (1991) and Kirkpatrick (1991b).

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WILL THE INTRODUCED EUROPEAN GREEN CRAB IMPACT UPON *PATIRIELLA VIVIPARA*, THE RARE ENDEMIC SEA STAR?

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INTRODUCTION

Carcinus maenas, or as it is more commonly known the European green crab, was introduced to Australia last century. However, it did not reach Tasmania until about a decade ago, first being found in the northeast of the State. Since then it has spread slowly south down the east coast, and west along the north coast. It has been found to pose a threat to the aquaculture industry, primarily shellfish farming,and also to native marine fauna.

Patiriella vivipara is a small endemic sea star. It has a restricted distribution, being found only at seven fairly well dispersed localities in southeast Tasmania. As it is only one of three species of viviparous sea stars known in the world, it has considerable scientific importance. In 1998 it was placed on the Tasmanian Threatened Species List.

Although *C. maenas* has not been found in any of *P. viviparas*' colonies to date, it is unknown whether it could pose a threat to them also. This was the purpose of the following experiment.

METHODS

Observations were conducted over 14 days (from 2nd May to 7th June 1999). Nine adult (radii 7 - 12 mm) and 18 juvenile (radii 1 - 2 mm) *P. vivipara* were placed in an all glass aquarium that contained approximately 50 L of sea water which was aerated. A sandstone rock covered with microalgae as food supply and providing shelter for *P. vivipara* was present in the aquarium. The sides of the aquarium also carried microalgae as it had been in use for two months prior to this experiment. The juveniles used had been born during that time. A male *C. maenas*, 50 mm across the carapace, was also placed in the aquarium. *C. maenas* was fed fish, molluscs and sandworms, but was not fed for periods of up to 48 hrs to see whether this would induce it to eat *P. vivipara*.

RESULTS

At no time over the 14 days did *C. maenas* show any inclination to eat, or otherwise interfere with, the well being of *P. vivipara*.

DISCUSSION

From the results it would appear that *C. maenas* does not pose a direct threat to *P. vivipara*, as it completely ignored both adults and juveniles. There is a remote possibility that it could affect the habitat of *P. vivipara* as it was found that it could overturn the rock in the aquarium. The rock weighed 1.7 kg, was slightly concave on the lower surface, and it was into this gap between the rock and the bottom of the aquarium that *C. maenas* inserted the rear of its carapace, tipping it over. Whether this was in search of food or trying to find cover is not known, but this practice on the shore could expose *P. vivipara*, especially juveniles, to wave action that could wash them away. This happened three times, and the rock was then left tipped over to eliminate the possibility of any *P. vivipara* getting squashed. What weight *C. maenas* is capable of moving is not known.

It was noticed that *C. maenas* has a definite aversion to the smell of the northern Pacific sea star *Asterias amurensis*. It is a sweet musky smell which is presumably carried in the mucus exuded by *A. amurensis* after they have been out of water for some time. Prior to feeding the crab one evening, several *A. amurensis* had been handled and also dissected to determine their sex. Prior experience showed that their smell is absorbed by the skin of the hands. Although my hands were washed well afterwards, traces of the smell must have remained. Firstly a small piece of mackerel was cut and offered to *C. maenas*. It put it in its mouth, took a couple of bites and literally spat it out, vigorously cleaning its mouth parts, and had nothing more to do with the fish. Exactly the same procedure took place with a piece of flathead. Both pieces of fish were removed from the aquarium. This caused food for thought, as it had never rejected either fish before. It was not until about an hour later that the smell, although faint, was detected coming from my left hand. This was indoors, well away from where the work had been carried out on *A. amurensis* and they had not been handled since. I washed and rinsed my hands well and waited about 15 minutes before trying to feed the crab again. No trace of the smell could be picked up on my hands. Another piece of flathead was tried, but again vigorously rejected. It can only be assumed that traces of the smell were left on the flathead used for the food supply. This was then well washed and used at later time, when it was eaten as normal. A piece of oyster was available, fed to *C. maenas*, and this was eaten without a problem. It has not been determined what causes this smell, or its purpose, if any.

Hashimoto and Yasumoto (1960) and Yasumoto *et al.* (1964) found a toxic component, a saponin, in *A. amurensis*. Whether this plays any part in the origins of the smell is not known.

ACKNOWLEDGEMENTS

My thanks to the Threatened Species Unit, Department of Primary Industries, Water and Environment for granting me Permit No. FA 99032 to hold *P. vivipara* in an aquarium at my home, enabling this experiment to be carried out.

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WILL THE INTRODUCED NORTHERN PACIFIC SEA STAR IMPACT UPON *PATIRIELLA VIVIPARA*, THE RARE ENDEMIC SEA STAR?

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INTRODUCTION

Asterias amurensis, or the Northern Pacific Sea Star as it is more commonly known, was positively identified from the River Derwent in Tasmania in 1992, although it was thought to have been in these waters prior to this time. Since its introduction it has developed a voracious appetite for the local marine fauna.

Patiriella vivipara is a small endemic sea star that has a restricted distribution, being found only at seven fairly well dispersed localities in southeast Tasmania. The species has considerable scientific importance as it is only one of three species of viviparous sea stars known in the world. In 1998 it was placed on the Tasmanian Threatened Species List.

Pittwater, approximately 20 kilometres east of Hobart, is home to the largest concentration of *P. vivipara*. There are several thousand animals living in various places around the shore at this locality. Late in 1998 *A. amurensis* was reported from the eastern side of Lower Pittwater. In March 1999 I was given the approximate locality, and have since done several surveys of that area finding them in concentrations ranging between 0 and 6/m^2 in an area of several hectares. None of them were very large; samples retrieved with a dip net ranged in size from 60 to 80 mm radius. Because *A. amurensis* has a voracious appetite there was speculation that it could pose a threat to *P. vivipara*. This was the purpose of the following experiment.

METHODS

Observations were conducted over 16 days (from 17th April to 2nd May 1999). Two *A. amurensis*, (radius of 60 and 65 mm respectively) and six adult *P. vivipara* (radii 7 - 12 mm) were placed in an all glass aquarium that contained approximately 50 L of sea water which was aerated. A rock covered with microalgal growth was placed in the aquarium to provide food for *P. vivipara*, and 12 mussels, 25 to 35 mm in shell length, as food for *A. amurensis*.

RESULTS

Between day 1 and day 6 *A. amurensis* virtually ignored *P. vivipara*. It would walk over them, or *P. vivipara* would go between the arms up to the disc of *A. amurensis* and out again with seemingly complete immunity, even though they were examined by the tube feet of *A. amurensis*. During this time it was noticed that the smaller *A. amurensis* could not open any of the mussels provided, whereas the larger one could open and eat an average of one per day. Under these circumstances mussels were opened and fed to the smaller *A. amurensis* at the same rate of consumption as the larger one, as it was assumed that it was not strong enough to open them itself.

On the early evening of day 6 only five *P. vivipara* could be seen. The larger *A. amurensis* was in full view moving around the side of the aquarium, but on checking the smaller one that was on the back glass, something yellow could be seen being held by its everted stomach. Closer examination revealed that it had one *P. vivipara* in the folds of its stomach, but on being disturbed it dropped it as presumably it had only just picked it up. Further observation that evening saw no more interest taken by either *A. amurensis* in *P. vivipara*, and the specimen that had been picked up was moving around as normal.

Nothing more happened until the evening of day 7 when the smaller *A. amurensis* was seen to be humped up, low down on the back wall of the aquarium and only five *P. vivipara* could be seen. This time it was not touched, letting nature take its course.

Examination next morning, day 8, showed that *A. amurensis* was still in the same position as the previous evening, but now there was a neat pile of regurgitated skeletal plates, from *P. vivipara*, on the bottom of the aquarium beneath it. On the late evening of this same day the smaller *A. amurensis* had another *P. vivipara* in the folds of its stomach. Neither one had been fed with mussels that day.

The morning of day 9 saw another pile of skeletal plates on the bottom of the aquarium. Both *A. amurensis* were fed mussels during the day.

On day 10 the smaller *A. amurensis* was fed, but the larger one was left to open its own mussels.

There were still four *P. vivipara* to be seen on day 11. More mussels were collected and put in the aquarium, also a large feral oyster, of which each *A. amurensis* received half. This kept them busy for the rest of the day, and also day 12. The four remaining *P. vivipara* behaved as normal.

Morning of day 13 saw little remaining of the oyster. The water in the aquarium had turned slightly cloudy, so fresh water was obtained and the aquarium cleaned out.

Nothing happened on day 14. Neither one was fed as each were humped up over a mussel.

Another *P. vivipara* had disappeared on the morning of day 15, as only three could be found, but which *A. amurensis* had eaten it was not certain. Each was fed an opened mussel late in the afternoon.

The culprit was identified on day 16. It was the larger *A. amurensis* that had eaten a *P. vivipara* this time, as around the empty mussel shell where it had been feeding overnight were numerous skeletal plates.

It was decided that it had been shown that *A. amurensis* would eat *P. vivipara*.

Not wanting to sacrifice any more *P. vivipara*, *A. amurensis* were removed from the aquarium and disposed of.

DISCUSSION

From the above results it can be seen that *A. amurensis* poses a threat to *P. vivipara* under controlled conditions. To what extent this threat would exist in their natural habitat is not known, as *A. amurensis* has not been found in any colony of *P. vivipara* to date. Indications are that *A. amurensis* may only consume *P. vivipara* if the natural food supply was depleted, as *A. amurensis* did not have an abundance or much choice of food available in the aquarium. It also appeared that *A. amurensis* did not consider *P. vivipara* 'preferred' food, as it was seen to move over and ignore *P. vivipara* even though it had previously consumed them. Nine juvenile *P. vivipara* were born in the aquarium during this period, but none of these were eaten.

A study by Hatanaka and Kosaka (1959) determined that specimens of *A. amurensis* weighing between 110 and 228 grams consumed the equivalent of 2.7% of their own body weight a day. A specimen of *P. vivipara* 10 mm in radius weighs an average of one gram. Theoretically *A. amurensis* within this size range could consume between three and six *P. vivipara* (10 mm radius) per day.

There is a difference in the habitat use of the two species that could favour *P. vivipara*. *A. amurensis* does not tolerate being exposed at low water (Byrne, pers.

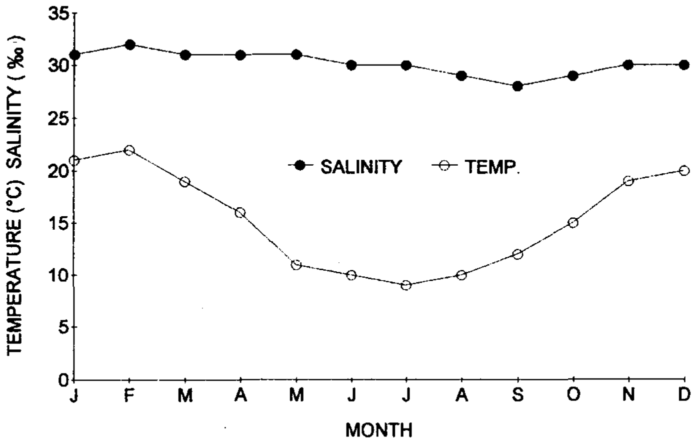

Fig. 1. Average temperatures and salinity in Lower Pittwater over a three year period (1979 - 1982).

comm). However, as *P. vivipara* lives in the upper limits of the intertidal zone their habitat is partially or completely out of water during low tide. The possibility exists that *A. amurensis* could, during a period when there is little difference between the height of high and low water, encroach upon the lower habitat of *P. vivipara*. *A. amurensis* can be seen in only a few centimetres of water at any tide level in the River Derwent in the colder months. Despite this, *A. amurensis* hopefully will have little impact on the population of *P. vivipara*.

Temperature has been raised as a factor that could restrict the spread of *A. amurensis* into shallow waters, its' preferred temperature being about 13°C or lower. During the short time they were in the aquarium the temperature of the water varied from 8 - 20°C with no apparent adverse effect on either specimen. In Lower Pittwater *Asterias amurensis* has endured summer water temperatures in depths varying from 0.5 - 1.5 m deep, depending on tidal conditions. Fig. 1 shows the average temperatures and salinity in Lower Pittwater over a 3 yr period. It would appear that *A. amurensis* is adapting to the warmer water of shallow bays better than first expected.

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NEST USE BY THE COMMON RINGTAIL POSSUM *PSEUDOCHEIRUS PEREGRINUS* IN COASTAL TEAT-REE ON FLINDERS ISLAND

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Abstract. This study documents seasonal nest occupancy and sharing by the common ringtail possum in a coastal tea-tree thicket on Flinders Island, Bass Strait. Single individuals and male/female pairs formed the dominant nest groups throughout the year. Nest groups of three or more animals were comprised of an adult male/female pair with juveniles that were young from a previous litter. The most frequently observed combination was that of an adult male/female pair and a juvenile female. The composition of nest groups appeared to vary according to the reproductive status of the adult female occupying the nest. Males moved from one nest to another significantly more often than females. Females suckling back-young made significantly fewer changes in nest site than did non-lactating females.

INTRODUCTION

The common ringtail possum, *Pseudocheirus peregrinus* (Boddaert 1785) is the smallest folivorous marsupial in Australia. Studies have shown that the ringtail possum exhibits behavioural, physiological and ecological strategies which enable it to minimise energy requirements whenever possible (Munks 1990; Munks *et al.* 1991; Munks and Green 1995; Munks and Green 1997). Such adaptations appear to have evolved in response to a limit to the rate at which it can acquire energy from its diet of leaves. One heat conserving strategy that the ringtail possum shares with other small folivores (e.g. the sportive lemur *Lepilemur leucopus*, Klopfer and Boskoff 1979) is the building and sharing of nests or dreys. The ringtail possum constructs spherical nests in dense understorey vegetation, in the open branches of suitable shrubs and trees or in tree hollows. Inland riparian scrub and coastal scrub appear to be its preferred nesting sites (Thompson and Owen 1964; Munks pers. obs)

There is little published information on nest use and nest sharing by the common ringtail possum in different habitat types. Such information is particularly useful in the determination of reproductive and social systems (Smith and Lee 1984). Smith and Lee (1984) in their review of the social group structure of possums and gliders categorise *P. peregrinus* nest group structure as either solitary or breeding pairs. However, the observations of Thompson and Owen (1964), Marsh (1967) and How *et al.* (1984) suggest that *P. peregrinus* is more gregarious than this, with nest group structure ranging from pairs during the breeding season to family groups following the emergence of young. Thompson and Owen (1964) observed up to eight individual ringtail possums occupying one multiple nest in their study area in southeastern Victoria. This study documents seasonal nest occupancy and sharing by the common ringtail possum in a mature coastal tea-tree thicket on Flinders Island, Bass Strait.

STUDY AREA

The study was undertaken on the west coast of Flinders Island in Bass Strait (148'01'E, 40'06'S). The study site was divided into two regions by the small town of Whitemark. One region, 'Whitemark Beach' (17.5 hectares), was situated north of Whitemark and the second, 'Paddies' (15 hectares), was situated south of Whitemark. Movement of ringtail possums between these two regions was known to occur. The area around the study site had been cleared for pasture but the site itself had been completely unaffected by fire or clearing since at least 1920 (D. Smith, personal communication). Coastal tea-tree, *Leptospermum laevigatum*, dominated the study area. Within each region *L. laevigatum* varied from dense stands of single-stemmed trees, 6-8 m tall with a diameter at breast height of about 13 cm, to more open stands of tall (12 m) and multi-stemmed trees (D.B.H. = 30 cm). The highest estimated densities of adult ringtail possums in Whitemark Beach and Paddies were 2.37 individuals per hectare and 2.47 individuals per hectare, respectively. Further details of the site are provided in Munks (1990, 1995).

METHODS

The study was carried out over 13 visits, each of approximately two weeks duration, between April 1986 and July 1988. Searches for nests built by ringtail possums were carried out during the day. The ringtail possums' nests or dreys were found predominantly in the branches of *L. laevigatum* although nests were also located in other tree species including the forked branches of *E. globulus* and in the understorey bushes of *L. parviflorus*. When a nest was located the tree containing the nest was gently shaken and any animals that emerged were encouraged to move away from the nest tree by further shaking of nearby trees. When the possum reached a suitable tree or bush, it was dislodged by shaking the tree vigorously and then caught by hand. This technique has also been used successfully in other studies on ringtail possums (Thompson and Owen 1964; Hird 1975; How *et al.* 1984; Pahl 1987).

All established nest sites (located on previous trips) in the study area were examined during each visit and new nests were located and recorded. The nest site and the number and identity of individuals sharing the particular nest site were noted at each capture. All individuals were released on the tree containing the nest immediately after handling. Animals were tagged in one ear with a numbered 1 cm fingerling fish tag (Saltlake City Stamp Co.). All animals were sexed and weighed with a Pesola (1.5kg) spring balance. The reproductive status of captured animals was assessed from testes size in males and condition of the pouch and nipples in the female (see Munks 1995). Females were classified as juvenile, non-lactating adult, lactating with pouch young and lactating with large mammary gland but no pouch young. Females in this latter category were accompanied by a "back-young" ie an offspring which usually clung to the back of its mother when out of the nest (Fig. 1).

Radio transmitters (tuned loop brass collar tags, Biotrack, U.K.) were attached to fifty-three animals (twenty-nine females and twenty-four males) at Whitemark Beach between October 1986 and June 1988 as part of an energetics study (Munks 1990; Munks and Green 1995). Daily location of these radio-collared animals in their nests over five day periods provided information on the frequency of changes in nest site by individuals. This information was collected on 47 occasions between October 1986 and January 1988.

Dependent young (i.e. back-young) were not included as a member of the nest in the analysis of nest sharing. Comparisons between two means were made using Student's t-tests (un-paired and two-tailed). Percentages were transformed using the arcsine transformation and a square root transformation was used for counts of nest site changes to improve normality of the data.

Fig1. Adult female ringtail possum with back-young.

RESULTS

A total of 323 observations of nest group composition were made throughout the capture-mark-release program (Table 1). No nests were observed to be occupied by more than four individuals (excluding back-young). Single individuals and male/female pairs formed the dominant nest groups throughout the year (Table 1).

The proportion of nests examined that were occupied by a single female was greatest during the late spring and summer months (41 - 63%) and lowest during August and September (2% and 6% respectively). The proportion of nests occupied by single males did not show as great a seasonal fluctuation as that for individual females with the highest percentage of nests occupied by single males found during the summer months (36 - 63%).

The percentage of male/female pairs was highest (25 - 41 %) during May and June and remained relatively stable throughout the winter and into early Spring. During January none of the nests examined were occupied by male/female pairs.

Only two nests were found to be occupied by two males. Both of these consisted of an adult and a juvenile. Similarly, the two female nest group always consisted of an adult and a juvenile. In many cases the juvenile was identified as the female's offspring from the previous year. One young female was found with her mother up to 16 months after her birth.

Nest groups consisting of three or more animals comprised a mixture of an adult male/female pair and juveniles that were young from a previous litter. The most frequently observed combination was that of an adult male/female pair and a juvenile female.

The composition of nest groups appeared to vary according to the reproductive status of the adult female occupying the nest (Fig. 2). Females suckling back-young usually nested by themselves. Occasionally a female was found alone with the back-young in another nest nearby. In contrast, a high percentage of nests occupied by females suckling pouch young also contained an adult male (Fig. 1). No lactating females were found in nests occupied by four animals (Fig. 1).

The number of changes to the nest site utilised over periods of five days for different categories of adults were as follows (mean ± standard deviation (number of individuals)): males 3.1 ± 0.8 (23); non-lactating females 2.9 ± 0.7 (10); females with pouch young 2.4± 0.9 (7); females with back-young 1.7 ± 0.5 (6); all females 2.5 ± 0.9 (24). Males moved from one nest to another significantly more often than females ($t = 2.52$, $df = 45$, $P<0.05$). There was no significant difference between the number of nest site changes made by non-lactating females and females suckling pouch young ($t=1.23$, $df = 15$, $P>0.05$). However, females suckling back-young made significantly fewer changes in nest site than non-lactating females ($t = 3.70$, $df = 14$, $P<0.01$).

Table 1. Seasonal variation in the percentages of nests occupied by different combinations of males (M) and females (F) (back-young excluded) at Whitemark Beach.

Month	Group composition										Total no.
	F	M	FM	2F	2M	2MF	2FM	2F2M	3MF	3FM	of nests
Jan.	44.4	40.7	-	11.1	-	3.7	-	-	-	-	27
Feb.	63.2	63.2	15.8	5.3	5.3	-	10.5	-	-	-	19
Mar/Apr.	25.6	27.9	30.2	2.4	-	7.0	2.3	2.3	-	2.3	43
May	18.7	15.6	40.6	3.1	-	6.3	12.5	-	3.1	-	32
June	35.0	20.0	40.0	-	-	-	5.0	-	-	-	20
Juiy	29.2	25.0	33.3	8.3	-	-	4.2	-	-	-	24
August	2.2	25.0	25.0	-	-	5.6	5.6	-	-	-	18
Sept.	6.1	35.5	38.7	-	-	3.2	6.4	-	-	-	31
Oct.	52.9	17.6	26.5	-	-	2.9	-	-	-	-	34
Nov.	52.6	21.0	10.5	10.5	5.3	-	-	-	-	-	19
Dec.	41.1	35.7	14.3	1.8	-	1.8	5.4	-	-	-	56
All	36.0	30.0	23.0	3.4	0.6	2.8	4.6	0.3	0.3	0.3	323

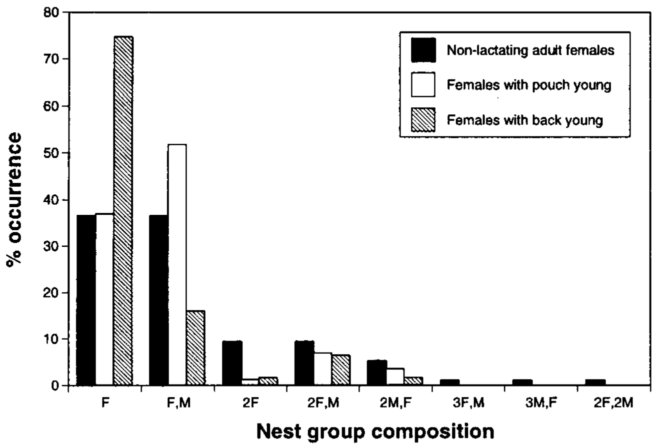

Fig. 2. Comparison of the occurrence of adult females of differing reproductive status in nest groups of different composition.

DISCUSSION

Nest groups of the ringtail possum in this study appeared to be composed of members of a family group as noted in other studies of ringtail populations (Thompson and Owen 1964; Marsh 1967; How *et al.* 1984). Intolerance between males may be the reason that few instances of nest sharing by adult males were found. Although immature animals of a previous litter were occasionally found sharing a nest with an adult male and female pair, juvenile males were rarely found in a nest with their parents after they had reached sexual maturity. This suggests that adult males, as well as being intolerant of unrelated males, are intolerant of their male offspring. In contrast, daughters were often found sharing a nest with their parents after they had become sexually mature. Henry (1984) has proposed that elimination of breeding competition is the basis of the intolerance of juvenile males by adult male greater gliders *Petauroides volans*. Pahl (1985) also proposed that older dominant male *P. peregrinus* exclude young males from females.

The long term fate of young male ringtails was not investigated in this study. However, a similar intolerance of male offspring in brushtail possum *Trichosurus vulpecula* (Dunnet 1964) and *P.volans* (Henry 1984) is followed by dispersal of juvenile males leading to a female-biased sex ratio. However, Pahl (1985) did not find a pattern of male-biased dispersal in *P. peregrinus*. In addition, the sex ratio of populations of *P. peregrinus* in Victoria (Thompson and Owen 1964; Hird 1975) and in this study did not appear to differ significantly from a 1: 1 ratio. How *et al.* (1984) did find the sex ratio to be biased toward females in a population at Sandy Point Victoria, but they attributed this to the higher survival of adult females compared with adult males (also noted by Pahl 1987). Further studies on the survival, dispersion and sociality of *P. peregrinus* are needed before the fate of young male ringtails excluded from the family group can be resolved.

During the breeding season and when the females are suckling pouch young (April-September, Munks 1995) male and female pairs were common. Nests containing more than two adults or juveniles were also mainly encountered at this time. The larger nest groups could be a result of the social behaviour of ringtails at this time of year. However, there may also be a physiological advantage gained by the larger sleeping groups. Smith and Lee (1984) suggest that the formation of sleeping groups noted in the smaller species of arboreal marsupials may be related to heat conservation. Individual ringtail possums were found on their own most commonly during the spring and summer months, both in this study and by How *et al.* (1984). The larger nest groups during the winter months may therefore be a strategy to minimise energy costs associated with thermoregulation during the cooler winter days.

Data presented here and by Thompson and Owen (1964) suggest that nest sharing between mated adults of *P. peregrinus* tends to cease after the young have emerged from the pouch. This was similar to the situation observed in *P. volans* by Henry (1984) in which nest sharing only involved females who had failed to raise young. Smith and Lee (1984) propose that when females are solitary they do not need to share resources and hence may obtain more nutrients for reproduction. Alternatively, the tendency of female ringtails to remain alone whilst suckling back-young may have a more specific physiological basis. Ringtail possums appear to suffer heat stress during hot summer days (Pahl 1987; personal observation) and to facilitate evaporative heat loss they lick their paws, forearms and tail. Females suckling back-young would need to avoid heat stress at a time when their energy and water requirements are greatest (Munks and Green 1995). Therefore exclusion of males from the maternal nest may be a strategy to minimise the sleeping group size and hence reduce the chance of heat stress.

Females tracked in this study appeared to remain in a particular nest site after their dependent young had emerged from the pouch. Similar observations were made by Morton (1977, cited in Read 1985) who found that female *Sminthopsis crassicaudata* with older young were most likely to be caught at the same nest site. In some mammal species, particular nests are built for warmth and protection of the young from predators. These maternal nests appear to be larger and more dense than ordinary sleeping nests (Walser 1977). Several observations were made in this study of ringtail possums moving on the ground. Attempts to observe the animal's behaviour on the ground were not successful since they were easily disturbed. However, most of these observations were made during mid to late spring and coincided with the appearance of new nests in the study area during October prior to emergence of the young from the pouch. Thompson and Owen (1964) also note increased nest-building activity at a time when most of the female ringtail possums carried pouch-young. Perhaps the construction of particular maternal nests is the reason behind this increased nest building activity.

The results of this study support the observations made in other field studies that the 'sleeping' group structure of *P. peregrinus* falls into either the solitary, maternal, pairs or family class as defined by Smith and Lee (1984). Changes to the nest group composition throughout the year may have a physiological as well as a social basis. The fate of dispersing juvenile males and the role of sexually mature daughters found sharing a nest with their mother and siblings requires further investigation.

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DISTRIBUTION OF THE BURGUNDY SNAIL *HELICARION RUBICUNDUS* ON THE FORESTIER AND TASMAN PENINSULAS

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Abstract. *Helicarion rubicundus* is an extremely localised species of snail that is restricted to wet sclerophyll and mixed forests on the Forestier and Tasman Peninsulas. The results of all surveys for the species were collated to better define the species' range and reservation status. *H. rubicundus* appeared to be more common in wet sclerophyll forests containing eucalypt species that shed copious bark in long sections, such as *Eucalyptus viminalis*, *E. globulus* and *E. regnans*. On the Forestier Peninsula no significant extension of its range beyond that previously documented was found. *H. rubicundus* was located in State Forest, Abel Tasman National Park and numerous smaller informal reserves and also occurs on private property. The southern section of Forestier appears to have a more continuous distribution, with a more patchy distribution north of (approximately) Hylands Road. On the Tasman Peninsula the species was located from over a five km north-south range between Arthurs Peak and Balts Road in State Forest and informal reserves. No snails were found further south along Fortescue Bay Road, west of Arthur Highway or east of Tatnells Hill Range.

INTRODUCTION

Surveys of the burgandy snail *Helicarion rubicundus* conducted in 1989 revealed a limited distribution in wet sclerophyll and mixed forests predominantly in State Forest on the Forestier Peninsula and a small area of the Tasman Peninsula (Taylor 1991). The species has been recommended by the Scientific Advisory Committee for inclusion on the schedule of the *Threatened Species Protection Act 1995* with the status of rare. Comprehensive surveying and collation of published and unpublished records were conducted to better define its range and reservation status.

METHODS

Searching was only conducted in wet sclerophyll forests with the presence of *Banksia marginata* and *Exocarpus cupressiformis* being used to delineate dry forests from wet forests. Dry forests were not searched as Taylor (1991) had shown *H. rubicundus* did not occur in this forest type. At each site surveyed, searching was conducted for 30 minutes or until an adult *H. rubicundus* (Fig. 1) was found, as juveniles of *H. rubicundus* and its congener, *Helicarion cuvieri*, were difficult to distinguish. Searching concentrated on curled bark, which appeared to be the preferred shelter site for the species (Taylor 1991). Other sheltering sites, including the underside of rocks and logs and within cutting grass (*Gahnia grandis*) clumps, were also checked, particularly in sites with less curled bark.

A number of habitat characteristics were recorded including dominant *Eucalyptus* species present and the number of *H. cuvieri* found. Grid co-ordinates were estimated from 1:25 000 maps.

Surveys of 96 sites were undertaken by Helen Otley in April-June 1999 and 34 locations by K. Bonham between 1985 and 1998. In addition the 26 locations searched by Taylor (1991), three locations by B. Brown in 1996 and the type locality from Dartnell and Kershaw (1976) were also collated. The described surveying technique was used in all cases.

HABITAT PREFERENCES

H. rubicundus was recorded at 41 of the 96 sites sampled by Helen Otley. The

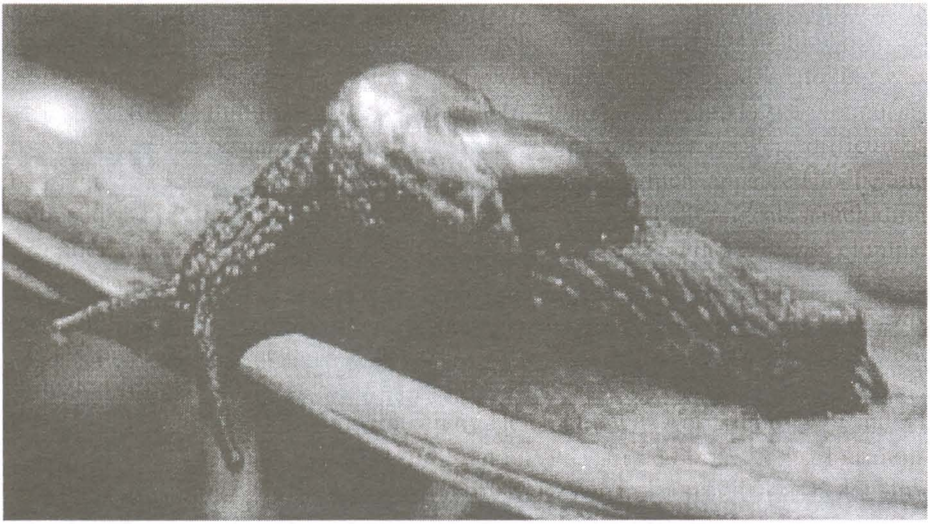

Fig. 1. The burgandy snail *Helicarion rubicundus*. Body length of the specimen shown is approximately 35 mm. Adults of this species are readily distinguished from its congener *H. cuvieri* by their burgandy body colour.

species appeared to be more common in wet sclerophyll forests containing eucalypt species that shed copious smooth bark in long sections, such as *E. viminalis*, *E. globulus* and *E. regnans*. Smooth bark was especially favourable as a shelter for juvenile specimens. In forests containing only *E. obliqua*, which has mostly fibrous bark, the snail was found on only six of 20 occasions and was more likely to be found in areas within its core range and/or areas with smooth bark species located nearby. The sites surveyed by Kevin Bonham also supported this finding. However this difference in rate of occurrence between these forest types was not significant (χ^2= 1.67, df=1). In general, Tasmanian snails are rarely affected by differences in eucalypt species present.

Snails were generally not found in damp sclerophyll forests, such as northerly facing slopes, suggesting that *H. rubicundus* is possibly highly sensitive to soil and litter moisture.

The lack of older plantations within the snail's core range on either Forestier or Tasman Peninsula made it difficult to assess whether the burgundy snail recolonises plantation areas. *H. rubicundus* was located in a 20 year old plantation on the Tasman Peninsula. However this plantation may not be representative of plantations today as it was a different eucalypt species (*Eucalyptus sieberi*) and different establishment methods may have been used. A recent survey has shown that many Tasmanian snail species are common in 15-20 year old eucalypt plantations, but that *Helicarion cuvieri* is very much scarcer in plantations generally than native forests (Bonham 1999). *H. rubicundus* was found within some 15+ year old silvicultural regrowth and areas with past selective logging (Taylor 1991; this study). *H. rubicundus* was also located at one unlogged site where there was evidence of a cool burn having occurred in the last five year.

There was no apparent relationship between the density of *H. rubicundus* and *H. cuvieri*. *H. cuvieri* was found in 97 % of the sites surveyed by Helen Otley, suggesting it is more uniformly distributed than *H. rubicundus*. However it was observed that *H. cuvieri* generally showed a greater variation in body colour (black, chocolate brown and orangeish) at sites where *H. rubicundus* was absent and more black individuals were present at sites with *H. rubicundus*. This suggests that more intensive searching may need to occur at sites with a high density of darkly coloured *H. cuvieri* individuals. Elsewhere in Tasmania, *H. cuvieri* is often darker in colour in very wet forest sites similar to those where *H. rubicundus* occurs (K. Bonham, personal observations).

DISTRIBUTION ON THE FORESTIER PENINSULA

On the Forestier Peninsula, no significant extension of its range was found, with the burgundy snail found in 34 of the 61 sites searched by Helen Otley. The southern section of the Forestier Peninsula appeared to have a more continuous distribution,

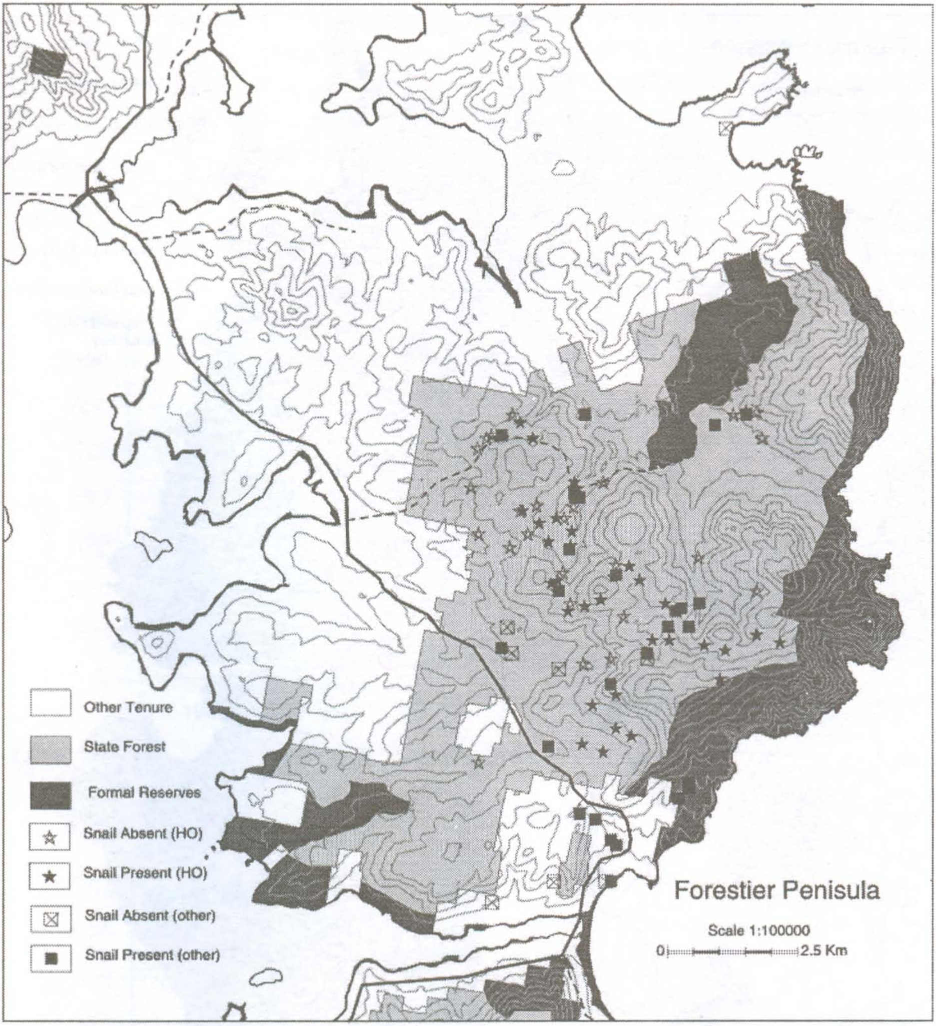

Fig. 2. The location of successful and unsuccessful searches for the burgandy snail *Helicarion rubicundus* on the Forestier Peninsula.

between Fazackerleys Range, Blackman Hill and Bellettes Creek/Browns Creek (Fig. 1). In the far northwest corner of its range *H. rubicundus* was only located at one of five sites searched by Helen Otley despite the abundance of smooth bark eucalypts. Information suggests the species is also present in low densities in the northeast section of its range. Thus the species was located at one site in this area by Taylor (1991) and by Kevin Bonham, but was not found in four separate 30 minute searches

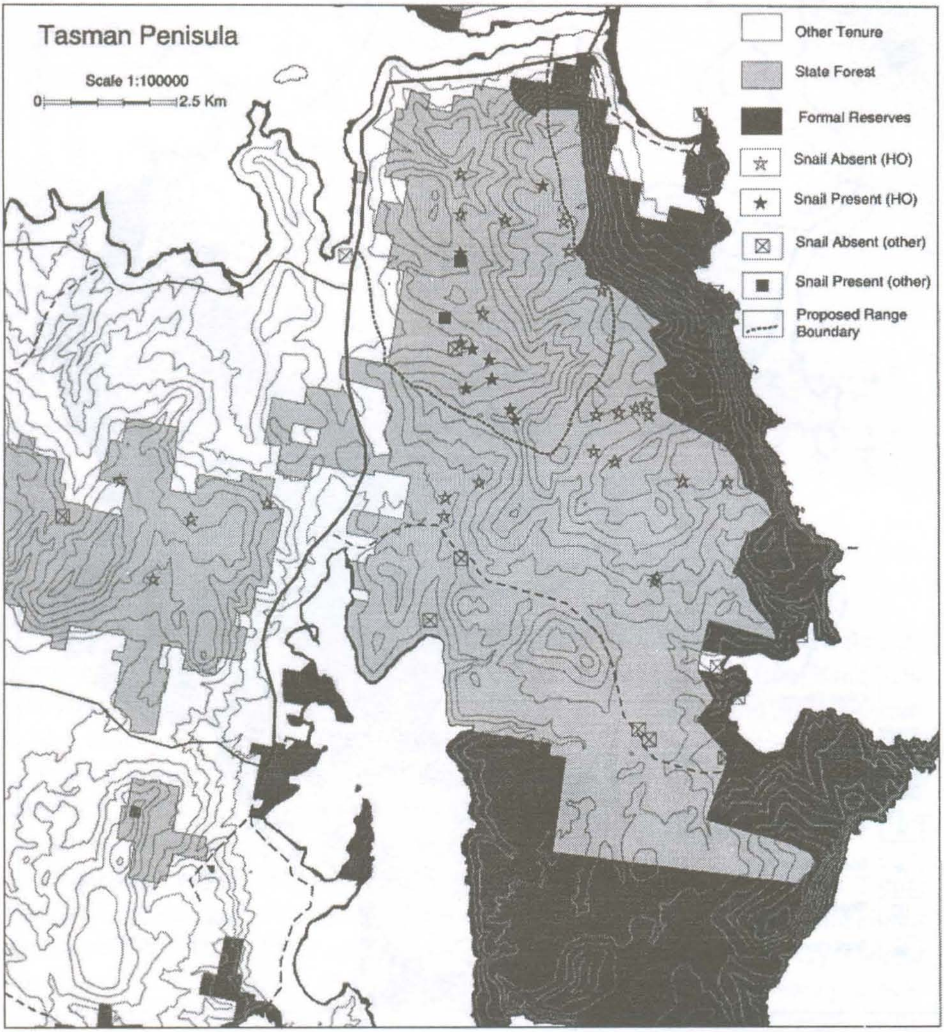

Fig. 3. The location of successful and unsuccessful searches for the burgandy snail *Helicarion rubicundus* on the Tasman Peninsula. The proposed boundary of the range on this peninsula is shown by the dotted line.

by Helen Otley. There were no other areas where the species appeared to be absent from wet sclerophyll forest on the Forestier Peninsula. Burgundy snails were also found in Abel Tasman National Park and numerous smaller informal reserves (Fig. 2).

DISTRIBUTION ON THE TASMAN PENINSULA

H. rubicundus had a far more restricted distribution on the Tasman Peninsula; seven sites located over a five km N-S range between Arthurs Peak and Balts Road (Fig. 3). The snail was also less easily found within its range here compared to the Forestier Peninsula.

No snails were found in forests south of the ridgeline along Balts Road, despite surveying at 18 sites. *H. rubicundus* was also not located in forests west of Arthurs Highway, despite six surveys in wet *Eucalyptus delegatensis* forest. The eastern limit of the species appears to be along Lichen Hill/Tatnells Hill Range. The reduced moisture content of soil and litter on the northern slopes of ranges may possibly limit the range of the species. Burgundy snails were located in three small informal reserves, including the Taranna Forest Walk, but Abel Tasman National Park is outside of the snail's range on the Tasman Peninsula.

STATUS

The species has been classified as rare by the Tasmanian Scientific Advisory Committee for threatened species. Only a very small proportion of the range of *H. rubicundus* occurs on private property. The species does occur in informal reserves and within the Abel Tasman National Park. However, the majority of its range is State forest designated for production forestry. The preliminary results suggest that the species can inhabit silvicultural regrowth and that it also may occur in older plantations. Intensification of plantation development on State forest is planned within the range of the species. Hence, the potential impact of plantation development upon *H. rubicundus* requires further investigation.

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DELINEATION OF CRITICAL HABITAT FOR THREATENED SPECIES

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INTRODUCTION

Under the *Threatened Species Protection Act 1995*, critical habitat for any listed threatened species is the whole or any part of the habitat that is critical to the survival of that species. The Act states that the Scientific Advisory Committee (SAC), which was constituted under the Act, is to provide advice on the criteria to be used to determine critical habitats for threatened species. This paper discusses the approach that has been adopted by the SAC in developing a logical and scientifically justifiable process for the delineation of critical habitat.

THE SUGGESTED APPROACH

In Victoria and elsewhere, critical habitat for threatened species has been defined as those areas in which the species occurs, and those areas that are necessary to maintain appropriate conditions for a species within the areas in which it occurs. This approach is based on the general assumption that all populations of threatened species are likely to be important to their future, and has the practical virtue of avoiding legal arguments about exactly how many individuals need to be maintained. However, this form of definition of critical habitat ignores meta-population dynamics and does not allow for the potential for recovery.

In order to account for such factors the SAC suggests the following approach for the delineation of critical habitat for threatened species in Tasmania.

The critical habitat for a threatened species includes that part of the habitat of any listed species that is critical to the survival of that species. Usually in the case of endangered and vulnerable species, this would include all areas that are currently occupied by the species and which are at risk from threatening processes, unless:

a) the threatening processes limiting a species' population do not relate to the availability of habitat or its modification (eg. hunting, fishing, predation by feral animals, diseases). In such cases no critical habitat would be declared;

b) part of the area occupied by the species is only inhabited intermittently, with individuals in this area not contributing to the perpetuation of the species. In this case only the areas necessary for the core populations would be declared critical habitat;

c) an area does not support populations of the species at present but needs to be protected in order to provide for future expanded populations, in which case it would be declared critical habitat.

CASE STUDIES FROM TASMANIA

In order to illustrate some of the issues associated with the delineation of critical habitat and how they would be dealt with by this proposal, a number of case studies of Tasmanian-listed species are presented below.

Vascular Flora

There are many species that exhibit different location patterns between years or decades, depending on climatic fluctuations or local successional processes. These species are generally moderately to highly vagile. The everlasting daisy, *Leucochrysum albicans* is one Tasmanian example. Populations have become extinct because of successional change that removes the bare ground necessary for their regeneration. Other populations have become established in places from which the species was previously absent but where appropriate regeneration conditions have been available. It is likely that the species has always been highly dynamic in its local occurrence. It is threatened probably because the distances between established populations and potential new sites have been increased by the widespread conversion of native grasslands and woodlands to the unsuitable habitats of improved pasture and crop lands. Any further loss of natural and semi-natural grassland and woodland in which it is not established at present for successional or stochastic reasons is likely to increase the probability of its extinction. Thus, in the case of this species, critical habitat for its long-term survival cannot be defined by its present distribution. In fact, its recovery might require translocation over land use barriers.

Other species also occur as metapopulations, but their distributions are very circumscribed, and are readily defined on maps. Thus the local endemic *Tetratheca gunnii* is restricted to the ultra mafic rocks in the hinterland of Beaconsfield and critical habitat for the species can be defined by reference to the geological map for the area.

Non-vascular Flora

The state of knowledge of the distribution, biology and threat status of non-vascular flora is very scanty. For all groups, information on the critical habitat is likely to be more important than raw distributional data. However knowledge of critical habitat, entails problems of scale - it is difficult to define the minimal area of habitat, and its nature and stability are often unknown.

Some species, especially fungi, are seasonal. Furthermore, many species are successional and it is unclear how criteria should be applied to colonisers. Distribution data can be indicative for species with many known locations. However, this is not the case for species that have only been recorded occasionally, and then only incidentally through other studies. These problems are complicated by the lack of specialists and the consequent difficulty of identifying species in the field and of verifying data. Identification itself may require removal of the specimen, so adding to the depletion of the species. Some examples of lichen species not currently listed but having narrow habitat ranges are given below.

Pyxine nubila (unlisted)

This species is found in Tasmania, Saudi Arabia, Ethiopia and Kenya. It is unreserved in Tasmania and is found only in the Dysart area, on dry sandstone or mudstone overhangs on bluffs in very dry open eucalypt woodland or rough pasture. It is a very rare localised species and all known sites are subject to fire, grazing and possibly fertilising. Critical habitat could be defined and mapped by the occurrence of the appropriate geological formations in the area.

Rocellinastrum flavescens (unlisted)

This Tasmanian endemic species is found only in alpine areas, mainly on the western Central Plateau, where it is confined exclusively to the leafy twigs of conifers (*Athrotaxis, Microstrobos, Diselma*). Although all known sites are reserved, the species and its habitat are highly vulnerable to fire. Definition of critical habitat is difficult because the species is not ubiquitous on the conifers. In this case critical habitat probably would not be defined. Rather, management should be aimed at maintaining the distribution, health and vigour of the conifer populations.

Heterodea muelleri (unlisted)

This species is found in all Australian States, New Zealand and New Caledonia. In Tasmania it is found in lowland grassy dry sclerophyll and woodlands, mainly in the Midlands, where it grows on soil in open sunny clearings. It is reserved at Trevallyn and in the Freycinet National Park. This species is very common in mainland Australia, but is localised in Tasmania. The reserved populations do not adequately represent the species, as they are at the margins of its ecological range. Grazing and trampling are deleterious but occur over much of the species' range. Many previously known populations have been eliminated by conversion to pasture. Its habitat is readily defined on maps, being some of the remnant native vegetation patches recognised as threatened by pasture establishment. These patches also contain many listed vascular plant species.

Vertebrate Fauna

Migratory and wide-ranging birds provide examples of threatened species that might have more extensive critical habitats than is indicated by their distribution at any given time. For example, the swift parrot requires adequate food (nectar) throughout its migratory range and suitable nesting habitat in Tasmania. The areas in which it feeds are likely to vary from year to year, depending on the patterning and intensity of flowering. Some of these areas could constitute critical habitat for the long term survival of the species, if the populations are limited by food in a part of their range.

Another example relates to the consequences of the mitigation of threatening activities within present ranges. For example, if the low population of orange-bellied parrots has been caused by inappropriate fire regimes in its breeding area, all of which is reserved, then the adoption of an appropriate patch-burning regime could lead to strong population growth. Its recovery might then be limited by the availability of its food plants in south-eastern Australia. At present potentially only a relatively small proportion of the salt marshes of Victoria might be sufficient to provide for its needs, whereas in the future a much greater proportion may be needed. Thus the concept of critical habitat based on present occurrence can potentially ignore habitat that might be necessary for the future recovery of a species.

Other problems arise in the delineating of critical habitat where the survival of a species depends not only on the maintenance of the area in which it lives, but also on material flows from a much larger, and often variable, area. The Pedra Branca skink provides an excellent example of this, with its survival depending on a seasonal flow of food brought in by nesting seabirds, which in turn depend on the availability of food over a wide area of ocean.

Some other specific examples of issues that arise are highlighted by the following species.

New Holland Mouse (rare)

This species is restricted to coastal areas in pockets from Asbestos Range National Park to Cape Portland. It is also in the Mt William National Park and has been recorded from Bicheno and Coles Bay. All known sites are below 200 m asl and within 15 km of the coast. The species requires a sandy substrate with a floristically diverse overstorey. On the basis of current knowledge, the species is largely confined to coastal reserve areas. The species requires regular burning to maintain suitable habitat conditions. Hence it could be threatened by loss of habitat if fire were to be excluded from heathland and open woodland within its range.

Critical habitat could be defined and mapped as being all the existing locations of the species. However this species is probably best dealt with by appropriate management regimes rather than declaring critical habitat.

Eastern-barred Bandicoot (nationally vulnerable)

This species is distributed mainly in the north-west, south-east and localised pockets in the north-east, but is largely absent from the midlands. Population density fluctuates according to season and rainfall patterns. Traditionally its native habitat was open grassy woodlands but today the species is flexible, preferring any open grassy areas on deep fertile soils, with good rainfall and dense cover available. Threatening activities include fragmentation of habitat especially loss of cover coupled with predation by domestic and feral animals.

The species is locally extinct in its native habitat but does well in disturbed agricultural lands. Remnant grassy woodlands in the Midlands could be defined as potential future critical habitat, or 'hot spots' containing good populations in disturbed areas (eg Huon) could be identified as core critical habitat, or both. However, in this case critical habitat is probably not the most appropriate way of proceeding to secure the future of the species.

Wedge-tailed Eagle (vulnerable)

This species is distributed throughout Tasmania and offshore islands. Total population is estimated to be 300 - 400 individuals (100 breeding pairs). Some biological factors limiting its distribution and population include: spacing of the territory of adjacent pairs and the requirement for tall old growth eucalypts in sheltered situations for nesting. Threats include loss of nests and/or nesting habitat (either through fire or clearing), disturbance during the breeding season and persecution.

It is not practicable to list all of the area the species occurs in. Thus the approach has been to protect known nest sites including a 10 ha buffer around the site. There are old growth patches containing suitable habitat throughout the State, but the density differs regionally. Determination of critical habitat would need to consider limiting factors in the various areas. The issue of identification of suitable habitat for future potential nest sites also needs to be considered.

Grey Goshawk (rare)

This species nests in wet and mixed eucalypt forest, rainforest, and swamp forest. Concentrations occur in the north and west with localised hot spots in the north-east and south-east. The population is estimated to be about 110 breeding pairs. Established pairs are sedentary with wide dispersal of juveniles. Threats involve loss of habitat and persecution.

The main elements to target for critical habitat are known nest sites and foraging and nesting habitat in hot spot areas. There is the issue of establishment of new nest sites by new pairs as well as that of locating nest sites for pairs where nest sites are not known. For this species critical habitat would be centred around hot spots.

Little Tern (endangered, nationally endangered)

The species nests on beaches and islets associated with estuaries of exposed sand and low vegetation. It migrates during winter. It is distributed mainly in the north-east and east but information is scant. The population is estimated at fewer than 10 breeding pairs. The species suffers major disturbance while nesting on beach fore dunes. Some of this disturbance is natural, such as unusually high tides, but it is mainly from humans eg recreation.

To determine critical habitat it is necessary to identify specific beaches used for nesting over a long period, and to include a buffer around nest sites. Management would then mainly need to be on a seasonal basis to provide control of human disturbance. Some longer term habitat protection measure such as control of marram grass might also be required.

Invertebrates

Many invertebrates are highly sedentary, with restricted powers of dispersal. Thus their critical habitat is likely to be a subset of their geographical range. Other species exhibit marked fluctuations in their geographical extent over seasons, years or decades. These may have core areas that act as the sources for expansion in good years, while the peripheral populations tend to die out as conditions worsen. One life stage of a species might be widely distributed, but not lead to any long-term establishment outside its core areas. However, in the case of threatened aquatic species, survival will be dependent on conditions upstream and in the catchment, not only because of water quality issues but also because current-induced drift moves invertebrates downstream so that there has to be an upstream recolonisation by adults. Cave invertebrates, both aquatic and terrestrial, are highly dependent on conditions in the cave's catchment. In these cases, assessment of critical habitat will have to include the catchment. A number of species at risk depend on decaying logs for at least some of their life cycle. For these species, an appreciation of the dynamics of log recruitment and decay is essential if their populations are to be maintained.

Jewel Beetle *Stigmodera insculpta* (presumed extinct)

This species is an endemic jewel beetle last recorded from near Miena in the 1920s. Jewel beetles are in decline in many parts of Australia, largely due to clearing of heathlands. In Western Australia, where several hundred species occur, land clearing and over-collecting have been identified as threats and all jewel beetles are protected by law irrespective of their population size or number. Larvae are stem borers, possibly in *Leptospermum*. In the case of the above species, survey is needed to confirm its status and to nominate critical habitat that cannot be identified at present.

Moth *Chrysolarentia decisaria* (presumed extinct, recently rediscovered)

This is a day-flying moth that occurs in open habitats. On the basis of unusually good historical records from 1888-1904, it appears this species was formerly widespread in the Tasmanian Midlands. All these sites have been revisited over the last ten years, along with many native vegetation remnants, without evidence of extant populations. In 1996 a precarious population was found at Township Lagoon Nature Reserve near Tunbridge where the larvae are associated with salt tolerant herbs. Loss of habitat and food plants are likely to be the key problems. At this site, hazards include vehicular movement, trampling and the potential for over collection. This species has also apparently disappeared from the western grassy plains of

Victoria since the 1920s.

On present knowledge critical habitat is the lower catchments of saline lakes in the Midlands which retain some native herbaceous flora.

Chaostola Skipper Butterfly (endangered)

This is arguably the rarest butterfly in Tasmania. Only a single breeding population is currently known although others probably exist. It is not known what threatens the species but it has been very uncommon at least since the 1940s. The mainland subspecies is also in decline.

Aspects of its biology make it vulnerable, especially its two year life cycle which subjects each generation to extended exposure to stochastic extinction events. Skipper butterflies typically suffer high parasitism and small populations are especially at risk. Although the larval food plant *Gahnia radula* is widespread in eastern Tasmania, only a tiny proportion of potential habitat appears to be used for breeding. *Pimelea nivea* is an important nectar source for the adults. Males are probably territorial like related species and hence population densities are likely to be low. There is currently minor illegal collecting pressure on this species.

Critical habitat in this case will be wherever breeding populations can be found in nature. Such sites might sometimes be quite degraded. For example, a recent population at Conningham was breeding in low open forest subject to very frequent fires. Detailed survey is an essential first step.

Moth *Amelora acontistica* (vulnerable)

This is a conspicuously patterned geometrid moth known from two coastal sites in south-east Tasmania (Cremorne and Lauderdale) and a site on Kangaroo Island in South Australia. Development of management prescriptions is inhibited by lack of knowledge of the life history. Based on knowledge of related species, larvae possibly feed on annual native herbs in saline coastal habitats.

Critical habitat can only be defined once the life cycle is understood. For example, the critical habitat must contain the food plant.

Ptunarra Brown Butterfly (vulnerable)

This endemic butterfly is sedentary and largely restricted to elevated grassy plateaux or grassy woodlands. Comprehensive surveys in recent years have found approximately 150 populations, although many of these may be too small to be viable in the long term. Threats include loss of native grasslands due to plantation forestry on private land, inappropriate burning and grazing regimes and weed invasion. The fluctuations in numbers of some populations are being monitored.

Critical habitat for this species are core areas (>10 ha) which support large perennial populations. Sites less than 5 ha in extent are probably subject to extinction and recolonisation cycles since many small habitat patches are unoccupied. The clinal variation in the phenotype of this species is noteworthy and should be conserved as an example of genetic biodiversity. Therefore samples of habitat across the geographical range are needed.

Mendum's cave beetle (vulnerable)

This troglodytic beetle has a restricted range within the large Exit Cave system where it is found on mud banks, flood litter and under stones at the edge of stream ways. Its critical habitat is thus smaller than the whole Exit Cave system, but it should include the catchment of the passages in which it is found. These may be quite local, both within the cave system and on the surface.

Carabid beetle *Catadromus lacordairei* (rare)

One of the largest beetles in Tasmania, this species is restricted to the northern Midlands. Being winged and fast running, it is capable of considerable dispersal but its actual distribution appears restricted to native grasslands on cracking soils. It is not known to survive in improved pasture. Both larvae and adults are predatory. Threats include conversion of native vegetation to pasture, and trampling by overstocking. A significant population occurs on the margin of Campbell Town and is potentially vulnerable to loss of habitat due to urban development in the future. All known populations are on private property.

Critical habitat will be remnant native grasslands on clay-rich soils (typically basalt derived) in the northern Midlands which are lightly grazed by stock or native herbivores.

Giant freshwater crayfish (vulnerable)

The world's largest freshwater invertebrate had a wide range across the north of the Tasmania, but with a clear disjunction at the Tamar graben. Its distribution has been fragmented by vegetation clearance, sedimentation and overfishing, and many populations have few large reproductive members. A moratorium on fishing for the species was declared in 1998. Gene flow between populations in neighbouring catchments is likely to be very low.

Critical habitat for the species will be coincident with its current area of occupation, but should include areas upstream because of the necessity to maintain high water quality. Insufficient information is currently available to determine how far critical habitat should extend upstream of the occupied area.

Blind velvet worm (endangered)

The blind velvet worm is restricted to an area east of St Marys where it is found in approximately 200 km^2 of forest around Mt. Elephant and the Nicholas Range. It has a parapatric boundary with the giant velvet worm, *Tasmanipetus barretti. T. anophthalmus* is sedentary, and is found in llitter and logs or in scree slopes. Despite its troglomorphic appearance, it has not been found in caves.

The forested parts of the species range are critical, but within that area fallen logs and rock screes are particularly important.

Marine Flora and Fauna

Many marine species can be treated in the same way as terrestrial species, but there are problems with some listed species which are effectively vagrants in Tasmanian waters.

Spotted Handfish (nationally endangered)

Three small populations are presently known in the Derwent estuary and Frederick Henry Bay. These areas (total area is about 5 km^2) can be defined on a map and comprise the critical habitat of the species. Other areas in the lower Derwent estuary where the species has been recorded in the past may be critical to the future survival of the species. However, presently it cannot be demonstrated that these areas are critical habitat that would be colonised if the population increases or colonies move.

Cirrulicarpus polycoelioides (red alga) (potentially endangered)

The present distribution of this endemic species is unknown. Collections have been made at only three sites ie Orford (pre 1876), Fluted Cape on Bruny Island at a depth of 23 m (1972) and Great Taylor Bay on Bruny Island at a depth of 2-5 m (1972).

The latter two sites can be defined on a map and possibly could comprise the critical habitat of the species. The location from Orford was the site where the holotype was collected (described in 1876), and is so general as not to be useful. Some uncertainty is also associated with the latter two sites as the species is possibly widespread but ephemeral. Surveys of areas from Bruny Island would need to be undertaken before critical habitat was declared.

Loggerhead turtle (endangered)

No critical habitat can be defined for this species as the area it occupies is inhabited intermittently and is not essential to the survival of the species.

CONCLUSION

The above examples demonstrate that no single approach is able to cater for the multiplicity of distributional, biological and ecological situations and threatening processes that apply in Tasmania and thus that each species needs to be considered on a case by case basis. It is recommended that critical habitat normally only be defined when it is the most appropriate mechanism for ensuring the future survival of the species.

BOOKREVIEW

John Gould in Australia: Letters and drawings

By Ann Datta

Published by Miegunyah Press, 1997.

Reviewed by Don Hird

John Gould was a man of many parts. Perhaps best known as the "Bird Man", his worked spanned several continents when both travel and communication were difficult. His work extended to the *Mammals of Australia* and *Kangaroos* as well as many volumes on regional bird faunas and families of birds. Gould has been the subject of many biographical works and notes; this volume concentrates on correspondence relating to his Australian work.

Gould's background was modest although well-connected as his father was a gardener to members of the English aristocracy. Growing up in this environment, Gould may well have followed close to his father's footsteps had not his interest and skill in taxidermy been noticed and rewarded. Reading this book one is struck by the fortuitous timing of Gould's career. Taxidermy and presentation of exotic birds was becoming both an academic and popular endeavour in England early in his career. An age of empire and exploration was providing an abundance of curiosities, and museums and newly-established scientific institutions, together with private collectors, were buyers of collected specimens.

Lavish presentation was the hallmark of Gould's published work. Typically artwork would be reproduced as lithographs and hand coloured in folio-size volumes including Gould's own text. This was no simple task. The business acumen required was considerable, with volumes usually being sold by installments from a prospectus. Their natural history value is inestimable. Some species, like the broad-faced-potoroo, were hardly seen after initial collection by Gould's principal collector John Gilbert, and thus the typically meticulous notes in *Mammals of Australia* are about as much as we know of its biology.

Much of the local interest in this large biographical work will stem from Gould's extensive contact and correspondence with residents of Van Dieman's Land. These included notables such as Governor and Lady Franklin, Ronald Gunn, Morton Allport, and the Rev. Thomas Ewing, who acted as subscription agent and with whom correspondence extended over several decades. Some correspondence is mundane, for example business matters such as bankrupt Van Dieman's Land subscribers! Although there are many snippets of natural history interest I looked in vain for elaboration on, for example, Gould's dismal but accurate prediction of the demise of the thylacine. This tends to amplify the impression of thoroughness in Gould's original text. Wider contacts included Charles Darwin, Alfred Russell

Wallace and Professor Richard Owen.

Illustrations are a feature of this volume and, as with the correspondence, many are reproduced here for the first time. Elizabeth Gould was the artist responsible for many of the earlier illustrations, and after she died in childbirth other artists were employed. This, together with the correspondence, indicate both the necessary perseverance and the inspiration evident in the Goulds' work.