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ONE HUNDRED YEARS OF SNOWFALLS ON MT WELLINGTON

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INTRODUCTION

Who hasn't stopped for a minute to admire Mt Wellington in its coating of winter snow? The mountain presents a unique view of the range of weather from sea level to almost 1300 metres. The approaching rain or snow squalls can be seen as they sweep across the mountain giving Hobartians time to don their rain gear. The first winter snowfalls soon attract locals and visitors to the Pinnacle. They slip about on the snow banks near the summit, throw snowballs and pile snow on the car's bonnet to display like a badge as they head down the mountain.

Living in South Hobart and having an interest in meteorology we have seen the mountain in its many moods. Weather patterns, clouds, temperature lapse rates, depth of snowfalls and drift areas have been observed for over twenty years. An estimate has been made of the levels to which the snow has settled, at what elevation the snow is falling in the air, the depth of snowfalls and the depths of any drifts on the mountain. This interest has also lead us to collect information on past winters.

In this paper we have collated information on snowfalls on Mt Wellington. Various sources have been utilised. Snowfall averages for Mt Wellington are available from the Hobart Weather Bureau although the recordings only cover the period 1961 to 1972. The records appear to have been taken by staff at the TV building adjacent to the Pinnacle. Detailed observations have been made by the authors since 1976 from 366 Huon Road (120 m) and many trips have been made to the mountain. Less systematic weather data were also recorded at this same address from 1958 to 1975 and at 311 Strickland Ave (260 m) from 1956 to 1958. Temperatures on the Pinnacle have been recorded at the Mt Wellington Automatic Weather Station at 1258 m since 1990. Other indirect sources of Mt Wellington snowfalls exist in the recordings taken at the Springs (731 m) between 1908 and 1967. Martin (1939) used these records to produce a paper for the Royal Society of Tasmania on Mt Wellington snowfalls. Old notes from the Hobart Weather Bureau also provide information on snowfalls in the city. Press articles over the years from the Hobart *Mercury*, Launceston *Examine*, and Burnie *Advocate* have also provided details on weather and 'cold outbreaks'.

SNOWFALLS IN HOBART

One of the first settlers in Hobart was the Rev Robert Knopwood and it is from his diaries that we can read about the first recorded snowfalls on Mt Wellington. "On July 19th 1804, the mountain was covered with snow. At 7pm a wind from the south east, all the hills about covered with snow". *Bent's News* (an early Hobart newspaper) reports heavy snow in Hobart in 1814 (Aug 15,16 and 18), and 20 cm in June 1836. The 1880s produced two deep falls. The first was on June 20th 1882 when 5 to 8 cm of snow was reported to have fallen and the second was in 1888 on July 21 when snow fell off and on all day. This was followed by snow around Hobart for a further three days.

In the early 1900s snowfalls in the city occurred at least once each winter, if not on more occasions. The Hobart *Mercury* reports on September 28th 1904 that "snowballs were thrown at newly weds outside All Saints Church in South Hobart". In June 1906 it was snowing prior to the Tasmania versus Fitzroy football match at the Domain's top oval. Surprisingly it was snowing again the following year on 7th July at the football. In 1913 snow showers occurred in the city very late in the year (November 5th). Snow down to the Hobart waterfront was recorded in 1919 with snow overnight on June 29/30th being 3 cm deep in the city. This fall, though, was exceeded two years later in 1921 by one of the heaviest falls in Hobart. Snow overnight on July 30/31st saw residents awake to a city of white covered with 7 to 8 cm of snow. A postcard shows snowballers at play opposite the Hobart railway station in a scene reminiscent of an English Christmas card. As if this was not enough falls continued off and on during the day with a build up to about 10-12 cm by 3pm. Further snow and sleet showers occurred throughout August 2nd to 4th to make this a prolonged cold snap by local standards. Snow fell again on odd occasions in Hobart prior to World War 2 but nothing near the intensity of 1921. Golfers and football players found conditions rather icy when snow fell one Saturday in July 1939. In 1951, almost 30 years from the 1921 fall, another big fall covered the city. This time 1 cm of snow fell overnight on August 8/9th, but it continued to snow during the day with 7 cm at the Weather Bureau as snow covered streets, houses, and parks to sea level. Brief falls came and went in the following years. However, it was Hobart Airport which made the news on August 20th 1962. It was the first time an Australian capital city airport had been closed by snow.

With the growth of Hobart into some of the more hilly areas it was no surprise that bus services were affected and the Southern Outlet closed after snowfalls to low levels on August 5th 1976. Soon after, a spring snowfall on September 13th 1978 settled down to the wharves with a 2-3 cm cover in upper suburbs. One of the most widespread falls of the century occurred on July 24/25th 1986. A cold change on the evening of the 24th kept snow falling until daybreak the following morning. Many suburbs reported a snow cover of 4 to 8 cm. Traffic was disrupted, bus services were cut and schools shut for the day. Skiers were reported to have crossed the Tasman Bridge. Many residents had the unusual experience of walking to work, whilst fellow workmates in hillside suburbs battled to make headway. Since that time there have been the occasional snowfall in winter but they have been mostly confined to the upper suburbs. Exceptions were in June 1993 and September 1994. Snow showers fell to sea level and were reported from even the eastern suburbs.

MOUNTAIN SNOWFALLS

Snow can be experienced at any time of year on the mountain. Often a summer's snow shower can be a welcome relief at the end of a hot spell. Heaviest snowfalls tend to be from mid-winter through to early Spring (Figs. 1 and 2). Winter snowdrifts tend to develop in the same period and, depending on the depth of falls, can last until November or early December.

Studying information on snowfalls over the span of 100 years seems to indicate a contraction of the colder weather into a winter core. An item in the *Mercury* in 1913 suggested that in past decades winters were not as hard as in the "old days" with "fewer frosts and snowfalls where once there had been regular gales with rain, sleet, and snow".

The writer may have been thinking of October 28th 1901. The barometer fell to a very low level ushering in heavy mountaintop snow, gales, floods in creeks and bringing trees down. The following year (1902) saw a June fall of over 40 cm on the mountain. Then on September 19th 1903 the infamous "Go As You Please Race' was run with 15 cm of snow on the tracks. The inclement weather saw the death of two of the competitors.

The advent of a weather station at the new Springs Hotel in 1908 gave an indication of the snowfalls to that level (700 m) on the mountain. Certainly readings in the first half of the century seem to outstrip falls in recent years. Sooner or later each winter seemed to produce snowfall depths of between 15 to 25 cm with even deeper snows at times. Records were off to an impressive start with snow at the Springs recorded as late as December 30th in 1909. September 1914 saw a day's fall of 45 cm, then January 1916 scored 243 mm of rain which produced floods in the city. Five days following June 18th 1919 produced over a metre of snow, and as if this was not enough, a further metre fell on July 1st. There is no record of the Pinnacle drifts but they must have been extensive. A high school trip to the Pinnacle found it all a bit too much with some students falling on the descent and needing to be rescued from a ledge. Just to show the contrast in conditions, the following summer saw a big fire burn out the lower slopes of the mountain from Ridgeway to the Organ Pipes. An item in the *Mercury* commented on how snow cover used to last all winter but that fires had removed the cover that protected the snow.

Late July and early August 1921 saw heavy falls on the mountain with the Springs recording 60 cm with 2 m drifts on the mountain tracks. An unfortunate traveller succumbed to the extreme conditions and went missing between the Waterworks and Ridgeway as snow drifted to depths of 1 m in the gullies. His body was found some weeks later.

The 1920's saw the development of skiing on the top slopes as increasing numbers of Hobartians visited the mountain each winter to see the deep falls and play in the snow. Walkers to the Pinnacle in April 1922 reported 1 m of snow at the Pinnacle. Some walkers had to be rescued in July 1925 with deep snow on the tracks and drifts on the top reported up to 10 m deep. Falls to lower slopes were that good in 1927 that a horse drawn

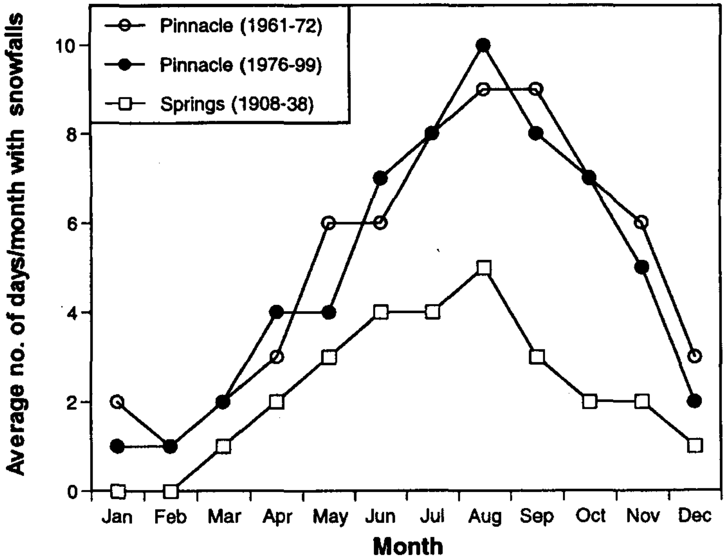

Fig 1. Average number of days per month with snowfalls. The Springs data are from Martin (1939) and those at the Pinnacle from the Weather Bureau (1961-72) and the authors (1976-99).

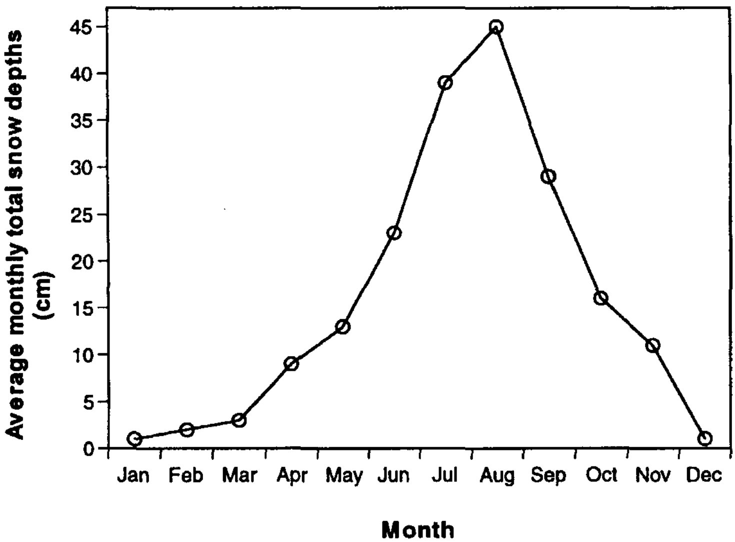

Fig. 2. Average total monthly depths of snow (cm) at the Pinnacle for the period 1976-1999. These data are from actual measurements or an estimate of the fall based on over 20 years of experience of the authors.

sleigh operated at the Springs. The *Mercury* noted in July that the mountain had not been without its mantle of snow for months past. Many trees and branches were broken by the weight of snow, whilst tracks were hard to negotiate. The mountain was a popular place to visit and the press reported in August 1931 that there 2000 visitors at the weekend to view and play in the snow. They would have got their money's worth in June of the following year when 12 days of snow left a heavy mantle on the mountain.

However, times were changing. The construction of a road to the Pinnacle commenced during the depression years and the roar of the motor car sounded at the summit in 1937. Skiing continued on the mountain with several metres of snow often reported from the Plateau. There was even sking at Fern Tree following a deep fall in July 1938. Following World War 2 the development of ski fields elsewhere and diminishing cover later in the century saw regular skiing become a thing of the past.

The expansion of roads into some of the more snow prone areas of the state saw the need to test a snow plough on the Pinnacle Road in August 1943. It was put to immediate use on the Lyell Highway which had been blocked by snow for a week. Previously skiers were used to patrol the road from Derwent Bridge to the Franklin River.

The winter of 1946 saw snow on the mountain from May until after Christmas when a drift south of the Pinnacle was still a couple of metres deep. Falls of up to 60 cm had been recorded at the Springs that year. Two years later 45 cm fell as low as Fern Tree, and a possible record 53 falls of snow were recorded at the Springs.

Heavy falls in August 1951 left a snow cover 45 cm deep at the Springs, 30 cm at Fern Tree and snow settled over a wide area of Tasmania. The following February (1952) a surprise fall settled well down the mountain. A photograph in the Mercury shows motorists in a snowball fight on the Pinnacle Road. Whilst the mountain experienced good falls for most of the 1950s, cover at the Springs showed something of a decline with only a few falls resulting in snow depths greater than 15 cm.

The arrival of television brought another change to the mountain skyline with the erection of towers and buildings at the Pinnacle. One small improvement was the recording of daily weather at the summit from 1960 until 1972. However, it was rain, not snow, that caused damage in April 1960. Heavy rainfall saw the Pinnacle Road subside just above the Chalet, whilst the rivulet caused problems in the city. A deep cover of snow in July 1961 saw the road closed to general traffic for three weeks. May 1962 brought gales with winds of 140 km/hr sweeping the summit in conjunction with 45 cm of snow. With technicians resident at the TV complex, clearing the road with a snow plough became a necessity. Drifts four metres deep were noted over the ABC access road and snow drifted even deeper over the Pinnacle Road on the last straight to the summit.

One of the biggest impacts on the mountain during the 1960s was the bushfire of February 1967. The fire raced across the whole of the mountain, leaving it and surrounding foothills a blackened ruin. Ironically a few days later (Feb 16) there were light snowfalls on the mountain. The fires destroyed the Springs Hotel, ending nearly sixty years of weather recordings, and soon after, weather observations ceased at the ABC buildings.

For those who like a white Christmas, a few have been noted on the mountain. December 25th 1972 brought a good fall of snow to the upper slopes. Snow had been noted in earlier years on Christmas day in 1925, 1944, and 1956.

The two big years for snow in the 1970s were 1976 and 1978. A week of snow in August 1976 produced large plateau drifts in the order of 5 to 10 m, the last patch of snow lingering until early December. Prolonged falls in 1978 saw similar drifts from 3 to 10 m in depth in September, with snow sliding down the Organ Pipe gullies. Again the last spots hung on into early December.

As the century progressed into the 1980s, so the winter falls seemed to be less as drier conditions prevailed at times. Cold outbreaks still occurred over the State but drifts failed to develop to the depths of previous decades. 1988 was mentioned as the mildest winter since records began in 1882, raising the possibility of an impact of global warming.

The mountain gave a taste of winters past in 1991 and 1994 as drifts at times reached 5 to 7 m depths. Skiers were able to negotiate their way across the Plateau or use the Pinnacle Road before it was cleared for traffic. In 1994 the best drifting for 20 years lasted until November/December. However, it could be said to have all been downhill in the past few winters with 1999 and its record breaking dry spells probably having the lowest snowfall for one hundred years.

DRIFT LOCATIONS

Depending on the strength of winter snowfalls, drifts form at favourable locations on the mountain most winters. The most extreme life noted for a drift has been from April/May to November/December. Usually drifting appears after a good fall in June/July which should last to October.

Ski Drift. A good drift for sking occurs on the site of an Ice Age nivation hollow 500 m south of the Pinnacle. A curving slope facing the south-east has its headwall at 1240 m and runs down to near 1220 m. Under extreme snowfalls the drift almost extends out to the head of the Zig-Zag.

Pinnacle Drifts. A number of drifts form to the east and north-west of the Pinnacle. Some small drifts can be noted between the Lookout and the Organ Pipes. The largest drift forms either side of, or across, the Pinnacle Road on the final straight to the summit. Depths of 5-6 m have been noted in this location. The drift faces north-east and tends to weather early in the direct sun of spring.

Skyline Drifts. A number of drifts/snowbanks form on the eastern facing slopes of the summit Plateau to the south of the Ski Drift. Drifts tend to form in the gullies and hollows at the 1240 m level between the Ski Drift and the southern summit (1265 m).

The development of the drifts is often dictated by the prevailing winds associated with a snowfall. On most occasions the drifts at the top of the two central gullies have the longest life span; the more northerly of these gullies providing shade during the early spring time.

South Drift. A lengthy drift occupies the south-east facing slope to the south of the Southern summit. The higher elevations are at about the 1220 m level. This drift tends to grow in length more than depth but often is one of the last to melt. It is not always viewed that well from the city.

North West Drifts. The saddle between Mt Wellington and Thark Ridge provides the location for a number of snowbanks that develop with good winter falls. Snow will drift across the Pinnacle Road above Gate 5. However, the drift with the longer life in this area lies at about 1160 m just to the west of Gate 5. In years with deep falls the area can provide some limited ski runs.

Thark Ridge. The ridge runs parallel to the mountain some 2 to 3 km to the west. The ridge runs north-east to south-west but does not provide any large drifts of note, possibly because the slopes lack major gullies and tend to be rocky with small cliffs. Pockets of snow do, however, last at a number of points along the ridge at the 1200 to 1240 m levels.

Zig-Zag Drifts. A long-life drift often occurs at the head of the Zig-Zag face at about the 1180 m level. Due to the angle of the slope the drift is probably never of great depth. The drift is sheltered from the prevailing winds and sun. During the winter months, much of the Zig-Zag is in the shade.

South Wellington Gap. Following good winter falls, a drift will form at 1160 m just east of the saddle north of South Wellington. On a few occasions in the 1970s this drift was metres deep and extended out over nearby trees and bushes.

Others. The heaviest of falls will obviously produce snowdrifts almost at any point on Mt Wellington. Other locations noted have been on the Zig-Zag track, some of the Organ Pipe gullies (1100–1200 m), at the southern end of the Lost World (Mt Arthur) at 1060 m, and the South West Plateau (1220 m) which carries a number of drifts, as do such places as Dead Island. Seepage on a crag just north of Smith's Monument is often frozen in cold winter spells, and at times a small drift forms just below the rocks at the 1160 m level. Drifts also persist near the South Wellington track on the southern facing slopes of the mountain around the 1200 m level.

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TERRESTRIAL MAMMALS OF DENNES HILL, NORTH BRUNY ISLAND

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INTRODUCTION

Dennes Hill Reserve was proclaimed in 1996 primarily to conserve habitat for the forty spotted pardalote, an endangered bird. Dennes Hill is located at the northern end of North Bruny Island in south-east Tasmania. Like many areas of Tasmania, North Bruny Island is poorly surveyed for native mammals. The Tasmanian Field Naturalists Club conducted a field survey of terrestrial mammals in June and July 1996, with the support of the Tasmanian Parks and Wildlife Service. The survey concentrated on Dennes Hill and the Quarantine Peninsula but the results are discussed in the context of the whole of North Bruny Island.

Bruny Island has been isolated from the Tasmanian mainland for an estimated 6750 years (Rawlinson 1974). Island faunas are of interest due to their smaller and potentially different gene pool and because they often contain different habitats and faunal structures. The potential of islands to act as areas of habitat insulated from their mainland equivalents can also be beneficial, e.g. some marsupials such as the western barred bandicoot are restricted to islands as a result of the introduction of the fox to mainland Australia. Documentation of the mammal faunas of islands around Tasmania has been undertaken by Hope (1974) for the Bass Strait islands, White (1981) for islands off south-west Tasmania and by Rounsevell (1989) and Rounsevell *et al.* (1991). Despite these studies there appears to have been little systematic attempt to accurately document and monitor the conservation status and security of island populations.

Broad habitat types on Bruny Island reflect rainfall patterns with the northern section having drier sclerophyll forest types (Jackson 1965) in a subhumid effective rainfall zone (Gentilli 1972), compared to wet sclerophyll forest and rainforest (Jackson 1965) in the humid effective rainfall zone (Gentilli 1972) of south Bruny.

A primary management objective for the Dennes Hill reserve is to preserve adequate food resources for pardalotes, which are principally gleaners on the foliage of *Eucalyptus viminalis*. The principal aim of this survey was to establish which mammal species occupied local habitats so that their management could be incorporated into that of the reserve.

STUDY AREA

Land use history of the Dennes Hill reserve has included grazing and some clearing for pasture in the natural open woodland vegetation. A small pine plantation was established in the 1960s. Preliminary plant lists have been produced for the reserve.

Native vegetation in the areas trapped is open forest and woodland to a height of 20m, with *Eucalyptus viminalis* the most common tree and *E. obliqua*, *E. globulus*, *E. pulchella* and *E. ovata* also present. The understorey is generally low and includes *Poa* spp. tussock grasses, *Lomandra longifolia* and *Pteridium esculentum*. The substrate is dolerite based but includes a lateritic gravelly component leading to a friable soil and some erosion gullies.

METHODS

Trapping was undertaken over four nights in the months of June and July 1996. Fifteen cage traps (20x20x80cm; Mascot Wire Works) were baited with peanut butter / potato baits and four were baited with meat for a total of 76 trapnights. Forty Elliott traps were baited with peanut butter / rolled oats amalgam, with 160 trapnights undertaken. Trap sites, each with one cage and two Elliott traps, were situated 15-20 metres apart along transects on the eastern slopes of Dennes Hill. Due to the steep terrain and wet conditions, access was limited to walking from the eastern side above the "Lauriston" property, although the areas trapped appeared representative of local habitat. Medium sized mammals were tagged using Salt Lake City monel fingerling tags.

Local faunas were discussed with residents of north Bruny. Tracks, signs and observations of mammals were also noted. No spotlighting was undertaken on the reserve.

RESULTS

A total of 13 individual potoroos *Potorous tridactylus* and one eastern quoll *Dasyurus viverrinus* were captured at Dennes Hill. One male potoroo was captured three times (22 June and 10 and 11 August) at trap sites up to 120m apart, with the pine plantation interposed between them. Details of individuals captured and tagged have been lodged with the Tasmanian Parks and Wildlife Service.

Echidna diggings were common both on Dennes Hill and around the Denne's farm. Scats of the wallabies *Thylogale billardieri* and *Macropus rufogriseus* were observed at Dennes Hill and individuals of these species were observed in August. An eastern quoll (black and white phase) was observed dead on the road at Australian Map Grid (AMG) reference 5285 2202.

Other records include a group of three ringtail possums *Pseudocheirus peregrinus* crossing a road (AMG 5262 2280). Two appeared to be large subadults, possibly born late in 1995. A male potoroo was found killed on a road (AMG 5297 2279) and another potoroo was seen on a road (AMG 5280 2264). Early in 1999 a potoroo was sighted by the author at Marks Point (AMG 5280 2248). Numerous brushtailed possums *Trichosurus vulpecula* were seen on roads.

Footprints of the water rat *Hydromys chrysogaster* were seen on the coast near "Lauriston" (AMG 5293 2295), and this species was reported to have raided poultry at

"Nebraska" (Lee Davis, pers. comm.).

DISCUSSION

Five new records of mammal species (additional to those of Rounsevell *et al.* 1991) are reported here for north Bruny, and two other possible new records are discussed. Further, the records of three other species reported by Rounsevell *et al.* (1991) are suggested to be doubtful.

The records of eastern quoll from the Quarantine Peninsula and Dennes Hill are the first from a Tasmanian offshore island (Rounsevell *et al.* 1991). Long-term residents of Bruny Island report that quolls have only been observed for around a decade, and speculate that they may have been introduced (Ross Denne, Lee Davis, pers. comm.). Both colour phases were observed during the study. Don Briggs, a north Bruny resident, stated that he had trapped a spotted-tailed quoll near Dennes Hill in a possum cage. This would be a first island record for the species and a written account is currently being sought.

Bandicoots have not been observed by local residents on north Bruny (Ross Denne, Lee Davis, pers. comm.). The presence of bandicoots is usually evident from their characteristic diggings. Thus the several barred bandicoot records of Rounsevell *et al.* (1991) which cover the 10x10 km grid squares that encompass north Bruny and the adjacent mainland are probably mainland records. The brown bandicoot *Isoodon obesulus* was recorded on far south Bruny by Rounsevell *et al.* (1991). Further confirmation of the status of this species on the island is desirable.

Bennett's wallaby occurs on both north and south Bruny (pers. observation) but was not recorded here by Rounsevell *et al.* (1991). Local belief is that Bennett's wallaby has increased in numbers in recent years, possibly having been introduced some decades ago (Ross Denne, pers. comm.). Bennett's wallaby is absent from Schouten Island (Hird 1993) but occurs on major Bass Strait islands (Rounsevell *et al.* 1991). Pademelons occur on many offshore islands around Tasmania including Schouten Island (Hird 1993), and their presence is therefore not surprising. Pademelons also occur on south Bruny (pers. observation).

The potoroo was mapped by Rounsevell *et al.* (1991) from south Bruny and its presence on north Bruny is therefore not surprising despite it not having been officially recorded there. The open structure of the vegetation at Dennes Hill contradicts the traditionally described habitat for potoroos. In Tasmania this is not unusual though as potoroos have been recorded from a range of open vegetation types (including grassy areas e.g. this study, Hird and Hammer 1995) as well as the more usual areas with dense ground vegetation. Potoroos occur on some small islands around Tasmania (e.g. de Witt Island, White 1981) but not other larger islands such as Schouten (Hird 1993). The mean body-mass of potoroos caught was high (1550 g), even by the standards of southern Tasmania (D. Hird, unpublished data). Insular variation in potoroo body-mass is worth investigating further.

The ringtail possum was not recorded from Bruny Island by Rounsevell *et al.* (1991). The species appears to be absent from Schouten Island (Hird 1993) but occurs on major Bass Strait islands (Rounsevell *et al.* 1991). *Trichosurus vulpecula* was only recorded for Bruny Island by Rounsevell *et al.* (1991) in those 10x10 km grid squares which included areas of the mainland and hence its occurrence on the island was uncertain. However, my observations indicate it is ubiquitous. *Cercatetus lepidus* is recorded from south Bruny (Rounsevell *et al.* 1991) and may occur on north Bruny in suitable habitat, although heathy coastal forest on north Bruny has been extensively cleared and degraded.

No small ground-living mammals such as *Rattus lutreolus* or *Antechinus* spp. were trapped at north Bruny, although three species of small dasyurid and *R. lutreolus* were recorded for south Bruny (Rounsevell *et al.* 1991) where wetter forests provide denser undergrowth. An absence of small mammals is regularly encountered in drier habitats in Tasmania (e.g. Hird and Hammer 1995).

The water rat was surprisingly unreported from Bruny Island by Rounsevell *et al.* (1991). This is almost certainly due to lack of systematic survey rather than prior absence as the species has a widespread coastal distribution.

Echidnas have been recorded previously on north Bruny and occur on other larger islands around Tasmania, e.g. King, Flinders, Cape Barren and Maria Islands (Rounsevell *et al.* 1991).

Bats were not explicitly surveyed in this survey as they were not active during the winter months when the survey was undertaken. No bats were mapped on Bruny Island by Rounsevell *et al.* (1991). Woinarski (1986) recorded a bat (probably a chocolate wattled bat *Chalinobus gouldii)* in the area and R. Taylor (pers. comm.) has recorded *Nyctophilus geoffroyi* from South Bruny.

The common wombat, *Vombatus ursinus,* was not recorded on Bruny by Rounsevell *et al.* (1991). Local residents of north Bruny recollect wombats in the area of The Neck and Mars Gully (Ross Denne, Lee Davis; pers. comm. respectively), but not in the last decade. Another Bruny Island naturalist, however, has not seen evidence of wombats (Dr Tonia Cochran, pers. comm.). The prominence of signs of the occurrence of wombats (eg scats, burrows) would usually lead to awareness of their presence and, as the species usually persists in the face of habitat change (as on Flinders Island), its presence on Bruny in historical time seems doubtful.

Other north Bruny mammal records indicated by Rounsevell *et al.* (1991) include the bettong *Bettongia gaimardi* and Tasmanian devil *Sarcophilus harrissi*. Local residents have not observed bettongs on north Bruny. Although Tasmanian devils have been reported from Bruny as roadkills (Ross Denne, pers. comm.) their presence amongst sheep farming communities would be expected to be common knowledge if a resident population occurred. Hence clarification of the records of these species would be worthwhile.

North Bruny has been subject to intensive land clearing for agriculture and residential development in recent decades (Kirkpatrick 1991), a process which appears to be ongoing. Until recently only linear coastal reserves have offered statutory protection for natural habitats. It is important that viable areas of habitat are protected on the island. Very little information is available on what constitutes a minimum viable population size for Tasmanian vertebrates, and hence the area of habitat required to support such populations. This is no less the case for north Bruny than for elsewhere in the State.

Concern by neighbouring landholders has been expressed about the potential of Dennes Hill Reserve to act as a reservoir for brushtail possums. This species is perceived as a pest of crops and a contributor to eucalypt dieback (Lee Davis, pers. comm.). Use of 1080 poison to alleviate possum damage in and around the reserve should be considered carefully as potoroos are susceptible to 1080 (McIlroy 1982). Eastern quolls are also susceptible to 1080 (McIlroy 1982) but populations appear to persist in areas subject to repeated poisoning (Statham 1983).

CONCLUSIONS

Management of Dennes Hill Reserve should take account of the requirements of the eastern quoll and potoroo, two species newly recorded from the reserve. Other mammals species not previously recorded from north Bruny are also worthy of protection in a reserve on the island. The disparity between the findings of this survey and the previously published records for the whole of north Bruny are symptomatic of the lack of systematic survey effort in Tasmania. The work of Menkhorst (1995) in Victoria provides a suitable model that could be applied in Tasmania. The lack of survey work is of particular concern in view of the extent of recent and ongoing habitat change in many areas of Tasmania, including Bruny Island. Further survey work at the northern end of the Bruny Island Neck Reserve (around the large lagoons) is considered worthwhile. Areas of coastal habitat in the east of north Bruny may also be worth surveying, although most of the land is privately owned to the high-water mark and subject to habitat alteration where conditions are suitable.

ACKNOWLEDGEMENTS

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AN OVERVIEW OF THE TASMANIAN MILLIPEDE FAUNA

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Abstract. There are at least 160 native species of millipedes in Tasmania, of which at least 130 are Polydesmida. The other native orders are Polyxenida, Sphaerotheriida, Polyzoniida, Spirostreptida and Chordeumatida. Twenty-seven of the natives have been formally described and another five are soon to be published. Species lists and brief notes are given for each order. Ten introduced millipedes (six Julida, three Polydesmida and one Polyxenida) are largely restricted to farms, gardens and degraded bushland. Native millipedes are widespread and abundant in most terrestrial habitats. Individual species are often restricted to one of a number of millipede 'regions' around Tasmania, some of which have remarkably sharp boundaries.

INTRODUCTION

Despite millipedes being familiar and relatively large arthropods, they are very little studied in Australia. This article summarises what is currently known about the taxonomy, general ecology and biogeography of Tasmanian millipedes. It is based on my own field experience and on the millipede collections in the Queen Victoria Museum and Art Gallery (QVMAG), the Tasmanian Museum and Art Gallery (TMAG) and the New Town Laboratories (New Town) of the Department of Primary Industries, Water and Environment. The QVMAG collection, which I curate, is by far the largest and consists of many thousands of specimens from all parts of the State.

To avoid making this issue of *The Tasmanian Naturalist* a monograph on millipedes, I have left out discussions of anatomy, life history and conservation, and global issues in millipede taxonomy and biogeography. General information on these animals can be found in most textbooks of invertebrate zoology. Shear (1999) has written an enthusiastic popular article on millipedes, and Hopkin and Read (1992) have produced a very readable text on millipede biology. For interested naturalists I highly recommend a beautifully illustrated introduction to centipedes and millipedes by Shelley (1999)[1].

TAXONOMY

Six of the 15 orders within the arthropod class Diplopoda (millipedes) are native to

[1]This article is available at no charge from Kansas School Naturalist, Division of Biological Sciences, Box 4050, Emporia State University, Emporia KS 66801-5087, USA.

Tasmania. A seventh order is represented by several introduced species (see below). The six native orders can usually be identified by eye in the field (Fig. 1).

Polyxenida

These tiny 'bristle millipedes' are rarely hand-collected but are sometimes abundant in leaf litter samples. Tasmanian polyxenidans are in the family Polyxenidae (Black 1997). None have been identified to species level. Polyxenidans seem to be most abundant in dry forest and heathland in eastern and northern Tasmania, but specimens have also been recovered from leaf litter in rainforest (near Weldborough).

Sphaerotheriida

Two Tasmanian species of 'pill millipedes', *Procyliosoma leae* and *P. tasmanicum*, were described by Silvestri (1917). Jeekel (1986) accepted *Procyliosoma* as a valid genus within the family Sphaerotheriidae, but the taxonomy of the Australasian pill millipedes is in need of review. Specimens tentatively identifiable as *P. leae* or *P. tasmanicum* are widespread in Tasmania. They seem to prefer the deep, moist humus found on the floor of long-unburned forest and under stones in dolerite talus. Neither species grows to a body width much above 8 mm. A much larger undescribed pill millipede, *ca.* 12 mm wide, is locally abundant in wet forest near St Marys and in the northern section of the Douglas-Apsley National Park.

Polyzoniida

Five widespread Tasmanian species in this colourfully marked group have been named but not yet published by Dennis Black of La Trobe University (*pers. comm.*). Another three species have been collected (one of them semi-aquatic; see 'General Ecology' section below) but have not yet been carefully studied. All are in the family Siphonotidae, and four of the five named species appear to be Tasmanian endemics.

Tasmanian polyzoniidans are semi-arboreal and often congregate in small, single-species groups under bark or dry fallen wood (Mesibov 1999). This clustering behaviour can make them very hard to find. In a survey near Tarraleah (Mesibov *et al.* 1995), only one specimen of a particular siphonotid was found during more than 70 hours of searching on 80 sampling plots. Just before the sampling started, *ca.* 40 individuals of this species had been collected from half a square metre of forest floor in the same area.

Spirostreptida

These long, black, cylindrical animals would be instantly recognised as millipedes by most people. Spirostreptidans are widespread and remarkably abundant in forest habitats. In two litter invertebrate surveys, spirostreptidans accounted for 65% (Mesibov 1993b) and 48% (Mesibov 1998) of all millipede specimens collected.

Four Tasmanian species have been described: *Amastigogonus tasmanianus* by Brölemann (1913), *Euethogonus hardyi* by Chamberlin (1920) and *Amastigogonus fossuliger* and *A. nichollsii* by Verhoeff (1944). The first two species were originally

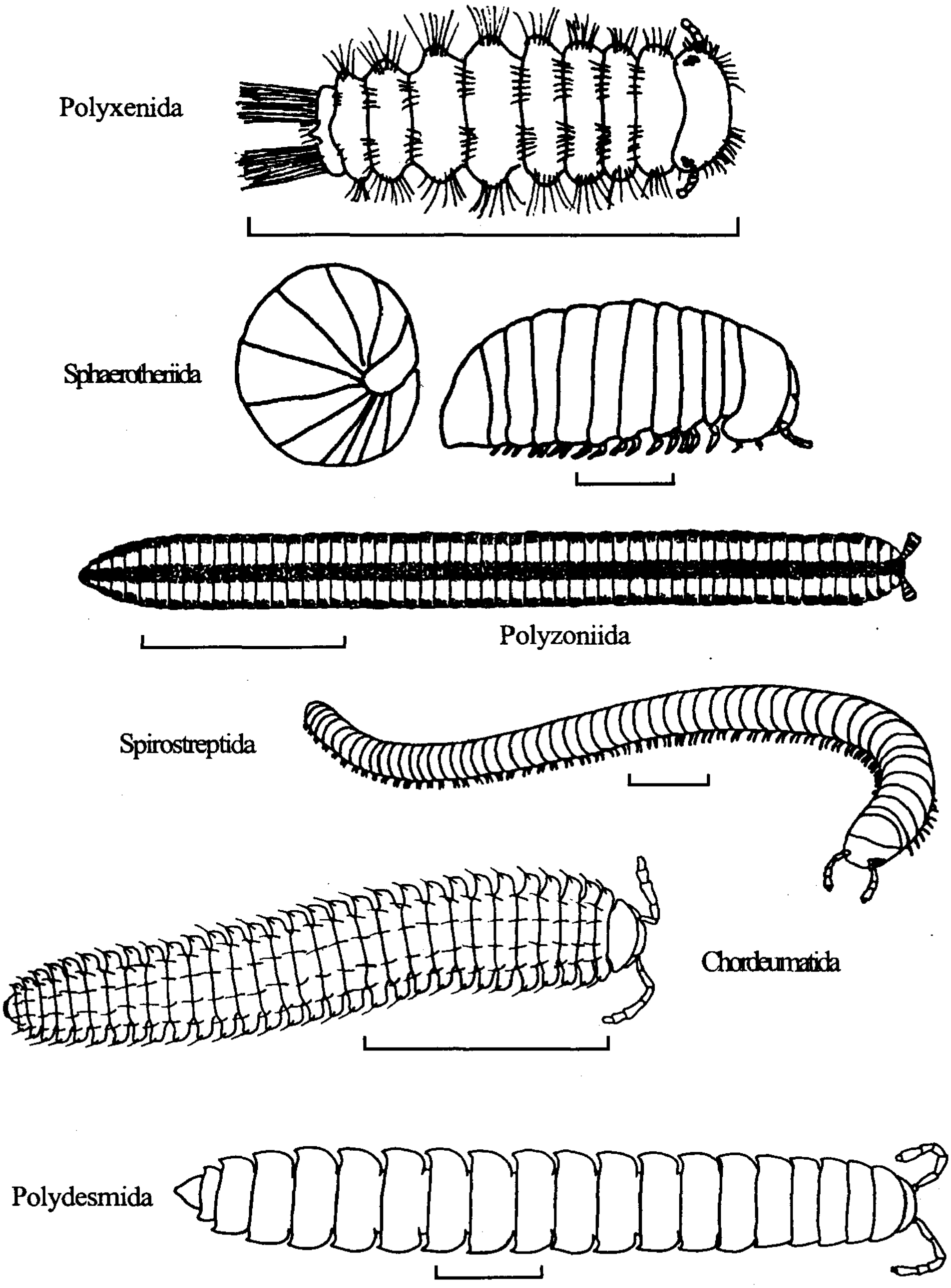


Fig. 1. Examples of Tasmanian millipedes. The scale bar = 3 mm in all cases. Sphaerotheriida after Holloway (1956). Spirostreptida and the introduced Julida have the same 'juliform' body shape.

placed in Cambalidae, but *Amastigogonus* was moved to Iulomorphidae by Verhoeff (1924). *Euethogonus* was synonymised with *Amastigogonus* by Hoffman (1972). Jeekel (1981) and Hoffman have both accepted the assignment of *Amastigogonus* to Iulomorphidae, although Verhoeff himself seems to have changed his mind, naming Iulomorphinae as a subfamily of Cambalidae and placing *Amastigogonus* in a second cambalid subfamily, Samichinae (Verhoeff 1944). More work is needed to clarify the taxonomic situation.

There are likely to be many undescribed spirostreptidan species in Tasmania. From one northwest site I sorted five morphospecies, none of which could be recognised as a named taxon. The sorting was done on the structure of the male sperm-transfer organs (gonopods). Spirostreptidans are morphologically very conservative and females and juveniles offer no clues to species identity.

Chordeumatida

Eleven chordeumatidans have so far been described from Tasmania, all apparently endemic. The species are as follows (see 'References' section for taxonomic papers indicated):

Metopidiotrichidae
- *Australeuma golovatchi* Shear and Mesibov, 1997
- *Australeuma jeekeli* Golovatch, 1986
- *Australeuma mauriesi* Shear and Mesibov, 1997
- *Australeuma simile* Golovatch, 1986
- *Neocambrisoma cachinnus* Shear and Mesibov, 1997
- *Neocambrisoma fieldensis* Shear and Mesibov, 1997
- *Nesiothrix mangana* Shear and Mesibov, 1997
- *Nesiothrix medialis* Shear and Mesibov, 1997
- *Nesiothrix tasmanica* (Golovatch, 1986)
- *Reginaterreuma tarkinensis* Shear and Mesibov, 1995

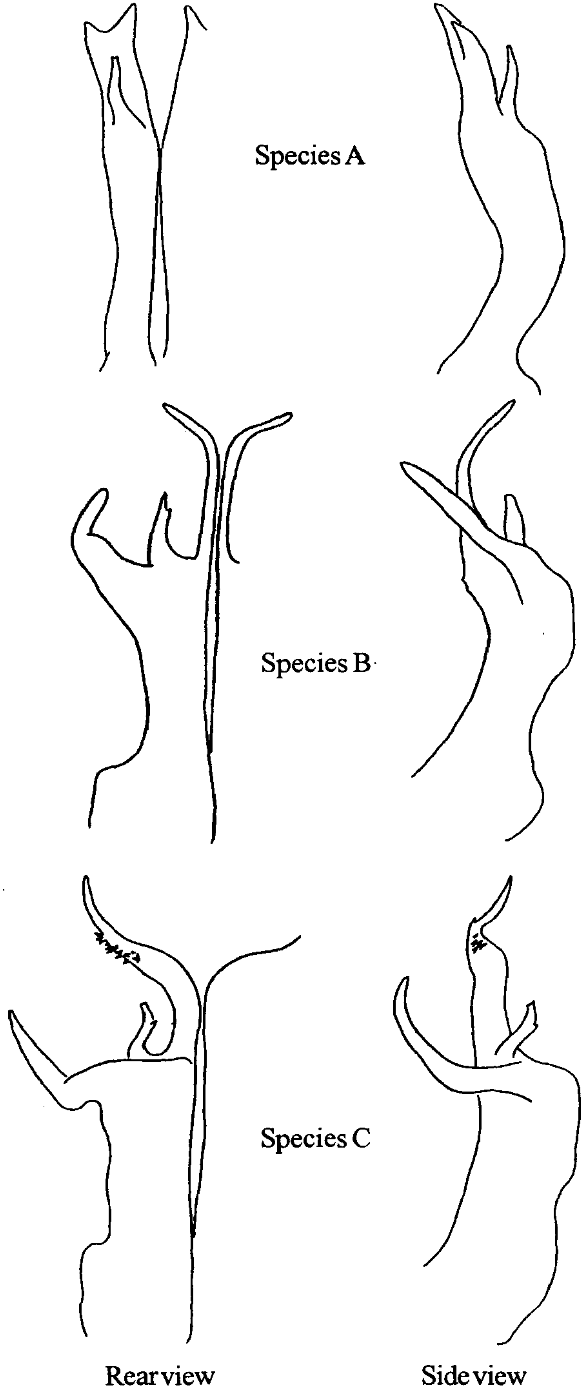
Peterjohnsiidae
- *Peterjohnsia titan* Shear and Mesibov, 1994

Another *Neocambrisoma* and another *Nesiothrix* species have been collected but not yet described. Most Tasmanian Chordeumatida are small, inconspicuous and uncommon millipedes living in forest litter, and it is likely that more species will be found. The exceptional *R. tarkinensis* is relatively large (to *ca.* 18 mm long) and very abundant in western Tasmanian rainforest.

Polydesmida

There are at least 130 native species of Polydesmida ('flatback millipedes') in the QVMAG collection, all apparently endemic. Only 10 have been formally named. All but a few have been deposited at QVMAG as sorted taxa ready for description, but it will be some years yet before the undescribed 120+ species have names. Species have been sorted, as is customary for Polydesmida, largely on the form of the male gonopods

Fig. 2. Rear (left) and side (right) views of the gonopods of three western species of *Gasterogramma* (Polydesmida: Dalodesmidae). The only way to distinguish these species is by examining the gonopods of mature males. The three *Gasterogramma* are otherwise nearly identical in appearance.



(Fig. 2), which are modified legs first appearing in the final, adult life-stage. Although the rate of collection of new species has dropped sharply in the past few years, there are very likely to be more geographically restricted polydesmidans waiting to be discovered. The most prospective area for new species is the Eastern Tiers. My current list of polydesmidan taxa is as follows (see 'References' section for taxonomic papers indicated):

Dalodesmidae
- '*Atalopharetra*' (4 undescribed species, of which 2 are troglobites)
- *Gasterogramma psi* Jeekel, 1982 (plus 7 undescribed species in this genus)
- *Lissodesmus adrianae* Jeekel, 1984
- *Lissodesmus alisonae* Jeekel, 1984
- *Lissodesmus margaretae* Jeekel, 1984 (plus 4 new *margaretae*-like species)
- *Lissodesmus modestus* Chamberlin, 1920
- *Lissodesmus perporosus* Jeekel, 1984
- *Lissodesmus* spp. (16 undescribed non-*margaretae*-like species)
- '*Rankodesmus*' (4 undescribed species)
- *Tasmaniosoma armatum* Verhoeff, 1936 (plus at least 13 undescribed species in this genus)
- *Tasmanodesmus hardyi* Chamberlin, 1920
- genus A (at least 4 undescribed species)
- genus D (at least 3 undescribed species)

Haplodesmidae
- *Asphalidesmus leae* Silvestri, 1910 (plus at least 4 undescribed species in this genus)
- *Atopodesmus parvus* Chamberlin, 1920 (identity uncertain, likely to be an *Asphalidesmus*)

Paradoxosomatidae
- '*Aethalosoma*' (1 undescribed species)
- *Dicranogonus* (1 undescribed species)
- *Notodesmus scotius* Chamberlin, 1920 (see also Jeekel 1979)
- *Pogonosternum* (2 undescribed species)
- *Somethus* (2 undescribed species)

Family uncertain
- genus C (7 undescribed species)
- genus E (at least 1 undescribed species)
- genus F (at least 3 undescribed species)
- ER group (at least 9 undescribed species)
- S group (at least 13 undescribed species)
- T group (at least 22 undescribed species, of which 1 is a troglobite)

GENERAL ECOLOGY

Millipedes live in almost all Tasmanian terrestrial habitats from sedgeland to closed wet forest, and from coastal dune fields to the rocky tops of mountains. They generally avoid periodically flooded ground, but an undescribed Northwest species, *Lissodesmus* sp. NW4, can be found sheltering with crabs under driftwood logs near the high tide mark (Mesibov 1993a).

There is also at least one diving Tasmanian millipede, a polyzoniidan (D. Black, *pers. comm.*). Diving millipedes are known from seasonally inundated Amazonian rainforest, streams in European caves and a few otherwise unexceptional Australian watercourses. Like diving spiders, diving millipedes are air-breathing animals which can walk under water for extended periods.

Cave-adapted millipedes are well known from karst areas in the Northern Hemisphere, but Tasmania's cave systems have so far yielded only three undoubtedly troglobitic species, all Polydesmida (Mesibov, unpublished review of the cave fauna collected by Stefan Eberhard). Two are in a widespread southern/southwestern genus and are restricted to caves at Ida Bay and Precipitous Bluff, respectively. The third troglobitic millipede is apparently well-distributed through the caves of the Florentine Valley and may turn out to be a group of very closely related species, each restricted to a particular cave or set of caves. Other millipedes have been collected in Tasmanian caves but specimens of these are indistinguishable, in most cases, from conspecifics in nearby surface populations.

Millipede abundance and diversity are greatest in forests. Tasmanian millipedes are particularly abundant in regrowth wet eucalypt forest, perhaps because this rapidly growing forest type annually produces very large quantities of litter per hectare. Within forests, millipedes can be found burrowing in the soil and rotting logs, wandering in leaf litter and sheltering on or under tree bark. Many millipedes appear to be undemanding in their macrohabitat requirements, and species from wet forest are often collected in nearby dry forest and scrub as well. The most ecologically tolerant local millipede appears to be an undescribed species of *Somethus* (Polydesmida: Paradoxosomatidae) which occurs throughout the North and Northwest. This robust brown species has been collected in coastal dune scrub, closed tea-tree and swamp forest, eucalypt woodland, dry eucalypt forest, wet eucalypt forest, oldgrowth rainforest and *Pinus radiata* plantations.

The larger Tasmanian millipedes, notably Spirostreptida and Sphaerotheriida, shelter by day and wander by night. Seasonal variation in activity is less obvious, although catches of millipedes in pitfall traps tend to be lower in winter (Mesibov *et al.* 1995) and richer in males in spring (Fig. 3). With careful searching, adults of all Tasmanian millipedes can be collected at any time of year, even on the Central Plateau.

Two species of paradoxosomatid Polydesmida, *Notodesmus scotius* and *Dicranogonus* sp., form spectacular 'mating swarms' in the spring in the Northeast.

Many thousands of the dark-coloured adult males and females of both species, some *in copula*, can be seen in the coastal heaths on warm, sunny days from late August through November.

Predators and parasites of Tasmanian millipedes have yet to be studied, but three of the local millipede orders are obviously well-defended. Sphaerotheriida roll up into smooth, hard 'pills' when disturbed. Spirostreptida secrete yellowish mixtures of strong-smelling quinones which can tan human skin to a purple colour in a few minutes and which almost certainly repel vertebrate predators. Polydesmida produce a defensive secretion containing hydrogen cyanide, and several of the local genera augment the secretion with pungent additives. I jokingly refer to one undescribed, especially smelly genus as '*Rankodesmus*'. The northeast species '*Rankodesmus*' sp. 2 can be reliably tracked down in its forest habitat by attentive sniffing.

Nothing is known in detail about the diet of Tasmanian millipedes, but all are presumed to be detritivores, consuming rotting plant material which has been upgraded in nutrient quality by bacterial, yeast and fungal fermentation. Unidentified Spirostreptida have been seen feeding at night on bracket fungi in Northwest eucalypt forest.

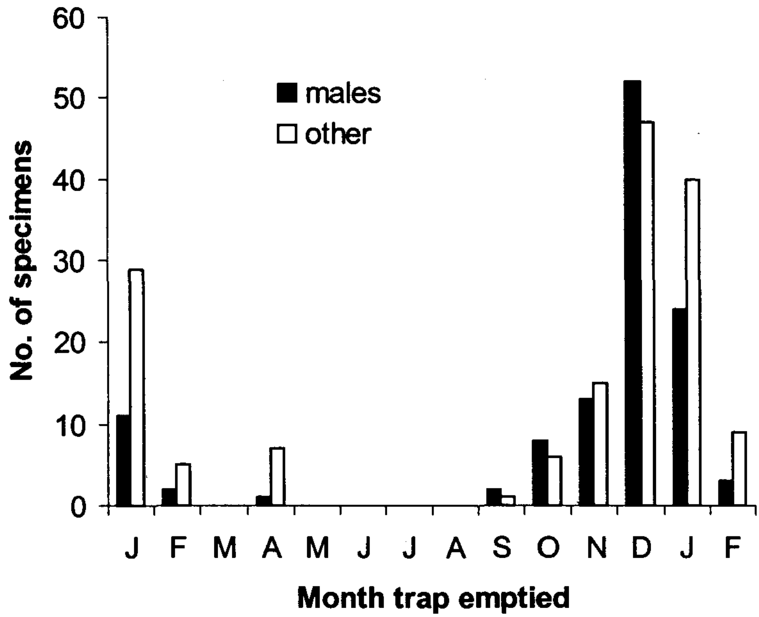


Fig. 3. Counts of the chordeumatidan *Australeuma jeekeli* from five pitfall trapping sites in the Picton River valley, January 1995 to February 1996. Solid bars are adult males, hollow bars are females and juveniles. Data courtesy Dick Bashford, Forestry Tasmania.

BIOGEOGRAPHY

No millipede is ubiquitous in Tasmania. The two most widespread dalodesmids, *Lissodesmus perporosus* and *Tasmanodesmus hardyi*, each range over less than half the State. Well-studied species have distributions ranging from *ca.* 2000 km^2 to *ca.* 30 000 km^2. Within many range envelopes there are blanks of apparently unoccupied country. Usually these blanks correspond to blocks of unsuitable habitat, such as heathland in the range of a species with a preference for forest, and *vice versa.*

When the ranges of well-studied species are drawn on a map of Tasmania, clusters of species occupying more or less the same region are apparent. Millipede regions can be remarkably distinctive. In 1990 I compared litter invertebrate faunas at oldgrowth rainforest sites in the Northwest (near Waratah) and the Northeast (near Weldborough). Both sites carried myrtle/sassafras/manfern forest, both were at 650-700 m and both had a northwest aspect. Of the 19 millipedes sorted to species, only one was found at both sites (Mesibov 1998).

Even more strikingly, the edges of millipede ranges often coincide in narrow zones known as *faunal breaks* (Mesibov 1994, 1996). Two faunal breaks have so far been intensively sampled for millipedes. On the East Tamar Break near Weavers Creek south of Nunamara, six polydesmidans have range boundaries crowded into a zone less than five kilometres wide, and another two polydesmidans are unusually abundant within the zone (Mesibov 1997).

A second and more spectacular faunal break has been mapped on the mid-north coast (Mesibov 1999). Just under half the polydesmidans, chordeumatidans and polyzoniidans known from this area occur either west or east (but not both) of the Mersey Break, which is a zone *ca.* 10 km wide running 70 km southeast from Devonport to the northeast corner of the Central Plateau. In all cases the Break-defining species are widespread on their respective sides of the zone and occur on a range of parent geologies, at a range of elevations and in a range of forest and woodland types. No major discontinuity in climate or vegetation is apparent across the Mersey Break.

When two species distributions meet with minimal overlap, the species are said to be *parapatric.* Parapatric distributions are sometimes explained as the result of interspecific competition. For example, species A might exclude species B from an area which B could occupy if A were not present as a competitor. This may be the ecological mechanism behind millipede parapatry in Tasmania, but it is not an adequate explanation for boundary clustering, e.g. of the four intrageneric parapatric boundaries and three 'ordinary' boundaries within the Mersey Break (Mesibov 1999).

Perhaps a dozen faunal breaks defined by millipedes are scattered around Tasmania. Their existence hints at a rich history of landscape and climate changes which have created and shifted local millipede faunas across the map. Millipede distribution mosaics are known elsewhere in the world (Shelley 1989, 1990), but have yet to be used in reconstructing landscape history at a local scale. Tasmania is particularly well-suited for future studies of this kind, given the State's richly endemic invertebrate fauna and its distinctive invertebrate regions and faunal breaks (Mesibov 1996).

On a broader biogeographic scale, two of the locally dominant millipede families are thought to be Gondwanan in origin: Dalodesmidae in the Polydesmida (Simonsen 1992) and Metopidiotrichidae in the Chordeumatida (Shear and Mesibov 1997).

INTRODUCED SPECIES

Most readers will have heard of the millipede plague in Adelaide caused by an explosion in numbers of the Portugese millipede, *Ommatoiulus moreleti*. Less well known are the facts that *O. moreleti* populations subsequently crashed in South Australia (Bailey 1997) and that no evidence has been found that this pest affected native millipede populations (Griffith and Bull 1995). Portugese millipedes also invade houses in Tasmania, where they do no damage but help to sell insect sprays. They are uncommon in non-weedy bushland up to *ca.* 500 m from houses and gardens, and virtually non-existent further out.

Most of the other exotic millipedes recorded from Tasmania (listed below) are similarly restricted to Europeanised habitats. Only *Cylindroiulus latestriatus* appears to be invasive, and is very widely distributed around the State. Even this species, however, seems to prefer disturbed places, such as coastal dune vegetation, forest in urban reserves and forest and scrub occasionally used for shelter by stock animals.

The polyxenidan *Propolyxenus forsteri* is the latest addition to the list of introduced species. A single specimen was collected by Dr A. Richardson (University of Tasmania) in rainforest adjoining a farm during a 1999 sampling survey along the route of the proposed magnesite rail link in the Northwest. Since no polyxenidan had previously been found in Northwest rainforest, intensive searches were made by the author and others within 10 km of the original locality. The only new specimens were found at the original collecting site. These were identified as the New Zealand species *P. forsteri* by Dr Monique Nguyen Duy-Jacquemin, a Polyxenida specialist at the National Museum of Natural History in Paris. It will be interesting to see whether this species succeeds in the Tasmanian bush, or whether, like most previous introductions, it remains closely associated with farms, gardens and roadsides.

The following introduced species are represented by specimens in QVMAG, TMAG or New Town and were identified by Dr C.A.W. Jeekel (1), Dr P.M. Johns (2), Dr M. Nguyen-Duy Jacquemin (3) or myself (4). (Author citations omitted from 'References' section.)

Order Polyxenida
  Polyxenidae
    Propolyxenus forsteri Condé, 1951 (3)
Order Julida
  Blaniulidae

Blaniulus guttulatus (Fabricius, 1798) (1,2,4)
Julidae
Brachyiulus pusillus (Leach, 1815) (1,2)
Cylindroiulus britannicus (Verhoeff, 1891) (2)
Cylindroiulus latestriatus (Curtis, 1845) (4)
Ommatoiulus moreleti (Lucas, 1860) (4)
Ophyiulus pilosus (Newport, 1842) (2,4)
Order Polydesmida
Paradoxosomatidae
Akamptogonus novarae (Humbert & De Saussare, 1869) (1)
Polydesmidae
Brachydesmus superus Latzel, 1884 (1,2,4)
Polydesmus inconstans Latzel, 1884 (1)

CONCLUSION

It is a remarkable fact that no Australian has yet published a single-authored taxonomic work on Australian millipedes. Until recently the majority of species descriptions were published by European or American specialists, and were based on a limited number of specimens in overseas museums. Millipede specimens by the thousands are now to be found in the major Australian arthropod collections. These large, often little-sorted millipede holdings are the product of biodiversity assessments, environmental impact studies and other bulk sampling projects of the 1980s and 1990s. A biodiversity study group at Macquarie University in Sydney has begun work on the NSW millipede fauna, and the taxonomy and biogeography of Tasmania's millipedes are much better understood than they were 10 years ago. Nevertheless, the following comments from the visiting diplopodologist C.A.W. Jeekel still ring true:

'The lack of interest in the systematic and faunistic study of millipedes among Australian biologists seems understandable. Unlike many other arthropods, diplopods are inconspicuous animals without bright colours or peculiar habits to attract the attention of people. There are no handbooks to facilitate identification or to give an easy access to the literature. No popular accounts to get acquainted with the diversity of the group are available.

'The state museums are isolated and widely separated from each other, and greatly under-staffed, especially in the arthropod sections. In spite of an apparent devotion to their tasks, one cannot expect these institutions to adequately cope with the immensely rich Australian arthropod fauna. Collecting activities are necessarily of an incidental nature, and useful as these may be in the absence of a coordinated program, they cannot provide the basis for comprehensive faunistic studies.

'One may wonder whether Australia, with its large territory and small population, will ever produce the broad scale of specialists needed for simply taking stock of the arthropod fauna of the continent.' (Jeekel, 1981, p. 2)

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OBSERVATIONS OF ECHIDNAS USING TREE HOLLOWS IN TASMANIAN FORESTS

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INTRODUCTION

Tasmania has many species of vertebrates that use tree hollows for some aspect of their life history (e.g. nesting, denning, roosting). Hollow-dependent forest fauna are often cited as one of the groups most vulnerable to forestry and clearing as such activities can result in a substantial loss of suitable hollow-bearing trees required by these species (Gibbons and Lindenmayer 1997). In Tasmania eight species of microchiropteran bats, five species of possums and about 35 species of birds utilise tree hollows. Based on the observations of V. Thompson and P. Hudler, it now seems that the echidna *Tachyglossus aculeatus* can be added to this list!

This note reports on two separate cases of echidnas using tree hollows and hollow trees in Tasmanian forests.

OBSERVATIONS

In December 1999 an echidna was found in northeast Tasmania in dry sclerophyll forest (dominated by *E. amygdalina* and *E. viminalis*) in a 26 m tall (60 cm diameter) *E. amygdalina* tree. The tree was fire-scarred with a burnt-out base which extended internally to about 7 m, and externally about 1 m. The individual was found within the hollow trunk of the tree at about the 6 m height mark (when the tree was split open at a log landing). The trees in the area, including the tree occupied by the echidna, were heavily infested with insects, including ants.

The second individual was found in October 1999 in high altitude *Eucalyptus delegatensis* forest in the Central Highlands. It occurred in a tree hollow, with an entrance of about 50 x 50 cm, about 1.2 m above the ground. The tree was a 35 m tall (>60 cm diameter) *E. delegatensis* tree with good form (i.e. no low branches). The tree was fire-scarred with a partly burnt-out base and the trunk was relatively vertical. The individual was found half covered in dry, rotted wood fragments.

DISCUSSION

There are few published accounts of echidnas using tree hollows. Morison (1999) cites an example of an echidna using a low (about 80 cm above ground) hollow in a box-ironbark tree in Victoria. In such forests, where the understorey is sparse, refuge sites may be few. In the two instances described in this note, however, abundant alternative refuge sites were available. More usual refuge sites would be under or within logs, rock overhangs and dense scrub (Augee 1995) but in areas where such sites are limiting, low tree hollows may provide a suitable alternative. Echidnas have been observed in Tasmanian forests in hollow stumps and hollows in fallen trees (Anderson and Nicol pers. comm.) and thus it is possible that such features are used routinely, albeit infrequently, as refuge sites. Wilkinson *et al.* (1998) report on sites used for shelter by echidnas in the highlands of Queensland but do not cite examples of use of tree hollows.

In both instances described, it is suspected that the individuals occupied the tree hollow or hollow tree as a result of foraging activities. Echidnas are adept climbers but they have not been reported climbing trees in search of food. Augee (1995) draws attention to the ability of an echidna to extend its spines and limbs, allowing it to become securely wedged in a rock crevice or hollow log, predominantly as a defence mechanism. It seems likely that such an ability could also be used to "climb" trees, particularly up inside hollow tree trunks.

In the first case described, it may be that the animal simply "climbed" higher into the internally hollow tree trunk following a food source. Of course, it is also likely that this individual was found so high up the hollow tree trunk because of disturbance from the tree felling. In the second case described, the echidna may have "detected" a potential food source within the tree hollow. It was found in the hollow covered in decayed wood fragments suggesting it may have been digging within the floor of the hollow, possibly in search of food. It is highly likely that echidnas could be drawn to the odour of decaying wood and termites/ants in such hollows (C. Spencer pers. comm.), particularly if wood particles are deposited on the ground below the hollow. In this instance, the individual would have needed to climb up the outside of a near vertical tree trunk. Echidnas have been observed climbing over a metre vertically up cage wire in captivity (H & A Wapstra pers. comm.) so it is likely that they possess the ability to climb rough-barked tree trunks.

From observations such as these, it would appear that echidnas may occasionally use tree hollows and/or hollow trees in Tasmanian forests. This further highlights the importance of maintaining these habitat features for a range of forest fauna, not only for those species that routinely use hollows for nesting such as the parrots and cockatoos, but also for the occasional users such as echidnas.

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VOCALISATIONS OF THE COMMON RINGTAIL POSSUM *PSEUDOCHEIRUS PEREGRINUS*

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Biggins (1984) reviewed the knowledge of auditory communication in marsupial possums and gliders. For the ringtail possum *Pseudocheirus peregrinus* Biggins (1984) noted two contexts in which vocalisations were known to be produced i.e. an individual advertising its location (chirruping) and distress calls of a juvenile separated from its mother (chirruping twitter, partly ultrasonic). During a study of the ringtail possum in the field at Flinders Island and in the laboratory (Munks 1990) the opportunity arose to more fully document the range of vocalisations produced by this species.

Vocalisations of free-living ringtail possums were noted during the capture, mark and release of individuals and whilst they were radio-tracked at Whitemark Beach, Flinders Island between April 1986 and July 1988. Sounds emitted by animals maintained in captivity at the University of Tasmania over the same period were also noted. The vocal sounds noted and the context in which they were emitted are listed below.

Chirruping

Emitted on numerous occasions, usually while animals fed. However, it was also produced by mothers whose back-young were feeding nearby. Chirupping calls were also exchanged between familiar conspecifics. Thomson and Owen (1964) also noted the use of this call by juveniles that had been separated from their mothers. Biggins (1984) concludes that this call serves to identify and locate individuals for the purpose of maintaining social contact. Eisenberg *et al.* (1975) classified marsupial vocalisations into four types. The chirruping vocalisation fits type I.

"Chi-Chi-Chi"

This vocalisation was produced by sucklings when separated from their mother. This vocalisation also fits type I. It is different from the juvenile distress call (chirruping twitter) noted by Binns (1984).

Sonic twitter

This sound was produced by animals when disturbed, either by some natural disturbance while an animal was feeding, or during capture. The sonic twitter fits a type II sound of Eisenberg *et al.* (1975). These are generally involved with agonistic interactions or when animals are startled and stressed by exposure to aversive situations.

Rapid clicking

This sound was produced by adults of both sex when approaching an occupied nest box. The nest box occupant responded by partially emerging from the box sniffing the intruder and then either attacking the approaching animal or allowing it to enter the nest box. A loud clicking noise was emitted by a male when the female occupying the cage with him was in oestrus. This noise was accompanied by 'courtship' behaviour in which the male pursued the female around the cage. This is a type III sound that in marsupials tends to be associated with close social encounters, particularly sexual interactions.

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DIET OF THE COMMON RINGTAIL POSSUM *PSEUDOCHEIRUS PEREGRINUS* IN COASTAL TEA-TREE ON FLINDERS ISLAND

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Abstract. Observations of feeding by common ringtail possums was used to provide a qualitative estimate of their diet in a mature coastal tea-tree thicket at Whitemark Beach on Flinders Island. Observations of fifteen radio-collared animals were made during the Spring/Summer months and nineteen animals during the Autumn/Winter months between April 1986 and July 1988. Foliage from coastal teatree *Leptospermum laevigatum* constituted the major portion of the diet (89% of observed feeding time). *Melaleuca ericifolia, Allocasuarina verticillata, Leucopogon parviflorus, Acacia mucronata, A. sophorae* and *Callitris rhomboidea* were also eaten. Animals were only observed feeding in *M. ericifolia* during the Spring/Summer months. Chemical analyses of the leaves eaten by the possums showed that the fibre content of the foliage on which the ringtails were observed to feed was particularly high. However, the concentration of other digestibility-reducing compounds (i.e. total phenols) appeared to be lower than those recorded for eucalypt species and understorey tree species in other studies.

INTRODUCTION

There is little published information on the diet of the common ringtail possum, *Pseudocheirus peregrinus,* in different habitat types. Studies in Victoria have shown that the ringtail possum feeds on foliage from a wide variety of trees and shrubs, particularly those belonging to the Myrtaceae (Thompson and Owen 1964; Pahl 1984, 1985, 1987). Such foliage is regarded as a poor food source due to a low available caloric density resulting from its high fibre content and allelochemicals (Cork and Pahl 1984).

A study of ringtail possums inhabiting a mature *Leptospermum laevigatum* thicket on Flinders Island found that when they were active they spend a major proportion of their time feeding (34 - 44%) (Munks 1990; Munks and Green 1995). Observations of feeding by ringtail possums have been used in this paper to provide a qualitative estimate of their diet in this habitat. Chemical analysis of the leaves eaten by the possums was also undertaken to provide insight into the quality of their diet.

STUDY AREA

The study was undertaken near the small town of Whitemark (148'01'E, 40'06'S) on the west coast of Flinders Island. The study area was divided into two regions: 'Whitemark Beach' (17.5 hectares) was north of Whitemark; and 'Paddies' (15 hectares) was south of Whitemark. The highest estimated density of adult ringtail possums was 2.37/ha at Whitemark Beach and 2.47/ha at Paddies. 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 both regions *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). Coexisting tree species in the study area were *Allocasuarina verticillata, Callitris rhomboidea, Melaleuca ericifolia, Acacia sophorae* and one individual *Eucalyptus globulus*. Shrubs/small trees of *Leucopogon parviflorus, Myoporum insulare* and *Acacia mucronata* were recorded in the understorey. Where the tea-tree canopy was open *Olearia axillaris* and *Boronia heteronema* occurred as ground covers. Only a few swamp paperbarks *Melaleuca ericifolia* were found amongst the tea-tree stands but this species dominated on swampy ground and around lagoons. Flowering, fruiting and production of young leaves of *L. laevigatum* and *M. ericifolia* occurred during the spring and summer months. Percentage canopy cover of each tree species, assessed in a hectare block, was *Leptospermum laevigatum* 74%, *Allocasuarina verticillata* 19%, *Melaleuca ericifolia* 5%, *Callitris rhomboidea* 1%, *Acacia sophorae* 1% and *Eucalyptus globulus* >1%. Further details of the site are provided in Munks (1990, 1995).

METHODS

Feeding Observations

The study was carried out over 13 field visits, each of approximately two weeks duration, between October 1986 and June 1988. Feeding observations were made on fifteen animals at Whitemark Beach during the Spring/Summer months and nineteen animals during the Autumn/Winter (Munks and Green 1995). All animals observed had been fitted with collars with radio transmitters and beta lights (Biotrack, U.K.) fitted under the possum's chin (Fig 1). The radio signal was monitored using a Customs Electronics CE 12 receiver in conjunction with a portable 2 element Yagi antenna. Each possum carried a radio-collar for 5-6 days. After this period the animal was radio-tracked to its nest during the day, caught by hand and the collar was removed. The activities of two to three possums were monitored on each visit. Animals were located by radio-tracking and then observed for up to six hours. Observations were made at different periods of the night to cover all of the animal's active period. Some animals were radio-tracked to their nest during the day and then followed after they had emerged

Fig. 1. Ringtail possum with collar containing radio transmitter and beta-light.

from the nest at dusk. The behaviour of animals that were followed was recorded continuously with the aid of binoculars. The time at each behaviour change and any tree species eaten was noted. When necessary, a portable spotlight masked with a red filter was used to confirm the activity of the possum and identify tree species. Dense foliage frequently obscured the view of the animal and on these occasions sound was relied upon to determine its behaviour (e.g. feeding was recognised by a 'snap-munch-munch-munch' sound). Every effort was made to prevent disturbance to the animal by the observer. The diet of ringtail possums was qualitatively estimated from the percentage of total feeding time spent feeding on a particular tree species.

Chemical Composition of Leaves

Samples of foliage from the major tree species in the study area were collected between 3.00 pm and 5.00 pm in April 1987, June 1987, September 1987, December 1987 and January 1988. Leaves that had their petioles attached were stripped from peripheral branches of trees chosen at random. Each sample, containing a mixture of young and old leaves, was placed in a sealed plastic container and transported to the laboratory in a cool-box. In the laboratory each sample of leaves was weighed to the nearest 0.01 g, dried in an oven at 50°C for 24-36 hours and then stored at –20°C. Prior to chemical analysis, subsamples were ground with a pestle and mortar (for determination of dry matter and energy content), or through a 1 mm screen in a centrifugal mill (for analyses of organic matter, total nitrogen, crude lipid, total phenolics and cell wall constituents).

Dry matter content was determined by drying the leaf samples at 80°C in a forced draught oven to constant mass (36-48hrs). Samples were ignited in a muffle furnace at

530°C for 3 hrs and the percent organic matter was determined as:

organic matter (%) = leaf dry mass - ash mass x 100 leaf dry mass

Ground dried leaf samples were compacted into discs and then ignited in a Gallenkamp Ballistic Bomb Calorimeter. The gross energy content (kJ/g) of each leaf species was then determined from the heat of combustion using benzoic acid as a standard. Total nitrogen was determined using the semi-micro Kjeldahl method (AOAC 1970). The crude protein content of the leaves was then estimated as N (% dry leaf mass) x 6.25 (Cork *et al.* 1983). Crude lipid content was estimated by the Soxhlet extraction method with petroleum ether as the solvent.

Total phenolics were determined following the method of Cork and Pahl (1984), modified by S. Cork (personal communication). Known weights of dried and ground leaf samples were extracted in 50% acetone and total phenolics were determined spectrophotometrically using the Folin-Ciocalteu method (Singleton and Rossi 1965). Gallic acid (75 mg in 50 mls of 50%MeOH) was used as a standard. Cork *et al.* (1983) found that oven dried leaf samples were lower (approx. 11%) in total phenolics than fresh leaf samples. However, it was not feasible to analyse fresh leaves in this study. Known weights of the dried and ground leaf samples (0.5 g) were extracted for three days in 50% methanol. Neutral-detergent fibre (total cell-wall constituents), acid-detergent fibre, cellulose and acid-detergent lignin were then determined following the procedures of Goering and Van Soest (1970), modified by Cork and Pahl (1984). Hemicellulose was determined as the difference between total cell wall constituents and acid-detergent fibre.

RESULTS

Feeding

Foliage from coastal teatree, *Leptospermum laevigatum*, constituted the major portion of the diet (Table 1). *M. ericifolia* was only observed being eaten during the Spring/Summer months and *Allocasuarina verticillata, Leucopogon parviflorus, Acacia mucronata, A. sophorae* and *Callitris rhomboidea* were only observed being eaten during the Autumn/Winter months. Feeding on *M. ericifolia* in Spring/Summer coincided with flowering by this species. However, the dense foliage prevented detailed observations of the particular dietary items selected by individuals.

Chemical composition of feed leaves

There was no obvious seasonal difference in the chemical composition of *Leptospermum laevigatum* and *Melaleuca ericifolia.* The results of the combined seasonal samples are presented in Table 2.

All the leaf samples were high in cell-wall content. *Acacia sophorae* had the highest concentration (73% dry matter), whereas *Callitris rhomboidea* and *L. laevigatum* had the lowest (60.8%). This lower total cell-wall content for *L. laevigatum* was due to a lower cellulose concentration compared with the other species.

Table 1. Percentage of the feeding time of ringtail possums at Whitemark Beach spent eating the foliage of different tree species.
The total time that feeding was observed in Spring/Summer was 18 hrs 23 mins and in Autumn/Winter was 24 hrs 6 mins.

	Percentage of feeding time	
Tree species	Spring/Summer	Autumn/Winter
Leptospermum laevigatum	88.03	89.3
Allocasuarina verticillata	-	5.53
Melaleuca ericifolia	11.97	-
Callitris rhomboidea	-	0.7
Acacia sophorae	-	1.04
Leucopogon parviflorus	-	2.07
Acacia mucronata	-	1.40

There was little variation in total phenolic content (ranging from 1.8% to 2.9% of dry matter), crude lipid content (4.6% to 6.7%), or gross energy content (20.3 to 22.7%) between the foliage of different tree species. Crude protein content ranged from 5.8 % to 9.1 % of dry matter.

There was no significant seasonal differences (paired Student's t-test) in the water content of the leaves of any of the tree species. *L. laevigatum* had the lowest water content (50.9% fresh weight) and *A. sophorae* foliage (63.2%) had the highest.

DISCUSSION

This study used direct observation of ringtail possums feeding to quantify their diet. However, disturbance from an observer may limit the effectiveness of this technique as a means of quantitatively determining diet composition (Pahl 1987). In addition, the proportion of time spent feeding may not represent actual intake of a particular species since different parts of the tree may require different handling times. For example, if young leaves have a lower fibre content than mature leaves (Cork and Pahl 1984), less time would be needed for their mastication and digestion. This study suggested that the diet of ringtails consisted primarily of *Leptospermum laevigatum* foliage supplemented by foliage from other less abundant tree species. Pahl (1987) used a different technique, analysis of faecal pellets, to study the diet of *P. peregrinus* inhabiting a coastal tea-tree thicket at Sandy Point in Victoria. He also found that the diet consisted almost entirely of *L. laevigatum* foliage.

Observations suggested that the second most abundant tree species, *Melaleuca ericifolia*, formed part of the diet of ringtail possums at Whitemark Beach during the

Table 2. Composition of the foliage from tree species eaten by ringtail possums at Whitemark Beach.

Values are % dry matter unless otherwise stated. Key to species: LL = *Leptospermum laevigatum*, ME = *Meialeuca ericifolia*, AV = *Allocasuarina verticillata*, AM = *Acacia mucronata*, CR = *Callitris rhomboidea*, AS = *Acacia sophorae*.

Constituent	Tree Species					
	LL	ME	AV	AM	CR	AS
Dry matter (% fresh wt)	49.4	44.9	46.2	39.0	39.3	36.0
Ash	2.8	4.5	5.2	4.2	3.5	2.9
Crude protein (Nx6.25)	5.8	7.9	8.9	9.1	6.6	-
Cell wall constituents:						
Neutral-detergent fibre	60.8	68.4	65.1	68.8	60.8	73.6
Hemicellulose	7.3	6.3	14.3	0.8	-	-
Acid-detergent fibre	53.5	62.1	59.8	68.1	-	-
Cellulose	16.6	28.0	27.1	21.6	-	-
Lignin	36.9	34.0	23.7	46.5	-	-
Total phenolics	6.8	9.2	6.1	7.2	5.8	-
Crude lipid	7.0	5.0	5.4	4.6	6.0	-
Gross energy (KJ/g)	23.0	21.3	21.1	21.0	22.3	20.3

spring and summer months but not during the winter. *Melaleuca ericifolia* produces flowers during the spring and early summer months at Whitemark Beach and since ringtail possums are known to consume flowers of other species (Pahl 1987), consumption of *M. ericifolia* flowers may account for the observations made of possums feeding in this tree species.

Animals were observed feeding on the less abundant tree species (eg. *Allocasuarina verticillata, Callitris rhomboidea*) during the autumn/winter months. This may be related to the lower quality of *L. laevigatum* foliage at this time of year. Pahl (1987) showed that the proportion of young *L. laevigatum* foliage in the diet of ringtails at Sandy Point was highest during the spring and summer and that this coincided with an increase in production of young *L. laevigatum* foliage (Pahl 1987). Assuming that *L. laevigatum* shows a similar pattern of production of young leaves at Whitemark Beach, the observations of ringtails feeding in the less abundant tree species during the winter may reflect a need to supplement the diet.

Proximate analysis of the leaves from the tree species in which ringtails were observed feeding revealed a high concentration of total cell-wall and lignin (i.e. 61 -74%

and 24 - 46% dry matter respectively). These values are greater than found in eucalypt species (23 - 56% and 9 - 27% respectively (Cork 1984; Foley 1987) that constitute the major food source for ringtail possums in other areas (Thompson and Owen 1964; Pahl 1984, 1985, 1987). However, these high levels of fibre were similar to those found in understorey tree species (i.e. *Leptospermum juniperum*, *Acacia melanoxylon*) in eucalypt forest (Cork and Pahl 1984).

Although the fibre content of the foliage on which the ringtails were observed to feed at Whitemark Beach was particularly high, the concentration of other digestibility-reducing compounds (i.e. total phenols) appeared to be low. In general, total phenolic concentrations were lower than those recorded for eucalypt species and understorey tree species (Cork 1984; Cork and Pahl 1984). However, in this study, leaf samples were analysed for total phenolics after they had been dried and since drying may cause some oxidation of phenolic compounds this may have lead to underestimates (S.Cork pers. comm.). Nevertheless, Cork (unpublished data) found similar low levels of total phenolics in samples of *L. laevigatum* foliage that had been analysed without prior drying. He also noted correspondingly low levels of tannins. Levels of crude lipid were also relatively low compared with eucalypt foliage (Cork 1984; Foley 1987). It is possible that this difference was due to a lower concentration of essential oils in the foliage analysed in this study.

In summary, the diet of the common ringtail possum inhabiting the mature *L.laevigatum* thicket in this study was found to be almost entirely of *L. laevigatum* foliage. This is similar to that recorded for ringtail possums inhabiting a younger stand of coastal tea-tree at Sandy Point in Victoria (Pahl 1987). The foliage available as food for the ringtail possums at Whitemark Beach in general shares the low nutritional qualities of foliage eaten by ringtail possums in other areas.

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IF THE CAP FITS.........

An intriguing interaction between forest species at Stonehenge in the eastern Midlands of Tasmania.

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The spring and early summer of 1999 was a period of profuse flowering of *Eucalyptus globulus* subsp. *globulus* (Tasmanian blue gum) in southeastern Tasmania. An observant farmer, who has large stands of *E. globulus* on his property at Levendale, described it as the heaviest flowering he has seen in the 40 years he has lived in the area.

In November 1999, I surveyed an area of bushland on Stonehenge property in the eastern Midlands [Whitefoord 1:25000 mapsheet – ^{5}583 (E), ^{53}061 (N)]. I was accompanied by Robyne Leven of North Forest Products. Dolerite tiers and slopes on the property mainly supported regrowth stands of *E. globulus* forest, with *E. pulchella* and *E. viminalis* present to varying degrees (the latter species were not associated with the site described below). The understorey had been grazed heavily by stock but was relatively diverse, and contained several dolerite endemics, such as *Clematis gentianoides, Hibbertia hirsuta* and *Lepidosperma inops*.

My eyes were drawn to a patch of *Lepidosperma laterale* (sword sedge), about 20x20 m in area, that emerged conspicuously from the close-cropped grassland that surrounded it (Fig. 1). It was reminiscent of the bristly tuft, also surrounded by close-cropped stubble, favoured as a hairstyle by American sailors and basketballers.

Inspection of the *Lepidosperma* patch revealed an intriguing connection between it and the heavily flowering *E. globulus*. Impaled on the sharp points of the *Lepidosperma* leaves were many opercula (caps) that had been forced off the *E. globulus* buds by the emerging stamens of the developing flowers. (The operculum actually comprises the fused petals and sepals of the eucalypt flower. A cross-section through the operculum shows these two distinct layers. In fact, the genus name, *Eucalyptus*, refers to this feature: from the Greek *eu* meaning well or good, and *calyptus* meaning cap or cover.) The *E. globulus* opercula in the area were disc-like in shape and typically 16-18 mm in diameter (at their widest point, about 2 mm above the rim) and 10 mm in height (from rim to tip). This falls within the range described and illustrated in Chippendale (1988).

Opercula that had committed hari kari on the *Lepidosperma* "swords" could be seen throughout the sedgeland. We conducted an intensive survey on a 2x2 m area, representative of the sedgeland. Forty-one caps were impaled on *Lepidosperma* leaves in the area sampled. Most caps were more or less "suspended" on the leaves of *Lepidosperma*, the leaf tips penetrating into but not through the opercula. However, about 40% of the caps were skewered, the leaf tip generally entering the inner (corolla) side of the opercula, before passing out through the outer (calyx) side (Fig. 2).

Fig. 1. The site of the impaled opercula of *E. globulus* on Stonehenge property showing the landscape context of the patch of *Lepidosperma laterale* surrounded by close-cropped grassland and distant trees.

Maximum distance of leaf emergence was 11 mm. Three buds or young capsules were also impaled in the 2x2 m area, as was a faecal pellet of a brush-tailed possum (*Trichosurus vulpecula*).

The edge of the *Lepidosperma* sedgeland was 29 m from the base of the nearest flowering blue gum, and at least 20 m from the closest branch of the same tree. To estimate the density of capfall under the canopy of this old-growth tree we randomly located twenty 20x20 cm quadrats within 5 m of its base. There was an average density of 9.5 fresh (1999) caps per quadrat (range 2-17), giving a rough density of 240 caps/m^2 under the tree.

We used the same techniques to assess the density of caps reaching the representative *Lepidosperma* site. The density of *E. globulus* opercula on this site (on the ground or held up by *Lepidosperma* leaves and other vegetation) averaged 5.9 caps per quadrat (range 0-15), giving a rough density of 150 caps/m^2, substantially less than under the tree. This means that the *Lepidosperma* leaves impaled about 7.5% of blue gum opercula that were deposited on the site.

Although the understorey at the sampled site gave the impression of being dominated by *Lepidosperma*, I estimated that *Lepidosperma* only covered about a quarter of the ground surface, with grass species (notably *Ehrharta stipoides, Danthonia* species, *Poa rodwayi, Themeda triandra*) and herbs being the major contributors to ground cover. There were about 38 "clumps" of *Lepidosperma* in the 2x2 m plot, the clumps varying in coherence from very distinct to somewhat diffuse. The average number of hard, pointed leaves per clump was 19.8 (range 6-38, 20 clumps assessed).

The efficiency of *Lepidosperma* leaves in intercepting opercula can be further examined using the information presented above. Assuming 25% effective cover of *Lepidosperma*, 30% of the opercula falling on *Lepidosperma* clumps were impaled or pierced by its leaves. About 5.5% of the *Lepidosperma* leaves on the site carried an

Fig. 2. *Lepidosperma laterale* leaves with attached opercula (caps) of *E. globulus* from Stonehenge property in the eastern Midlands. The photograph shows leaves collected from across the sampled plot and not a single clump of *Lepidosperma*.

operculum of *E. globulus*.

The heights of *Lepidosperma laterale* leaves varied, but most were 25-40 cm in length. The threat posed by *Lepidosperma* leaves to incoming opercula is largely a function of leaf age and height. The most effective interceptors were taller, mature leaves with hard and sharp tips. These are probably "lethal" for long periods. Very young leaves are unlikely impalers because they have soft tips and are shorter (i.e. less emergent) than mature leaves. Old leaves have hard tips, but these were often broken or blunt.

Another important variable in this phenomenon is the resistance (or penetrability) of the opercula. Freshly fallen caps are softer, moister and more pliable than older caps. It takes only a short period for caps to dry out and become rigid. Some caps on the ground at Stonehenge appeared to have been liberated from their capsules for only a couple of days, but had already developed a hardness that would prove too great a barrier for a *Lepidosperma* leaf to penetrate. This is probably a moot point: opercula that are impaled on *Lepidosperma* leaves will (like many of the American sailors seen wandering around Hobart) have only recently been separated from their buds.

From the detailed analysis presented, it can be seen that the leaves of *Lepidosperma* are effective interceptors of downwardly mobile opercula. The flight path of the caps is likely to vary with their aerodynamic attributes and wind parameters. The distance from nearby trees indicates that the angle of opercula approach would be less than 45°. Unfortunately, over-stretched departmental resources did not permit further investigation of the interactions between *Lepidosperma* leaves and falling *E. globulus* opercula. These included velocities reached by falling opercula, and the forces of impact when opercula make contact with a hard, sharp point. The possibility of incoming opercula developing a frisbee action in flight cannot be discounted, as most caps were impaled on their lower side. The dimensions and mass of *E. globulus* opercula may also be critical. The opercula of other Tasmanian eucalypt species are considerably smaller and lighter than those of *E. globulus*, and may not reach sufficient momentum to be impaled when confronted with a sharp object. In addition, most have a more conical shape, which is more likely to shear or ricochet off an acute leaf, compared to the relatively flat cap of *E. globulus*. Though here too are dimensional uncertainties, as the cylindrical possum pellet was well impaled! There is potentially fertile ground for a major long-term interdisciplinary university research program.

The situation observed at Stonehenge does not seem to have been previously recorded in Tasmanian botanical literature. Despite the location of the site, it is unlikely that paranormal forces were responsible. The interactions analysed in this paper may occasionally occur elsewhere in southeastern Tasmania, as *Lepidosperma laterale* and *E. globulus* are commonly associated in grassy forests and woodlands. There may be fewer opportunities for similar events on the eastern Australian mainland, despite the widespread dominance of eucalypts in the landscape. Apart from other members of the

E. globulus complex, there are no eastern mainland eucalypts with opercula approaching the size and mass of those of *E. globulus* (Brad Potts, pers. comm.). The Western Australian goldfields region may hold promise, with its rich heritage of large flowered Myrtaceae.

In an interesting adjunct to the situation described in this paper, the bodies of grasshoppers impaled on the leaves of *Lepidosperma* species have also been observed in the Midlands (Louise Gilfedder pers. comm.), suggesting that the taxonomic relationships between *E. globulus* and the order Orthoptera may require revision.

ACKNOWLEDGMENTS

I thank Robyne Leven for field assistance, though I suspect that she did not appreciate the wider implications of our research at the time. Louise Gilfedder provided food for thought, and Rob Taylor had some useful comments on the manuscript, particularly in relation to future research requirements and priorities. I would also like to thank John Hickey for encouraging me to analyse and publish quantitative data on forest ecology.

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ECOLOGY AND CONSERVATION OF THE CHAOSTOLA SKIPPER BUTTERFLY (*ANTIPODIA CHAOSTOLA LEUCOPHAEA*) IN TASMANIA

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Abstract. The Chaostola skipper butterfly *(Antipodia chaostola leucophaea)* is known to occur at four sites, two of which lack the identified food plant, *Gahnia radula*. This strongly indicates that there are alternative food plant species but this is yet to be confirmed. The butterfly is notoriously difficult to observe and may occur more widely than is currently known. *Gahnia radula* was once widespread and abundant on the eastern seaboard of Tasmania, but land development and increased urbanisation has caused a dramatic reduction in the distribution and abundance of the plant, and in the health of remnants of native vegetation in which the plant occurs. The poor condition of the remaining habitat, and the lack of observations of the butterfly indicates that, until there is evidence to the contrary, *A. c. leucophaea* should be considered to be endangered. Future surveys of the species are urgently required. These should focus on those areas most likely to support populations and on the four sites from which recent records have been obtained. Further investigation of the plant species utilised as food is also required.

INTRODUCTION

The chaostola skipper *Antipodia chaostola* occurs in New South Wales, Victoria and Tasmania. However, the Tasmanian populations are considered to be a separate subspecies, *A. c. leucophaea* (Fig. 1). Couchman and Couchman (1977) considered the chaostola skipper to be rare in Tasmania. *Antipodia chaostola leucophaea* was known from only two specimens before Len Couchman (with the assistance of J. R. Cunningham and S. Angel) located colonies near Hobart at Knocklofty and Kingston. At the time, he considered that the colony at Kingston had been lost due to the encroachment of housing and that the butterfly was "extremely local in its distribution". Apart from some incidental collections made by P. McQuillan, there has been little additional data gathered on the chaostola skipper since the active collecting by Couchman and his associates in the late 1940's and 1950's. This paper discusses the results of recent surveys to determine the current conservation status of the chaostola skipper in Tasmania.

Fig. 1. The chaostola skipper *Antipodia chaostola leucophaea* with the food plant *Gahnia radula* (from McQuillan and Virtue 1994).

METHODS

The habitats used by the species in Victoria were investigated during a field trip in September 1992. The trip was guided by David Crosby, a Victorian butterfly enthusiast of long standing who had discovered many of the known colonies. The floristics and structure of the vegetation at each site was recorded, and most sites were photographed. It is considered likely that the preferred habitats of the Victorian race are comparable to those used in Tasmania.

All the existing Tasmanian records of the species were collated. Areas in Tasmania considered likely to support populations were identified by the following methods. Initially, the habitat preference was determined from the known Tasmanian sites and the sites surveyed in Victoria. The chaostola skipper was known to feed on *Gahnia radula*. A list of locations where the food plant occurred was compiled from herbarium, literature, and Tasmanian Parks and Wildlife Service database records. Potential sites for the butterfly, based on the list of known food plant locations and the likely habitat preferences, were identified by field work prior to the commencement of the flight season for *A. c. leucophaea* (October and November, Common and Waterhouse 1982). Additional likely habitat was also located during searches for the butterflies. Approximately 26 days were spent searching for *A. c. leucophaea* during the flight season in 1992.

TAXONOMIC STATUS

Atkins (1984) reassessed a number of Hesperiid genera, and assigned *Hesperilla chaostola leucophaea* to a new genus *Antipodia*, based on differences in the genitalia. In addition the pupae and larvae of *Antipodia* rest in a head downward position within shelters on their food plant whereas all *Hesperilla* spp. rest in an upright position.

HISTORY

Specimens of *Antipodia chaostola leucophaea* are held in the Australian National Insect Collection in Canberra, the Australian Museum in Sydney and the Tasmanian Museum and Art Gallery in Hobart. The earliest records are from Huonville (1899, Holotype, collected by J. R. Norman), Hobart (1915, collected by C. Cole), Snug River, (undated, collector I. Harman) and Bicheno (1945, collected by S. Angel). Colonies were located in the 1950's by J. R. Cunningham, Couchman and others, at Kingston (the type locality of the Tasmanian form of the species), and on Knocklofty near Hobart. Both Couchman and Couchman (1977) and Common and Waterhouse (1982) regarded the species as rare and localised in Tasmania. Douglas (1984) located a colony of the butterfly on the Sheppards Hill at Conningham, (12 km south of the type locality), from where he took specimens in 1981 and 1982. Douglas (1984) also located the species at Kingston in 1980, 1981 and 1982 and reported that in November 1982 a further expansion of housing into the area at Kingston occupied by the butterfly was taking place. During 1992, Peter McQuillan (pers. comm.) collected specimens from Mt. Nelson near Hobart and The Old Coach Road, west of Bicheno.

HABITAT

All the colonies observed in Victoria were in areas of low open sedgey woodland. The dominant eucalypts were short in stature, often with a mallee form. Eucalypt cover was low and the understorey was dominated by sedges (with *Gahnia radula* prominent) with a diverse array of heathy shrubs scattered through the ground layer. In Tasmania, sites with vegetation most comparable to the Victorian sites are rare and occur at She Oak Hills Road, Cherry Tree Hill and Old Station Road at Conningham.

BIOLOGY

A. c. leucophaea is unusual among the Hesperiids because it has a two-year life cycle rather than the usual one-year. The larvae are nocturnal feeders, hiding by day in a shelter created by joining the edges of several *Gahnia* leaves together with silk that forms a tunnel with an opening at the base. Young larvae can be recognised from other Tasmanian Hesperiids by a patch of bright red colouration on the ventral surface behind the head. Also atypically for Hesperiidae, it rests head downward within this shelter. Mature larvae pupate head downwards in shelters constructed at the base of the food plant. Eggs are laid in October and November and the larvae develop slowly over the next twelve months. The final instar remains quiescent until the end of the second winter and then pupates, emerging two years after the egg was laid (Common and Waterhouse 1982).

FOOD PLANT

Gahnia radula, a known food plant of *A. c. leucophaea,* was found throughout eastern Tasmania. It extends from Devonport to Cape Portland in the north of the State

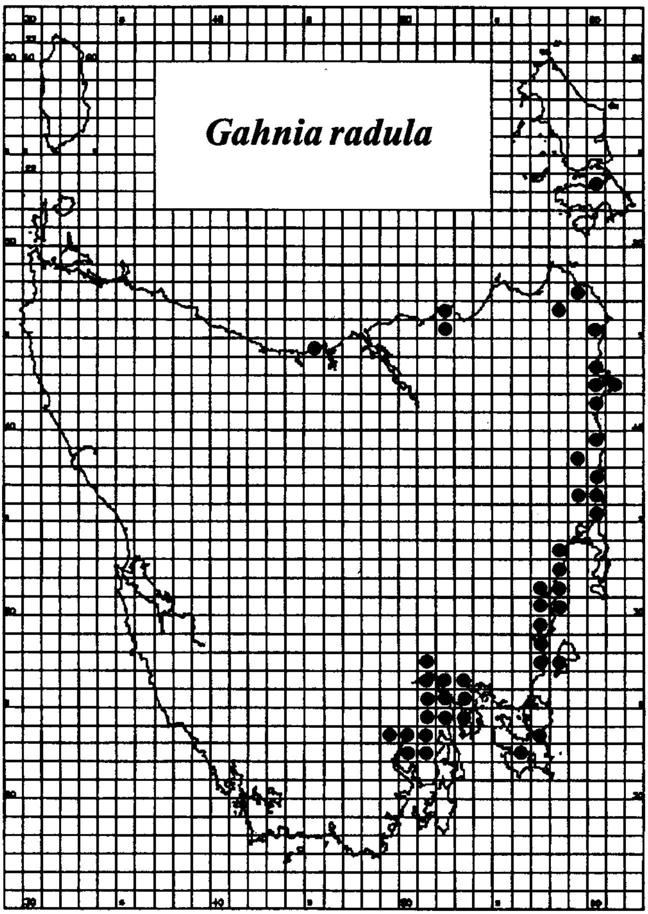

Fig. 2. The known locations of the food plant *Gahnia radula.*

and down the East Coast to the lower reaches of the Huon River in the south. Throughout this range its distribution is coastal, rarely extending inland (Fig. 2). It is generally found on infertile substrates, such as soils derived from mudstones, siltstones, granites and aeolian sand. It is rare on dolerite and usually is found on doleritic soils only when it is abundant nearby on poorer soils from where it appears to have spread. It occurs as a minor species in the understorey of open forest dominated by one or more of *Eucalyptus amygdalina*, *E. sieberi* (north-eastern Tasmania only), and *E. viminalis* with *E. obliqua*, *E. ovata*, and *E. globulus* sometimes present. *Gahnia radula* dominated the understorey at sites that have been burnt frequently, (e.g. Humbug Point State Recreation Area).

The two sites where McQuillan collected the butterfly in 1992 have no local populations of *Gahnia radula*. This suggests that the butterfly may also feed on other species of *Gahnia*. The larvae of *A. c. chares*, which occurs in Victoria, usually feeds on *Gahnia radula*, but in the Grampians, in western Victoria, larvae have been collected from *G. sieberana* and *G. microstachya* (Common and Waterhouse 1982). *Gahnia sieberana* does not occur in Tasmania but *G. microstachya* is scattered throughout north-eastern Tasmania, usually on granite. The most common *Gahnia* in Tasmania is *G. grandis* which is widespread and abundant. Further research is required to determine whether other species of *Gahnia* are food plants of *A. c. leucophaea*.

During this survey only small, scattered areas of *G. radula* were found at Kingston. The rapid spread of housing in this area has been responsible for the local decline of the butterfly. Two Herbarium records of *G. radula* for Maranoa Road and Maranoa Estate (recently developed parts of Kingston) date from 1979. *Gahnia radula* could not be located in that area during the survey and housing in the area continues to expand.

Throughout the range of *G. radula* the native vegetation has been substantially altered through agricultural and urban development. In the Huon Valley and on the East Coast from Orford to Scamander the food plant is now largely restricted to roadsides, although there are some small pockets of forest in reasonable condition that contain *G. radula*. Known locations for these are Bicheno (Australian Map grid references 6051 53652 and 6084 53597), Bridport Back Road (5300 54513), Bridport Tip (5319 54608), Cherry Tree Hill (5946 53520), Humbug Point Nature Recreation Area (6100 54307), Lagoon Road at White Beach (5602 52252), Malcolm's Hut Road (5325 52648), Pines Road (5778 53081), She Oak Road (4882 52364) and Whittons Road (5186 52233).

Urbanisation, and the associated pressure this brings to remnants of native vegetation, has probably caused the local extinction of the butterfly in some areas. Roadside and fenceline stands of *G. radula* indicate that the plant was once extensively distributed throughout South Arm and the Acton area, which is now sub-divided into five acre holdings. The continuing subdivision of these areas will eventually result in the local extinction of many native species of flora and fauna.

SURVEY RESULTS

Twenty-six days were spent in the field searching for both the butterfly and for areas of apparently suitable habitat. All apparently suitable sites were searched for the butterfly for at least two hours. The site at Snug, which was presumed to be the site from which the butterfly was most recently recorded, was searched for around 16 hours. The only specimen of *A. c. leucophaea* located during the 1992 survey was found at this site, on Old Station Road within the Conningham State Recreation Area, on the 15th of December 1992. Identification was confirmed by P. McQuillan and the specimen is lodged with the Tasmanian Museum and Art Gallery.

It is assumed that this is the site where Douglas (1984) took specimens of this species in the early 1980's. It is a mosaic of heathland, heathy woodland and dry sclerophyll forest, all of which show evidence of being frequently burnt. The single butterfly located was found in an area in relatively good condition where the understorey was dominated by *G. radula*.

The weather through the 1992 flight season was not very favourable, with very few warm days of sunshine and light winds. D. Crosby in Victoria expressed little surprise that so few butterflies were found during this survey. His experience indicated that within some large areas of suitable habitat the butterflies are patchily distributed and restricted to small discrete sites. He found it was possible to search through areas of apparently suitable habitat, that could have supported a colony, without actually observing the butterfly. He found that repeated exhaustive wanderings are often required to locate colonies. Atkins (1984) also describes the butterfly as being "generally very scarce and local" and also notes that the adults are rarely observed.

Since the 1992 survey one new site for the species has been located at Little Swanport south of Swanston Road. In August 2000 pupal casts were found in dry sedgy/ grassy forest dominated by *Acacia mearnsii* and *E. globulus* with an abundant understorey of *G. radula*.

CONSERVATION STATUS

The results of this survey show that the butterfly currently occurs in at least four locations (Old Station Rd, Snug, Old Coach Rd, Mt. Nelson and Little Swanport; Fig. 3). However, given the difficulty in observing the butterfly and the poor weather in the 1992 flying season, it is probable that other colonies also exist. It is equally probable that they will be small colonies.

The habitat of the butterfly has been severely reduced both in extent and in quality over the last two hundred years and this reduction is continuing. This continuing fragmentation and destruction of the habitat of the species is the primary cause of its decline. The species is listed as endangered under Tasmania's Threatened Species Protection Act.

RECOMMENDATIONS

Future surveys of *A. c. leucophaea* should be undertaken in areas where good populations of the food plant *G. radula* exist, and in the four sites from where the butterfly has been recorded recently. The range of food plant eaten by the species also requires investigation.

ACKNOWLEDGMENTS

Peter Brown (Parks and Wildlife Service) assisted with support and encouragement and gentle reminders not to forget to record frogs. Peter McQuillan (University of Tasmania) provided some curious site records, shared ideas about butterfly behaviour and collection and curation techniques and identified the larval and pupal casts from Little Swanport. David Crosby provided a guided tour of known sites in Victoria as well as useful advice on finding and identifying the larvae and pupae. Max Moulds of the

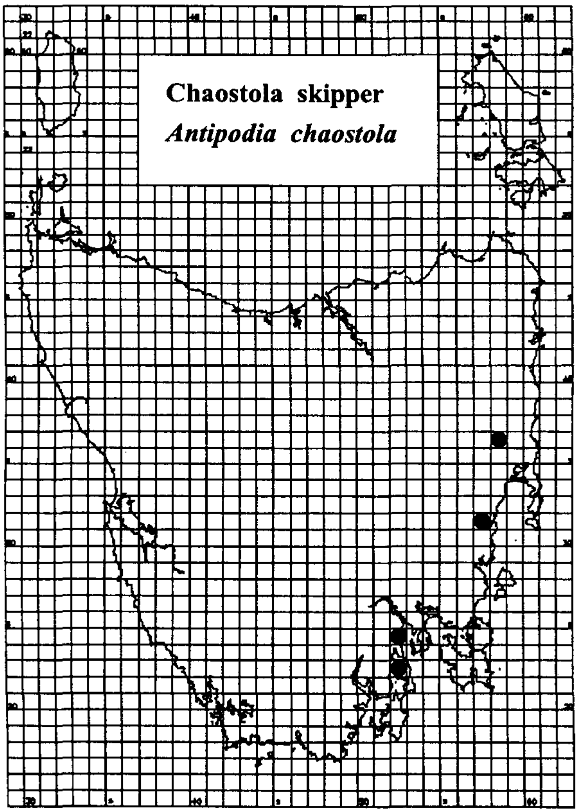

Fig. 3. The locations from which the chaostola skipper *Antipodia chaostola* has been collected in recent years.

Australian Museum and Ebbe Nielsen of the Australian National Insect Collection provided details of their holdings of specimens of the butterfly. Alex Buchanan of the Tasmanian Herbarium provided locality records for the food plant. Funds for the project were provided by the National Estate Grants Program.

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BOOKREVIEW

The Orchids of Tasmania

by David Jones, Hans Wapstra, Peter Tonelli and Stephen Harris,
Miegunyah Press at Melbourne University Press. 317 pp. RRP $79.95.
Reviewed by Kevin Bonham

This long-awaited book is a major publication in Tasmanian natural history. It is the first single publication to combine maps, colour photographs and extensive notes on all Tasmanian orchid species. Furthermore, it incorporates the enormous taxonomic changes which have occurred in the last decade (changes which have affected about three-quarters of the orchid flora). It therefore clearly makes all previous popular guides to Tasmanian orchids totally redundant. *Orchids of Tasmania* is as close to definitive as is possible at this time, and will not be surpassed for at least a decade.

The book features 195 orchid taxa, four more than last year's *Contributions to Tasmanian Orchidology* volume, Jones' formal taxonomic precursor to this work. A full page is allotted to each taxon, including a lengthy description and notes on recognition, confusing species, distribution, habitat, flowering period and miscellaneous facts. All species except two are photographed and every species is mapped on a 10x10 km square grid. There is also a key to species within each genus, and a key to the genera, and a separate technical diagram showing flower features for each genus. The latter will be especially useful to beginners trying, for instance, to come to terms with the fact that *Prasophyllum* have inverted flowers. An outstanding innovation is the double-page spread of Les Rubenach's fine colour close-up photographs of *Thelymitra* columns (p. 260-1). Tedious squinting at line drawings is finally a thing of the past.

The photographs by various photographers (mostly Rubenach, Tonelli and Hans and Annie Wapstra) are generally of very high to excellent standard. Impressively, nearly all are of Tasmanian specimens. The species descriptions, although often more compact than those in Curtis' (1979) *Students Flora of Tasmania 4A*, are also more precise and make more use of quantitative measurements. The maps (drawn heavily from David Ziegeler's *Tasmanian Orchid Atlas* project) are a splendid biogeographical resource and represent excellent coverage of the state. Some of the maps, through no fault of the authors, can only show representative localities because so many old records became ambiguous when several species (for instance the old *Chiloglottis gunnii*) were split. This generally only affects common species and does not greatly undermine the usefulness of the maps. The reservation status notes are generally very good, and it is pleasing to see the authors formally define the term "well represented" (p. xiii): "occurs in three or more State Reserves or Forest Reserves, which ... can only be revoked by an Act of Parliament." The identification keys (for those who use such things) are somewhat more approachable than Curtis', especially as the authors (unlike Curtis) include an excellent glossary of terms.

The book includes useful discussions of Tasmania's orchid flora by habitat type, and sensible and informative comments on the conservation status of our orchids. Taken together, these reveal that the most severe threat to Tasmanian orchids is permanent habitat clearing, chiefly for pasture development. However, the authors are positive about the prospects for co-operation with landholders, and give two excellent case histories in support of this. With so many species likely to be confined to narrow ranges and remnants, it is not surprising that the authors nominate 23 species and one subspecies for national Critically Endangered status.

The book contains just a few contentious points. The "confusing species" selections are sometimes on the miserly side (many amateurs might find *Caladenia echidnachila* and *C. helvola* confusing, for instance) although the miscellaneous notes often partly make up for this. There are perplexing inconsistencies between the text and mapped distributions for *Caladenia anthracina* (p. 59) and *Prasophyllum secutum* (p. 203)and also in at least four cases the given locality of the photographed specimen is not mapped. The proposed Endangered status for *Caladenia caudata* (p. 68) is surprising, given that the species has 40 mapped grid squares and is described as "widespread" and "well reserved". Three very rare species found on Knocklofty and another found at the Waterworks (both Hobart City Council reserves) are strangely classified as unreserved. While such reserves may not require an Act of Parliament to revoke them, in all likelihood they will remain at least as politically secure as, and better resourced than, some reserves within the state system.

The price-tag may depress potential buyers, but you get what you pay for: a brilliantly presented and produced hardback packed with detail and expertise and based on massive research efforts. It will be interesting to see what advances on the existing taxonomy are still possible and how many species still remain undiscovered, and hopefully a revised edition of this book a decade or two down the track will incorporate these. An abbreviated pocket version might also be desirable, as this book is too bulky and lavish to be tortured in the field. Meanwhile, I recommend *Orchids of Tasmania* as an outstanding contribution to Tasmanian natural history.

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