Not all dead wood is the same – a selection error reveals an unusual emergence of beetles from decaying celerytop pine logs

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Abstract

An unexpected outcome of a study of beetle emergence from cut eucalypt logs in Tasmania's southern forests was that three of the 60 logs in the study were later discovered to be celerytop pine rather than *Eucalyptus obliqua*. These three logs turned out to be a relatively high species-rich dead wood habitat type, with 43 species collected from 969 individual beetles. The diversity, however, within celerytop pine logs was markedly lower than similar-sized eucalypt logs of the same decay stage and occurring in the same forest type. In particular, the weevil, *Ancyttalia oleariae* Lea, 1906 represented 82% of all individuals collected from the celery top pine logs, and of the 44 species, 19 were represented as singletons and 11 as doubletons. While the emergence pattern observed from decaying celerytop pine logs was found to be very different and markedly lower in diversity to that observed from eucalypt logs, this selection error does highlight that not all dead wood is the same, but they all collectively contribute habitat for biodiversity.

Introduction and background

Serendipity is not a word that is often associated with scientific experimentation, where it is accepted that good experimental design and execution is an essential part of the protocol and procedure. However, circumstances often intervene that result in unforeseen outcomes, with potentially disastrous consequences for the experimenter. Sometimes even the best of designs hit a snag for a variety of reasons, but still produce a propitious outcome. Such was the case with one part of the PhD study of one of the present authors (Yee 2005), which involved cataloguing the beetle species and contrasting the beetle assemblages in small- vs. large-sized logs taken from mature vs. regenerating study sites within the tall wet *Eucalyptus obliqua* native forests in southern Tasmania. The plan was to have 60 logs, i.e. felled tree trunks not rooted in the ground, all derived from *E. obliqua* trees. After the initial sampling period, it was discovered that three of the small-sized logs (one at one site, and two at another site) taken from regenerating forest, were not derived from *E. obliqua* but were from *Phyllocladus aspleniifolius*, celerytop pine (also sometimes written as Celery Top Pine or celery-top pine). This shortfall of small logs within regenerating forest posed some problems in the writing up and presentation of the results for a scientific communication based on the *E. obliqua* logs, which is to be published elsewhere. But here is where serendipity came into the picture. It turned out that the results for the beetle fauna in the celerytop pine logs exhibited some interesting differences, as well as showing some similarities, with those of the beetle fauna in the eucalypt logs. This communication is concerned with the beetles that emerged from the celerytop logs, and how they contrast with the beetles that emerged from the eucalypt logs.

Methods

Study area

The study was conducted at ten sites in the tall wet lowland *E. obliqua* forests in the Southern Ranges bioregion, approximately 60 km south-west of Hobart, Tasmania. The sites, all within 10 km of each other, were in the vicinity of the Huon and Picton Rivers and fell within the rectangle bounded by latitude 43º 05'–43º 11' S and longitude 146º 39'–146º 45' E. Five of the sites (M, PO1, PO2, R, WR) were mature forest that had not been logged for at least a century. The other five sites (E, PR1, PR2, S, W) were early- to middle-stage regeneration after having been logged using clearfell, burn and sow silviculture during the previous 20–30 years. Within each of the 10 sites, a 50 m x 50 m study plot was established, located at least 50 m from the access road to minimise likely edge effects.

Logs and traps

Three large logs (>100 cm diameter) and three small logs (30–60 cm diameter) were selected from the study plot at each site. It was intended that saproxylic beetles be sampled from all *Eucalyptus obliqua* logs of an intermediate decay stage (also known as decay stage 3) based on the classifications of Lindenmayer et al. (1999) and Meggs (1996). These logs typically had no bark, were often covered in moss, had soft sapwood and had solid heartwood with some rot in places. However, it was later found that, of the 60 logs, three of the small logs, all within regenerating sites, were logs of celerytop pine. This selection error was partly due to the logs being covered in moss, with very few distinguishing features. Thus, instead of having 15 eucalypt logs for each combination of size and forest management history, there were only 12 logs for the 'regen/small' combination. To sample the saproxylic beetles emerging from the 60 logs, each log was fitted with an emergence trap like those described by Bashford et al. (2001). Trap length varied between 1.6–4.8 m and consisted of strong netting (<1 mm fine mesh to ensure trapping small beetles) encasing the log (Figure 1a). Trap design was kept simple so that traps could be assembled by one person.

Netting material was attached to the log using a staple gun and supported above the log by 15 cm long modified wooden stakes (Figure 1b). Similar to Bashford et al. (2001), emerging beetles were captured in any of two to three collecting containers, one at the top to catch those that move towards the light, and one to two fixed containers at the base of the trap to catch beetles whose behaviour was to crawl off the log (Figure 1d). The top container consisted of an empty PET 2-litre fruit juice bottle connected to a piece of elbow piping, which directed emergent insects from the trap into the container (Figure 1c). This top system was kept in place using a support bracket constructed from pre-cut and pre-drilled wooden stakes held together by flexible wire. Diluted ethylene glycol (50–70%) was used as preserving fluid.

Visits

The emergence traps were sampled at irregular intervals between November 2000 and May 2002. The focus for sampling was late spring to mid-summer and late autumn.

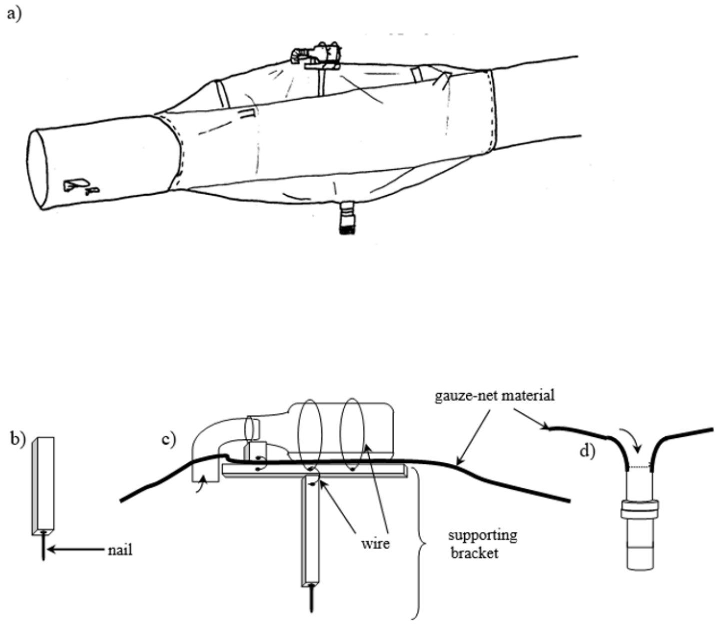

Figure 1. Log emergence trap showing the a) overall design, b) wooden stakes used to support material off log, c) top collecting container and support bracket, and d) bottom collecting container.

Diversity indices

For the calculation of a wide range of diversity indices, some of which measure species richness or combine a measure of richness and evenness, species abundance data for each trap were pooled across the sampling period of 19 months. All diversity indices were carried out using the ecological package PRIMER, version 6 (2006). These comprised the following: S, total number of species; N, total number of individuals; d, Margalef species richness ($=(S\text{-}1)/\log_e N$); H', Shannon diversity index (calculated using logarithms to the base e); J', Pielou's evenness index ($=H'/\log_e N$); 1-λ', Simpson's index; Hill no. N_1, ($=\exp(H')$); Hill no. N_2, ($=1/\Sigma P_i^2$, where P_i is the proportion of the total number of individuals N that is accounted for by the ith species, i=1,2,…,S). Interested readers should consult Clarke & Gorley (2006) for more information about these diversity indices.

Results

The three celerytop logs harboured a relatively high degree of saproxylic beetle richness, with 44 species from 969 emerged individuals. This compares with 5585 records of 318 species that emerged from 57 eucalypt logs (Yee 2005); 43 species were common to both kinds of logs, with the one species that was unique to celerytop having only a single record. Considering that there were only three celerytop logs, i.e. one-nineteenth the number of eucalypt logs, this richness is considerable. In addition, the celerytop logs were also considerably rich at the family level, with representatives of 23 families having emerged from the three logs (Table 1). However, despite the richness at the family level, the abundance of one particular species was very unevenly distributed, with *Ancyttalia oleariae* (Lea, 1906) (Curculionidae) represented by 790 individuals, which is 82% of all individuals. This unevenness is further illustrated by the fact that of the 44 species, 19 are represented only as singletons and 11 as doubletons (Table 1).

In addition to species richness, other measures of beetle diversity reveal differences between the beetle fauna present in the celerytop logs and that present in the eucalypt logs. As the

Plate 1. Photographs of *Ancytallia oleariae* (approximately 2 mm body length) courtesy of Simon Grove and Jingyi Chen, Tasmanian Museum and Art Gallery.

celerytop logs were all of a small size and derived from regenerating forest, only the 12 eucalypt logs in the 'regen/small' (RS) category were used for this comparison. One striking result is the closeness of each of the diversity indices for celerytop log SSET1 and the average of the corresponding diversity index for the 12 eucalypt logs (Table 2). However, the two celerytop logs from the W site gave very different results, so that overall the celerytop logs produced a greater number of individuals, but with a lower species richness and evenness, than the eucalypt logs (Table 2).

Using the 14 most frequently recorded beetle species from the celerytop pine logs (singletons and doubletons excluded), differences in the number of records for each of those species are explored in Table 3. For a given species, three differences in the species abundances are shown, the difference of the total beetle records between the three celerytop logs and all 57 eucalypt logs, between the average number of records in the three celerytop logs and the average number of records in all 57 eucalypt logs, and between the average number of records in the three celerytop logs and average number in the 12 small eucalypt logs in regenerating forest (RS). One species, the weevil *Ancyttalia oleariae* (Figure 2), with a body length of 2 mm, stands out as being exceptionally more prevalent in the celerytop logs than in the eucalypt logs. This species accounts for almost 14% of the beetle emergence records obtained overall in the 19 month sampling period, or 82% of the beetle emergence from celerytop pine logs. The remaining 13 species in the table had more or less similar abundance between eucalypt logs and celerytop logs when considering average abundance.

Discussion

This selection mistake of trapping beetles emerging from three celerytop pine logs provides a glimpse into the ecology of saproxylic beetles in Tasmania's wet eucalypt forests and their adaptation to dead wood arising from different species, in this case dead wood from *Phyllocladus aspleniifolius,* a softwood podocarp versus dead wood from *Eucalyptus obliqua,* a hardwood species. In the Northern Hemisphere, where saproxylic beetle fauna has been studied more extensively, distinct assemblages associated with softwoods, such as pines, firs, spruces and larches, compared to the broad-leaved hardwoods, such as beech, birch, aspen, oak, hornbeam and maple, have been well documented.

For example, in France, Brin et al. (2011) used *in situ* emergence traps to examine saproxylic beetle diversity in temperate oak and pine forests. The hardwood forest, with 227 saproxylic beetle species, was richer than the softwood forest that had 87 saproxylic beetle species, with 9% of the species common to both forests. These results mirror those of the present study, in that hardwood was richer than softwood (in the present case eucalypt vs. celerytop) and many species present in hardwood were absent from softwood. In southern Sweden, Jonsell (2008) studied the species of saproxylic beetles that inhabit hardwood (aspen, birch, oak) and softwood (spruce) in

Table 1. Species of saproxylic beetle present in the celerytop logs, listed in decreasing order of abundance at family level. Within a family, species are listed in alphabetical order by genus, if known.

Family	Records	Species (no. of records)
Curculionidae	862	*Ancyttalia oleariae* (790), *Ancyttalia tarsalis* (14), *Decilaus bryophilus* (1), *Decilaus lateralis* (2), *Decilaus nigronotatus* (38), *Decilaus striatus* (2), *Exeiratus* TFIC sp 01 (1), *Exithius cariosus* (3), *Mandalotus muscivorus* (4), *Platypus subgranosus* (1), *Roptoperus tasmaniensis* (6)
Carabidae	48	*Pterocyrtus globosus* (30), *Sloaneana tasmaniae* (4), *Stichonotus piceus* (12), *Trechimorphus diemenensis* (2)
Zopheridate	10	*Enhypnon tuberculatum* (10)
Throscidae	6	*Aulonothroscus elongatus* (6)
Melandryidae	5	*Orchesia alphabetica* (4), *Orchesia austrina* (1)
Clambidae	4	*Clambus bornemisszai* (4)
Corylophidae	4	*Holopsis* TFIC sp 01 (2), *Holopsis* TFIC sp *04* (1), *Sericoderus* TFIC sp 05 (1)
Scarabaeidae	4	*Heteronyx pilosellus* (2), *Telura vitticollis* (2)
Silvanidae	4	*Cryptamorpha* TFIC sp 01 (3), *Cryptamorpha victoriae* (1)
Staphylinidae	3	*Ischnoderus parallelus* (1), *within Aleocharinae* TFIC sp 015 (1), within *Aleocharinae* TFIC sp 034 (1)
Anthribidae	2	*Xynotropis* TFIC sp 01 (2)
Latridiidae	2	*Cortinicara* REIKE sp nov 1 (2)
Oedemeridae	2	*Dohrnia simplex* (2)
Prostomidae	2	*Prostomis atkinsoni* (2)
Sphindidae	2	*Aspidiphorus humeralis* (2)
Tenebrionidae	2	*Brycopia hexagona* (1), *Coripera deplanata* (1)
Cerambycidae	1	*Enneaphyllus aeneipennis* (1)
Cleridae	1	*Lemidia subaenea* (1)
Elateridae	1	*Parablax padmuri* (1)
Leiodidae	1	*Nargomorphus confertus* (1)
Nitidulidae	1	*Amlearcha elegantior* (1)
Phalacridae	1	*Litochrus brunneus* (1)
Pyrochroidae	1	*Binburrum ruficollis* (1)

three diameter classes (1–15 cm) and two decay stages of logging residues by rearing them from 794 wood samples. In total, 49 109 individuals were found, belonging to 160 species. Host tree species, diameter class and decay class of the wood were important in determining saproxylic species specificity. In Nova Scotia, Canada, Kehler et al. (2004), using window flight-intercept traps in 41 forest stands in both hardwood and softwood, caught over 17,000 individual beetles, representing ca. 200 morphospecies from 45 families. Hardwood stands had greater beetle richness than softwood stands. Correspondence analysis revealed distinct groupings of species assemblages in softwood and hardwood stands.

The present study, albeit having a selection error, is worthy of documentation as it highlights that there are differences in dead wood types in Tasmania's wet eucalypt forests, and that a diversity of dead wood types is important to maintain support and promote its large diversity of native saproxylic beetle fauna. While celerytop pine logs were markedly lower in diversity compared to that of eucalypt logs, their substrate represented similar habitat for a large number of species, albeit at lower densities. While dead wood levels in these forests are exceptionally high at this point in Tasmania's relatively young history of industrial forestry, without careful planning dead wood habitat levels may dramatically reduce with ongoing rotations. Such an outcome could result in substantially lower volumes and diversity of dead wood habitats in timber production areas, in which case all types of dead wood, including celerytop pine logs, will be important in maintaining Tasmania's rich saproxylic beetle fauna.

Table 2. Diversity indices for saproxylic beetle emergence, celerytop logs compared with eucalypt logs.

Diversity index	Celerytop logs				Eucalypt logs
	SSET1	WSET1	WSET2	Averages	[average over 12 logs in 'regen/small' (RS) category]
S	24	24	16	21.3	25.9
N	73	731	189	331	110.7
d	5.361	3.488	2.862	3.9	5.502
H'	2.405	0.557	1.216	1.39	2.385
J'	0.757	0.175	0.439	0.46	0.784
1-λ'	0.852	0.184	0.508	0.51	0.851
N_1	11.08	1.75	3.37	5.40	11.61
N_2	6.25	1.23	2.02	3.16	6.76

Table 3. Contrasts between the beetle fauna emerging from eucalypt logs (*E. obliqua*) and celerytop logs (*P. aspleniifolius*) for the 14 most abundant species.

Species	CT	E_{ALL}	E_{RS}	CT_{av}	E_{RSav}	E_{ALav}	CT-E_{ALL}	CT_{av}-E_{RSav}	CT_{av}-E_{ALav}
Ancyttalia oleariae	790	143	0	263.3	0.0	2.5	647	263.3	260.8
Decilaus nigronotatus	38	584	97	12.7	8.1	10.2	-546	4.6	2.4
Pterocyrtus globosus	30	29	0	10.0	0.0	0.5	1	10.0	9.5
Ancyttalia tarsalis	14	105	0	4.7	0.0	1.8	-91	4.7	2.8
Stichonotus piceus	12	24	1	4.0	0.1	0.4	-12	3.9	3.6
Enhypnon tuberculatum	10	100	19	3.3	1.6	1.8	-90	1.8	1.6
Roptoperus tasmaniensis	6	58	10	2.0	0.8	1.0	-52	1.2	1.0
Aulonothroscus elongatus	6	81	5	2.0	0.4	1.4	-75	1.6	0.6
Mandalotus muscivorus	4	44	19	1.3	1.6	0.8	-40	-0.3	0.6
Orchesia alphabetica	4	172	11	1.3	0.9	3.0	-168	0.4	-1.7
Sloaneana tasmaniae	4	26	1	1.3	0.1	0.5	-22	1.3	0.9
Clambus bornemisszai	4	14	0	1.3	0.0	0.2	-10	1.3	1.1
Cryptomorpha TFIC sp 01	3	340	179	1.0	14.9	6.0	-337	-13.9	-5.0
Exithius cariosus	3	30	2	1.0	0.2	0.5	-27	0.8	0.5

Notes: CT = number of records in 3 celerytop logs; E_{ALL} = number of records in 57 eucalypt logs; E_{RS} = number of records in 12 small eucalypt logs in regenerating forest; CT_{av} = average no. of records in the celerytop logs; E_{RSav} = average no. of records in the small eucalypt logs taken from regenerating forest; E_{ALav} = average no. of records in all eucalypt logs; CT-E_{ALL} = difference between CT and E_{ALL}; CT_{av}-E_{RSav} = difference between CT_{av} and E_{RSav}; CT_{av}-E_{ALav} = difference between CT_{av} and E_{ALav}.

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