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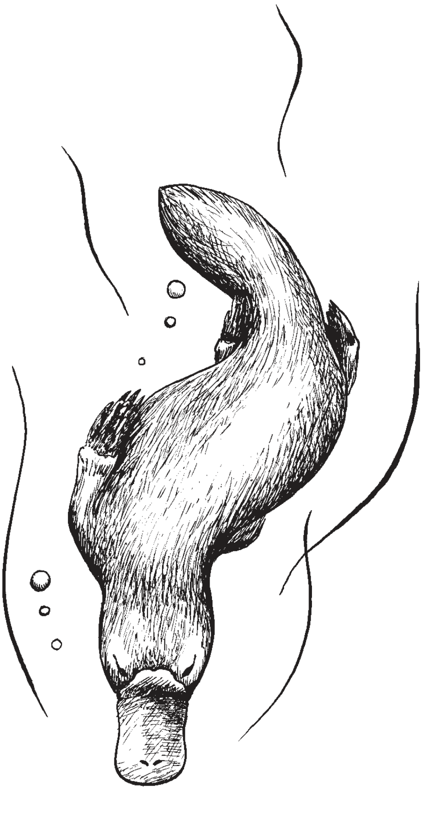

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A precious gift: the Lambkin–Knight butterfly collection donated to the Queen Victoria Museum and Art Gallery

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Plate 1. A selection of butterflies from the Lambkin–Knight collection showing the high professional standard of curation. Photograph: David Maynard

Introduction

One of Australia's largest private butterfly collections has been donated to the Queen Victoria Museum and Art Gallery (QVMAG). The Lambkin–Knight collection comprises around 16,000 butterflies representing over 300 species, including extremely rare and critically endangered species (Plates 1 & 2). The collection is spatially and temporally diverse, having been assembled over half a century, and from Hobart to the Torres Strait islands. The donation also includes a significant collection of Australian cicadas (Plate 3) and beetles (Plate 4), as well as a smaller amount of butterfly material historically collected by prominent Queensland entomologists Murdoch De Barr and Neil Gough (both deceased), and from

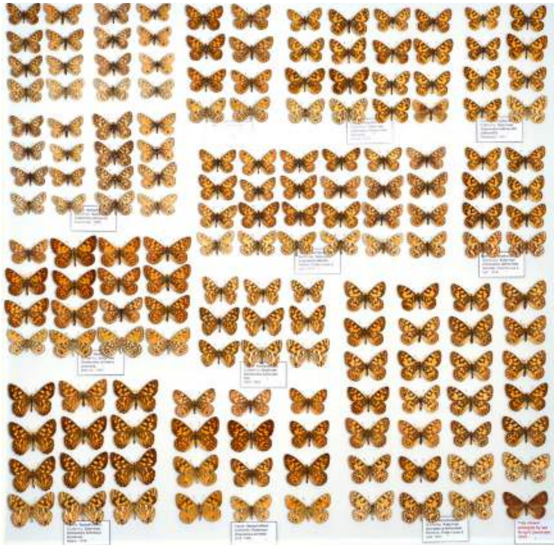

Plate 2. A drawer of *Oreixenica* butterflies from the Lambkin–Knight collection including series runs of Tasmanian species. Photograph: David Maynard

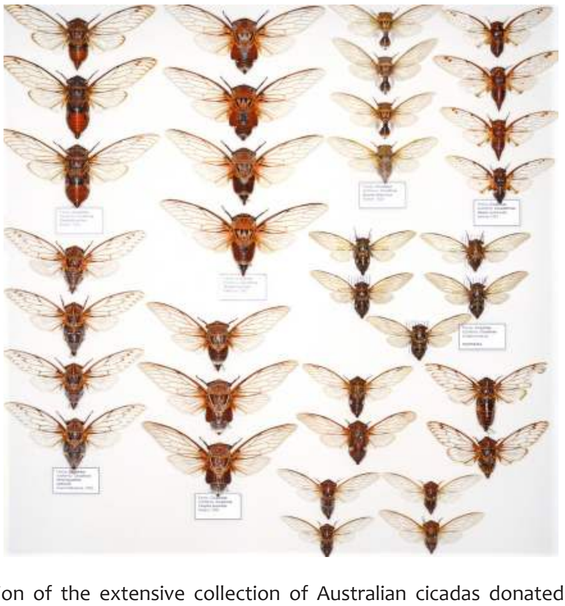

Plate 3. A portion of the extensive collection of Australian cicadas donated as part of the Lambkin–Knight collection. Photograph: David Maynard

Plate 4. A sample of Coleopterans donated as part of the Lambkin–Knight collection. These Passalidae were collected in the 1960s, highlighting the temporal importance of the collection. Photograph: David Maynard

other locations in Oceania and South-East Asia. QVMAG is working to house the collection and, in time, make the data available through the Atlas of Living Australia (ALA). Already, 36 publications have been produced from the collection (Appendix 1) on species discoveries, species assemblages and life histories. The collection is a nationally significant resource for biodiversity research, and climate change-related research. This paper describes the collection, its significance and research potential.

The Lambkin–Knight collection

This magnificent collection is the fifth largest private collection in Australia. It includes over 300 identified butterfly species, over 100 cicada species and around 1000 Coleoptera specimens, including known but undescribed species. The butterflies include 49 paratypes, CITES-listed species, extremely rare species, endangered species including Tasmania's *Oreisplanus munionga larana* Couchman, 1962, and critically endangered species like Queensland's *Argynnis hyperbius inconstans* Butler, 1873, which is presumed extinct by some authorities (Lambkin 2017; T. Lambkin, pers. comm.).

The donation contains important collections of entire genera across their range. An example from the tropics is the *Euploea* crow butterflies that are represented by multiple species/populations from western Malaysia east through the Philippines, Indonesia,

Plate 5. An example of papered butterflies and a specimen that has been relaxed and set after storage. Photograph: Simon Fearn

Papua New Guinea (PNG), the Torres Strait and throughout tropical and eastern Australia. Another example more relevant to Tasmania is the *Toxidea* skipper butterflies, of which a number of mainland specimens with subtropical and temperate distributions represent a future invasive risk to Tasmania (discussed below).

The collection includes a complete set of the 55 recognised Tasmanian butterfly species and subspecies, including series runs from poorly collected areas and habitats.

The Lambkin–Knight collection also contains several sub-collections from prominent Queensland entomologists. Murdoch De Barr (1945–2011) and Neil Gough (1946–1992) both passed away with large numbers of papered butterflies collected throughout the Australasian region from the 1960s to 80s still in their possession. These specimens found their way into the Lambkin–Knight collection. While they have been papered for up to 50 years, they were kept in sealed plastic tubs with naphthalene and are in remarkable condition (Plate 5). Once prepared, these specimens will add substantially to the collection's value because they were field-collected from remote regions of PNG and throughout Indonesia and Malaysia, in areas that have undergone significant deforestation in the ensuing years. For an overview of the careers and collecting of both De Barr and Gough, visit the Archive of past Queensland Entomologists in the Entomological Society of Queensland website.

The Lambkin–Knight collection will be delivered in three roughly equal instalments, with the first few thousand specimens already in the QVMAG collection, and the balance being delivered from late 2021 to 2023. The donor, Trevor Lambkin, continues to work on parts of the collection, and his will reflects his desire for the museum to complete the donation if he passes away prior to completing his current research.

A nationally significant collection

This butterfly collection is nationally significant, firstly for its scientific and research potential, and secondly for its provenance, rarity and representativeness, condition, completeness and interpretive capacity (see Russell & Winkworth 2009). This is a professionally curated collection of high-quality specimens, presented to the highest standard. Appendix 1 lists the 36 peer-reviewed papers about specimens in the collection covering species discovery, assemblages, and species biology, ecology and life history that have already been published. The collection will continue to support research into the future (discussed below).

Large private collections such as this will probably never be assembled again due to societal changes in attitudes towards collecting, the increasing difficulty to obtain collection permits, particularly overseas, and the sheer logistics and increasing costs involved with travel, collecting and housing such a large collection.

Future research opportunities

The donor, Trevor Lambkin, continues to produce ecological and life history papers on species present in this collection. However, the collection will also support research into the impacts of climate warming on species distributions. It is well established that changes in climate zones under global warming can have far-reaching impacts on ecological systems. Accelerated global warming has already led to shifts in climatic conditions over large areas. Tropical and arid-zone climates are expanding into the middle and high latitudes, while high-latitude climates are shifting poleward and upward (Chan & Wu 2015; Malhi et al. 2020). Climate warming has driven changes and contractions in the geographic ranges of many species including butterflies (Wilson 2007). The Lambkin–Knight collection will play a vital role in charting the spatial changes of Australian butterflies. However, other anthropogenic impacts are pushing some butterfly species towards extinction. This has been outlined recently in an article by by Geyle et al. (2021), in which 26 species were identified at risk of extinction due to (amongst others) habitat loss, habitat fragmentation and invasive species. Again, this unique butterfly collection will play an important role in understanding how the many human-induced changes have influenced, and will influence, butterfly species and populations.

About the donors: Ian Knight and Trevor Lambkin

Ian Knight (1930–2021) (Plate 6, top), originally from South Africa, was interested in nature from an early age, but it was not until the early 1970s that his passion for butterflies was realised. In just a few years he collected over 400 of the 660 species known to occur in South Africa. Ian migrated to Brisbane in the late 1970s, and much of that collection was donated to the Queensland Department of Primary Industries insect collection at Indooroopilly, Brisbane (now Department of Agriculture and Fisheries, Queensland). By the early 1980s Ian was well connected with other butterfly enthusiasts in Queensland, including Murdoch De Barr, Don Sands and Trevor Lambkin. Ian's relationship with Trevor lasted over forty years; they worked together in the field, and eventually combined their collections into what is now referred to as the Lambkin–Knight collection.

Ian retired to Exton, Tasmania, in 1996 and spent the next two years building

Plate 6. The donors, (Arthur) Ian Knight (top) and Trevor Lambkin (bottom) curating their collection at QVMAG. Photographs: Simon Fearn and David Maynard

two identical collections of Tasmanian butterfly species and subspecies, one acquired by QVMAG in 2000 and the other previously on display at the Ashgrove Cheese Dairy Door and Visitor Centre, Elizabeth Town, in north-west Tasmania. Ian continued to collect into his 90th year and was invited by a landowner to put together an extensive single-property collection of Tasmanian insects for a private client during the previous decade.

Ian was integral in receiving and housing the first instalment of the Lambkin–Knight collection at QVMAG. Using a draftsman's T-square to lean on while lining up each row of specimens, Ian meticulously arranged specimens of each species so they precisely filled each drawer. It was a pleasure to work with Ian on this project and he was very keen to pass on to the second author his years of experience in setting challenging insect specimens such as micro-moths. Shortly after his 90th birthday in 2020 the COVID-19 outbreak prevented him from returning to QVMAG to continue his curatorial work. Sadly, Ian passed away in April 2021. Ian's significant contribution to the study of Australian Lepidoptera is detailed in Lambkin (2021).

Dr Trevor Lambkin (Plate 6, bottom), a well-known Queensland lepidopteran taxonomist, was an entomologist for 35 years with the then Queensland Department of Primary Industries, where he worked on biological controls for pest species, and understanding beetle ecology. Trevor's greatest contribution to science has been his study of Australian butterflies, particularly the biogeography of the butterfly fauna of the Torres Strait islands in northern Queensland. Trevor has collected and studied butterflies extensively across eastern Australia, as well as Costa Rica, the United States, Europe, Indonesia and Timor-Leste, authoring 36 peer-reviewed journal articles on the distribution, ecology, taxonomy and biology of Australian butterflies. Trevor continues to study butterflies, most recently undertaking a Masters degree on the butterflies of Torres Strait at the University of Queensland. Trevor continues to publish, most recently on the critically endangered Australian fritillary butterfly, and is contributing to the 'Butterflies on the Brink' assessment of the vulnerable and endangered butterfly species in Australia (see Geyle et al. 2021). Trevor is active with citizen scientist programs in south-east Queensland, and continues his work in preparing the Lambkin–Knight collection for delivery to QVMAG.

Conclusion

The Lambkin–Knight butterfly collection is an extremely generous and scientifically important contribution to QVMAG and Tasmania. Its curation, specimen labelling as well as taxonomic and geographical spread will make it an important research tool well into the future. It has been an honour for the authors to work with Ian and Trevor in securing this collection in its new home at QVMAG and to begin the next important step of registering the specimens so the data is available to the community and researchers.

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Tasmania on the *iNaturalist* platform

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Introduction

iNaturalist is a worldwide social network for sharing biodiversity information. It serves as a crowdsourced identification tool and as a platform from which occurrence records are harvested for research purposes. In 2020 alone *iNaturalist* hosted more than 23 million observations of almost 200 000 species (https://www.inaturalist.org/stats/2020).

In this article I explore 88,546 *iNaturalist* observations from Tasmania. My focus is on the "what", "where", "when" and "by whom" of the observations, but before I present those results I need to explain briefly how *iNaturalist* works.

Observations and identifications

Registered *iNaturalist* users are invited to upload one or more images (or sounds) of a particular organism (or its tracks or signs) observed at a particular location on a particular date, with or without time of day. The organism should be "wild", i.e. not captive or cultivated. The uploaded data constitute an *observation*. If the observation includes an image or images (or sounds) and has a date and a georeference, then the observation has *verifiable* status on the *iNaturalist* platform. For sensitive species and sensitive areas, *iNaturalist* can obscure the georeference by scrambling the latitude/longitude coordinates within a small bounding box.

Observations that lack one or more of the basic requirements can remain on *iNaturalist* but have a *Casual* quality rating. Verifiable observations can also be classed as *Casual* by the *iNaturalist* community if the data seem weak or doubtful. A good-quality verifiable observation will move to the *Needs ID* category.

Users are also invited to identify the subjects of their observations as best they can. The *iNaturalist* community, all of whom are volunteers, can add identifications that agree with, disagree with or improve the original identification. If more than two out of three community identifications are in agreement, the observation achieves *Research Grade* quality with the agreed-on identification. *Research Grade* observations are accepted by the Global Biodiversity Information Facility (GBIF) as credible occurrence records. The Atlas of Living Australia (ALA) accepts both *Needs ID* and *Research Grade* observations but distinguishes them (in the *identificationVerificationStatus* data field for the individual record).

For much more information on quality ratings and how the *iNaturalist* community functions, please see the *iNaturalist* help page: https://www.inaturalist.org/pages/help.

About the Tasmanian dataset

On 15 May 2021, I selected and downloaded all observations from the *iNaturalist* website for the geographical unit "Tasmania" (not including marine waters in the Australia Exclusive Economic Zone). Downloaded datasets like mine are not made publicly available by *iNaturalist*, so I deposited both the download and a working version of the data in the Zenodo data repository, where the archive is freely available and has a DOI: https://doi.org/10.5281/zenodo.4775031.

My working version of the 88 546 observations (here called "the Tasmanian dataset") is a tab-separated table (TSV) with 63 *iNaturalist* fields. I did some minor data cleaning as explained in the Zenodo metadata, and added a *taxon_type* field for the formal rank or other category of the name in the *scientific_name* field.

More than 50 000 of the Australian observations in *iNaturalist* were first contributed to the online *BowerBird* project moderated by Ken Walker (Senior Curator of Entomology, Museums Victoria). When *BowerBird* began closing down in 2018, much of the data migrated to the *iNaturalist* platform with permission from individual *BowerBird* contributors (https://www.ala.org.au/newsletter/bowerbird-builds-new-nest-on-inaturalist/). Fewer than 1000 of the observations in the Tasmanian dataset were migrated from *BowerBird* (Thomas Mesaglio, pers. comm.).

What was observed?

The Tasmanian dataset has 7.2% *Casual*, 36.7% *Needs ID* and 56.1% *Research Grade* observations. The relatively low *Research Grade* component is partly explained by the large proportion of observations so far identified only to higher taxonomic categories (Table 1). Only one identification above genus rank reached *Research Grade*, and only 1.1% of genus-level identifications. In contrast, more than three-quarters of the species-level identifications (76.3%) reached the highest quality category. (The low proportion of genus-level *Research Grade* identifications is partly explained by an additional scoring requirement; see https://forum.inaturalist.org/t/genus-level-id-as-research-grade/12508).

The *Research Grade* observations of species-level taxa (species, subspecies, species hybrids; see Table 1) are the most valuable answers to the "What was observed?" question. They document 4893 taxa, of which 1457 were only observed once and 3785 were observed 10 or fewer times. The distributions of the observations across kingdoms are shown in Table 2, together with the "top 10" phyla, classes, orders, families and genera. As an amateur entomologist I am delighted to see in the "class" list that the number of insect observations was larger than bird and mammal observations combined!

Continuing the "top 10" theme, Table 3 lists the 10 most-observed species in both the *Research Grade* and *Needs ID* categories. Note that for the Tasmanian devil, which appears in both lists, all the *Needs ID* images are of scats or tracks! But the two "top 10" lists suggest an interesting question, namely which species-level identifications were most and least often agreed by the *iNaturalist* community?

Table 4 offers some answers. The top block of data shows the "top 10" of the 2562 *Research Grade*-only observations, and the bottom block shows the "top 10" of the 1160 *Needs ID*-only. In the two intermediate blocks are the top- and bottom-ranked taxa for the 2331 species-level taxa with both *Research Grade* and *Needs ID* observations. The ranking for these two blocks is by the *Research Grade*/*Needs ID* ratio, not weighted for the absolute numbers of identifications.

From bottom to top, Table 4 reflects increasing confidence in the identification by the *iNaturalist* community. If all uploaded images were of the same quality, and if the *iNaturalist* community judged each image with the same level of expertise and attention, it could be argued that these lists point to the most and least easily recognised species. Image quality varies, however, as does *iNaturalist* community effort, and even high-quality images of scats, tracks, eggs or feathers may be unidentifiable. The Table 4 results are interesting but unsurprising: seagulls and blue wrens are more easily imaged and identified than noctuid moths.

iNaturalist identifications are not always correct. As a millipede specialist I was puzzled to see a 2018 observation of the millipede family Rhiscosomididae in the Tasmanian dataset. The family is in the order Chordeumatida and is restricted to western North America, but the *iNaturalist* images showed a millipede from Melaleuca in southwest Tasmania. The identification came from an American millipede expert. When I contacted the expert, he apologised: he had not noticed that the observation was from Tasmania. The *iNaturalist* observer at Melaleuca had previously contributed large numbers of millipede images from California, and the expert thought this was another Californian observation.

[Note for Tasmanian readers: it is usually impossible to identify our millipedes to species without close examination of the genitalia of mature males. A whole-animal millipede image on *iNaturalist* should almost always remain at *Casual* or *Needs ID*. To identify Tasmanian millipedes "in the flesh", see this online guide: https://www.datafix.com.au/tasmanian_millipedes).]

Where was it observed?

Every *iNaturalist* observation has a georeference, i.e. a latitude and longitude, that can be added to the observation directly by the user (with or without the assistance of a mapping program) or indirectly, with *iNaturalist* selecting the observation spot from user-provided information. The georeference can also come from metadata embedded into an image file by a smartphone app, or by geotagging software working on images from a GPS-enabled digital camera.

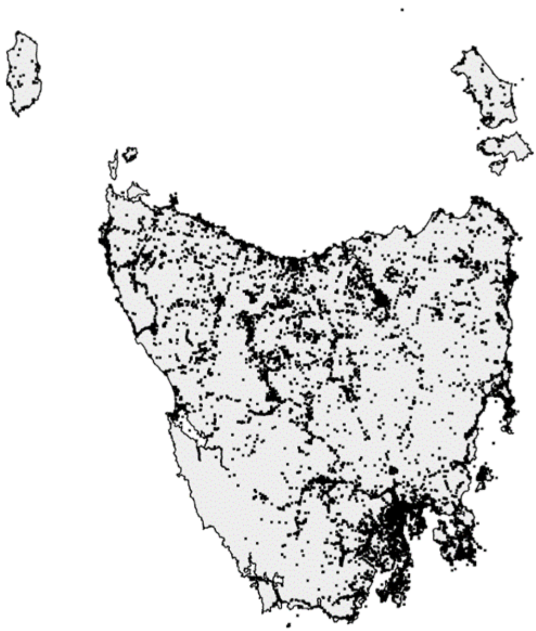

Figure 1. Tasmania (excluding Macquarie Island) with the locations of 83,596 iNaturalist observations with coordinates not obscured, to 15 May 2021.

Unfortunately the origin of each georeference is not clearly specified in an *iNaturalist* download, and spatial uncertainty is poorly controlled. Every location really needs a triplet of data items: latitude, longitude and an estimate of how close the observation was to the specified point. The estimate is usually the radius of a circle within which the observation was made, with the latitude/longitude point at the circle's centre. This spatial uncertainty is called "positional accuracy" by *iNaturalist* and can either be specified by the user or assigned by *iNaturalist* geospatial algorithms. The results are sometimes strange. For example, in the Tasmanian dataset two well defined Circular Head locations have a positional accuracy of more than 3200 km, and 27 observations have a positional accuracy of zero, which is impossible.

To look more closely at locations I first deleted all the observations with coordinates obscured by *iNaturalist* (as requested by the user) and 599 observations from Macquarie Island. The remaining ca 83 000 locations are plotted in Figure 1. All of Tasmania's main roads can be recognised as strings of observations, along with the South Coast Track and some other wilderness

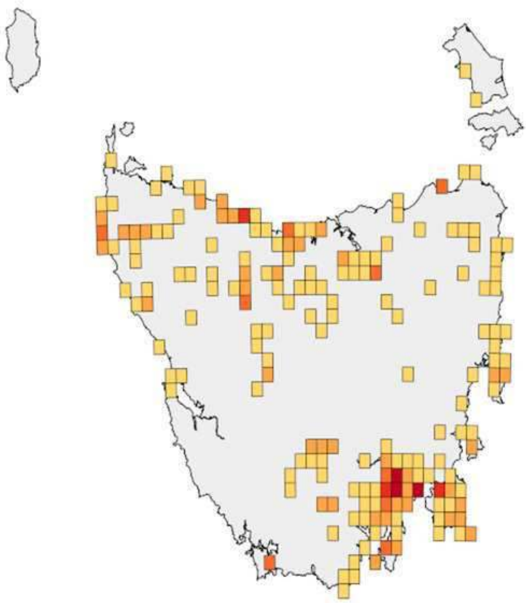

Figure 2. Density map of the observations shown in Figure 1, with Tasmania divided into 0.1 × 0.1 degree grid cells. Colour classes follow breaks in the numbers of observations, and cells with counts fewer than 76 observations are not shown. The five remaining classes are 76–335 (light orange), 335–824 (orange), 824–1876 (dark orange), 1876–3214 (light red) and 3214–4485 (red) observations.

routes. There is a clear concentration of observations in the Hobart area, shown more clearly in Figure 2. The 0.1 × 0.1 degree grid cell centred on Taroona contains 4485 non-obscured observations.

When was it observed?

Almost all the observations in the Tasmanian dataset have three dates. The *observed_on* entry is the date the organism was observed, *created_at* is the date (and time) the observation first entered the *iNaturalist* platform, and *updated_at* is the date (and time) of the last edit or comment for the observation. A small number (141) of *Casual* observations had neither an *observed_on* date nor a user-entered *observed_on_string* that I was able to convert to a date. For parts of my analysis I ignored the 141 dateless observations, as well as four observations with suspicious software-epoch dates (one with Microsoft's "1900-01-01" and three with the UNIX "1970-01-01"), leaving 88 401 observations.

iNaturalist in its current form began accepting observations about 10 years ago. Tasmanian observed_on dates start much earlier (Table 5) and the earliest entry is from 1962. This record consists of images of a beetle specimen in a museum and of the accompanying specimen label. The *iNaturalist* advice is that "... as long as you know the correct date and location, it's fine to post older photos", but I think that 1962 beetle record, created in 2019, pushes the boundaries!

The *observed_on* dates for individual species might be useful in Tasmanian natural history studies. For example, Figure 3 tallies the number of *Research Grade* observations per month of the tiger snake *Notechis scutatus*. The graph probably reflects the daytime activity of tiger snakes through the year, but also the daytime activity of *iNaturalist* observers, who are less field-active in winter (Figure 3).

In the Tasmanian dataset, created_at entries start on 3 August 2011 and finish on 15 May 2021, the day I requested the download. Growth in contributions has been very impressive (Table 6). Projecting from 2020, the 17 905 new Tasmanian contributions to 15 May 2021 could grow to ca. 50 000 by the end of the year.

There has been a spectacular decline in the delay between *observed_on* and *created_at* dates for individual observations (Table 7). The most likely explanation is that more and more contributors have

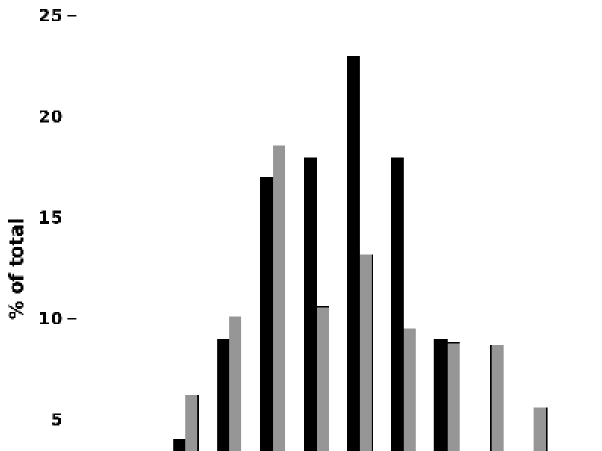

Figure 3. Monthly distributions of Research Grade observations of *Notechis scutatus* (black bars) and all Tasmanian observations (grey bars).

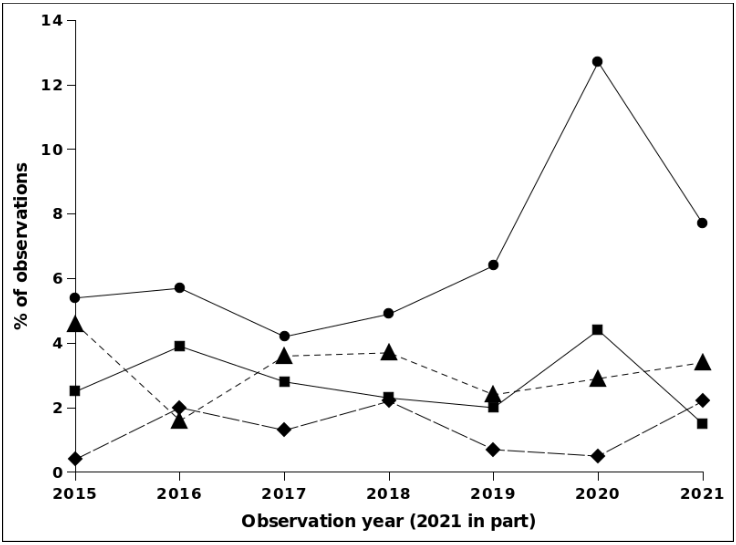

Figure 4. Percentage of all observations in a year for selected taxa in all quality categories. Class Actinopterygii (bony fish; diamonds), order Araneae (spiders; triangles), kingdom Fungi (circles), family Orchidaceae (orchids, squares).

been using an *iNaturalist* smartphone app, i.e. taking pictures with a smartphone and uploading the images and related data on the same day. In 2021, more than half the observations to 15 May have identical or almost identical *observed_on* and *created_at* dates. (The delay calculation is approximate because I did not correct the *observed_on* dates for time zone; see also below, *Who observed it?*).

No *iNaturalist* observation can achieve *Research Grade* status without an update, because updates include the identifications contributed by the community, and those community identifications form the basis for assessing observation quality. About 8% of the observations in the Tasmanian dataset have never been updated. Because edits, comments and identifications might continue to be added to observations over a period of years, the span between *created_at* and *updated_at* does not signify a great deal when examined over long periods. However, in 2021 to 15 May, the average delay between *created_at* and *updated_at* dates in the Tasmanian dataset was only 3.8 days for *Research Grade* observations, showing that the community identification process works quickly.

It is not clear whether *iNaturalist* contributors follow fashions in natural history. If users see a usually neglected taxon among the newest observations on the *iNaturalist* website, are they motivated to image that taxon in their own area? Do observations of a particular taxon "spike" following publicity about the taxon in the media, or because of increased *iNaturalist* activity in a specialised interest group? It would not be easy to test these questions, but I looked at observations created in each of the last seven years for four popular groups, as a percentage of all observations created in that year (Figure 4). There are no obvious trends for bony fish, orchids or spiders, but fungus observations seem to be booming.

Who observed it?

Assuming that each unique *user_login* entry corresponds to one particular individual, there were 2385 contributors to the Tasmanian dataset, and 19 of those contributors uploaded 1000 or more observations (Table 8). The top three users were Alan Melville ("gumnut", 5410 observations), Jim Duggan ("tas56", 4833) and Jan Kokavec ("j-k", 3351). Two-thirds of all users uploaded fewer than 10 observations, and 30% contributed just one observation.

Many users prefer to contribute pictures of their favourite organisms. Heather Elson ("franklinhermit") has been documenting fungi in the Huon district, and 1219 of her 1261 observations were of Ascomycota and Basidiomycota. Moth enthusiast Jim Duggan had Lepidoptera as the subject of 4470 of his 4833 observations. Kristi Ellingsen ("zosterops99") is a co-founder of the *Insects of Tasmania* website, and she featured arthropods in 1187 of her 1235 contributions. Conversely, among users with 100 or more observations, "juliefielder" (394 observations) and "ngaruru" (605) had the most even spreads of observations across kingdoms, with about one-third each for Animalia, Fungi and Plantae.

The *iNaturalist* dataset does not (of course) include home-address details for contributors, and it is not possible to determine directly from the dataset what proportion of observations come from Tasmanian residents. A rough surrogate for non-Australian users might be the time zone recorded for uploads, and observations made at tourist hot-spots tend to be rich in non-Australian time zones. For example, of the 2000 observations with the phrase "Cradle Mountain" in the *place_guess* field, more than half (1180; 59%) have a non-Australian *time_zone* entry. In contrast, for "Burnie" in *place_guess* the non-Australian time zone component is only 102 of 2440 observations (4%).

Of the 2385 contributors, 1879 uploaded observations in only one year during 2011–2021 (Table 9). The most consistent user was Clare Hawkins ("dunnart-at-large", 971 observations), who contributed observations in each of the seven years 2015–2021. Jim Duggan had the most contributions in a single year: 3142 in 2020, or about 10% of all the 2020 Tasmanian contributions. Two-thirds of Duggan's 2020 contributions (2070, 66%) were observations made in that year.

Besides contributing observations, Tasmanians registered with *iNaturalist* also identify what was observed. Among the top four identifiers of Tasmanian observations are Miguel de Salas and Matthew Baker (Tasmanian Herbarium) and Simon Grove (Tasmanian Museum and Art Gallery). As of 15 May 2021, the three experts had made 11 552, 4739 and 8051 identifications, respectively (https://www.inaturalist.org/observations?created_d2=2021-05-15&place_id=6829&verifiable=any&view=identifiers).

Discussion

When *iNaturalist* observations (*Research Grade*) are harvested by GBIF and ALA, they become occurrence records with the same scientific status as the data from museum or herbarium specimens. But do they have the same scientific value?

That might seem like a provocative question, but the reliability and usefulness of occurrence records varies substantially both within the *iNaturalist* platform and within natural history collections (NHCs).

On the plus side for *iNaturalist*, the data quality is better. There are fewer of the formatting errors, pseudo-duplicates and other data processing hazards commonly found in NHC data. Another plus is that with smartphones and GPS-enabled cameras, the location and date/time of an observation can be written into an image file as EXIF data (and presented by *iNaturalist* unless the user has opted for "geoprivacy"). The image and these digital data then stay together. In contrast, the collection data in NHCs are never part of the specimens. Instead, the details are written or printed on labels and (usually) entered into a collection database. The connection between NHC labels and specimens can be lost or confused, and errors might be made when entering details in a database.

It can also be argued that *iNaturalist* images, unlike NHC specimens, preserve natural objects in a particular state. Unlike an NHC specimen (think of a dried plant or fungal fruiting body) the digital object will not dramatically deteriorate over time.

That last argument impacts on the identification question, which is central to the reliability of occurrence records. How trustworthy are *iNaturalist* identifications, as opposed to NHC identifications for the same taxa?

The answer is "It depends". A specimen in an NHC can be thoroughly examined for its diagnostic features, while an *iNaturalist* image may not show those features. The viewing angle might not have been ideal or the image sharp enough, or perhaps the image was acquired in the wrong season or life-stage. Furthermore, many species simply cannot be identified from whole-organism views. Identifiers might need to study real-world specimens under a microscope, or dissect or prepare them in particular ways.

But the NHC specimen might have been viewed by only one identifier, of unknown competence, while an *iNaturalist* image might have been examined by dozens of people, including taxon specialists. This situation may change as NHCs digitally image their holdings and put them online, but the "image inspection imbalance" will remain for many years to come, particularly for small invertebrates.

I sometimes hear the arguments "You can't get DNA from a picture" and "If the specimen had been collected you could inspect it again, but the *iNaturalist* subject is long gone". Both of these are true, and both are great arguments for scientific investigators to not only collect a specimen for deposit in an NHC, but also to image the specimen in the field and upload that image and its associated data to *iNaturalist*.

My own view is that whatever their source, occurrence records need to be viewed with scepticism. High-quality (*Research Grade*) *iNaturalist* observations from Tasmania are mixed in ALA and GBIF with high- and low-quality records from museums and herbaria, and from the poorly curated *Tasmanian Natural Values Atlas*. At least you can *see* the subject of an *iNaturalist* observation from anywhere with an internet connection, without needing to visit an NHC or request a specimen loan.

There is much more information in the Tasmanian *iNaturalist* dataset than has been summarised in this article, and I encourage interested readers to download their own datasets for analysis, or explore the 15 May 2021 dataset I deposited in Zenodo (https://doi.org/10.5281/zenodo.4775031).

Acknowledgements

I am very grateful to Thomas Mesaglio (https://inaturalist.ala.org.au/people/thebeachcomber), who read an early draft of this article and offered corrections and additional information about the workings of *iNaturalist*. I recommend reading the article by Mesaglio and Callaghan (2021) for further insights into *iNaturalist* and its future.

Reference

Mesaglio, T. and Callaghan, C.T. (2021). An overview of the history, current contributions and future outlook of *iNaturalist* in Australia. *Wildlife Research* 48(4): 289–303. https://doi.org/10.1071/WR20154

Table 1. Numbers of Tasmanian observations by taxonomic rank or category, and by quality (research = Research Grade, needs_id = Needs ID, casual = Casual)

No.	Category	Quality
33	kingdom	casual
1295	kingdom	needs_id
123	phylum	casual
641	phylum	needs_id
28	subphylum	casual
262	subphylum	needs_id
51	class	casual
1017	class	needs_id
6	subclass	casual
134	subclass	needs_id
1	infraclass	casual
12	infraclass	needs_id
3	subterclass	needs_id
23	superorder	needs_id
35	order	casual
1714	order	needs_id
3	suborder	casual
212	suborder	needs_id
1	infraorder	casual
100	infraorder	needs_id
10	superfamily	casual
477	superfamily	needs_id
1	epifamily	needs_id
181	family	casual
3856	family	needs_id
19	subfamily	casual
953	subfamily	needs_id
14	tribe	casual
417	tribe	needs_id
1	tribe	research
3	subtribe	casual
35	subtribe	needs_id
670	genus	casual
10252	genus	needs_id
123	genus	research
2	subgenus	casual
75	subgenus	needs_id
1	subgenus	research
4675	species	casual
10401	species	needs_id
47725	species	research
70	subspecies	casual
140	subspecies	needs_id
1697	subspecies	research
2	species complex	needs_id
30	species hybrid	casual
26	species hybrid	needs_id
96	species hybrid	research
1	virus (plant disease)	research
46	clade	needs_id
3	obsolete infraorder	needs_id
3	section	casual
74	section	needs_id
18	subsection	needs_id
2	unranked taxon	casual
4	unranked taxon	needs_id
447	(no name)	casual
244	(no name)	needs_id
2	informal species	needs_id
1	informal species	research
14	informal taxon	casual
41	informal taxon	needs_id

Table 2. Numbers of species-level Tasmanian observations by kingdom, and the 10 most numerous observations by phylum, class, order, family and genus

No.	Kingdom	No.	Phylum
28442	Animalia	17794	Tracheophyta
17962	Plantae	12662	Arthropoda
2671	Fungi	12411	Chordata
266	Protozoa	2513	Mollusca
173	Chromista	2261	Basidiomycota
4	Bacteria	409	Ascomycota
		383	Echinodermata
		266	Mycetozoa
		235	Platyhelminthes
		193	Cnidaria

No.	Class	No.	Order
12872	Magnoliopsida	5752	Lepidoptera
11344	Insecta	2800	Passeriformes
7600	Aves	2190	Asparagales
3244	Liliopsida	2123	Coleoptera
2801	Mammalia	1792	Asterales
2111	Agaricomycetes	1553	Diprotodontia
1846	Gastropoda	1530	Fabales
1277	Polypodiopsida	1462	Ericales
878	Actinopterygii	1349	Charadriiformes
866	Arachnida	1314	Agaricales

No.	Family	No.	Genus
1483	Geometridae	611	*Acacia*
1477	Orchidaceae	517	*Macropus*
1464	Asteraceae	456	*Thylogale*
1407	Fabaceae	346	*Tachyglossus*
1380	Ericaceae	345	*Richea*
973	Macropodidae	339	*Vombatus*
954	Myrtaceae	336	*Eucalyptus*
946	Proteaceae	326	*Platycercus*
730	Anatidae	317	*Drosera*
645	Meliphagidae	299	*Sarcophilus*

Table 3. Number of observations for the 10 most-observed species-level taxa in the Research Grade and Needs ID quality categories

Research Grade

No.	Scientific name	Common name
456	*Thylogale billardierii*	Tasmanian pademelon
339	*Vombatus ursinus*	Common wombat
299	*Sarcophilus harrisii*	Tasmanian devil
266	*Malurus cyaneus*	Superb fairywren
257	*Banksia marginata*	Silver banksia
249	*Platycercus caledonicus*	Green rosella
248	*Chroicocephalus novaehollandiae*	Silver gull
238	*Tribonyx mortierii*	Tasmanian native hen
238	*Tachyglossus aculeatus*	Short-beaked echidna
229	*Macropus rufogriseus*	Red-necked wallaby

Needs ID

No.	Scientific name	Common name
52	*Carinascincus metallicus*	Metallic cool-skink
48	*Engaeus granulatus*	Central North burrowing crayfish
47	*Leptospermum scoparium*	Manuka
44	*Thoracolopha melanographa*	Variable noctuid
44	*Pulchrocladia retipora*	Snow lichen
42	*Caladenia carnea*	Pink fingers
39	*Carpobrotus rossii*	Pig face
36	*Stylidium graminifolium*	Grass triggerplant
34	*Sarcophilus harrisii*	Tasmanian devil
32	*Hibbertia procumbens*	Spreading guinea flower

Table 4. Research Grade (RG) and Needs ID (NI) observations of species-level taxa, ranked in the top and bottom blocks by number and in the middle two blocks by the RG/NI ratio

Scientific name	Common name	No. RG	No. NI	RG/NI
Chroicocephalus novaehollandiae	Silver gull	248	0	
Cygnus atratus	Black swan	171	0	
Bombus terrestris	Buff-tailed bumblebee	163	0	
Telopea truncata	Tasmanian waratah	162	0	
Vanellus miles novaehollandiae	Masked lapwing	151	0	
Phylidonyris novaehollandiae	New Holland honeyeater	140	0	
Egretta novaehollandiae	White-faced heron	130	0	
Apis mellifera	Western honeybee	122	0	
Dacelo novaeguineae	Laughing kookaburra	120	0	
Ornithorhynchus anatinus	Platypus	111	0	
Malurus cyaneus	Superb fairywren	266	1	266.0
Calyptorhynchus funereus	Yellow-tailed black cockatoo	127	1	127.0
Platycercus caledonicus	Green rosella	249	2	124.5
Notechis scutatus	Tiger snake	120	1	120.0
Actinia tenebrosa	Waratah anemone	117	1	117.0
Liopholis whitii	White's skink	112	1	112.0
Tachyglossus aculeatus setosus	Short-beaked echidna	108	1	108.0
Heteronympha merope	Common brown	104	1	104.0
Tiliqua nigrolutea	Blotched blue-tongued lizard	98	1	98.0
Strepera fuliginosa	Black currawong	194	2	97.0
Crassula sieberiana	Australian stonecrop	1	10	0.10
Cortinarius submagellanicus	(cortinaria fungus)	1	10	0.10
Caladenia fuscata	Dusky fingers	1	10	0.10
Tasmanicosa godeffroyi	(wolf spider)	1	11	0.09
Mniodendron comosum	Palm moss	1	11	0.09
Euphrasia striata	Striate eyebright	1	11	0.09
Tylopilus brunneus	(bolete fungus)	1	12	0.08
Neumichtis spumigera	Green cutworm	2	25	0.08
Dasygaster melambaphes	Black-on-black armyworm	1	14	0.07
Thoracolopha melanographa	Variable noctuid	3	44	0.07
Engaeus granulatus	Central North burrowing crayfish	0	48	
Anthela rufifascia	(anthelid moth)	0	14	
Proteuxoa bistrigula	(noctuid moth)	0	12	
Lepidosperma elatius	Tall swordsedge	0	11	
Philobota hydara	(oecophorid moth)	0	10	
Ectopatria virginea	(noctuid moth)	0	10	
Neumichtis aplectoides	Green cutworm	0	9	
Opisthoncus parcedentatus	(jumping spider)	0	8	
Dicranoloma menziesii	(moss)	0	8	
Brachyscome spathulata	Coarse daisy	0	8	

Table 5. Numbers of Tasmanian observations by observed_on date to the end of 2020

Half-decade	No.
1961–1965	1
1966–1970	1
1971–1975	8
1976–1980	4
1981–1985	27
1986–1990	0
1991–1995	50
1996–2000	142
2001–2005	684
2006–2010	2624
2011–2015	6136
2016–2020	63258

Table 6. Numbers of Tasmanian observations by created_at date

Year	No.
2011	63
2012	272
2013	21
2014	352
2015	240
2016	3205
2017	5531
2018	12136
2019	18569
2020	30252
2021 (in part)	17905

Table 7. Mean delay between observed_on and created_at dates

***observed_on* year**	**Mean delay (days)**
2015	1504
2016	522
2017	235
2018	103
2019	59
2020	15
2021 (in part)	8

Table 8. Numbers of observations per user (o/u), on three scales of observation numbers

o/u	No.	o/u	No.	o/u	No.
1	718	1–9	1638	1–99	2269
2	297	10–19	258	100–199	55
3	164	20–29	130	200–299	17
4	126	30–39	70	300–399	10
5	88	40–49	65	400–499	7
6	83	50–59	33	500–599	4
7	53	60–69	20	600–699	1
8	56	70–79	24	700–799	0
9	53	80–89	18	800–899	1
		90–99	13	900–999	2
		100+	116	1000+	19

Table 9. Tally of years of contribution for users

No. of years	No. of users
1	1879
2	348
3	103
4	31
5	16
6	7
7	1

The rediscovery of the short-tailed rain crayfish (*Ombrastacoides parvicaudatus* Hansen & Richardson 2006)

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Introduction

In the early and mid-1970s staff and students in what was then the Department of Zoology at the University of Tasmania had a strong interest in freshwater crustaceans, particularly mountain shrimps (Syncarida), phreatoicid isopods and freshwater crayfish. As access to western and southwestern Tasmania improved, many field trips were organised to collect and study these animals. As part of these activities, in 1970 I.S. (Bill) Wilson collected two crayfish from a creek near the Lyell Highway in the King River valley, and in 1975 a group including P.S. (Sam) Lake, students Brenton Knott and Phil Suter, and one of the present authors (AR), collected another crayfish in a tributary of the highly polluted Comstock Creek that drains part of the Mt Lyell mines.

Along with many other crayfish, these specimens were carefully labelled and stored in the Department of Zoology's collections, to be joined there by three other specimens collected in the same area by Pierre Horwitz in 1988 (amongst many other specimens of crayfish from all over western Tasmania). Thanks to initiatives such as to the Lower Gordon River Scientific Survey (Richardson & Swain 1978) and the Wilderness Ecosystems Baseline Survey (Smith 1998), collections of what we now call the "rain crayfish" (i.e. the two Tasmanian endemic genera known at that time as *Parastacoides*) grew substantially, and it became increasingly obvious that the existing taxonomies did not recognise the full species diversity in this group. In the early 2000s, Brita Hansen took on a PhD project to re-examine the collections and describe any new species, which led to a major revision (Hansen & Richardson 2006) that erected two new genera (*Ombrastacoides* and *Spinastacoides*)

Plate 1a. *Ombrastacoides parvicaudatus* from site 16 showing typical colour: most rain crayfish have the orange leg bases.

Plate 1b. Unusually pale *Ombrastacoides parvicaudatus*, probably reflecting a recent moult

to replace *Parastacoides*, described ten new species in the two genera, and confirmed the status of four others that had been described previously.

Among these new species was *O. parvicaudatus*, known as the short-tailed rain crayfish (Plate 1), which was described from the six specimens described above. Hansen and Richardson (2006) also assessed the conservation status of the various rain crayfish, and noted that *O. parvicaudatus* might be extinct, due to the flooding of the King River valley to form the Lake Burbury hydro-electric impoundment in the 1990s. The sites where Bill Wilson and the Sam Lake party collected specimens are now almost certainly under water (these collections pre-dated the 1:100,000 Tasmap series, so the location data were not very precise), and the Horwitz site (located using a 1:100,000 map, not GPS) was on the very edge of the new lake (Figure 1). From what is known from studies at the Gordon and Pedder impoundments, these crayfish do not survive long after inundation. The loss of their food source, and predation by introduced brown trout, *Salmo trutta* Linnaeus 1758, apparently eliminated *Ombrastacoides* spp. from the hydro-electric storages Lakes Pedder and Gordon since none have been recorded in dredge samples (Forteath & Osborn 2012) and many crayfish were observed in the guts of the very large trout that were caught

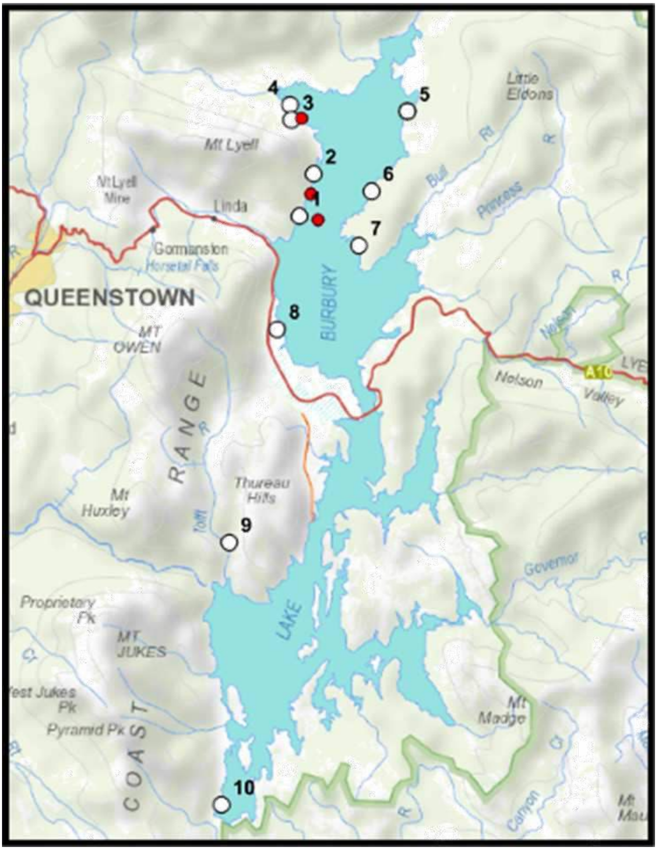

Figure 1. Lake Burbury, showing the collection sites visited in the initial survey (red dots mark the approximate locations of the sites at which the original specimens of *Ombrastacoides parvicaudatus* were collected)

in the first few years after flooding (personal observation). Collections from sedgelands south of the Linda Valley (by AMMR & B. Hansen in the early 2000s) failed to collect *O. parvicaudatus*. The species is listed as Critically Endangered on the IUCN Red List (Richardson 2010), but is not listed on either the Tasmanian *Threatened Species Protection Act 1995* or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The characters distinguishing *O. parvicaudatus* from other members of the genus are quite subtle (Plates 2a–c), as is often the case among the *Ombrastacoides* species. Most of the new *Ombrastacoides* species were verified by DNA sequencing, but it was not possible to extract good sequences from the old material in the preserved *O. parvicaudatus* specimens. The decision to recognise *O. parvicaudatus* as a new species was made because it showed morphological differences of the same level as those seen between species in the genus that had been determined through their DNA.

At least three other *Ombrastacoides* species occur around Lake Burbury: *O. leptomerus* to the north, and *O. professorum* and *O. brevirostris* to the south. Table 1 shows some of the characters that separate these species.

In 2020, Hydro Tasmania, as part of their King-Yolande Sustainability Review, wished to establish the current status of *O. parvicaudatus* and engaged the authors to survey the area. This provided an opportunity not only to establish the species' existence but also to collect fresh material for DNA analysis that would confirm its taxonomic status.

Methods and Findings

Initial survey

Since the known sites for *O. parvicaudatus* were all north of the old Lyell Highway (i.e. the eastern end of the Linda Valley), the survey in November 2020 initially concentrated on the shores of the northern part of the lake, accessed by boat. Of the existing collections, only those of Horwitz recorded any habitat details ("shallow burrow under rocks at edge of creek"), but Hansen and Richardson (2006) suggested that the species "digs Type 1b and 2 burrows (as described by Horwitz and Richardson 1986), with burrows located in creeks". Type 1b burrows are found at the edge of creeks, but with entrances on land as well, while type 2 burrows are away from standing water, but penetrate down to the water table. Consequently, we proceeded clockwise around the lake shores from the Linda Valley, sampling small creeks by turning rocks, moss or root mats at the creek edges, and excavating burrows where they were found in adjacent sedgelands and tea-tree swamps. Finally, we surveyed three sites south of the old Lyell Highway in the southern basin of the lake (Figure 1).

The collected crayfish were sexed and measured, and the characters listed in Table 1 were assessed. It quickly became apparent that the rostrum characters (profile of the rostrum floor and angling of the lateral ridges) were difficult to assess reliably in the field due to the distortions caused by water films. Since

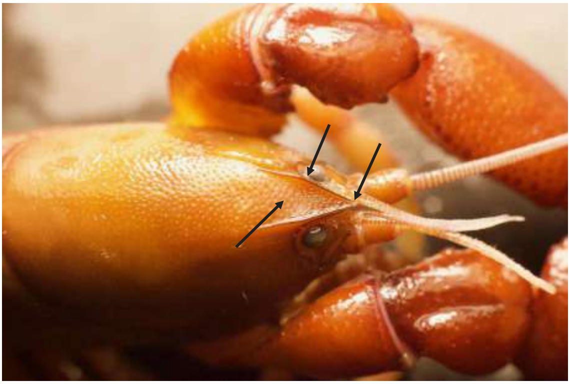

Plate 2a. *Ombrastacoides parvicaudatus* from Site 9 showing rostrum area on a preserved and dried specimen (note the flat rostrum floor, angled rostral carinae and acute rostral tip)

Plate 2b. *Ombrastacoides leptomerus* from site 6 showing rostrum area on a preserved and dried specimen (note the narrower rostrum, concave rostrum floor and sharp rostral tip)

Plate 2c. *Ombrastacoides ingressus* from site 6 showing rostrum area on a preserved and dried specimen (note the broad rostrum, concave rostrum floor and rounded rostral tip)

Table 1. Characters distinguishing *Ombrastacoides* species in the King River valley

OCL = orbital carapace length: from rear of the orbit to posterior edge of the carapace; CW = maximum width of the carapace. See Plates 2a-c.

Character	*O. parvicaudatus*	*O. professorum*	*O. leptomerus*	*O. brevirostris*
rostrum floor profile in cross section	flat	flat	concave	flat
rostrum lateral carinae	angled	angled	straight	straight
rostrum apex	acute	acute	acute	rounded
CW/OCL	0.46-0.49	0.50-0.53	0.48-0.53	0.47-0.64
chela carpus groove	weak to well-developed	absent	weak to well-developed	absent

it was possible that we might be dealing with a very rare species, all the animals were released after being measured; however, one rear leg was removed and fixed in 100% ethanol for later DNA analysis (note that crayfish readily regenerate lost limbs).

In the UTAS Molecular Genetics Facility, DNA was extracted from the leg samples, and the polymerase chain reaction (PCR) was used to amplify an approximately 530bp fragment of the 16s gene. This gene fragment was sequenced, and the sequences were aligned. This allowed us to assess the relationships between the samples.

Initial survey results

We collected crayfish at seven of the ten survey sites: all were *Ombrastacoides* species, apart from those at site 9, a steep, rocky creek in rainforest running into the Tofft River arm of the lake, where we found two specimens of the western spiny rain crayfish, *Spinicaudatus catinipalmus*, and one of the western spiny crayfish, *Astacopsis tricornis*.

Two characters separate *O. parvicaudatus* from *O. leptomerus*, the most likely species to be found in the same range: the relative width of the carapace and the shape of the rostrum floor (Table 1). The angling of the rostral carinae was too subtle to evaluate on wet specimens in the field. The animals collected from creek edges at sites 1 & 2 on the western shore all had flat rostrum floors, and all but one had carapace widths narrower than those of *O. leptomerus*. Animals collected from burrows on the eastern shore and southern basin mostly had wider carapaces and some had concave rostrum floors.

The habitat from which we collected the crayfish at sites 1 & 2 was quite specific. They were not found under rocks in the small creeks, but rather under moss beds, root mats or logs at the creek edge where some water was flowing, or seeping, beneath the surface. The lateral extent of this habitat was limited to only a metre or two from the creek edge.

The DNA analysis showed that the animals from sites 1 & 2 were clearly distinct from the other crayfish collected from the northern basin of the lake at sites 4 & 6. As a group, all the latter crayfish were distinct from the animals from sites 5 & 10. Interestingly, the animals from site 5 were closely related to a sample from a crayfish collected from sedgeland near the Lyell Highway just east of Bubs Hill, a specimen of *O. ingressus*, which we included as a check.

Taken together, this evidence confirms that the short-tailed rain crayfish is a good species that persists in at least two steep rocky creeks flowing off Mt Lyell, and that it lives in type 1b burrows. Based on these results, Hydro Tasmania agreed to support a further survey to investigate the range of the species.

Range survey

In May 2021, we returned to the area, targeting as many creeks as possible flowing off Mt Lyell, initially by boat between the Linda Valley and the

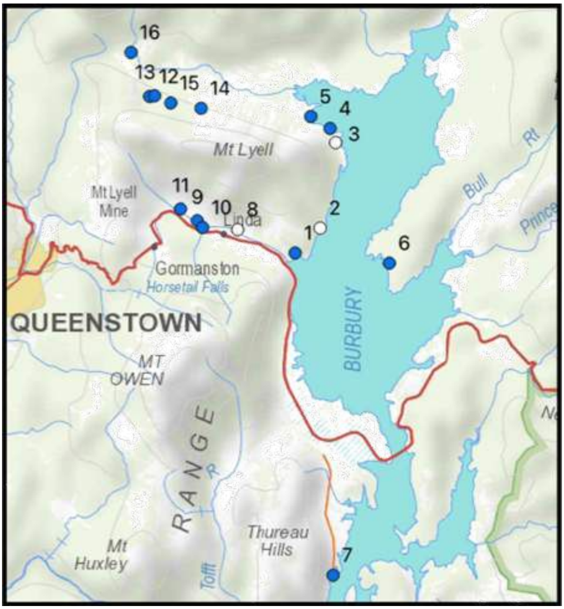

Figure 2. Lake Burbury, showing collection sites visited in the second survey (open circles mark sites where no crayfish were collected)

Comstock Valley. We then sampled several creeks running south from Mt Lyell into the Linda Valley, and finally via the Mt Lyell mine area we sampled creeks flowing north from Cape Horn Spur into the upper reaches of the Comstock Valley (Figure 2). We also returned to one site (site 6) on the eastern shore of the lake where we had seen burrows in the initial survey but had not been able to catch any animals, and we sampled a small creek at the Thureau Hills boat ramp (site 7) that had habitat similar to the stream edges where we had collected previously *O. parvicaudatus*.

In this survey we only sampled creek edges (apart from site 6, where we excavated burrows in a teatree swamp), and as well as taking legs for DNA analysis as before, we also collected the whole animals to form the basis of a voucher collection to allow a better description of *O. parvicaudatus*. The animals were kept alive in takeaway containers and then euthanised in the freezer of a domestic fridge before being fixed in 70% ethanol. The preserved animals were examined in the laboratory where they were sexed, measured and the qualitative characters that distinguish *O. parvicaudatus* were assessed. The rostrum area of each animal was dried to eliminate the distortions from liquid meniscuses, and photographed to better assess the profile of the rostrum floor and the shape of the lateral carinae.

Range survey results

We collected crayfish at all but three of the 16 sites visited; once again all the crayfish were species of *Ombrastacoides*, apart from site 7 in the southern part of the lake, where *Spinastacoides catinipalmus*, the western spiny rain crayfish, was found. We found that the crayfish were not restricted to short burrows under root mats and moss beds, but were also found under rocks in the creek banks. The banks were often formed from broken rocks, and between these were partly water-filled channels and chambers extending some distance back from the creek. It was not always clear whether these tunnels were excavated by the crayfish or were simply results of water flushing the soil and sediment from between the rocks. However, the burrows could all be classified as type 1b.

Only five of the 21 crayfish captured were males, and of the females, one was carrying early-stage juveniles. Most of the animals had carapace width/length ratios less than 0.49, flat rostrum floors, angled rostrum carinae, and acute tips to the rostrum. The morphological analysis suggested that all but one of the animals was *O. parvicaudatus*, the exception being one of the two animals collected from burrows on the eastern lake shore at site 6.

The DNA sequence results were combined with the data from the first survey, and the results showed that all the crayfish we collected in this second survey were *O. parvicaudatus*, the short-tailed rain crayfish, apart from two specimens from Comstock Bay (*O. leptomerus*) and two more from the eastern shore of the lake (*O. leptomerus* and *O. ingressus*). The analysis showed that *O. parvicaudatus* is quite closely related to *O. leptomerus*, and taken together those two species are more distantly related

Figure 3. Northern basin of Lake Burbury, showing records of all *Ombrastacoides* species collected in Nov. 2020 and May 2021 (blue: *O. parvicaudatus*; green: *O. leptomerus*; magenta: *O. ingressus*; white: no crayfish collected. The arrow indicates that *O. leptomerus* and *O. ingressus* were both found at that site.)

to the other two *Ombrastacoides* species we collected: *O. professorum* from the collections at the southern end of the lake, and *O. ingressus* from the eastern shore.

The known distribution of *O. parvicaudatus* now extends almost all around Mt Lyell and the associated ridge of Cape Horn Spur (Figure 3).

Discussion

We have confirmed that the short-tailed rain crayfish is a good species, and that its distribution extends further than just the northwestern parts of the King River valley. We can also define its habitat quite precisely: it lives in the zone at the edge of creeks where water flows under root mats, moss beds and though cavities between rocks that are not part of the mobile bed or edge of the creek but are held together by roots or cemented together by finer sediment. These are clearly type 1b burrows as described by Horwitz and Richardson (1986). Plates 3a–d show examples of the habitats where we collected *O. parvicaudatus*. It is encouraging that they were found in disturbed habitats and adjacent to the very polluted Linda Creek.

O. parvicaudatus is closely related to the northern rain crayfish, *O. leptomerus*, and the two remain frustratingly difficult to identify from their morphology. Plates 2a–c show the typical rostrums of the three species found around the northern basin of Lake Burbury (*O. parvicaudatus*, *O. leptomerus* and *O. ingressus*), but there is much variation around these. What's more, the northern rain crayfish can occupy the same stream-edge habitat as *O. parvicaudatus*. In the northern part of its range (which extends almost to the coast near Penguin) *O. leptomerus* is found exclusively in that stream edge habitat, but in the south of its range in the Lake Burbury area it is usually found in type 2 burrows in sedgelands and swamps. In this survey we collected it from three sites close to the edge of streams, but none of them were in exactly the same habitat as *O. parvicaudatus*. Rather, they were in soil and root mats, not in burrows and chambers under them.

Tasmanian crayfish are often found living alongside each other, but dividing up the habitat on subtle differences in soil drainage (Richardson & Swain 1980). In this survey we found *O. leptomerus* and the Bubs Hill rain crayfish, *Ombrastacoides ingressus*, in burrows close to each other, but we did not notice any obvious difference in habitat (and we did not know that we were dealing with two species at the time). The two records of *O. ingressus* on the eastern shore of Lake Burbury extend the records of this species by some 15 km westwards from its previously known sites, which are confined to sedgelands at the western end of the Collingwood River catchment along the Lyell Highway.

We were not able to define the range of *O. parvicaudatus* precisely. Lake Burbury forms the eastern boundary, since these burrowing crayfish cannot survive flooding for long. Northwards, it appears to be replaced by *O. leptomerus* in the Comstock Valley, but our westernmost collection was still *O. parvicaudatus*. However, it may not extend further west than the upper Comstock Valley since museum records show that *O. leptomerus* is present around Lake Margaret and in the Yolande River catchment. The rest of the western edge is probably formed by the extensive Mt Lyell mine estate where little suitable habitat remains. To the south, its boundary probably lies between the Linda Valley and Mt Jukes, since the stream edge habitat there is occupied by the western spiny rain crayfish, *Spinastacoides catinipalmus*.

O. parvicaudatus is certainly not extinct, and its IUCN Red List status as Critically Endangered is probably no longer justified. To assess its status under the Tasmanian *Threatened Species Protection Act 1995*, we need data on its area of occupancy (i.e. the accumulated area of all colonies), how much that area is fragmented, the size of its population and whether its numbers or distribution are declining. Figure 4 shows two estimates of its extent of occurrence (i.e. its entire range), one a maximally conservative minimum convex polygon (20.2 km^2), the other a best guess based on the arguments above (44.8 km^2). Its actual area of occupancy would of course be very much less. We could make a weak estimate of the area of occupancy by measuring the lengths of creeks with suitable habitat, but that would depend on the scale of mapping, and since we found at least one animal in a tiny seepage crossing an old mining track (Plate 3c), it would probably be an underestimate. Similarly, we could make a very imprecise estimate of population size by multiplying the lengths of suitable

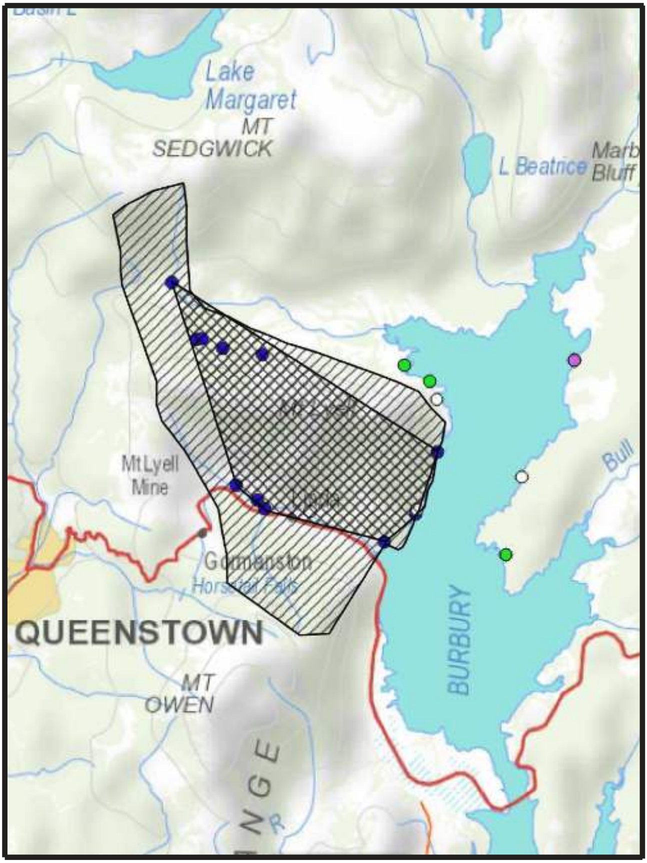

Figure 4. Lake Burbury area, showing two estimates of the area of occurrence of *Ombrastacoides parvicaudatus*: the inner area is a minimum convex polygon around the collection sites; the large area is an estimate based on catchments and the ranges of other related crayfish (for dot colours see Figure 3).

creek habitat by an "expert guess" of the number of animals per metre of creek bank.

Although almost all the range of *O. parvicaudatus* has been severely affected by mining activities (principally fires and polluted mine drainage) and flooding in the past, these factors have now stabilised, so probably the biggest threat to the species is climate change. The creeks that the species inhabits are often tiny, with very small catchments, and so they are vulnerable to lower rainfall and higher evapotranspiration. Current predictions about the climate of the Tasmanian West IBRA region (Grose et al. 2012) suggest that summer rainfall will decline, while winter rainfall may increase. There will also be a tendency for occasional severe rainfall

Plate 3a. Habitat of *Ombrastacoides parvicaudatus* (site 9) with burrows (arrowed) in moss at the edge of a tributary of Linda Creek

Plate 3b. Habitat of *Ombrastacoides parvicaudatus* (site 16) showing excavations at the edge of Comstock Creek (well upstream of the polluted zone)

Plate 3c. Habitat of *Ombrastacoides parvicaudatus* (site 15): the species was collected from a shallow burrow under the moss in a seepage on this old track

Plate 3d. Habitat of *Ombrastacoides parvicaudatus* (site 1) showing steep creek emerging from culvert, with introduced blackberry (the species was collected under streamside rocks)

events in winter and early spring. The number of summer warm days will increase, though no significant change in drought frequency or severity is projected. Crayfish can survive low water levels if their burrows remain moist, but they are then more vulnerable to high temperatures, especially in shallow burrows where the vegetation cover is sparse. Destructive spates, because of extreme rainfall events, are another potential threat to the streamside habitat of this species.

O. parvicaudatus is one of several rain crayfish that have very small (<50 km^2) areas of occurrence: the Bubs Hill rain crayfish (*O. ingressus* 15 km^2), the Little Denison River rain crayfish (*O. denisoni* 28 km^2), the south-east rain crayfish (*O. dissitus* 17 km^2), the rough-clawed rain crayfish (*O. asperrimanus* 18 km^2) and the professors rain crayfish (*O. professorum* 20 km^2). Before this study, *O. parvicaudatus* had the smallest known range, but now it moves up the rankings. It is probable that further collecting will enlarge the known ranges of some of these species, as happened in this study with *O. ingressus*.

Acknowledgements

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Persistence and recolonisation of the endangered stag beetle *Hoplogonus bornemisszai* Bartolozzi, 1996 (Coleoptera: Lucanidae) following a timber harvesting operation in north-eastern Tasmania

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Introduction

The lucanid beetle, *Hoplogonus bornemisszai* Bartolozzi (Plate 1), is one of three species of *Hoplogonus* Parry, 1875, all of which are endemic to the Blue Tier region of north-eastern Tasmania. All three are currently listed as threatened on the Tasmanian *Threatened Species Protection Act 1995* (TSPA), the federal *Environment Protection and Biodiversity Conservation Act 1999* and International Union for Conservation of Nature Red List, due to anthropogenic disturbance and environmental change. Occupying a mere 700 ha within an 11-km^2 extent of occurrence, *H. bornemisszai* has the most restricted range of the *Hoplogonus* species and is listed as endangered on the TSPA. The larval stage of *Hoplogonus* is entirely edaphic, with the three larval instars consuming humus-rich, granitic soil (Richards & Spencer 2019). The larvae are energetic burrowers, occupying the upper 30 cm of the soil profile, while the adults also extensively tunnel and oviposit beneath the soil surface (Richards & Spencer unpublished data). Within its range, *H. bornemisszai* is most abundant and widespread in the wetter, southern forest communities, while being restricted to riparian areas in the drier, northern sector (Munks et al. 2004), where the soils contain a higher percentage of coarse granite and less soil humus.

Historical logging, including selective harvesting and conversion to tree plantations, has occurred throughout much of the beetle's range, while illegal firewood harvesting continues. Some conversion of private forest to pasture has taken place along the south-eastern range boundary, while one property containing a portion of cleared pasture is located central to the species range, surrounded by intact native forest.

Forest harvesting operations require assessment for the presence of threatened species and identification of suitable habitat prior to certification and commencement of logging activities. In areas where *H. bornemisszai* occurs there

Plate 1. *Hoplogonus bornemisszai* adult male

Plate 2. Excavated larval pit

is a requirement to exclude significant habitat for the species from operations and retain patches of suitable habitat within the harvestable area (FPA 2014). Retained areas should support the best quality habitat for the species within the operation area. Coupe dispersal and limitations on harvest method also apply.

Conducting searches of leaf litter for the presence of living adult and disarticulated exoskeletal remains has been a standard method applied to surveys for *Hoplogonus* species (FPA 2011), developed by Meggs for work on *H. simsoni* Parry, 1875 (Meggs 1996, 1997) and applied by Yee et al. (2008) to *H. bornemisszai*, and by Munks et al. (2004) to *H. bornemisszai* and *H. vanderschoori* Bartolozzi, 1996. Meggs et al. (2003) speculate that *H. simsoni* larvae may be better indicators of the species' presence and viability than adults, but given differing microhabitats, presence and abundance, they conclude that adults represent 'appropriate' indicators for the species. While a valid survey method for *H. simsoni* adults, which often occur in greater densities, its appropriateness when applied to the other *Hoplogonus* species is questionable, particularly as these typically occur in low densities. A larval pit excavation method to survey for *Hoplogonus* species is trialled here by us to provide information on its utility as an alternative to the standard survey approach for these beetles.

Methods

In 2008, the 67-ha Goulds Country forest coupe GC 148A (41° 15.067', 148° 5.037') was partially harvested using seed tree and advanced growth retention silviculture methods (Forestry Tasmania 2010). The resulting forest debris was piled in well-spaced bark heaps for ignition after drying. The location comprised dry eucalypt and damp sclerophyll forest communities on granitic soils and extends along the north-eastern side of the Ransom River; its south-western boundary follows a historic water race which parallels the course of the river. The area had previously been subjected to illegal firewood harvesting, extensive historical alluvial tin mining and selective logging. Fire scars on many trees also suggest wildfire had affected the area within the last 50 years (Yee et al. 2008).

A pre-logging survey of the coupe was undertaken in March 2008 applying two methods, the standard litter sampling as well as log rolling, both acceptable techniques at the time (Yee et al. 2008). The pre-harvest survey confirmed the presence of *H. bornemisszai*, determining the species to be confined to the south-eastern sector of the coupe, an area displaying soil structural change (reduced A1 horizon), likely the result of historic tin mining; this sector was selected for the current study. At the completion of the harvest operation, a monitoring program for *H. bornemisszai* was established. A post-logging visit was conducted in September 2008 and a second undertaken in June 2009, 3 days post-ignition of the bark heaps. Annual monitoring continued for a further 8 years until 2018, carried out in January to coincide with increased beetle activity.

All six treatment sites (T1–6) within the

Plate 3. *Hoplogonus bornemisszai* larval instars: from left 1st, 2nd, 3rd

Plate 4. Completed leaf litter quadrat

harvested area, three in-coupe control sites (CC1–3) located in reserved habitat clumps and three control sites (C1–3) in unharvested adjacent forest were established within a 1-ha section of the coupe. The three treatment sites (T3, 5 & 6) were associated with bark heaps and treatments (T1, 2 & 4) randomly placed within the harvested but unburned areas of the coupe.

Surveys were conducted using a larval pit survey method involving excavation of multiple pits (30 × 30 × 30 cm) in the soil (Plate 2) and recording the number of *H. bornemisszai* larvae, pupae and adults present. At each site, three larval pits were randomly located and excavated within a 2.5-m radius of the site centroid to provide data on beetle population density, structure and uniformity. Larvae of the species of *Hoplogonus* have been described (Richards & Spencer 2014) and are morphologically distinguishable from other scarabaeoids by external features (Ślipiński & Lawrence 2019). Larvae were categorised by their three growth instars (Plate 3) and the co-occurring soil macro-invertebrate fauna documented. Following identification and counting of *H. bornemisszai* and invertebrate by-catch, all excavated animals were reinstated as the pits were infilled. At each site a single 1-m^2 quadrat of ground debris (Plate 4) was also systematically searched for live *H. bornemisszai* and exoskeletal fragments (heads counted only) on each survey. Beetle material recovered within the quadrats, including living *H. bornemisszai*, were identified and removed from the site to ensure they were not re-counted in future surveys.

During the September 2008 pre-ignition survey, larval pits in T3, 5 & 6 were randomly placed within 10 cm of the outer edge of each bark heap. Subsequently, post-ignition pits were located within (central), near-edge (10–30 cm inside burn footprint) and directly on the burn footprint perimeter.

Results

Larval pit surveys

Data from the three larval pits excavated at each site were combined. The total number of each larval instar, pupae and adults per site is presented in Table 1.

The habitation zone (depth) of *H. bornemisszai*, both larvae and adults, was limited to the upper 20 cm soil horizon. Larvae were recorded in the soil profile for a maximum of the first three survey events (2008–2010: encompassing a period of 16 months) at two of the six treatment sites, present only as third instars or pupae in 2010. Larvae were then undetected in treatment (T) sites for a minimum of 5 years, on two occasions for 8 years, while remaining unobserved at the completion of the study in sites T1 and T3. Larvae were present in all control sites on most occasions. Live adult *H. bornemisszai* were exhumed from four of the six treatment sites during the first two sampling events only (10 months apart), with a single adult again only located in T4 in the final year of the study. Adult male and female stag beetles were sporadically recorded in larval pits at controls in most years of the study.

The soil temperature inside the fire

Table 1. Combined *Hoplogonus bornemisszai* pit data (larvae and adults) per site, per year.

Superscripts L1 = Larval instar 1, L2 = larval instar 2, L3 = larval instar 3, P = pupa, F = adult female, M = adult male.

Year	T1	T2	T3	T4	T5	T6	CC1	CC2	CC3	C1	C2	C3
2008	1^{L2} 1^{L3}		2^{L1} 3^{L2} 7^{L3} 3^{F} 3^{M}		3^{L1} 4^{L2} 1^{M}	2^{L2}	1^{L3} 1^{M}	2^{L1} 2^{L2}	4^{L1} 2^{L2} 7^{L3} 1^{M}	3^{L1} 5^{L2} 4^{L3}	1^{L1} 4^{L2} 2^{L3}	4^{L1} 3^{L2}
2009	1^{L1} 1^{L2} 5^{L3} 1^{F}	1^{L3} 1^{M}		1^{L2} 3^{L3}	1^{L3} **(cooked)**		2^{L1}	1^{L1} 1^{L3}	3^{L1} 1^{L2} 4^{L3} 1^{F}	1^{L2} 2^{L3}		1^{L2} 1^{L3}
2010	6^{L3}			1^{P}			1^{L1} 2^{L2} 2^{L3} 1^{F}	1^{L3}	1^{L2} 1^{L3}	1^{M}	1^{L2} 2^{L3}	
2011							1^{L2} 1^{L3}	1^{L1} 3^{L2}		1^{L1} 2^{L3}	1^{L2} 1^{L3} 1^{F}	1^{L1} 3^{L3} 1^{F}
2012								1^{L2}	2^{L2}		1^{L2}	
2013							3^{L1} 2^{L2} 2^{L3}	1^{L1} 1^{L2}	1^{L2} 1^{L3}	3^{L2} 4^{L3}		1^{L2} 3^{L3}
2014							2^{L2} 2^{L3}		3^{L2} 3^{L3}	1^{L1}	1^{L1} 2^{L2} 1^{L3}	5^{L2} 2^{L3}
2015								1^{L3}	2^{L2}	1^{L2}	1^{L1} 1^{L2} 6^{L3}	1^{M}
2016				1^{L3}	1^{L2} 3^{L3}		1^{L3}		1^{L1} 2^{L2} 3^{L3} 1^{F}, 1^{M}			
2017				1^{L3}	1^{L3}	1^{L3}	1^{M}		2^{L3}	3^{L1} 3^{L3} 1^{M}		1^{L2}
2018		2^{L1} 1^{L2}		2^{L1} 1^{L2} 1^{F}		2^{L1} 1^{L2}	3^{L1} 1^{L2} 1^{M}	2^{L1}	1^{L1} 3^{L2} 1^{L3}	2^{L2} 2^{L3} 1^{F}	2^{L1} 1^{L3}	

Plate 5. Burn-impacted *Hoplogonus bornemisszai* larva

footprints remained elevated 3 days post-burning and the substrate was completely desiccated to a depth of >20 cm; no living animals were recorded. Subsurface larvae and adult beetles were found to be incapable of escaping the heat (Plate 5), although it was suspected that worms might escape by retreating deep into their underground tunnels, as no dead specimens were located. Desiccation of edaphic invertebrate biota was confined to the immediate footprint of the surface area actually burned, with no evidence of heat transfer affecting the adjacent soil biota.

Leaf litter surveys

The leaf litter layer was minimal or absent at most of the treatment (T) sites prior to 2015, 6 years post-burning, and despite the survey effort no exoskeletal fragments or live *H. bornemisszai* were located. Low numbers (1–2) of beetle fragments were recorded in litter surveys in adjacent control (C) sites in most years, as well as a total of three live *H. bornemisszai* (1 female and 2 males) over the study period. Fragments of four *H. bornemisszai* were also found within the in-coupe control (CC) sites between 2008 and 2018. All exoskeletal remains displayed obvious signs of degradation, suggesting several years of exposure to the elements (Richards & Spencer in prep.).

Results of by-catch

By-catch diversity was low, limited to a handful of species including: sand scarab *Cheiroplatys latipes* (adult and larvae), dung beetle *Onthophagus pronus* (adult), click beetle *Elatichrosis trisulcata* (adult), unidentified click beetle Elateridae (larvae), ground beetle *Meneristes australis* (adult and larvae), unidentified rove beetle Staphylinidae (adult), unidentified carabid beetle Carabidae (larvae), flower wasp *Thynnus zonatus* (cocoon containing adult female), unidentified march fly Tabanidae (larvae), unidentified centipede Chilopoda (adult), scorpion *Cercophonius squama* (adult and juveniles), mole cricket *Gryllotalpa australis* (adult), raspy cricket *Kinemania ambulans* (adult), unidentified amphipod spp. Amphipoda (adult and juveniles), swift moth *Oxycanus* species (larvae) and unidentified worm spp. Oligochaeta (adult). The most frequently encountered invertebrate groups in order of abundance were: Amphipoda, Oligochaeta, Tenebrionidae, Scarabaeidae, Carabidae, Tabanidae, Elateridae, Bothriuridae, Chilopoda, Staphylinidae, Gryllacrididae, Gryllotalpidae and Hepialidae; other listed taxa were limited to single specimens.

All the by-catch taxa identified are widespread across the Blue Tier region and consistent with the soil fauna observed across the range of *H. bornemisszai* (Richards & Spencer unpublished data). Little variance in this diversity was noted between the sites surveyed prior to the operational burn. Post-ignition, no living by-catch was recorded beneath burn footprints for a period of 4 years, following which

Table 2. Post-harvest vegetation regeneration of GC148A treatment survey area

Year	Ground cover (m)	Ground cover (%)	Understorey (m)	Understorey (%)	Overstorey (m)	Overstorey (%)	Dominant overstorey species
2009	0	0	0	0	0	0	Nil
2010	0	0	0.1	5	0.4	2	*P. apetala*
2012	0.10	2	0.5–2.0	50	2.5	2.5	*P. apetala* (*A. dealbata*, *A. verticillata*)
2013	0.15	2	0.5–2.0	70	2.5	5	*E. obliqua*, *E. amygdalina* (*A. dealbata*, *O. lirata*, *P. apetala*)
2016	0.20	5	1.0–2.5	70	5.0	10	*E. obliqua*, *E. amygdalina* (*A. verticillata*, *O. lirata*, *P. apetala*)
2017	0.20	5	1.0–3.0	70	6.0	20	*E. obliqua*, *E. amygdalina* (*A. verticillata*, *O. lirata*, *P. apetala*)
2018	0.25	5	1.0–3.5	70	6.0–7.0	25	*E. obliqua*, *E. amygdalina* (*A. verticillata*, *P. apetala*)

( ) denotes subdominant species

only Oligochaeta and scarabaeoid larvae were recovered at some locations in low numbers. The density of soil invertebrates exhumed at control (C) sites was found to be greater than that recorded at the non-burned treatment (CC) sites.

Vegetation regeneration

Natural revegetation of the harvested area was slow (Table 2). Four years post-harvest (2012) eucalypt regrowth remained sparse. The dominant overstorey included *Acacia dealbata*, *A. verticillata* and *Pomaderris apetala* with subdominant *Olearia lirata* and an understorey of *Pteridium esculentum*, *Gahnia grandis* and *Pultenaea juniperina*. Ground-cover species were scattered and limited to the herbs *Viola hederacea*, *Acaena novae-zelandiae* and the tussock grass *Poa labillardierei*.

In 2013, *Eucalyptus obliqua* and *E. amygdalina* began to dominate the regenerating overstorey, but due to the patchiness, much of the area still comprised mainly *A. dealbata*, *A. verticillata*, *P. apetala* and *O. lirata*. Ground cover remained sparse, covering less than 2% and was dominated by *A. novaezelandiae*.

At the conclusion of this study in 2018, *E. obliqua* and *E. amygdalina* were the dominant trees, averaging 6–7 m high, with *P. apetala* and *O. lirata* subdominant and *Acacia melanoxylon* forming several dense patches in the wetter section of the study area. Regeneration of the burned bark heap sites remained incomplete, with *P. esculentum* the only coloniser within the footprint and a dense stand of eucalypts encircling the burn perimeters.

Discussion

Despite standard methods able to confirm presence of *Hoplogonus* exoskeletal fragments of varying decompositional stages in leaf litter accumulations, our larval pit excavation method provides a means of better ascertaining the species' response to habitat disturbance, as well as confirming larval persistence in the soil profile. The subterranean life-stages and shallow habitation zone of larval *H. bornemisszai* render the species highly susceptible to soil desiccation and compaction from anthropogenic and environmental disturbance, resulting in event-related mortality. Forest harvesting and regeneration burn intensity have the potential to debilitate critical ecosystem components required for the survival of *H. bornemisszai*. As can be seen from this study, harvesting and fire events disrupt the species' life-cycle, resulting in temporary loss of the species leading to population fragmentation.

Species persistence is contingent on the recovery of suitable habitats (forest and soil) following a disturbance event within an appropriate time frame. The temporary disappearance of *H. bornemisszai* from the operational footprint and period required to re-establish following a selective harvest event given close proximity of extant sources of propagules is here documented. The findings emphasise the importance of retention of suitable habitat in intact native vegetation within and adjacent to the harvest operation to allow recruitment of apterous beetles with limited dispersal capabilities.

Survivorship of soil-dwelling invertebrates has been shown to decline as the level of soil heating increases, either directly as a result of fire, or changes in other environmental parameters such as exposure of soil leading to increased solar heating and evaporation (Malmström 2010; York et al. 2012; Certini et al. 2021). Equally, edaphic functions may be disrupted by particular fire regimes, rendering the soil unsuitable for habitation for extended periods. Several factors are likely to explain the absence of *H. bornemisszai* larvae from the soil profile in treatment sites after 16 months, including a lack of dispersing adults to oviposit, soil modification leading to unsuitable habitat available for oviposition, dispersing adults producing eggs which failed due to poor-quality habitat, or elevated predation levels, desiccation and death of propagules from prolonged exposure. Additionally, larval mortality may result from pathogenic fungal attack and parasitism; however, the complete absence of larvae cannot be attributed to biotic factors alone.

The period between depopulation and recolonisation of *H. bornemisszai* and other soil-dwelling invertebrates is reliant upon the re-establishment of a multi-layered floristic community and leaf litter accumulation, resulting in improved moisture retention and restoration of soil structure. In summary, application of the larval pit excavation method has been demonstrated to be an effective survey technique to determine the presence and persistence of *H. bornemisszai* in the landscape and is a useful addition or alternative to the suite of survey methods available to researchers and ecologists.

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Searching for Castles in the Sky: A rare atmospheric phenomenon in Tasmania's mountains

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The air was crisp, cold, and still. I could feel the winter air bite in the back of my throat as I panted, catching my breath. I looked back up the ridge and saw the snaking S-bends I had just carved into the snow. Some of the turns were well executed. Others looked a little clumsier. Regardless of the need to improve my style, it had been an enjoyable descent. My friends were on another part of the mountain that was too challenging for my meagre ability. One of the great things about cross-country skiing on Mt Rufus is the variety of slopes suitable for skiers of varying abilities. At the time, there was also delight in being the first person to descend an untouched slope.

The night before had been particularly cold but this gave rise to the morning's joys. The pre-dawn purplish alpenglow gave way to a sunrise bathing the surrounding snow-covered peaks in early-morning red. The ice crystals covering the snow around me sparkled like jewels, sometimes with rainbow colours. As the skis knocked them off, they made soft tinkling sounds as they skittled down the surface.

And then I saw distant mountains off to the east, far beyond the Central Plateau. The air was almost entirely free of haze, so what I was looking at was particularly clear. But there are no high mountains in that general direction that should have been visible. Could I have been looking at Freycinet Peninsula? Or maybe Nicols Cap or St Patricks Head? But these mountains did not look right. They seemed to be floating. In fact, some seemed to have high precipices with unrealistic overhangs. Why were there holes in these mountains? There was something unusual going on. I took off my backpack, raised my camera, and took some photos, including Plate 1.

I had just had my first encounter with what I came to know as *Fata Morgana* or Castles in the Sky. Some simple high-school physics helps to understand this phenomenon.

Everyone who has rowed a boat would have seen how an oar sitting in the water looks bent at the point it enters the water. Anyone who has gone night spear fishing off a boat for flounder knows that to be able to spear one, you must compensate for this bending of light. This bending of light is called *refraction*. When light passes at an angle from a medium of one density to another, its direction is changed: the greater the change in density, the greater the bending of the light. With the sudden change of density from air to water, the bend of the light forms a sharp angle. Where there

Plate 1. Fata Morgana (Castles in the Sky), looking over the Central Plateau from Mt Rufus

Plate 2. Sunrise over Mt Arthur showing the impact of air inversions refracting light

is a gradual change in density between media, the light bends slowly with the change, effectively in a curve.

Hot air is less dense than cold air. As light passes from cold air to warm air, it bends, too. Because the change in density is not great, the amount of refraction is relatively small. The effect is most easily seen as mirages on a road in summertime. The hot, less dense air just above the heated road forms a layer close to the road surface. As light from the sun passes through from the cooler, denser air layer above it, it refracts, looking like a shimmering reflection. As the difference in density is not great, you can only see mirages at an acute angle. As you drive towards a mirage on a road, the angle of your view becomes less acute, and the mirage slowly disappears.

Air close to the earth's surface can have layers of different density, too. When the air is still, it can become layered. Cold air drainage can cause freezing fogs in valleys, but a little higher on the hills, the air temperature can be warmer. This is an example of an air temperature inversion. Plate 2 shows how refractions from air temperature inversions cause the image of the rising sun to distort. The lower part of the sun shows two distinct layers in the atmosphere where refraction between the layers distorts the light reaching the camera, leading to a layered appearance. A close look around the edge of the disk of the sun also shows smaller distortions, which suggests other, less-well defined inversions were present in the atmosphere.

Fata Morgana, or Castles in the Sky, is also caused by the refraction of light from air layers of different densities. Figure 1 shows a simplified diagram of how this refraction occurs. Light bends as it passes through the transition zone from cold, dense air to the warmer, less dense air above. Because the light coming from the top of the mountain has undergone less bending than the light coming from lower on the mountain, the apparition seen is upside down so the top of the mountain being refracted looks to be underneath its lower part. The apparition seen can look like an anvil. This also explains the precipice edges to the apparition in Plate 1. Where two precipice edges are close together ovals of light also show through the apparition.

Just like the mirages on hot roads described above, Fata Morgana is only seen extremely close to the horizon. It is often barely visible without binoculars or a telephoto lens. The air temperature inversion also needs to be close to the viewer's elevation.

The name Fata Morgana has its origin in the stories about King Arthur, so I thought it appropriate that Plate 2 included Mt Arthur. Morgana le Fay was said to be an apprentice of Merlin the Magician and became the adversary of King Arthur, Queen Guinevere and the Knights of the Round Table. She lived in a castle that floated in the sky and hence the common name of Fata Morgana, Castles in the Sky. In Sicily's Strait of Messina, sailors who saw this phenomenon believed it was created by Morgana le Fey to lure them to their death. Apparently, Fata Morgana is how Sicilians refer to Morgana le Fey.

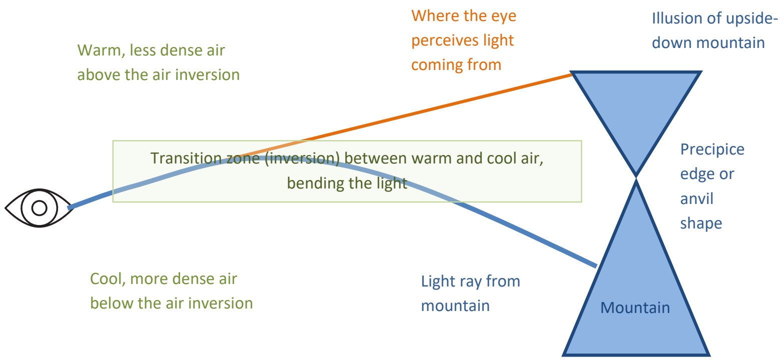

Figure 1. Simplified diagram of how bending of light gives rise to Fata Morgana

Fata Morgana is most commonly seen over very large, calm bodies of water or polar ice sheets. Where the air inversion has several distinct layers, Fata Morgana can be seen as several images stacked on top of each other, like a pile of pancakes. Seeing Fata Morgana from mountains is relatively uncommon. It only occurs in Tasmania when the air is very stable, such as when a large, powerful and slow-moving high-pressure system sits directly above the island. Even the slightest air disturbance will break up the atmospheric stability required to create the Fata Morgana phenomenon. When I was skiing on Mt Rufus, the apparition remained for several hours because of unusual atmospheric stability.

I have often speculated which mountains appeared in the apparition I saw that day from Mt Rufus as there are few landmarks in its direction that give clues as to what the image was of. It is possible the bulk of the mass being refracted was Ben Lomond, though it may have been of lower hills and mountains a little further to the south. Ben Lomond and the hills of the Eastern Tiers are about 120 kilometres from Mt Rufus so some of the apparitions I saw may have been of mountains that would normally be hidden beyond the horizon.

Sunrises observed from kunanyi/Mt Wellington can be spectacular. In the early darkness of another morning, I had set off in torchlight to tread on crunchy fresh snow. As I walked over the plateau following occasional track markers, the pre-dawn glow rose over the distant Tasman Sea and the night lights of Hobart far below. The first rays of the rising sun glinted red off the snow and ice on the Rocking Stone. As the light slowly changed to gold, the hum increased from the waking city below. I had taken the photos I wanted so it was time to head home for an early morning coffee. As I walked over the rise, icy fog covered the headwaters of the North West

Bay River. Above Thark Ridge I could see what I thought was smoke over a distant mountain. Winter is not the time of year to expect forestry burn-offs. Was it a trick of light?

It was another encounter with Fata Morgana. One hundred kilometres away, Wylds Crag had an inverted summit above its peak. It was the characteristic anvil shape that I could now identify with ease. Yes, an air temperature inversion was playing its tricks again. No other mountain around had any trace of Fata Morgana. I took a couple of quick photos (including Plate 3), and it was gone. It had not even lasted 15 minutes. The sun had already warmed the air enough to break up the temperature inversion.

I had been lucky enough to be at the right place at the right time to catch another fleeting apparition. I am told Fata Morgana is usually only a transient phenomenon.

Morgana le Fey has cast her spell on me. From frosty winter morning mountain tops, I continue to search for another glimpse of her castle. Perhaps one day I might be lucky enough to see Fata Morgana with several images stacked one on top of another. It looks like I really am searching for castles in the sky!

Plate 3. Fata Morgana, from Thark Ridge, appearing as an anvil over Wylds Crag

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Ongoing monitoring of Flame Robin (*Petroica phoenicea*) in June 2021 in south-east Tasmania

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Introduction

Els Wakefield and Bill Wakefield surveyed six transects in south-east Tasmania between April and July from 2009 and 2014 to monitor Scarlet Robin (*Petroica boodang*) and Flame Robin (*P. phoenicea*) populations (Wakefield & Wakefield 2016). These surveys were repeated on the same routes in June 2020, June being a month when robins had been present on all routes during the previous years of sampling (Wakefield & Vaughan 2020). There were significant differences in Flame Robin numbers between the initial surveys and the 2020 effort. In 2021, Els Wakefield repeated these surveys to increase recent data and contribute to future baseline monitoring.

Both Flame Robins and Scarlet Robins were counted; however, the primary focus was to enumerate Flame Robins. This is because Scarlet Robins tend to join Flame Robins in small numbers as Flame Robins flock during the colder months. This facilitates population counts of both species before they disperse during warmer months, but more predictive inference can be made about the Flame Robins' movements as these respond directly to biological and environmental cues.

Methods

Field methods

The six routes were located around Blackbrush, Brown Mountain, Bruny Island, Runnymede, Tasman Peninsula and Tooms Lake. Each was surveyed on separate days, using the same design as previously published.

Analytical methods

All data visualisation was performed in R Studio (R Core Team 2021). Flame Robin numbers were calculated along all routes travelled in June 2021. The number of individuals observed was also generated for June data of all previous years sampled, to compare counts across years.

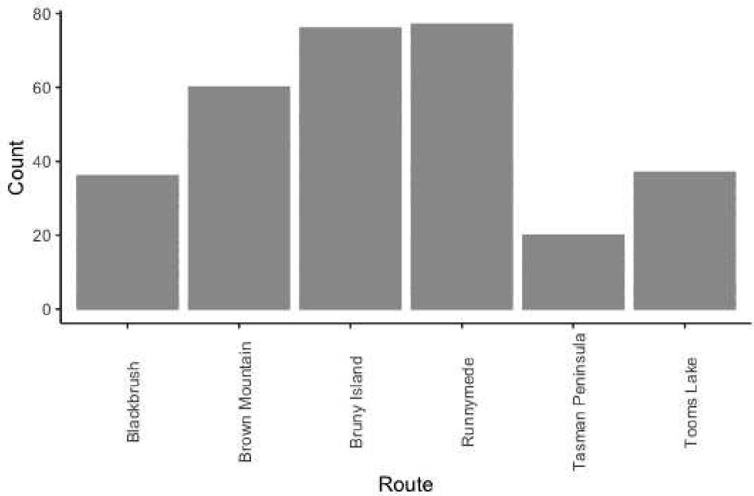

Figure 1. Frequency of Flame Robins (*Petroica phoenicea*) in June 2021 along six transects in Tasmania, Australia.

Results

Flame Robins were most commonly observed on the Bruny Island and Runnymede routes (Figure 1). While there was substantial variation in numbers encountered across routes, at least 20 individuals were encountered on each route (Figure 1). Counts in 2021 were consistently approximately half those observed in 2010, and slightly below those observed in 2020 (Figure 2).

Conclusion

There are several possible causes for different counts across years, including environmental factors, overall population change, or site selection over time. Without wider and more consistent sampling it is impossible to determine what the true cause of this pattern could be. However, it is still valuable to investigate these causes, as the decadal differences in counts are substantial. The cause may be unknown, but it appears there are factors at work influencing the numbers of Flame Robins occurring along the survey routes.

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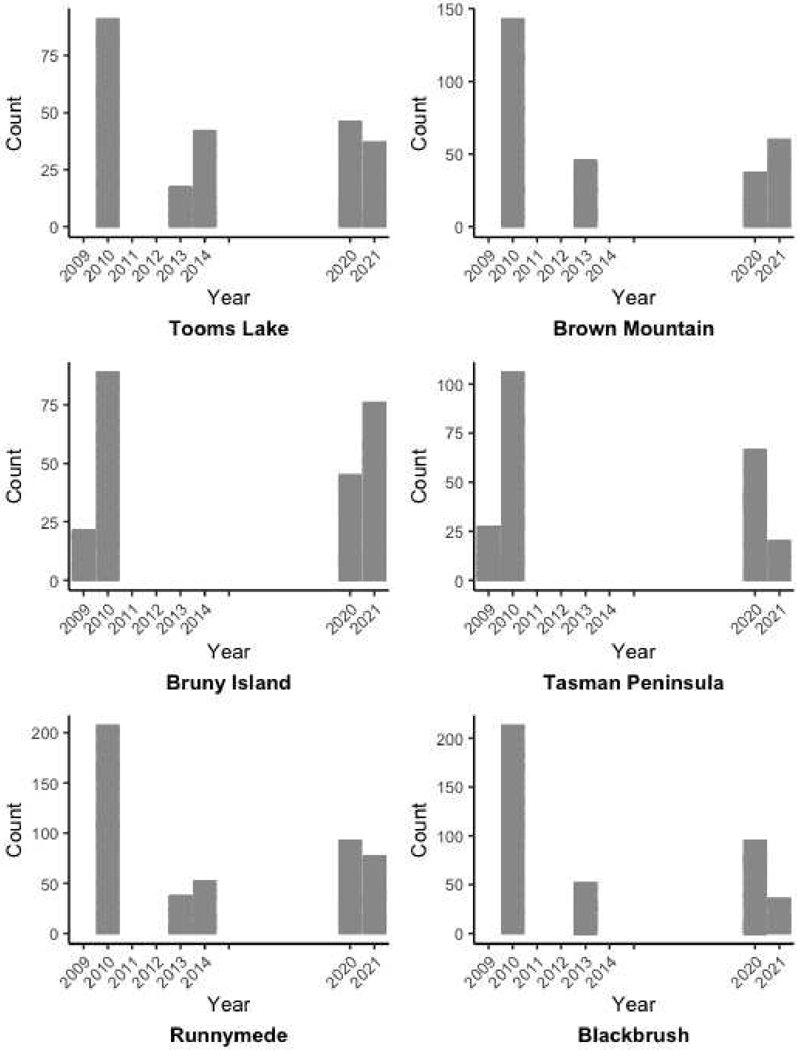

Figure 2. Frequency of Flame Robins (*Petroica phoenicea*) in June (2009–21) along six transects in Tasmania, Australia. The years 2015–19 were not sampled.

The apparent sudden arrival of *Crassula alata* in Tasmania

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Abstract

Crassula alata subsp. *alata* (winged crassula) is reported as a new addition to Tasmania's naturalised flora, recorded for the first time in August 2020. The species has a widespread distribution from Southport in the state's south to near Smithton in the north-west. It is often abundant on gravel verges of major highways and arterial roads and also extends to disturbed sites such as gravel car parks and gaps in sealed footpaths. Whether the species is a recent introduction or has been hitherto overlooked is open to speculation, but the former is considered most likely given the species' distinctive, although diminutive, appearance.

Introduction

The naturalised flora of Tasmania is steadily increasing in number, with new species not native to Tasmania regularly added to the official list of the Tasmanian flora: *Census of the Vascular Plants of Tasmania, including Macquarie Island* (de Salas & Baker 2021). As of 2021, the *Census* contains 2729 vascular plant species, of which 810 (30%) have become naturalised (de Salas & Baker 2021). Fortunately, many of these species remain doubtfully or only sparingly naturalised (e.g. Baker et al. 2019). Documenting the naturalised flora is a critical part of developing appropriate management strategies, prioritising actions and resourcing (e.g. Baker 2005, 2007, 2009, 2011, 2016).

The present paper documents the apparent sudden arrival of a species not previously reported from Tasmania. *Crassula alata* (Viv.) A.Berger subsp. *alata* (winged crassula), first detected in August 2020 in southern Tasmania and documented through to December 2020

Plate 1. The characteristic bright red new annual growth of *Crassula alata* subsp. *alata* readily distinguishes it from other annual *Crassula* species (Plates 2 & 3) [Dover, 1 Oct. 2020, M. Wapstra]

Plate 2. New growth of *Crassula alata* subsp. *alata* (circled in red) growing with *Crassula decumbens* (circled in blue) [Dover, 1 Oct. 2020, M. Wapstra]

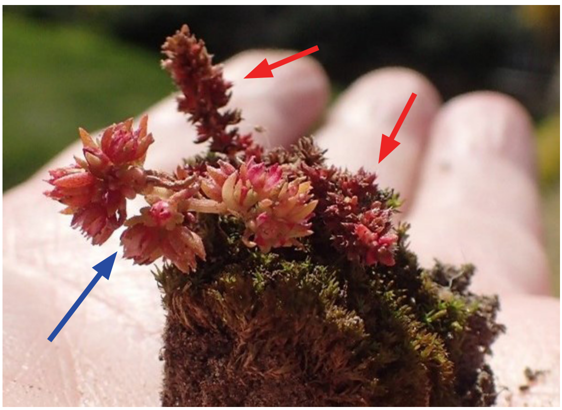

Plate 3. The tightly packed and red-green growth of *Crassula alata* subsp. *alata* (arrowed in red) compared to the lighter-coloured, more open (and more succulent) growth of *Crassula sieberiana* (arrowed in blue) [Don, 10 Sep. 2020, M. Wapstra]

from numerous sites across the state, joins the ranks of ephemeral/annual herbs in Tasmania's flora. This paper explores its possible origins in Tasmania.

Background on species

Crassula alata* subsp. *alata (Viv.) Berger in Engler & Prantl, Pflanzenfam. Ed. 2, 18a: 389 (1930)

Tillaea alata Viv., Pl. Aegypt. Dec IV:16 (1830)

Common name: winged crassula

Annual herb with erect stems to 5 cm long, scarcely branched; leaves linear-lanceolate to linear, 1.5–3 mm long, 0.5–0.8 mm wide; lamina ± flat above, strongly convex below, green to reddish-brown; apex acute with hyaline tip. Inflorescence 1(–3)-flowered, axillary; pedicels absent or almost so; flowers usually 3-merous; calyx lobes oblong-lanceolate, 1.5–2 mm long, acuminate to cuspidate with a colourless point, fleshy, green to red; corolla cup-shaped, off-white often tinged red; lobes triangular, 0.7–1 mm long, usually cuspidate, erect; nectary scales oblong-cuneate to almost square, rounded, slightly broadened at the apex, membranous, pale-yellow; ovaries almost conical, at first gradually later abruptly constricted into short styles, with 2 ovules. Follicles erect, smooth, splitting along the whole suture but opening only in the upper half.

Crassula alata subsp. *alata* can be distinguished from other species of *Crassula* that grow in Tasmania by its scarcely branched habit, presence of prominent marginal ridges on the stems, the pronounced hyaline leaf apex, and by the usually 3-merous flowers. Refer to Plates 1–3. The related *C. alata* subsp. *pharnaceoides* (Fisch. & C.A.Mey.) Wickens & M.Bywater differs in having flowers that are 5-merous. It has a narrower distribution than the type subspecies and occurs naturally in northern Africa and the Arabian Peninsula (Wickens 1987; Wickens & Bywater 1980).

Methods

Global, national and statewide collecting history, distribution and habitat data of *C. alata* subsp. *alata* were accessed from the Global Biodiversity Information Facility (GBIF Secretariat 2021), *Atlas of Living Australia* (ALA 2021) and the collections of the Tasmanian Herbarium, Tasmanian Museum & Art Gallery.

The last comprise 43 collections of the taxon from Tasmania (Table 1), and included a review of all Tasmanian specimens of annual *Crassula* species to check for the presence of misidentified specimens of *C. alata*. subsp. *alata*. These were examined due to the superficial similarity of several species and their predilection to co-occur.

Results

Global distribution and habitat

Crassula alata subsp. *alata* is native to the Mediterranean region where it extends southwards into Africa and east into Asia (Wickens 1987; Figure 1). It is considered naturalised in New Zealand and Australia. In New Zealand, it was first recorded and considered a non-naturalised casual record in 2003, after

Figure 1. Global distribution of *Crassula alata* [source: GBIF Secretariat (2021)]

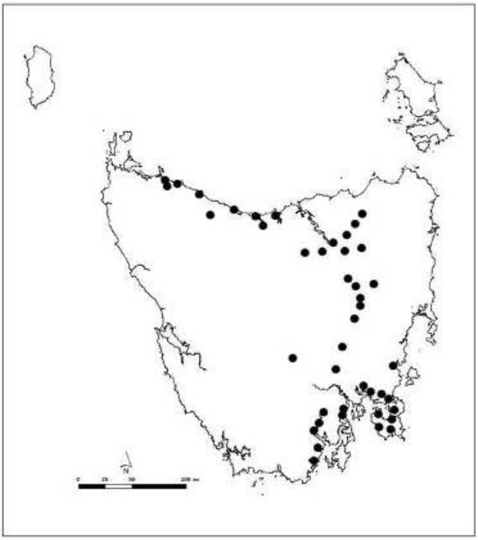

Figure 2. Tasmanian distribution of *Crassula alata* subsp. *alata* [source: collections of M. Wapstra]

it was found growing in peaty sand on damp vehicle tracks (Heenan et al. 2004) After finding the species to be it should be considered fully naturalised.

Mainland Australian distribution and habitat

In Australia, *C. alata* subsp. *alata* has been recorded in Western Australia (first recorded in 1977), South Australia (1961), Victoria (1975), Australian Capital Territory (1971) and New South Wales (1993) (ALA 2021). The species is widespread throughout Victoria, south-east South Australia and south-west Western Australia, where it is recorded growing as a weed in a range of habitats including paths, roadsides, lawns, carparks, and in crevices in masonry (VicFlora 2021, eFLoraSA 2021, PlantNET (2021)).

Tasmanian distribution and habitat

Crassula alata subsp. *alata* was first recorded in Tasmania on 13 August 2020, on the verge of the Channel Highway near Cradoc in the state's south-east. The somewhat serendipitous detection was followed by several subsequent collections, most also from road verges (Figure 2). In Tasmania, the species is most commonly found growing on gravel/dirt verges between the sealed edges of roads and adjacent vegetation. It rarely extends beyond bare ground. Collecting history and observations show that it is abundant along the Tasmanian highway network and extends to numerous minor roads. It also occurs as a weed of footpaths and, in more rural areas, on gravel roads or disturbed sites and along the gravel verges of the railway corridors. Refer Plates 4–6.

It often co-occurs with the native annuals *C. sieberiana* (Schult. & Schult.f.) Druce (rock stonecrop) and *C. decumbens* Thunb. var. *decumbens* (spreading stonecrop), although these three taxa are easily distinguished in the field by their growth habit and colour (Plates 1–3).

Widespread surveying through the spring of 2020 and continuing into the spring of 2021 indicate that the species occurs mainly in lowland and warmer parts of Tasmania, and is seemingly absent from higher elevations (e.g. Central Highlands) and parts of the state with higher rainfall (e.g. west/ south-west).

Examination of other data sources indicates that no collections were made prior to 2020 in Tasmania. Apart from the collections detailed in Table 1, there is a single record reported from Tasmania (N. Fitzgerald, 7 Oct. 2020, Illawarra Road), well within the range of the species reported herein. Following postings of images of the species on the public Facebook group Tasmanian Weeds and discussions with other field botanists, it became apparent that the 2020 observations were the first for the state.

Discussion

Given how widespread *C. alata* subsp. *alata* is on mainland Australia and in New Zealand, it is surprising that 2020 was the first year it was observed in Tasmania. It is possible that the species

Plate 4. Typical habitat of *Crassula alata* subsp. *alata* (red-green plants growing in gravel verge) [Midland Highway, 6 Oct. 2020, M. Wapstra]

Plate 5. *Crassula alata* subsp. *alata* colonising bare ground amongst mown grass – North Esk Memorial Hall [19 Oct. 2020, M. Wapstra]

Plate 6. Habitat of *Crassula alata* subsp. *alata*: gravel verges of the rail corridor – the species is the patch of red in the front left of image [Dawsons Siding Road, 8 Sep. 2020, M. Wapstra]

has been overlooked in Tasmania, either because it was in very low abundance and difficult to detect or due to misidentification or confusion with other annual *Crassula* species. Neither explanation is particularly likely because the state's roads have been subject to ongoing botanical assessments since the mid-1980s, and the species is conspicuous due to its bright red-green appearance. When present even in small numbers, single plants stand out amongst other low green herbs in the roadside gravel. If it was in low abundance, and perhaps widespread, it may be that 2020 was a suitable year for the rapid growth and subsequent spread of annual herbs. This was certainly the case for other annual species, particularly orchids, with 2019–2020 representing the breaking of a non-declared drought period. Similar speculation has been made by Ogle (2008) in regard to its late discovery and the subsequent realisation of it having a widespread distribution in New Zealand. Ogle (2008) suggests that it is more likely that it has expanded its range and abundance quite recently in New Zealand rather than being overlooked. However, Ogle et al. (2020) suggest that because of its diminutive size, strict late winter to spring growth habit and superficial similarity to other species of *Crassula*, the naturalised presence of C. *alata* in New Zealand has almost certainly gone unrecognised for much longer than the official recognition date of 2003.

If 2020 was the first year it was present in Tasmania, this represents a very sudden appearance with no obvious source of transport to Tasmania, beyond perhaps routine road users. The last few years have seen higher than usual activity in major road infrastructure projects on most major highways and arterial routes, to the extent that once present it is easier to envisage how the species has spread.

It is also possible that the species has been present in the state for some time but climatic conditions were unsuitable for it to persist in the landscape at detectable levels. With a warming climate, it may be that parts of Tasmania are now suitable for the species. This appears to the case with other mainland native and naturalised species now well established (e.g. the grasses *Eleusine tristachya* (Lam.) Lam., *Chloris truncata* R.Br. and species of *Eragrostis*) or being reported for the first time (e.g. the grass *Enneapogon nigricans* (R.Br.) P.Beauv.).

In coming years, it will be interesting to survey distribution gaps. For example, it seems unlikely that the species is not present on the major Bass Strait islands and parts of the east coast. It will also be interesting to observe changes in the distribution of the species and whether it remains as apparently abundant as its first year of occupation in Tasmania, or if it spreads to higher elevations and colder/wetter parts of the state. People are encouraged to submit observations to a formal database (e.g. iNaturalist, Natural Values Atlas, Atlas of Living Australia) and to submit specimens to the Tasmanian Herbarium for sites that extend/fill in the range.

The species does not present a serious management risk. At present, it appears to be confined to immediate road verges (and only very occasionally beyond this). It is probably merely another member of a suite of weedy native/naturalised annuals that colonise/recolonise disturbed sites during suitable conditions.

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Table 1. Tasmanian collections of *Crassula alata* subsp. *alata* [source: collections of M. Wapstra; collection no. refers to the code used by MW to submit specimens to the Tasmanian Herbarium – specimens will be later allocated a formal HO accession code; site is as per locality given in submission details]

Date	Site	Easting	Northing	Habitat	Collection no.
13/08/2020	Cradoc, Channel Highway (first Tasmanian collection)	502285	5229303	road verge	s.n.
22/09/2020	Arthur Highway, near Lewisham Road turnoff	550098	5261475	gravel road verge	MW2942
22/09/2020	Arthur Highway, near Gunns Hill	560739	5258826	gravel road verge	MW2941
22/09/2020	Arthur Highway, north of turnoff to Marion Bay	567227	5254106	gravel road verge	MW2940
22/09/2020	Coal Mine Road	557701	5238683	gravel road verge	MW2936
22/09/2020	Taranna	570466	5233372	gravel footpath	MW2937
22/09/2020	Arthur Highway, east of Murdunna	572710	5242909	gravel road verge, edge of quite new pull-off	MW2939
08/09/2010	Dawsons Siding Road, near Railton	450031	5430407	gravel flat adjacent railway line	MW2919
08/09/2020	Stony Rise Road, Don	443136	5440483	road verge, dirt bank	MW2920
18/09/2020	Tasman Highway between Leprena Road & Branders Road, Orielton	543916	5267195	gravel verge of highway	MW2928
19/09/2020	Southport, Kingfish Beach Road	497595	5191175	gravel road verge	MW2931
19/09/2020	Port Huon, Huon Highway	497299	5221846	gravel road verge	MW2932
22/09/2020	White Beach Road	557899	5225226	gravel road verge	MW2935
22/09/2020	Port Arthur, between entrance to historic site & Safety Cove Road	568894	5223034	gravel road verge	MW2938
23/09/2020	Midland Highway, Campbell Town (outside cemetery)	540744	5356908	gravel road verge	MW2943

Table 1 continued

Date	Site	Easting	Northing	Habitat	Collection no.
24/09/2020	Wynyard, corner York & Inglis streets	390823	5462239	sealed footpath - nature strip verge	MW2944
01/10/2020	Southern Outlet, Kingston end, eastern side (south-bound)	525463	5244099	gravel pull-off (large area)	MW2947
01/10/2020	Huon Highway near Grove opposite Pages Road	506534	5240123	gravel road verge	MW2948
01/10/2020	Dover (near playground)	500926	5204038	gravel road verge/car park	MW2949
06/10/2020	Midland Highway, north of Bagdad	518264	5284441	gravel verge of highway	MW2964
06/10/2020	Midland Highway, near turnoff to Jericho	524066	5307206	gravel verge of highway	MW2965
06/10/2020	Midland Highway, just north of Tunbridge Tier Road	535444	5335618	gravel verge of highway	MW2966
06/10/2020	Midland Highway, north of Ross	540948	5348909	gravel verge of highway	MW2967
11/10/2020	Orford, information pull-off	571257	5287791	sealed/loose gravel verge of car park	MW2968
19/10/2020	Midland Highway, Conara	536663	5369002	gravel verge of highway	MW2972
19/10/2020	Midland Highway, Epping Forest	529260	5376702	gravel verge of highway	MW2973
19/10/2020	North Esk Memorial Hall	542120	5407592	gravel patch in "lawn" outside hall	MW2974
19/10/2020	Blessington Road	526556	5404695	gravel road verge	MW2975
20/10/2020	Meander Valley Road near Bass Highway	488991	5402686	gravel verge of road	MW2984
20/10/2020	Rutherglen	505111	5403932	gravel footpath	MW2985

Table 1 continued

Date	Site	Easting	Northing	Habitat	Collection no.
21/10/2020	Tasman Highway, south of Nelson Road	528240	5421249	roadside gravel	MW2987
21/10/2020	Sideling Lookout car park	536084	5432589	bare dirt/light grass at edge of concrete kerb of car park	MW2988
21/10/2020	Scottsdale, at the Big Thumb information sign	542732	5442697	gravel footpath	MW2989
06/11/2020	Howden Road, Howden	523741	5237363	gravel verge of road	MW3065
05/11/2020	Magnet Street, Waverley	515391	5413404	cracks in old asphalt lane between houses	MW3066
02/11/2020	Ridgley Highway, Highclere	400777	5441477	gravel verge of highway	MW3067
03/11/2020	Bass Highway, west of turnoff to Rocky Cape	370418	5473095	gravel verge of highway	MW3068
03/11/2020	Bass Highway, Black River campground entrance	359003	5476581	gravel verge of highway	MW3069
03/11/2020	Mawbanna Road, near Loosemores Road junction	360964	5470870	gravel verge of road	MW3070
04/11/2020	Parkers Ford Road, Port Sorell	461550	5440575	gravel verge of road	MW3071
02/11/2020	Bass Highway, near Penguin	422968	5446850	gravel verge of highway	MW3072
09/11/2020	Esk Main Road, between Avoca and Hanleth	553620	5370992	gravel verge of highway	MW3073
07/12/2020	Lyell Highway, east of Ouse	477662	5295539	gravel verge of highway	MW3074

Invertebrate discoveries arising from a survey of the Musselroe Wind Farm

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Introduction and description of property

In 2018–19 we conducted an invertebrate survey at the Musselroe Wind Farm, as part of the Tasmanian Museum and Art Gallery's annual 'Expeditions of Discovery' program. In a similar manner to the Australian Government's Bush Blitz species discovery program, the program aims to document the flora and fauna at particular locations and to support the observations with a more-or-less comprehensive collection of voucher specimens. Here we present an account of some of our more notable invertebrate finds. These are based on our own particular areas of field and taxonomic expertise (chiefly various insect groups, but also molluscs and crustaceans), and so not all taxonomic groups are covered equally. We have grouped our observations by habitat, to provide some ecological context for what might otherwise seem like a daunting multiplicity of unfamiliar

Figure 1. The approximate boundary of the Musselroe Wind Farm property and some of the features named in the text. Base-map is from Google Maps.

scientific names.

Musselroe Wind Farm is a 5500-hectare private property on Tasmania's far north-east coast (Fig. 1), some 20 km north of Gladstone. Its coastal or near-coastal boundary extends from just inland from Petal Point and Lemons Beach to Cape Portland and The Salties; thence along the north coast by way of Lanoma Point and what we dubbed 'Stone House' Beach to the estuary of the Little Musselroe River (which is not part of the property); and then continuing further east from Little Musselroe Bay to the northern half of Great Musselroe Bay (other than a narrow coastal reserve). Inland, it extends from this coastal or near-coastal fringe south to the border of the Rushy Lagoon grazing property, taking in the Tregaron Lagoons, a series of fossil dune-ridges, and the lower reaches of the Little Musselroe River.

The property is managed primarily for its 56 wind turbines, which are mostly sited in agriculturally improved pasture that is also used for cattle-grazing. Despite these predominant land uses, the property retains significant areas of native vegetation, with further areas in the process of rehabilitation from pasture and from thickets of non-native gorse and boxthorn. These areas are scattered throughout the property, but are concentrated along the coastal fringe, particularly at its eastern and western ends. The largest area of native vegetation – chiefly coastal heathland and scrubland on flatter ground, with she-oak forest and stands of grass-trees on dune tops and ridges – is found in the eastern third of the property. Coastal scrubland is also widespread on the ridges and dunes in the Tregaron Lagoons area. Small areas of tea-tree and paperbark swamp forest and wet heathland occur along the course of the Little Musselroe River (including around the waterbody that we dubbed 'Bullseye' Lagoon) and at Tregaron Lagoons. The coastal area between Tregaron Lagoons and Cape Portland supports significant areas of native tussock-grassland. Salt flats and saline lagoons, some ephemeral and others more permanent, are numerous from Tregaron Lagoons to Cape Portland and along the northern coastal fringe as far east as Little Musselroe Bay.

Materials and methods

The survey involved three invertebrate zoology staff from TMAG (SG, CB and KM), as well as two TMAG honorary researchers (KB and LC). The property was extensively surveyed on 5–9 November 2018, with follow-up trap-sample collection (by SG) on 16 December 2018 and 16 January 2019, plus some further, targeted sampling (by SG) on 9–11 September 2019. We sampled insects and other arthropods through a mix of direct observation (including spotlighting at night), hand collection (including the use of sweep nets, beating trays and dip nets), and trapping (Malaise traps, pitfall traps, yellow pan traps and ultraviolet light traps). Molluscs were sampled (by KB) through hand-searching. Arthropod specimens were lodged in the TMAG zoology collections, where they were later identified (by SG, CB and LC) at the best taxonomic resolution feasible given available resources. Some mollusc specimens have been temporarily retained in the private collection of KB. Information from all survey material curated and accessioned into the TMAG collection is being made available online via the Atlas of Living Australia and the Tasmanian Natural Values Atlas.

Results

We collected 757 invertebrate taxa during the survey (Table 1). These comprised 736 insect taxa (8 non-native), 5 spider taxa, 4 crustacean taxa and 12 gastropod mollusc taxa (4 non-native). The most taxon-rich insect groups were the beetles (with 259 taxa),

Table 1. Overview of invertebrate taxa recorded from Musselroe Wind Farm and surrounding coastal reserves

Group	Total taxa	Introduced species
Insects		
Archaeognatha	1	
Blattodea	4	
Coleoptera	259	6
Dermaptera	3	
Diptera	141	
Hemiptera	75	
Hymenoptera	91	1
Lepidoptera	137	1
Mantodea	2	
Mecoptera	1	
Neuroptera	4	
Odonata	1	
Orthoptera	17	
Other groups		
Araneae	5	
Amphipoda	2	
Decapoda	1	
Isopoda	1	
Gastropoda	12	4

the flies (141 taxa) and the moths (136 taxa). Many specimens collected remain unidentified or only partially identified (e.g. to family or genus level). Of those with firmer identifications, at least seven are probably new to science and several more represent new finds or significant rediscoveries at the state level. Two Threatened arthropods were discovered – the Endangered Schayer's grasshopper *Schayera baiulus* and the Endangered salt-lake slater *Haloniscus searlei*.

Because of their small size and the small spatial scales at which they run their lives, invertebrates are often associated with specific microhabitats that do not always readily translate into traditionally defined vegetation communities. A vegetation community might comprise many different microhabitats, some of which (such as temporary 'islands' of carrion) might be shared with other vegetation communities. Similarly, bare sand or rock is often a key microhabitat for invertebrates, yet is by definition devoid of vegetation. Outlining this microhabitat 'granularity', and the specific invertebrates dependent on it, gives due attention to their ecological significance. For these reasons, we present below some of our invertebrate observations according to a range of the more prominent habitat/micro-habitat features present on the property – only some of which conform to traditional vegetation types.

Heathland

Heathland is one of the most widespread vegetation types in the property, comprising a significant proportion of the vegetation east of the Little Musselroe River. One surprise find here was the unusual bombyliid fly *Acridophagus paganicus* (Plate 1) (the sole local representative of the 'atypical' subfamily Methicomyiinae, sometimes given family status). The two individuals collected (one from the eastern heathlands, the other from one of the inland fossil dune ridges) represent the first museum specimens of this species in a hundred years, when it was first described, based on a specimen from the Hobart area. Their biology is not known, but related species are parasitoids of the subterranean egg-clusters of grasshoppers. Certainly, the heathlands here host quite a few grasshopper species, including two specialists of this habitat, *Cirphula pyrrhocnemis* and *Urnisa rugosa*. A further grasshopper species found here, *Vandiemenella viatica*, is a rarity in Tasmania, though more widespread on the Australian mainland. The heathland also supports Tasmania's largest fly species, the robberfly *Neoaratus hercules* (Plate 2). This is a predatory species that preys on cicadas, catching them in mid-flight. It is widespread on the Australian mainland, but in Tasmania is confined to the far north-east.

Over 80 moth species in 15 families were recorded from heathlands, including several rarities and putative new species. Geometrid moths dominated the fauna, with 25 species. The most prevalent moth was the common heath moth *Dichromodes ainaria* (Geometridae). Five further species in the same genus were also represented, which is not surprising as their caterpillars feed on various heathland shrubs such as *Kunzea*, *Melaleuca* and *Leptospermum*. At the other extreme of abundance, only one specimen of the relatively uncommon geometrid *Antasia flavicapitata* was collected. A species in the genus *Limnaecia* (Cosmopterygidae) (Plate 3) found here is probably new to science. Little is known about the biology of this genus, but some species feed on fungi (Common, 1990). Two rare moths from the largely Australian family Xyloryctidae were also collected in this area. One, an undescribed species in the genus *Araeostoma*, had only been recorded once before in Tasmania, at Mount Nelson in 1980; the other, *Bida radiosella,* had not been recorded in Tasmania since 1934. Nothing is known of the biology of these species but most xyloryctids are arboreal, boring into branches, under bark or into flowerheads, or feeding on lichens. Also of note in this area were three moth species that represent new records for Tasmania. The first is the footman moth *Thallarcha phalarota* (Erebidae), which belongs to a tribe whose larvae are lichen-feeders. Little is known regarding the biology of the second species, *Taxeotis intermixtaria* (Geometridae). The third is Donovan's tiger-moth *Paramsacta marginata*

Plate 1. *Acridophagus paganicus*

Plate 2. Robberfly *Neoaratus hercules*

Plate 3. Moth *Limnaecia* species

Plate 4. Donovan's tiger-moth *Paramsacta marginata*

(Erebidae) (Plate 4), whose larvae are thought to feed on a wide variety of host plants; previously it appears to have been known in Tasmania from just two specimens collected at Bridport in the early 1900s, though it is widely distributed elsewhere in Australia. This large moth and several noctuid species were seen flying around and nectaring on *Kunzea* shrubs at night.

Lagoon fringes, saltmarsh and salt-flats

The saline lagoons on the Cape Portland headland and towards the northern coastline hosted the salt-lake slater *Haloniscus searlei* (Plate 5). This isopod – an aquatic member of an otherwise terrestrial lineage – is associated with inland saline lagoons across southern Australia and is a very rare species in Tasmania, where it is listed as Endangered and has otherwise only been recorded from a couple of inland saline lakes in the Midlands, so its presence here was unexpected. Its means of historical dispersal between and among these widely separated sites is also enigmatic, since it has no resting stage in its life cycle. Perhaps it is very occasionally carried on the feet or feathers of migrating waterbirds. The cracked-mud fringes of Tregaron Lagoons, though sparsely vegetated, supported the fossorial ground-beetles *Clivina vagans and C. vittata*, both highly localised species typical of such habitats. Also present in this area, as well as around salt-flats, and generally found under stones or pieces of wood, was the large earwig *Labidura riparia*, a highly localised yet cosmopolitan species typical of such habitats. The salt-lagoon snail *Coxiella striata* was widespread throughout the coastal lagoon systems, while the marsh-snail *Austrosuccinea australis* (Plate 6) was only found around the fringes of lagoons at The Salties and the freshwater snail *Glyptophysa novaehollandica* only around Tregaron Lagoons. A Malaise trap near Tregaron Lagoons collected several males of a species of axe-fly in the genus *Axinia*, which appear to represent an undescribed species. Males can be distinguished by their distinctive, highly modified and vaguely axe-shaped antennae. Axiniines were previously considered to be a family in their own right but are now subsumed into the Rhinophoridae. They are an entirely Australasian lineage whose members are mostly parasitoids of woodlice (slaters), although other hosts have also been reported. An unexpected find among the tea-tree scrub fringing one of these lagoons was an as-yet unidentified (and probably undescribed) species of handsome fungus-beetle in the genus *Idiophyes*; interestingly, most other members of this family (Anamorphidae, formerly considered part of the Endomychidae) favour wet forests.

Dunes and areas of bare sand

In the dunes behind Lemons Beach, a single adult male specimen of a distinctive grasshopper was collected, which we have since determined as the Endangered Schayer's grasshopper (*Schayera baiulus*). Our find (detailed in Driessen et al. 2020), represents the first known specimen of this species since 1988, and the only known example of an adult male – hence the identification

Plate 5. Salt-lake slater *Haloniscus searlei*

Plate 6. Marsh-snail *Austrosuccinea australis*

Plate 7. Peacock-spider *Maratus tasmanicus*

Plate 8. Flea-beetle *Psilliodes marcida*

remains provisional. The 1988 records were from nearby Rushy Lagoon as well as from Woolnorth in the far north-west of Tasmania. The large, coastal dune-associated ground-beetle *Scaraphites rotundipennis* was found in the dunes in the vicinity of Tregaron Lagoons. Foredunes at Lemons Beach hosted a range of species including the picture-winged fly *Trupanea prolata*, a species associated with the flowers of variable groundsel *Senecio lautus*, and the peacock-spider *Maratus tasmanicus* (Plate 7), a species which is largely confined to dunes along the Tasmanian north coast. Various solitary bee and wasp species nest in bare sand in dunes and heathland, and these are targeted by a range of kleptoparasitic insects whose own larvae usurp the hosts' nest and feed on both the stored food and the brood. At Musselroe these include the bee-fly *Meomyia fasciculata*, the flesh-fly *Protomiltogramma laticeps*, the oil-beetle *Palaestra cyanipennis*, the velvet-ant *Odontomyrme cordatiformis* and an as-yet unidentified species of spider-wasp in the genus *Psoropempula*. The small, predatory robberfly *Bathypogon nigrinus* is also associated with bare, sandy ground at Musselroe.

Sandy beaches

South-east Australian sandy beaches are hot-spots for a highly specialised fauna. Regrettably, we did not sample the beach crustacean (sandhopper and slater) fauna. However, we found a relatively intact fauna of beach-dwelling insects here, perhaps reflecting the property's relative inaccessibility to beachgoers and vehicles. Many of the species of this habitat in Tasmania, including most of those found at Musselroe, are discussed and illustrated in Grove and Forster (2019). For instance, we found no fewer than five species of kelp-fly (Coelopidae): *Amma blancheae*, *Chaetocoelopa sydneyensis*, *Gluma musgravei*, *G. nitida* and *Rhis whitleyi*. Another kelp-associated fly found here, the australomyzid *Australimyza mcalpinei*, is a representative of a family that is endemic to Australian shores. Kelp-fly larvae are among the main consumers of decomposing kelp along the strandline. The presence of their larvae and other small arthropods then attracts specialist predatory rove-beetles, which at Musselroe included *Bledius aterrimus*, *Cafius australis*, *C. sabulosus* and *C. seriatus*. The phycosecid beetle *Phycosecis litoralis* was found on 'Stone House' Beach. Phycosecids are an Australasian family of beetles confined to sandy shores, where they feed on the remains of dead insects blown or washed in along the strandline. Three sandy-beach scavenging darkling-beetles, *Edylius canescens*, *Hyocis bakewelli* and *Sphargeris physodes*, were also found at this beach. The first of these is a Tasmanian endemic mostly recorded from the east of the state. Two predatory sandy-shore anthicid beetle species, *Lagrioida australis* and *Mecynotarsus leai*, were also present at 'Stone House' Beach, the latter being abundant in the low dunes, but only observable at night. The non-native (European-origin) flea-beetle *Psilliodes marcida* (Plate 8) was also commonly observed at night on the low dunes. At the time of the survey this species was not known from Tasmania, or indeed from anywhere in the Southern Hemisphere, and it is only subsequently that its identity has been elucidated (by SG) and its presence at a number of north- and east-coast beaches confirmed. It is a herbivore, feeding exclusively on the leaves of sea-rockets, *Cakile* species, which are also introductions from Europe and North America. Also observable by night on this beach were the specialist beach-dwelling weevils *Aphela algarum* and *A. helopoides*. These hide in the sand during the day but emerge at night, apparently to feed on freshly beached kelp. The predatory sandy-shore muscid fly *Lispe cana* also frequented this beach at night, as did two as-yet unidentified species of surf-fly (family Canacidae). One further species found in this area was the foredune-associated chloropid fly *Apotropina ornatipennis*. Meanwhile, the foredunes at Lemons Beach hosted the specialist stiletto-fly of this habitat, *Anabarhynchus maritimus*, as well as the beach wolf-spider *Tetralycosa oraria*.

Rocky shores and headlands

The coastal bristletail *Machiloides hickmani* was found (by KB) among semi-vegetated rock crevices above the strandline at Lanoma Point. The species is sparsely recorded around the Tasmanian coastline, in generally similar settings. *Scelidoropa officeri*, a land-snail typical of coastal terrain in south-east Australia, was found widely on the property inland from the shoreline, as was another widespread land-snail, *Laomavix collisi*. Saltbush blue butterflies (*Theclinesthes serpentata*) were also observed here. Their caterpillars feed on the saltbush *Rhagodia candolleana* but also on *Atriplex* species. The butterfly is widespread over the southern half of Australia where it more often inhabits saltmarshes and inland saltpans.

Small waterbodies

Ephemeral pond habitats were found in a few locations, and include roadside pools and perched shallow lagoons over sand dunes. The riparian predatory rove-beetle *Paederus cruenticollis* was found around the fringes of the roadside ponds /puddles in the eastern heathlands, as was a species of toad-bug in the genus *Nerthra* (Plate 9), in characteristic habitat, and an as-yet unidentified species of burrowing crayfish, *Engaeus* species. A range of water-beetle and water-bug species characteristic of these habitats was also collected (by LC), including the hydrophilid beetle *Limnoxenus zealandicus*, the diving-beetles *Exocelina australiae*, *Onychohydrus scutellaris* and *Limbodessus gemellus*, the backswimmer bug *Enithares woodwardi* and the Tasmanian endemic water-boatman bug *Sigara neboissi*. The freshwater amphipod *Austrochiltonia subtenuis*, a species which is widespread on the Australian mainland but apparently not so in Tasmania, was also found here.

Fringes of the Little Musselroe River, including 'Bullseye' Lagoon

Relatively few aquatic insect species were recorded (by LC) from the lagoon, which is a well-vegetated waterbody separated from, but close to, the Little Musselroe River. There was some overlap with the fauna of smaller waterbodies, but additionally the lagoon supported the widespread pygmy water-boatman bugs *Micronecta annae* and *M. robusta*, and the screech-beetle *Hygrobia australasiae*. The last of these is widespread on the Australian mainland but in Tasmania is largely confined to the far north-east. The widespread freshwater amphipod *Austrochiltonia australis* was also present. An apparently new and undescribed species of *Scelidoropa* land-snail, here denoted as sp 'Little Musselroe', was found in the tea-tree scrub fringing the lagoon.

Light trapping (by CB and KM) in this area yielded many interesting moths among the 55 species caught. Two species collected from riparian vegetation near 'Bullseye' Lagoon are likely to be new to science. The first is in the genus *Batrachedra* (Batrachedridae: fringed moths). All Australian species in this family belong to this genus but very little is known about their biology; globally, species in this genus use a wide variety of host plants (Common, 1990). The second is in the tortricid genus *Peraglyphis*. This mostly endemic genus contains 15 species; known caterpillars feed between the tied leaves of Proteaceae (Common, 1963). Trapping also produced records of several moth species that are either new to Tasmania or have not been recorded in the state for many years. The large notodontid moth *Scythrophanes stenoptera* is a species which is widespread on the Australian mainland. Little is known about the biology of this species, but others in

Plate 9. Toad-bug *Nerthra* species

Plate 10. Wattle-pig weevil *Leptopius duponti*

Plate 11. Enicocephalid bug *Oncylocotis tasmanicus*

Plate 12. Darkling-beetle *Pterohelaeus peltatus*

this family have large caterpillars that feed on woody shrubs and trees. A rare, undescribed species of erebid moth in the lichen-feeding genus *Philenora* was also collected; it was previously known only from three specimens collected on King Island in 1979. Also recorded was the oecophorid *Barea atmophora*, which was seemingly previously known only from the type specimens collected by the government entomologist A.M. Lea in Hobart and Burnie in 1925, plus two further specimens collected at around the same time by A.J. Turner. Another species in the same genus, *B. exarcha*, which was previously only known from single specimens collected at St Helens and Strahan in 1979, was also collected. Both of these *Barea* species also occur in south-eastern mainland Australia. *Barea* larvae typically live under the bark of dead trees and logs, feeding on damp sapwood. A further important find is *Eutorna intonsa,* a depressariid moth that had not been recorded in Tasmania for almost 100 years. Previous records were from Campbelltown (1884), Launceston (1925) and Burnie (1937), with only five specimens then collected in total. Nothing is known on the biology of this species, but larvae of a related species feed on flower-buds and young fruit. A geometrid moth collected on the banks of the Little Musselroe River, the large and striking *Dinophalus serpentaria*, is a new specimen record for mainland Tasmania, as previously it had only been collected from Flinders Island (though it has since been observed at Calverts Lagoon, near Hobart). The caterpillars are thought to feed on *Hakea*. The Little Musselroe River was the only site at which the Helena gum moth (*Opodiphthera helena*) was collected, presumably associated with the eucalypts fringing the river.

Coastal scrub

Coastal scrub supported some characteristic insect species. The large, knobbly weevil, *Leptopius duponti*, known as the 'wattle pig' (Plate 10), was widespread; its larvae feed underground on the roots of coast wattle. The fungus-weevil *Araecerus palmaris* was also found on coast wattle, where its larvae feed in galls of fungus origin. Coast wattle in the eastern heathlands supported a species of piesmatid bug in the genus *Mcateella*. The small, metallic-green scarab beetle, *Diphucephala smaragdula*, an uncommon species in Tasmania, was found widely, often on the leaf buds of coast wattle on which the adults may feed (the larvae are root-feeders).

She-oak woodland

Several insect species that are associated with drooping she-oak were recorded at Musselroe. During an evening foray along the track leading to Cape Portland, swarms of the enicocephalid bug *Oncylocotis tasmanicus* (Plate 11) were in evidence. These bugs spend most of their lives under bark, presumably of she-oak since it seems to be only in this habitat where these swarms can be observed. The weevil *Haplonyx casuarinae* was found near the Little Musselroe River; its larvae feed in the developing cones of she-oaks as well as in the tissue of coccid-induced galls on these trees. One of Tasmania's smallest jewel-beetles, *Germarica lilliputana*, feeds as a larva on drooping she-oak cladodes and was collected in a Malaise-trap sample from the eastern heathlands. Two she-oak foliage-feeding bugs were also recorded at Musselroe: the widespread *Omyta centrolineata* and the more local *Diaphyta* species, provisionally identified as *D. rosea*. Old she-oaks near 'Stone House' Beach hosted a range of deadwood-inhabiting darkling-beetles, including *Pterohelaeus peltatus* (Plate 12) and *Bassianus colydioides*, which could be observed grazing algae and lichens on the bark after dark. The she-oak-feeding geometrid moth *Rhychopsota delogramma* also came to light here. A single specimen of an apparently undescribed species of tineid moth in the genus *Edosa* was collected in old *Allocasuarina* forest. *Edosa* is a very diverse genus of brightly coloured moths, well represented and common in Australia, but nothing is known of its biology (Common 1990). Males of the hoverfly *Psilota femoralis*, whose larvae probably live in rot-holes in old trees, were recorded hill-topping among stands of drooping she-oaks on a ridge above the eastern heathlands; these trees would seem to be the most likely host for their larvae. The feather-horned beetle *Rhipicera femorata* (Plate 13) was also found here; its larvae are thought to be parasitoids of subterranean cicada nymphs, and it seems to have a preference for coastal she-oak country. The predatory green lacewing *Mallada signatus* was found among drooping she-oak trees on an inland fossil dune-ridge. Though common on the Australian mainland, it is apparently rare in Tasmania. A known but undescribed species of *Scelidoropa* land-snail, denoted as sp. 'Pioneer' after its first-known locality, was also found in this area. The more widespread land-snail *Paralaoma hobarti* was found more widely on the property, often also in association with she-oak litter.

Seasonally wet grassland

Two highly localised rush-associated beetle species were recorded from seasonally wet grassland adjacent to the track to Cape Portland: the leaf-beetle *Eurispa albipennis* (Plate 14) and the belid weevil *Stenobelus tibialis*. Both are atypically proportioned for their respective families, having adopted a long, thin shape and brown colouration that affords them excellent camouflage on stems of their food plant. The especially slender and equally well-camouflaged, predatory assassin-bug *Nyllius asperatus* was also recorded in this vegetation. The grasshopper *Austroicetes frater* was recorded in similar habitat further out towards Cape Portland. Though widespread on the Australian mainland, it is rare in Tasmania. Two largely coastal (in Tasmania) orb-weaving spiders, *Austracantha minax* (Plate 15) and *Argiope keyserlingi* (Plate 16), also frequented this habitat.

Grasstree stands

Three unusual, grasstree-associated fly species were found on or near one of the inland fossil dune-ridges: the lauxaniid fly *Paranomina unicolor*; the soldierfly *Octarthria brunnipennis*; and the hoverfly *Orthoprosopa grisea*. Little is known about these species or the reason for their dependence on grasstrees. The last of these, though widespread on the Australian mainland, is recorded in Tasmania only from the north-east; observations on larvae noted on labels attached to museum specimens from New South Wales state that they feed within grasstrees, in which case they are probably to be found in the plants' sappy exudates. Another fly species found here was the platystomatid *Lamprogaster laeta*. Adults feed on sap, which may explain the species' presence here given the propensity for grasstree flower-spikes to exude sap. The deadwood-associated darkling-beetle *Adelium brevicorne* was common among fallen grasstree flower-spikes, which is presumably one of the habitats where their larvae develop. Also recorded in this area was the pyralid moth *Meyriccia latro*, whose caterpillars burrow into the seed heads of *Xanthorrhoea* and are a favourite food for cockatoos.

Carrion

The abundance of mammalian carrion at Musselroe provided for a rich associated insect fauna. Among the beetles, this included the common carrion-beetle *Ptomaphila lacrymosa*, whose larvae feed on the rotting flesh, and the common devil's coach-horse beetle *Creophilus erythrocephalus*, which is a

Plate 13. Feather-horned beetle *Rhipicera femorata*

Plate 14. Rush leaf-beetle *Eurispa albipennis*

Plate 15. Spiny spider *Austracantha minax*

Plate 16. St Andrew's cross spider *Argiope keyserlingi*

predator of the fly larvae feeding within carrion. The hide-beetle *Attagenus pellio* and the ham-beetle *Necrobia rufipes* are later arrivals at carrion (Grove 2020); the former was found on a dead kangaroo near Tregaron Lagoons, the latter on a dead wombat in the eastern heathlands; neither is common in Tasmania, though their distributions are cosmopolitan. Also found in association with well-decomposed carrion was the common hide-beetle *Omorgus australasiae*, the signal-fly *Parapalaeosepsis plebeia*, and an as-yet unidentified species of bone-skipper fly (Piophilidae), whose larvae feed on bone marrow. Light-traps set at Little Musselroe River and near the trackway to Cape Portland caught several specimens of an as-yet unidentified species of hybosorid beetle in the genus *Liparochrus*. These are thought to be scavengers of protein-rich food such as carrion and carnivore dung, as well as fungi. The family was previously unknown from Tasmania, though specimens have since been found in the TMAG collections that were light-trapped at Waterhouse (by CB), also in the far north-east of Tasmania.

Dung

Cattle dung is not much favoured by native insects, but at Musselroe is consumed by the European-origin dor-beetle, *Geotrupes spiniger*. Native dung-beetle species found at Musselroe were primarily associated with the dung of macropods and wombats, and include *Onthophagus fuliginosus*, *O. posticus* and *O. pronus*. Moth-trapping at Musselroe turned up two specimens of the oecophorid moth, *Oxythecta hieroglyphica*, whose larvae feed on the scats of wallabies.

Discussion

Our invertebrate surveys, together with the botanical surveys of our TMAG colleagues, and ornithological surveys before us, demonstrate the outstanding ecological and nature conservation values of the Musselroe Wind Farm. It is rich in specialist species of highly localised habitats that are regionally uncommon, such as saline and non-saline wetlands, coastal heathlands, dunes and beaches; and it hosts many species that in Tasmania seem only to maintain a toehold in this far north-east corner of the state. In these characteristics it compares well with the as-yet unpublished findings from our 2020–21 Bush Blitz survey of Stony Head, another far north-eastern property: both share similar suites of localised species, with Musselroe having the edge regarding habitat and micro-habitat diversity. Four of our moth records represent undescribed species, as – probably – do some of the other yet-to-be identified insect finds. We also found quite a few species that represent new records for Tasmania or rediscoveries after a long period of absence; we discovered two species that are on Tasmania's Endangered species list; and we found several apparently undescribed species. Beyond that, the property packs a lot of habitats and species into its relatively small area. These values are not evenly distributed: the enclosed paddocks tend to have the lowest values while the established reserves have the highest.

That said, there are many areas both inside and outside of reserves that require ongoing conservation management if they are to persist. Fortunately, the landowners have implemented a series of practices that go a long way towards achieving this. For instance, all native vegetation areas have been fenced, and the licensed grazier is required to ensure that the fencing is maintained and cattle effectively excluded as part of the licence conditions. Invasive weeds are, for the most part, now well controlled, though sea-spurge remains a major issue on the beaches, and gorse and boxthorn could readily reinfest fenced areas from isolated plants or cut stumps left on the property, from soil-stored seed (gorse) or from bird droppings (boxthorn). *Phytophthora* controls include largely restricting vehicular access to a network of formed roads, with strict hygiene requirements around any off-road activity. A burning plan for the heathlands and other areas has been developed and is currently under assessment. Almost no fertiliser is applied on the property, and what little is applied is confined to the core paddocks around the farm buildings where there is a low risk of nutrient runoff or transfer to more-natural areas. And there are strict controls on access to all the beaches and conservation areas, with a network of wildlife/surveillance cameras in place, linked by mobile network so that any unauthorised incursions can be reported directly to the police. Continuation of these conservation management practices for the longer term will be important if Musselroe's exceptional natural values are to persist.

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Above-ground larval activity and pupation by the golden stag beetle *Lamprima aurata* (Scarabaeoidea: Lucanidae) from northern Tasmania

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Introduction

The life history and habits of *Lamprima aurata* Latreille, 1817 in Tasmania are well-documented (Fearn 1996, 2015, 2016, 2017a, 2020; Fearn & Maynard 2018); this species displays considerable trophic flexibility in both the adult and larval stages. Adults feed on sappy exudates (usually made available to both sexes by the males cutting shoot tips with their mandibles) of a wide range of native and ornamental trees and shrubs. Larvae appear to feed in dead timber of any suitably sized species of tree or shrub that has decomposed through the action of the white rot fungus *Omphalotus nidiformis* (Berk.) O.K. Mill (Marasmiaceae), which provides the nourishment for developing larvae (Fearn 2017b; Hangay & De Keyzer 2017).

Lamprima aurata has a wide distribution in eastern mainland Australia from the wet tropics of north Queensland to the cooler, mesic coastal regions of South Australia. A disjunct population occurs in southern Western Australia (Reid et al. 2018). In the more humid tropical portions of its range, both standing dead trees and logs lying on the substrate are utilised as a larval food source (Hangay & De Keyzer 2017). In cooler, drier portions of the species range (including eastern Tasmania) decaying root systems and stumps become the most common larval food sources. There may be several interrelated reasons for this. Substrates in tropical habitats may become waterlogged in the wet season preventing larval development in decaying root systems (Reid et al. 2018). In addition, establishment of white rot fungus and timber decomposition is probably accelerated in tropical habitats providing more opportunities for larval development in standing dead trees and logs on the substrate. In Tasmania, it is relatively rare to find *L. aurata* larvae that are not below soil level in the decaying root systems of dead trees and shrubs. Such habitats appear to provide the necessary year-round moisture for establishment and growth of white rot fungus. All the relatively rare examples of above-ground larval activity the author has observed in Tasmania involved logs of soft wooded species (silver wattle (*Acacia dealbata*), black wattle (*A. mearnsii*) and willow (*Salix* spp.)) that were in contact with the ground.

This paper reports the first example recorded in Tasmania of *L. aurata* larvae occurring in dead, standing timber.

Field observations

On 26 July 2021 the author was pruning out the dead portion of a large, 45-year-old apricot tree, *Prunus armeniaca* L. (Rosaceae) (Plate 1A). A portion of limb was cut off 800 mm above the ground revealing larval frass and pupal chambers of *Lamprima aurata*. The pupal chambers contained fully hardened adults awaiting warmer weather to emerge, typically in December (Plate 2). An adult female was unfortunately destroyed by the chainsaw but three adult males exposed in their pupal chambers were collected as vouchers and lodged in the entomology collection of the Queen Victoria Museum and Art Gallery (QVM.2021.12.2186-88). The diameter of the limb at the cut was 130 mm (Plate 1B); all the *L. aurata* larval activity was confined to a 40 mm section of white rot between the heartwood and the bark (Plate 2). An axe was used to determine the extent of the *L. aurata* larval activity. To the author's surprise, the tunnels extended down the limb and into the main trunk for a distance of 560 mm but stopped well short of the ground. Further investigations revealed the most likely point of access for the ovipositing female was rotted-out portions of heartwood where limbs had been sawn off in a previous pruning some 10 years previously (Plate 1C). The lower portion of the larval activity had been secondarily utilised by the darkling beetle *Meneristes australis* Boisduval, 1835 (Tenebrionidae: Tenebrioninae); four adults were found in a chamber that they had tunnelled out of *L. aurata* larval frass.

Discussion

This is the first example seen by the author in Tasmania of larval feeding and pupation of *L. aurata* in a standing dead tree. Female *L. aurata* typically tunnel into the soil at the base of dead trees and stumps or directly into rotten stumps where they oviposit eggs in small chambers they construct in the rotting wood (Fearn 1996). It was apparent in this case that a female or females had been able to tunnel into this limb via decomposed heartwood exposed in a previous pruning event (Plate 1C).

The entire life cycle of *L. aurata* in Tasmania from egg to emerging adult is three years (Fearn 1996), with approximately six months spent as fully formed adults within pupal chambers. Pupation takes place in late summer as the current generation of adults is dying off. Because of Tasmania's cool climate with a distinct winter season, adults remain in torpor within pupal chambers for six to seven months before emerging around the longest day in December each year – earning them the ubiquitous common

Plate 1. A: Apricot tree showing dead portion that was pruned away. B: Position of dead limb when cut off. Arrow points to chainsaw cut. C: Decomposing heartwood exposed during pruning 10 years previously. Photos: S. Fearn

Plate 2. Exposed larval galleries packed with frass and adult pupation chambers of *Lamprima aurata* in dead section of apricot tree limb containing white rot fungus. The adult male was exposed in the left pupal chamber. Photo: S. Fearn

name in Tasmania of Christmas beetle. It is therefore common to find fully hardened adults within pupal chambers for half the year in Tasmania (Plate 2).

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Highlights of pelagic birding from Eaglehawk Neck 2020–21

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This is the tenth in a continuing series of articles summarising the highlights of pelagic sea birding off Tasmania's coast.

From July 2020 to June 2021 there were 29 pelagic trips leaving from Pirates Bay on the Tasman Peninsula on the MV *Pauletta* skippered by John Males, Brock Males and Michael Males. Deckhands included Adam Mackintosh, Bridget de Lange, Karen Dick (in training), Craig Hansen, Rob Beganti and Craig's son Dru. Throughout the year John Males spent many months caring for his wife Anne, leaving his sons to skipper the boat. Anne sadly passed away in April 2021. She will be sorely missed by her family and friends.

On 9 August 2020, after a short gap when pelagics were not permitted due to COVID-19, our trips resumed with numbers reduced to no more than 10 passengers. The trip was organised and led by Paul Brooks and skippered by Brock Males, with Bridget de Lange on board for the first time as an excellent deckhand. John males waved us out. With a light westerly wind, a 1–2-metre swell and light chop, 12 species of tubenose were observed. A Northern Royal Albatross (*Diomedea sanfordi*) was the only highlight of the day but it was wonderful to be out at sea after lockdown.

Paul Brooks organised the trip and compiled the report for 12 September, describing it as another somewhat quiet trip with low numbers and relatively low diversity for a September trip. At times they could not see a bird of any description from horizon to horizon. Highlights were a couple of Northern Royal Albatross and a distant Brown Skua (*Stercorarius antarcticus*) that was harassing Fairy Prions (*Pachyptila turtur*) in pelagic waters.

The pelagic trip on 13 September, organised by Paul Brooks, had 15-knot north-westerly wind which lightened before strengthening to 30 knots with corresponding heavier seas. Rob Hamilton compiled the report for us. It was another quiet day for September with only 15 species of tubenose. The highlights included a couple of Northern Royal Albatross, an immature Buller's Albatross (*Thalassarche bulleri*), rarely seen in Tasmanian waters, and a fleeting visit of a very worn-looking Providence Petrel (*Pterodroma solandri*).

Paul Brooks led the trip on 21 November and compiled the report.

This was an amazing trip with 26 species observed and record counts for Eaglehawk pelagics of 123 Gould's Petrel (*Pterodroma leucoptera*) and 16 Cook's Petrel (*Pterodroma cookii*), all travelling south. Other highlights were 39 Mottled Petrel (*Pterodroma inexpectata*), 3 White-headed Petrel (*Pterodroma lessonii*), also travelling south. We also had a first Eaglehawk November record of an immature Sooty Albatross (*Phoebetria fusca*). In addition, we saw a Salvin's Albatross (*Thalassarche salvini*), 2 Parasitic Jaeger (*Stercorarius parasiticus*) and an uncharacteristically inquisitive Brown Skua (*Stercorarius antarcticus*). We were also treated to several close sightings of Humpback Whales, some feeding beside the boat. There had been an unusual concentration of krill off the Tasman Peninsula for over a month causing many whales to stay around rather than pass straight on to the Southern Ocean feeding grounds.

Peter Vaughan wrote the report for the trip on 12 December. Peter described the day as pleasant, in great company, with a good number of White-headed Petrels, a single Mottled Petrel, and close views of Salvin's Albatross as the highlights. There were in fact 18 White-headed Petrel that day. They also saw two Humpback Whales when halfway out from Pirates Bay to Cheverton Rock.

Paul Brooks led the following trip and compiled the report on 13 December. Skies were mostly clear all day and we had strengthening north-westerly winds which made for a slow ride to the shelf but a quick return trip. High numbers of *Pterodroma* petrels were again heading south, many paying us close attention, giving excellent views. Highlights were 55 White-headed Petrel, 2 Cook's Petrel, 3 Mottled Petrel, singles of Soft-plumaged Petrel (*Pterodroma mollis*) and Buller's Shearwater (*Ardenna bulleri*), 3 Providence Petrel and a Long-tailed Jaeger (*Stercorarius longicaudus*). In addition, we had approximately 20,000 Short-tailed Shearwater (*Ardenna tenuirostris*) heading south in waves beyond the shelf break. After the trip we all enjoyed hot chips at the food van parked near the blowhole.

On the inshore leg of the pelagic on 24 January, organised and led by Paul Brooks, we observed some recently fledged Black-faced Cormorants (*Phalacrocorax fuscescens*). The light wind, under 5 knots, combined with a 3-metre swell, made viewing of birds a challenge as they often stayed low, disappearing in troughs. As we headed further north, a forecast north-easterly came in, with winds picking up to 10 to 15 knots. Almost immediately we had a Black-bellied Storm-Petrel (*Fregetta tropica*) and then a beautiful Salvin's Albatross, but the highlights of the day were yet to come, when 3 Cook's Petrels made close passes. Finally, another White-headed Petrel put in an appearance, to bookend the trip after a bird we saw in the morning. It was exciting to see the return of Fluttering Shearwater (*Puffinus gavia*) and Hutton's Shearwater (*Puffinus huttoni*). It was also good to see an array of age-related plumage variation in Southern Royal Albatross (*Diomedea epomophora*), with juvenile birds all the way through to quite white adults.

On 7 February Karen Dick organised a pelagic led by Peter Vaughan, who reported a Soft-plumaged Petrel as the highlight of the trip. Also observed were 42 White-faced Storm Petrel.

Peter guided for an Inala Nature Tours trip on14 February, on which there were very few species and no highlights.

On 20 February, Paul Brooks reported highlights of Cook's Petrel, Gould's Petrel, Buller's Shearwater and Northern Royal Albatross, on a relatively quiet day otherwise. A mystery whale species was also observed blowing some way away from the vessel; the identification was never resolved, although it was obviously a large animal.

The pelagic organised by Paul Brooks for 21 February was led by Rob Hamilton. Mona Loofs-Samorzewski took notes. On this trip 18 species were observed and it was a quiet day with light south-easterly winds. One Buller's Shearwater and one Northern Royal Albatross were reported as the only highlights of the day.

On Wednesday 24 February there was an Inala Nature Tours trip. The highlights mentioned were a Northern Royal Albatross and a Parasitic Jaeger.

Paul Brooks organised and compiled the report for 25 April. John Males skippered the boat with Michael Males as deckhand. This was the first pelagic after his wife Anne had passed away after a long struggle, and both John and Michael seemed pleased to be out on the water. We had great views of one of Eaglehawk's May specialties (a little early this year), a Westland Petrel (*Procellaria westlandica*) as well as 2 White-headed Petrel, plenty of Great-winged Petrel (*Pterodroma macroptera*) and Grey-faced Petrel (*Pterodroma gouldi*) plus eight species of albatross. An early Humpback Whale and a huge pod of Short-beaked Common Dolphin were good additions to the trip list.

We had an unusual encounter when a floatation device was spotted in the water while we were beyond the shelf. The skipper radioed police and the police vessel *Van Diemen*, which was at The Hippolytes monitoring a tuna fishing rally, came out to meet us and collect the device. It may have been one that was reported washed overboard south of Bruny Island the previous week.

On Saturday 1 May, Greg Roberts led the first of two of a series of Tasmanian pelagics organised by visiting mainland birders. Unfortunately, I was not on board for the first trip where the standout highlight was a Spangled Drongo (*Dicrurus bracteatus*), a most unusual sighting for Tasmania, and possibly the first Australian sighting out at sea. Other highlights included a Salvin's Albatross, Providence Petrel and White-headed Petrel.

On Sunday 2 May I enjoyed meeting up again with my mainland friends on board. The highlights of the trip were Northern Royal Albatross, Providence Petrel and White-headed Petrel.

Due to the restrictions on numbers being relaxed for pelagics, I was invited to join both of Rohan Clarke's winter trips. On Saturday 8 May conditions were fine with good light and we had a good variety of birds with highlights of close passes of a Wedge-tailed Shearwater (*Ardenna pacificus*), a Parasitic Jaeger, a Providence Petrel, Soft-plumaged Petrel and a White-headed Petrel. There was also an interesting sighting of an Eastern Cattle Egret (*Bubulcus coromandus*).

Conditions were again fine on Sunday 9 May. Rohan Clarke seems to be very lucky with his timing as the day proved to be an outstanding one. After a variety of Petrels and a lovely close view of a White-fronted Tern (*Sterna striata*), a magnificent Sooty Albatross did a number of close turns around the boat. Soon after, an immature Light-mantled Sooty Albatross (*Phoebetria palpebrata*) appeared with a beautifully mottled back and pale collar. Then, with great excitement on board, a second Sooty Albatross appeared. There was further excitement when an estimated 7 Grey Petrel (*Procellaria cinerea*) appeared, the first appearing before we reached the shelf and some staying around the boat for close views. The final highlight was when three individual Black-bellied Storm Petrel skimmed the water between the waves, giving clear views of the jagged black markings along the base of their bellies.

The pelagic on Saturday 15 May was led by Paul Brooks, who also wrote the report. We started with a light breeze and low swell but the breeze picked up and the waves became choppy before conditions calmed again. However, when we saw a south-westerly front with heavy rain and winds approaching, it was decided to head in to shore. A highlight was a Southern Fulmar (*Fulmarus glacialoides*), which made two brief but close passes not long before we headed for port. Either the same or a different bird was seen much closer to the edge of the shelf as we headed back. These were the first sightings of what would prove to be a good season for this species, with unprecedented numbers seen on trips in the following months. Also notable was the appearance of three Westland Petrel. The second two birds made several close passes of the boat to give us good views.

On Sunday 23 May Paul Brooks organised the trip led by Rob Hamilton and we enjoyed fine weather. It started with an interesting sighting near the Hippolytes of an unusual-looking Humpback Whale that was covered in white patches like mosaics and seemed to be drifting with the tide. I sent my images to Madeleine Brasier, who told me that she was seeking advice from vets and pathologists. On Cheverton Rock two adult White-bellied Sea Eagles (*Haliaeetus leucogaster*) watched us passing by and later we observed a juvenile perched on the pile of branches on top of the Hippolyte. The highlight was 8 Southern Fulmars feeding around the boat and in the slick. Robert Hamilton also reported one Eastern Cattle Egret, which was an oddity out at sea.

The pelagic on Thursday 27 May was led by Bruce Richardson and as we boarded the vessel with calm waters inshore, John Males was apprehensive of conditions that were forecast from the south. Not long after we reached the Hippolytes, there was a series of enormous waves that caused us to make a hurried return to shore. Nevertheless,

Plate 1. Antarctic Tern in flight Photos: Chris Young

we had highlights of up to 20 Southern Fulmar and 2 White-fronted Tern. After retreating for hot drinks at the Blue Seal, a recently re-opened cafe near the Neck, the group spent the rest of the day birding at Lime Bay, followed by an evening of searching for owls which was rewarded with 2 Tawny Frogmouths.

Sadly, the pelagic on Friday 28 May led by Bruce Richardson was cancelled due to forecast horrendous bad weather. Instead we did some sea-watching from Pirates Bay and then from the lookout at Remarkable Cave. This was followed by birding at Taranna and more sea-watching from the blowhole lookout at Pirates Bay. Unfortunately, Bruce Richardson and James Cornelious needed to return to the mainland so they could not join us when the pelagic was rescheduled for Tuesday 1 June.

Rob Morris led the two trips on the last weekend of May and, on Saturday 29 May, I was fortunate to be able to join them. May can be a good month for rarer birds and this trip did not disappoint with 31 species seen at sea including highlights of a Light-mantled Sooty Albatross, no less than two immature Grey-headed Albatross (*Thalassarche chrysostoma*), 2 immature Southern Giant Petrel (*Macronectes giganteus*), 15 to 20 Southern Fulmar, 3 Blue Petrel (*Halobaena caerulea*), 2 Westland Petrel, c. 10 White-headed Petrel, 1 Soft-plumaged Petrel and 2 Antarctic Prion (*Pachyptila desolata*). The juvenile Antarctic Tern (*Sterna vittata*) (Plate 1) that appeared as we headed back towards the Hippolytes was my first for Tasmania, but the species was first reported from Tasmanian waters in 2008 (Wakefield 2008).

On Sunday 30 May, Rob Morris and the group decided to head straight out to deeper water east-south-east of the Hippolyte without stopping en route. This was rewarded with highlights of 1 adult Grey-headed Albatross, 1 Southern Giant Petrel, 15 to 20 Southern Fulmar (5 on the way out, 8 together offshore, plus multiple sightings during the day), 2 Blue Petrel, at least 4 Westland Petrel, 1 or possibly 2 Grey Petrel, circa 10 White-headed Petrel, at least 2 Antarctic Prions and a juvenile Antarctic Tern that gave them prolonged close views.

After birding on Bruny Island for a few days, Bruce Richardson's group returned to Eaglehawk Neck for the rescheduled pelagic on Tuesday 1 June. Fortunately, one participant was even able to fly over from Perth to join us, making it a total of 11 on board. This time the sea was described by Alan Stringer as quite gentle and we managed to get to the drop-off with fairly light seas. The highlights of the trip included brief visits by a Blue Petrel and a White-headed Petrel. There were up to 23 Southern Fulmar, 2 Westland Petrel and 4 White-fronted Tern. The highlights of the albatross were 2 Southern Royal and 1 Northern Royal as well as a Wandering Albatross (*Diomedea exulans*).

The following trip was on Saturday 5 June. Inshore there was a total of 32 Southern Fulmar; 2 inshore, 5 around Cheverton Rock and 25 around the Hippolyte. Out at the shelf, there were 12 Southern Fulmar seen at one time around the back of the boat. Other highlights out at the shelf were 4 Westland Petrel, a Blue Petrel and an Antarctic Prion.

On Sunday 6 June, Peter Vaughan reported 17 Southern Fulmar as an accurate minimum count of birds visible at one time around Cheverton and the Hippolyte. Out at the shelf the highlights were 10 Southern Fulmar, 3 Providence Petrel, 2 Blue Petrel, a large flock of 550 Fairy Prion (*Pachyptila crassirostris*) and 2 Slender-billed Prion (*Pachyptila belcheri*).

For the pelagic on Saturday 19 June, Paul Brooks wrote the report. The day started as dull and murky and the sea was quite bumpy with the 1–2-metre easterly swell reflecting off the cliffs. In deeper water, the breeze picked up, often hitting 15 knots plus, but the skies cleared at lunchtime for some nice sunshine. The air temperature was in single digits all day. Highlights for the trip were a Blue Petrel, a Westland Petrel, 9 Southern Fulmar and a Northern Royal Albatross. An additional highlight was the appearance of three Brown Skuas that could be separated on plumage wear and moult. Two birds came and went but the last bird came very close and hung around for a short while. We were amused to see all the Skuas being harassed by a young Kelp Gull. The first two Skuas even appeared to be driven off by the aggressor.

On Sunday 20 June, Paul Brooks organised the pelagic and Rob Hamilton wrote the report. The day started well inshore with a total of 19 Southern Fulmar including 16 counted on the water together. Conditions were overcast until after 1 pm when the sun appeared. There was a low 1- to 2-metre swell and minimal chop. Out at the shelf, despite conditions, there were plenty of birds around the boat including highlights of 2 White-fronted Tern, two magnificent, almost completely white Wandering Albatross (Snowy), 6 Southern Fulmar, 5 Providence Petrel, 3 Blue Petrel and an Antarctic Prion.

At one stage there was a call of a possible Salvin's Albatross as it flew past the boat and disappeared. Fortunately, Peter Vaughan managed to take two photos which were later identified by Rohan Clarke as being of an older immature Chatham Albatross (*Thalassarche eremita*)

Plate 2. Immature Chatham Albatross Photo: Peter Vaughan

(Plate 2)! A BARC submission is in preparation. Peter's sighting caused great excitement among birders around Australia. The Chatham Albatross is a vagrant species that has only been seen five times in Australia, all sightings being in Tasmania. The last sighting was on 3 September 2011, when I photographed an adult that landed in full sun behind the *Pauletta* (Wakefield 2011).

On our return, the skipper noticed a Humpback Whale near Cape Hauy. My photo of the tail that I sent to Madeleine Brasier revealed its identity as "Speckles", which had already been sighted on 15 and 23 June.

On Saturday 26 June, a group from the mainland plus a few locals were on board after some cancellations due to an upsurge in COVID-19 in Victoria and New South Wales. Peter Vaughan wrote the report. Unfortunately ,I was unable to join them on the Saturday when the conditions were perfect with blue skies and light winds. When I joined the group at the Lufra, they were all very excited about a beautiful white morph of Southern Giant Petrel with black chevrons that was seen inshore on the return trip. They showed me some photos of the bird that looked magnificent. In addition, they had an amazing total of 44 Blue Petrel, the estimation based on a constant stream of birds passing the boat for two hours at the second berley point, with up to 16 individuals attending the boat at one time. Some landed on the water around the boat to give excellent photo opportunities. Other highlights included 6 Southern Fulmar, 10 Providence Petrel, a Westland Petrel and a Soft-plumaged Petrel.

The following morning, Sunday 27 June, the skipper was concerned about the front that was forecast but we headed out past the shelf drop-off as far as was safe, returning earlier than usual when the front approached. The highlights for the day included 3 Blue Petrel, 4 Southern Fulmar, a single Providence Petrel and an almost pure white, old Wandering Albatross that was banded with a British Trust for Ornithology band. Peter Vaughan managed to photograph some numbers on the band which have been sent to the Trust as well as to the Australian Bird and Bat Banding Scheme to help with possible identification of the bird and where it was banded.

Acknowledgements

Thanks to Paul Brooks for checking this article before it went to the editor. Also thanks to all the deckhands, trip leaders and report writers.

I wish to give a special thankyou to John Males and his family, who took us out to sea during a time of great personal sorrow and grief.

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Wakefield, E. (2011). Two Crippling lifers and a first: observations of the Chatham Albatross and Wandering Whistling-duck in Tasmania. *The Tasmanian Naturalist* 133: 29.

Bird species list pelagic highlights 2020–21 IOC taxonomy v. 10

Diomedeidae: Albatross

Wandering Albatross (*Diomedea exulans*)

Southern Royal Albatross (*Diomedea epomophora*)

Northern Royal Albatross (*Diomedea sanfordi*)

Sooty Albatross (*Phoebetria fusca*)

Light-mantled Sooty Albatross (*Phoebetria palpebrata*)

Chatham Albatross (*Thalassarche eremita*)

Salvin's Albatross (*Thalassarche salvini*)

Grey-headed Albatross (*Thalassarche chrysostoma*)

Buller's Albatross (*Thalassarche bulleri*)

Procellariidae: Petrels and Shearwaters

Southern Giant Petrel (*Macronectes giganteus*)

Southern Fulmar (*Fulmarus glacialoides*)

Blue Petrel (*Halobaena caerulea*)

Antarctic Prion (*Pachyptila desolata*)

Slender-billed Prion (*Pachyptila belcheri*)

Fairy Prion (*Pachyptila crassirostris*)

Great-winged Petrel (*Pterodroma macroptera*)

Grey-faced Petrel (*Pterodroma gouldi*)

White-headed Petrel (*Pterodroma lessonii*)

Providence Petrel (*Pterodroma solandri*)

Soft-plumaged Petrel (*Pterodroma mollis*)

Mottled Petrel (*Pterodroma inexpectata*)

Gould's Petrel (*Pterodroma leucoptera*)

Cook's Petrel (*Pterodroma cookii*)

Grey Petrel (*Procellaria cinerea*)

Westland Petrel (*Procellaria westlandica*)

Wedge-tailed Shearwater (*Ardenna pacificus*)

Buller's Shearwater (*Ardenna bulleri*)

Short-tailed Shearwater (*Ardenna tenuirostris*)

Fluttering Shearwater (*Puffinus gavia*)

Hutton's Shearwater (*Puffinus huttoni*)

Hydrobatidae: Storm Petrels

Black-bellied Storm-Petrel (*Fregetta tropica*)

Ardeidae: Herons and Bitterns

Eastern Cattle Egret (*Bubulcus coromandus*)

Phalacrocoracidae: Cormorants

Black-faced Cormorants (*Phalacrocorax fuscescens*)

Accipitridae: Eagles

White-bellied Sea Eagle (*Haliaeetus leucogaster*)

Laridae: Terns

White-fronted Tern (*Sterna striata*)

Antarctic Tern (*Sterna vittata*)

Stercorariidae: Skuas

Brown Skua (*Stercorarius antarcticus*)

Parasitic Jaeger (*Stercorarius parasiticus*)

Long-tailed Jaeger (*Stercorarius longicaudus*)

Dicruridae: Drongos

Spangled Drongo (*Dicrurus bracteatus*)

What species share your backyard? The unexpected suburban faunal diversity from Moonah

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Having spent 16 years living in a species-rich rural environment, it was not without some trepidation that we took up residence in suburban Moonah. Our backyard adjoins an abandoned quarry overgrown with scrub, but is overshadowed by the eucalypts *Eucalyptus viminalis*, *E. pulchella* and *E. globulus*. Sadly, the shrub layer is dominated by exotic hawthorn and cotoneaster. However, our first spring rewarded us with a friendly pair of black-headed honeyeaters, *Melithreptus affinis* (Lesson, 1839), successfully rearing a family of three, in a pink-flowered hawthorn only a few metres from our kitchen window. The avian fauna on offer has presented a few surprises, none greater than a pair of grey goshawks, *Accipiter novaehollandiae* (Gmelin, 1788), which are observed most days, the male recorded on many occasions through November and December carrying prey, and always to the same location on New Town Rivulet, the likely nesting site in the middle of suburbia!

Our new home had not been occupied for quite a few years while the previous owner carried out renovations, and the grounds had been totally neglected, falling well short of our expectations for a productive garden space. Many full trash packs, expletives and gallons of sweat and later, we do now enjoy some vegetables, and the fruit trees have more than reimbursed us for the lavish care awarded to them. Unfortunately the hordes of Argentine ants, *Linepithema humile* (Mayr, 1868), despite our eradication attempts, are still in residence and perhaps best met with the philosophical acceptance of inevitability.

Jumping spiders, *Apricia jovialis* (L. Koch, 1879) (Plate 1) and *Helpis minitabunda* L. Koch, 1880, are our constant companions, both inside the house and in the garden. A female orb-weaver, *Backobourkia heroine* (L. Koch, 1871), maintained a successful web on the brick wall of our deck for a period (Plate 2), until becoming a meal for a scavenging house sparrow, *Passer domesticus* (Linnaeus, 1758). Specimens of the spotted swift spider, *Nyssus albopunctatus* (Hogg, 1896), are also occasionally found in the garden. A male peacock spider, *Maratus pavonis* Dunn, 1947, (Plate 3) turned up on the deck railing; most amazing was the fact that only a few minutes prior to the event we had been discussing how delightful it would be to see one here, having previously located specimens of

Plate 1. The jumping spider *Apricia jovialis* made itself at home both inside and outside

Plate 2. Orb-weaving spider, *Backobourkia heroine*, camouflaged in brickwork

Plate 3. The jumping peacock spider, *Maratus pavonis*, found displaying on the deck handrail

the related *M. harrisi* Otto and Hill, 2011 on Mount Wellington.

To date, the coleopteran fauna observed has been limited. However, golden stag beetles, *Lamprima aurata* Latreille, 1817, (Plate 4) were recorded exiting a small decaying stump. Several specimens were observed in mid-December, all of small size, perhaps reflecting the low quality of the larval food source.

An outstanding find came from beneath the cover of the outside gas stove: a female raspy cricket, *Kinemenia* sp. Since we are familiar with *K. ambulans* (Erichson, 1842), this appears almost certainly to be a different species (Plate 5). She seemed delighted to be released on a nearby eucalypt trunk, swiftly disappearing beneath a bark slab. Specimens of the white-flash cicada, *Cicadetta torrida* (Erichson, 1842), emerged from the vegetable garden in December, adjacent to a large *E. viminalis*; most likely the nymphs had fed on the eucalypt roots. Both adult and nymphal bush katydids, *Caedecia simplex* Walker, 1869, were quick to accept our parsnip and basil crops as food, shelter and a safe place to 'zzit' on warm evenings.

A most interesting find for us was a colony of at least 67 venomless spiders, *Philoponella congregabilis* (Rainbow, 1916), in the garden shed. The species is small (female 4.5 mm, male 3.2 mm) and the rather untidy web structure occupies an area of approximately 1 m^2. The spiders come in two colour morphs (Plate 6) and are known to wrap their prey in up to 140 m of web then cover it with digestive enzymes to liquefy the food (Douglas, 2019).

We are delighted and constantly surprised by the faunal diversity in this part of suburbia, the list of which continues to expand, and as our cultivated garden increases we anticipate an escalation of invertebrate species, some welcome, some less so. A list of species recorded to date, from or within 100 m of our garden, is presented in Table 1. Participation in the Biosecurity Tasmania 'Adopt-A-Trap Multi-Pest Survey' may also serve us well, allowing for 28-day trapping surveys in November/ December and February/ March in our new garden, which hopefully will give an insight into the diversity of very small insects, both benign and of pest status (results pending).

Plate 4. The golden stag beetle, *Lamprima aurata*, on a log in the garden

Plate 5. Raspy cricket, *Kinememia* sp., found sheltering in the outside gas stove

Plate 6. The venomless spider, *Philoponella congegabilis*, establishing a colony in our shed

Reference

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Table 1. List of fauna recorded from Sinclair Avenue, Moonah 2020–21

Vertebrata		
Avifauna	Cattle egret	*Bubulcus ibis*
	White-faced heron	*Egretta novaehollandiae*
	Tasmanian native hen	*Tribonyx mortierii*
	Masked lapwing	*Vanellus miles novaehollandiae*
	Silver gull	*Larus novaehollandiae*
	Pacific gull	*Larus pacificus*
	Collared sparrowhawk	*Accipiter cirrocephalus*
	Brown goshawk	*Accipiter fasciatus*
	Grey goshawk	*Accipiter novaehollandiae*
	Swamp harrier	*Circus aeruginosus*
	Tasmanian wedge –tailed eagle	*Aquila audax fleayi*
	White-bellied sea eagle	*Haliaeetus leucogaster*
	Brown falcon	*Falco berigora tasmanica*
	Little falcon	*Falco longipennis*
	Peregrine falcon	*Falco peregrinus*
	Sulphur-crested cockatoo	*Cacatua galerita*
	Yellow-tailed black-cockatoo	*Calyptorhynchus funereus*
	Musk lorikeet	*Glossopsitta concinna*
	Swift parrot	*Lathamus discolor*
	Tasmanian green rosella	*Platycercus caledonicus*
	Eastern rosella	*Platycercus eximius diemenensis*
	Rainbow lorikeet	*Trichoglossus moluccanus**
	Black-faced cuckoo shrike	*Coracina novaehollandiae*
	Welcome swallow	*Hirundo neoxena*
	Spotted pardalote	*Pardalotus punctatus*
	Striated pardalote	*Pardalotus striatus*
	Yellow-rumped thornbill	*Acanthiza chrysorrhoa*
	Brown thornbill	*Acanthiza pusilla*

	Grey fantail	*Rhipidura albiscapa*
	Superb fairy-wren	*Malurus cyaneus*
	Eastern spinebill	*Acanthorhynchus tenuirostris*
	Little wattlebird	*Anthochaera chrysoptera*
	Yellow wattlebird	*Anthochaera paradoxa*
	Black-headed honeyeater	*Melithreptus affinis*
	Strong-billed honeyeater	*Melithreptus validirostris*
	Yellow-throated honeyeater	*Nesoptilotis flavicollis*
	New-Holland honeyeater	*Phylidonyris novaehollandiae*
	Crescent honeyeater	*Phylidonyris pyrrhoptera*
	Grey-breasted silvereye	*Zosterops lateralis*
	Grey shrike-thrush	*Colluricincla harmonica*
	Grey butcherbird	*Cracticus torquatus*
	Australian magpie	*Gymnorhina tibicen hypoleuca*
	Grey currawong	*Strepera versicolor*
	Forest raven	*Corvus tasmanicus*
	Tawny frogmouth	*Podargus strigoides*
	Common starling	*Sturnus vulgaris**
	Common blackbird	*Turdus merula**
	European goldfinch	*Carduelis carduelis**
	European greenfinch	*Chloris chloris**
	House sparrow	*Passer domesticus**
	Laughing kookaburra	*Dacelo novaeguineae**
	Feral pigeon	*Columba livia**
	Spotted dove	*Spilopelia chinensis**
Mammalia	Common brush-tailed possum	*Trichosurus vulpecula*
	Rufous-bellied pademelon	*Thylogale billardierii*
	Red-necked wallaby	*Notamacropus rufogriseus*
	European rabbit	*Oryctolagus cunicularis**
	Feral cat	*Felis catus**

	Feral dog	*Canis familiaris**
Amphibia	Brown tree frog	*Litoria ewingii*
	Common eastern froglet	*Crinia signifera*
Reptilia	Metallic skink	*Carinascincus metallicus*
Invertebrata		
Hymenoptera	Bull ant	*Myrmecia forficata*
	Meat ant	*Iridomyrmex* sp.
	Vampire ant	*Amblyopone australis*
	Argentine ant	*Linepithema humile**
	Sawfly	*Lophyrotoma* sp.
	Bumblebee	*Bombus terrestris**
	European honey bee	*Apis mellifera**
	European wasp	*Vespula germanica**
Coleoptera	Leaf beetle	*Chrysomelidae* sp.
	Golden stag beetle	*Lamprima aurata*
	Honeybrown beetle	*Ecnolagria grandis*
	Long-nosed lycid	*Porrostoma rhipidius*
	Clerid	*Lemidia nitens*
	Longhorn beetle	*Amphirhoe decora*
	Longhorn beetle	*Pseudohalme walkeri*
	Tasmanian ladybird	*Cleobora mellyi*
	Eleven-spotted ladybird	*Coccinella undecimpunctata**
	Common spotted ladybird	*Harmonia conformis*
	Fungus-eating ladybird	*Illies galbula*
	Eucalyptus weevil	*Gonipterus* sp.
	Rough strawberry weevil	*Otiorhynchus rugostriatus**
Diptera	Blowfly	*Calliphora hilli*
	Blowfly	*Calliphora stygia*
	Sheep blowfly	*Lucilia cuprina*
	Common hoverfly	*Melangyna viridiceps*
	Drone fly	*Eristalis tenax**

Lepidoptera	Corbie	*Oncopera intricata*
	Emperor gum moth	*Opodipthera helena*
	Wattle goat moth	*Endoxyla liturata*
	Day-flying moth	*Eutrichopidia latinus*
	Bark moth	*Agriophara* sp.
	Klug's xenica	*Geitoneura klugii*
	Cabbage white butterfly	*Pieris rapae**
Hemiptera	Flat shield bug	*Notius depressus*
	Harlequin bug	*Didymus versicolour*
	Black scale	*Saissetia oleae*?
Cicadidae	White-flash cicada	*Cicadetta torrida*
Arachnida	Social huntsman	*Delena cancerides*
	White-tailed spider	*Lampona cylindrata*
	Wolf spider	*Venatrix pseudospeciosa*
	Spotted swift spider	*Nyssus albopunctatus*
	Harvestman	*Pholcus phalangioides*
	Peacock jumping spider	*Maratus pavonis*
	Jumping spider	*Apricia jovialis*
	Jumping spider	*Pungalina* sp.
	Aussie bronze jumper	*Helpis minitabunda*
	Orb-weaving spider	*Backobourkia heroine*
	Venomless spider	*Philoponella congregabilis*
	Dysderid spider	*Dysdera crocata**
Scorpionida	Scorpion	*Cercophonius squama*
Blattodea	Common wood roach	*Platyzosteria melanaria*
Gryllotalpidae	Mole cricket	*Gryllotalpa australis*
Gryllacrididae	Raspy cricket	*Kinemenia* sp.
Tettigoniidae	Bush katydid	*Caedecia simplex*
Isopoda	Slater	*Porcellio scaber**
Dermaptera	European earwig	*Forficula auricularia**
Diplopoda	Portugese millipede	*Ommatoiulus moreleti**

The stranded plants of the Furneaux Group

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Introduction

There are many similarities between the coastal plants of north-eastern Tasmania, familiar to this writer, and those seen on Flinders Island. After all, the southern-most islands of the Furneaux Group are really only about 20 kilometres north of Cape Portland on Tasmania's north-eastern tip. Both areas are home to the many different species of saltbush, tea trees and, of course, boobyalla and coast wattle. *Leucophyta brownii* is common in both places, as is *Correa alba*. There is *Muehlenbeckia adpressa* and *Lomandra longifolia*, and many other plants the two places have in common.

These hardy plants thrive in a harsh coastal environment. In fact, all the plants we have in common seem to be stronger, more robust, and even more compact on Flinders Island. Being pruned by the constant wind is possibly a factor. They are, after all, in the full force of the Roaring Forties (see Plate 1).

After yet another visit to this beautiful group of islands I began to compare the differences and similarities in the flora, and the following remarks draw heavily on various published sources that helped inform my observations while travelling around Flinders Island.

Plate 1. Boobyalla on headland at Emita pruned by constant harsh winds

Geographical background

During the last glacial period the sea level dropped and the 'islands' were part of a ridge of mountains between Wilsons Promontory and north-east Tasmania rising above the Bassian Plain.

After the last glacial period when sea levels rose, from around 10,000 years ago, many plants that were remnants from that time became isolated on the islands in the Furneaux Group. Now, the islands form a vestige of what was once that land-bridge (Harris, Buchanan & Connolly 2001).

There are up to one hundred islands in the Furneaux Group. These biogeographically important islands support a wide range of habitats: there is rainforest in the mountains of Strzelecki National Park in the south of Flinders Island, wet eucalypt forest in deep gullies across the island, and woodland and scrubland across much of the island. On the east coast there are many inlets and saline lagoons with the accompanying coastal scrub, beach dunes, grasslands and heathlands.

Notes on the flora

The Furneaux Group straddles the divide between the Tasmanian and mainland Australian floras, being at the northern-most range of about five Tasmanian endemics, and at the southern-most range of several mainland species not otherwise found in Tasmania.

Most of the threatened species on the islands are growing at the edge of their range. For example, *Lomatia tinctoria* grows at its northern distribution limit here, whilst *Acrotriche cordata* and *Melaleuca armillaris* grow at the southern limits of their distributions.

The native tobacco, *Apalochlamys spectabilis* (Plate 2), is hardly ever seen in Tasmania but can be seen on Flinders Island and all along the Victorian coast. It is also known as the showy cassinia. When you see it in flower, it looks as though it is dying as the flowers are a brownish colour. Often though, the leaves closer to the ground are indeed dead. This strongly scented biennial herb of up to 2 metres in height favours alkaline soils and because it colonises

Plate 2. Native tobacco (*Apalochlamys spectabilis*) in flower; growing on the roadside at Palana, in the north of Flinders Island

Plate 3. Saw banksia, *Banksia serrata*

disturbed areas, can be easily mistaken for an introduced weed. Indeed, an information panel I read indicated "it appears soon after an area is disturbed and disappears almost as quickly".

Gardeners and others might be familiar with the saw banksia, *Banksia serrata* (Plate 3). There are only two small populations of this plant in Tasmania. One in the north-west of the state is mainly restricted to the Rocky Cape National Park. The other is a small population of approximately 100 plants in Wingaroo Nature Reserve on Flinders Island. These areas are the southern limits of this species' distribution. However, if you drive through the Gippsland forests in Victoria, you will see a massive concentration of *B. serrata* all the way along the south-eastern coastline, often in single-species groves and forests.

Classified as Rare by the *Threatened Species Protection Act 1995* in Tasmania, the Wingaroo population is rapidly declining due to the incursion of *Phytophthora cinnamomi* – a soil-borne root mould that causes dieback. During a Bush Blitz carried out in the reserves on Flinders Island (Australian Government et al. 2014), seed of *Banksia serrata* was collected by staff from the Tasmanian Royal Botanical Gardens just prior to the site being burnt as part a management regime. The seeds were taken from 50 plants and 80% germination was achieved (J. Wood pers. comm. 2021).

On the windy headlands of the Bass Strait islands, there is a purple pea flower twining at ground level called poison pea, *Swainsona lessertiifolia* (Plate 4). It is poisonous to stock; it was reported by one collector to make horses go mad. Although it is also found on King Island, it is most common all along the coasts of Victoria and South Australia. Indeed, it is endemic to south-eastern Australia.

Plate 4. Poison pea, *Swainsona lessertiifolia*

The coast twin-leaf, *Zygophyllum billardierei* (Plate 5), a scrambling, low-growing, dune-stabilising plant from the calcareous sands and rocky shorelines of the Furneaux Group, is listed as a threatened species (Rare) in Tasmania, although it is reasonably common on the coast of Victoria.

Plate 5. Coast twin-leaf, *Zygophyllum billardierei*

In the small relicts of wet forest on Flinders and King islands in Bass Strait, there is a beautiful small tree, the blueberry ash, *Elaeocarpus reticulatus* (Plate 6), growing naturally at its southern-most limit. It can also be seen in the southern forests of Victoria but is found nowhere else in Tasmania. Fire is a significant threat to this plant as it does not recover vegetatively after it is burnt. The deep gullies where it grows have obviously provided refuge from fire and drought.

In the deep wet gullies in the centre of Flinders Island, *Eucalyptus globulus* and *Eucalyptus viminalis* co-occur and are habitat for the forty-spotted pardalote, a bird species listed as Endangered on the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. A

Plate 6. Blueberry ash, *Elaeocarpus reticulatus* (unfortunately not in flower); foliage and fruit (Photo: Ruth Dinning)

Plate 7. Vegetation on calcarenite, Fotheringate Bay

project to mount nesting boxes in trees has been carried out and the research team is waiting for citizen scientists to send in their observations. These two tree species are also growing together at sea level and may be visited by the swift parrot. Indeed, breeding swift parrots were observed and recorded formally in the Strzelecki National Park for the first time in 2012.

The Furneaux flora includes plants occurring on calcarenite substrates (Harris & Kitchener 2005) (see Plate 7). Such habitat supports plants more commonly found growing in the calcareous soils of the limestone coasts of mainland Australia.

Such calcicoles can be observed, for example, at Fotheringate Bay, Settlement Bay and Killiecrankie Bay where intricately weathered and sometimes jagged formations of calcarenite are present. Calcarenite is a carbonate limestone consisting of small sand-sized particles of shells and sand cemented together with crystallised lime over tens of thousands of years. It is rare elsewhere in Tasmania and especially significant in the Furneaux Group because here, these calcarenites correspond with low rainfall and produce vegetation communities similar to those that can be found on the coast of South Australia.

The following plants grow on the local calcareous soils: the coast bonefruit, *Threlkeldia diffusa*, a prostrate, succulent spreading plant extremely common in coastal South Australia through to the north-west of Western Australia, though rare on mainland Tasmania; other plants in this rare community include *Lasiopetalum bicolor* and *L. macrophyllum*, *Eutaxia microphylla* and *Acrotriche cordata* (see Fig. 1).

Figure 1. Map showing distribution of *Acrotriche cordata* (corresponding closely to that of the coast bonefruit, *Threlkeldia diffusa*). Source: State Herbarium of South Australia/Google Maps 2021.

Below are some notes on other threatened species from the Natural Values Survey 2012:

- Dwarf wedgepea, *Gompholobium ecostatum*, endangered TSPA. Within Tasmania, this species is restricted to Flinders Island, but is present in the Grampian Ranges, Victoria.
- Swamp beardheath, *Leucopogon esquamatus*, rare TSPA. Within Tasmania this species is restricted to Cape Barren Island and Flinders Island.
- Furze needlebush, *Hakea ulicina*, vulnerable TSPA. Found Flinders and Cape Barren Island. Fairly common in Victoria.

While Flinders Island hosts many threatened species, there are also a range of significant threats to its biodiversity. These threats were studied in detail during the Natural Values Survey (Hamish Saunders Memorial Trust & Department of Primary Industries, Parks, Water and Environment, Tasmania 2012); the main threats are environmental weeds and the spread of the root-rot fungus *Phytophthora cinnamomi* that causes dieback.

For example, sea spurge, *Euphorbia paralias*, is widespread in coastal areas and poses a significant weed problem. Cape beach daisy, *Arctotheca populifolia,* is also common and spreading on the east coast.

Pampas grass, *Cortaderia selloana*, was recommended for planting as a shelter plant by government agencies in the early 1990s because it is swift-growing, has a dense habit, is able to withstand strong salty winds and can be used as emergency fodder.

Boxthorn, *Lycium ferocissimum*, first used by settlers on Goose Island in the 1840s to create windbreaks and for boundary fencing, and Chilean needle grass, *Nassella neesiana*, were also noted in the Hamish Saunders report as significant problem weeds. The report also identified 48 plant species and 15 plant communities as being likely to be impacted by *P. cinnamomi* infestation (p. 10).

Management and preservation of species refugia and isolated populations is a high priority on these islands. Many rare species and their habitats on Flinders Island constitute sites of significance for conservation.

Acknowledgements

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First Tasmanian records of the introduced common chrysalis snail *Lauria cylindracea* (Stylommatophora: Lauriidae)

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Abstract

The common chrysalis snail *Lauria cylindracea* (E. M. da Costa, 1778) is recorded from Tasmania for the first time, based on records from Launceston in December 2020 and Hobart in July 2021. The Launceston population appears well established but only five specimens have been found in Hobart to date. The species is not known to be an economic or environmental hazard but potentially suitable areas within Cataract Gorge should be monitored, because of potential competition with native species.

Identification

Lauria cylindracea (Plates 1 & 2) is a small, cylindrical-shaped many-whorled snail around 4 mm high. The aperture of the shell has a thickened outer lip and usually a single prominent parietal tooth (Plate 3). The spire is blunt-topped and the shell has a narrow umbilicus. The shell is dextral and typically a dark honey-brown colour. In the Tasmanian snail fauna, *L. cylindracea* superficially resembles the pupillid *Omegapilla australis* (A. Adams & Angas, 1864), which occurs locally on the eastern and northern coasts and Furneaux and Kent Group islands, but *O. australis* is sinistral. The most similar exotic species recorded in the state is *Cochlicopa lubrica* (Muller, 1774) but that species is larger (6–7 mm), with a pointier spire and no parietal tooth. Juvenile specimens of *L. cylindracea* are lower-spired and in shape resemble punctids but have two prominent lamellae within the aperture (Plate 4).

Occurrence outside Tasmania

L. cylindracea is considered native primarily to Western Europe with its range extending into Northern Africa and adjacent Atlantic islands, Asia Minor and the Black Sea/Caucasus region (Forsyth, 1999). The online Global Biodiversity Information Facility database (gbif.org) lists museum records well outside this region from:

North America: British Columbia,

Plate 1. *L. cylindracea* specimen affixed to a wall at Forest Road, Trevallyn.

Plate 2. *L. cylindracea* specimen from Dynnyrne crawling on a petri dish.

Plate 3. Adult *L. cylindracea* showing aperture with tooth. Shell height 3.3 mm. Forest Road, Trevallyn, 28 December 2020.

Plate 4. Juvenile *L. cylindracea* showing apertural lamellae. Shell height 2.0 mm. Forest Road, Trevallyn, 28 December 2020.

Washington (state), San Francisco;

Central America: Jamaica (possibly extinct according to Forsyth (1999)), Bahamas;

Africa and surrounding oceans: St Helena, South Africa, Reunion;

Oceania: New Zealand, Norfolk Island, Melbourne.

Most of these introductions have been previously compiled or reported in published literature (e.g. Barker (1999), Forsyth (1999), Herbert (2010), Vendetti et al. (2018)).

In Melbourne the species is widespread but records have previously not been well documented. The known records are from Singleton Rd, Balwyn North (K. Bonham 11/12/1990); Elder St, Watsonia (QVM 9:22789, 25/6/2005); Norman St, Ivanhoe (K. Bonham 2/1/2016); Macarthur Street, CBD (K. Bonham 1/12/2017); and Melbourne Royal Botanic Gardens ((https://www.inaturalist.org/observations/ 73740896, first observed July 2016). These records generally involve large numbers of specimens.

L. cylindracea is noted for occurring in mostly dry conditions, often being found attached to walls. The initial Melbourne record from Balwyn North was on garden rocks covered by ivy. Barker (1999) noted that although *L. cylindracea* had by that time been present in New Zealand for at least 47 years, it had nonetheless not been recorded from native forest sites.

Launceston records

On 28 December 2020, about 20 specimens of *L. cylindracea*, mostly alive, were seen on a low wall on Forest Road, Trevallyn (510163 E, 5413138 N). On 30 December 2020, walls at the front of gardens along West Tamar Road near the Forest Road site were searched. The species was recorded intermittently, with sightings at the following grid references along a 550-metre stretch of West Tamar Road: 510153 E, 5413201 N (eight specimens); 510268 E, 5413059 N (four); 510340 E, 5412955 N (two); and 510479 E, 5412773 N (three). No further specimens were seen on walls along Trevallyn Road and Gorge Road, or on rock faces in Cataract Gorge between Kings Bridge and First Basin.

Plate 5. Main *L. cylindracea* site at Proctors Road, Dynnyrne. Three specimens were found on the bare concrete wall in front of the electricity substation and one on the ground behind it.

Hobart records

On 17 July 2021, two live adults of *L. cylindracea* were collected from a wall along Proctors Road, Dynnyrne, near Lord Street (525892 E, 5250150 N) (Plate 5). A further live adult was collected 300 metres away on another wall on Proctors Road near Richardson Avenue (526072 E, 5249920 N). On 26 July 2021, two more live adults were collected at the original site. No further specimens have been found in about 5 hours' total searching across South Hobart, Dynnyrne and Sandy Bay north of the University of Tasmania.

Discussion

The Launceston population of *L. cylindracea* appears to be well established and has probably been present for some time. The status of the Hobart population is not yet clear, but the species could well be present undetected in other Hobart suburbs or in gardens within the surveyed area.

In general, papers and reports referring to introductions of this species do not regard it as invasive or an economic pest. Herbert (2010) describes the species as "locally invasive" in South Africa but even there, records are confined to "suburban areas, pine plantations and vineyards" and the species is considered unlikely to be a pest on account of its "fungal" diet.

However, the Launceston population occurs very close to Cataract Gorge, the only locality where the threatened native punctid *Pasmaditta jungermanniae* (Petterd, 1879) occurs. The largest of three known populations of *P. jungermanniae* occurs in an area of dolerite cliffs along a walkway with heavy traffic. The author currently visits this area at least once a year. It is plausible that *L. cylindracea* could establish in this area given its tendency to occur on walls and the prevalence of plant weeds in the area. If it is ever found in the area, attempts should be made to eradicate it.

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Natural worlds together and apart – ACT and Tasmania

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As a Tasmanian living temporarily in Canberra in the Australian Capital Territory (ACT), I have found interest in comparing the natural world of the two places. There are many similarities, and many differences. Those things that are similar assuage my homesickness and I take pleasure in observing and learning about those things that are different.

In my exploration of the natural world in the ACT, I have found companionship and learnt much from Canberrans in the local clubs. These clubs include the Field Naturalists Association of Canberra, the Canberra Ornithologists Group (COG), and the Canberra and Brindabella bushwalking clubs. In this article I will use the names of Canberra and the ACT interchangeably (both being Ngunnawal Country), and I will use the colonial names for Tasmania (lutruwita), Hobart (nipaluna) and other places. I do wish to acknowledge the Indigenous Elders and peoples of both places.

When I first moved to the ACT, I took time to consider the night sky. Essentially it is the same as Tasmania's, with the same constellations, and the Moon orientated in the same direction. The night sky as seen from Canberra is not as dramatically different as the night sky seen in the Northern Hemisphere. In the ACT, I was gladdened to see the same southern stars that twinkled above my Hobart home. In August, Aquila the Eagle is flying boldly into the east in eager anticipation of the coming spring in both places. Bright white Canopus has long been significant in my island home and shines as faithfully and brilliantly over the ACT as it does over Tasmania. However, I soon realised that I could see stars much further to the north. In winter, I could easily see Arcturus, the great reddish star blazing away in the constellation Boötes, and which in times past guided Polynesian mariners on the Pacific Ocean. By contrast, Arcturus is barely visible from Hobart, being just too low on the northern horizon, and from my Hobart home it is hidden somewhere in the vicinity of Mt Direction. Sadly, the Canberran night sky rarely has the aurora australis that appears so regularly over Tasmania. Occasionally a faint aurora is reported in the ACT, but I have never seen one here. To observe an aurora in the ACT, one must have excellent timing, follow the aurora websites assiduously, and be prepared to travel well out of Canberra to escape the city's significant light pollution. One could never expect to see the spectacular powerful auroras that defy even Hobart's city lights. And in Canberra's

Aurora australis seen from Taroona. Photo: Mick Brown

current lockdown, such excursions are not permissible in any case.

Below the firmament in both places is the rocky crust of the Earth. Canberra's geology does not compare very easily to Tasmania's. Canberra does not have Tasmania's great dolerite or quartzite mountains. The National Capital Rock Garden in Canberra does feature a large Tasmanian dolerite boulder as that state's contribution to the eight states and territories represented in the Federation Rocks. The dolerite boulder comes from Leslie Vale, and has been partly polished so that one can see the texture of its constituent minerals. Sometimes when homesick, I have sat on that dolerite boulder and thought of my family home in West Hobart, where in 1836, Charles Darwin inspected the travertine in the weathered dolerite in the former quarry which is now John Doggett Park. The ACT is represented in the Rock Garden by a boulder of grey Canberra limestone of mid-Silurian age, which reminds me of Tasmania's grey Ordovician limestones. Both limestones have Gondwanan origins and contain similar marine fossils. Much of the eastern ACT, and Canberra itself, is dominated by Silurian and Ordovician volcanic rocks which don't evoke a Tasmanian equivalent, though they are similarly 'middle-aged' remnants of Gondwana. In Canberra's fabulous Tidbinbilla Nature Reserve, itself quite a Tasmaniesque place, there are beautiful shale peaks heavily encrusted with lichen. There is some Tertiary basalt in the very far south of the ACT, which brings to mind the Tertiary basalts of northern Tasmania. Devonian granite is another rock type that both the ACT and Tasmania have in common. In the CD accompanying *A Geological Guide to Canberra Region and Namadgi National Park* (Finlayson 2008), Canberra's expansive Namadgi National Park is described as a 'granite wonderland'. The great white granite peaks in Namadgi are

Tasmanian dolerite in the National Rock Garden, Canberra. Photo: David Dedenczuk

most reminiscent of the granite seen at Tasmania's Mt Cameron, while not strongly evoking the pink granite peaks of Freycinet. Canberra does have some pink granite peaks, the leucogranite peaks of Booroomba Rocks and Mt Tennent (Tharwa), which are quite different from their Tasmanian cousins. Irrespective of their geology, for the 68 Canberra named peaks over 1000 m ASL, I devised a list called 'The Percies' to match the Tasmanian 'Abels' (see Evans 2020). The name is in recognition of Percy Schaeffe, who was one of a team surveying the borders of the ACT in the early twentieth century. No-one has yet climbed all of the ACT's Percies, and it is unlikely that anyone ever will; too many of the Percies are topped by giant tors of granite, where the actual summit is accessible to rock climbers only. Tasmania's Abels are similarly challenging, though a few bushwalkers have succeeded in climbing them all.

On top of the rocks in both the ACT and in Tasmania can be seen beautiful flora. It has been said that the South Eastern Australian flora extends as far north as Mt Coree, the striking shale/siltstone peak in the Brindabellas, on the very north-west corner of the ACT. Indeed, the ACT and Tasmania do have many plant species in common. The *Field Guide to the Native Trees of the ACT* (National Parks Association 1983) lists 20 tree species that are found in both the ACT and in Tasmania, including six species of eucalypt. The ACT's wet sclerophyll forests contain stands of *Eucalyptus delegatensis*, *E. pauciflora* and *E. dalrympleana*, species which are also found in Tasmania. The ACT forests, like the Tasmanian forests, face considerable climate-related challenges. The 2003 and 2019–20 bushfires in the ACT did shocking damage to stands of *E. delegatensis* near to Billy Billy Rocks and in the Brindabellas. A further effect of these bushfires in the ACT was to set the scene for vigorous regrowth, making many of the Percies, referred to above, even more inaccessible. While there are the aforementioned similarities, there are also many differences in the forests of the two places. The ACT has stands of dry scrubby box woodland and scribbly gum/red stringybark woodland, which are unlike the woodlands seen in Tasmania. There is less of an understorey in the ACT's woodlands than what might typically be seen in a Tasmanian woodland. If the word 'understorey' is substituted for 'scrub', and post-bushfire regrowth notwithstanding, most Canberrans are spared the very thick scrub (or indeed mud) that is such a feature of Tasmanian bushwalking. Tasmania, of course, has many wonderful species of flora that are not found in the ACT. Canberra does not have deciduous beech in its Namadgi highlands, nor does it have the *E. regnans* forest giants or *E. vernicosa* alpine garden miniatures. While Canberra's Australian National Botanic Gardens do have specimens of *E.* r*egnans* and *E. vernicosa*, the tiny fagus there long ago gave up the ghost, probably on some 40degree summer's day.

There are many similarities and differences in the fauna of the two places, too. Eastern grey kangaroos are so numerous in the ACT that they are subject to annual culling by shooting. Certain Canberra nature parks are closed at night during the culling period and night-time walking therein is prohibited, lest the walker be mistaken for a kangaroo. Shooting of eastern grey kangaroos in Tasmania, by the early British colonists, had restricted the kangaroos to a small area around Mt William National Park in the north-east and another area in the Northern Midlands. A translocation program in the 1970s and 1980s has seen the population extended across much of its former range.

For the purposes of this short article, I will restrict further remarks about the fauna to a comparison of the bird species that are found in both places. Birders have seen approximately 290 bird species in the ACT, and 310 species in Tasmania. One might expect Tasmania to have more species, as it is a larger geographical area, and has a maritime/coastal environment, which the ACT does not have (don't get me started on Jervis Bay!). The ACT does, however, have the advantage of being ensconced well within the mainland, and an amazing variety of continental species pay occasional visits to Canberra. Like Tasmania, the ACT does have a wide variety of habitats suitable for many types of birds. If one compares the species listed by Taylor and Day (2013) with species listed in Watts' (2003) or Morcombe's (2018) Tasmania field guides, one can see that approximately 130 species may be found, with some perseverance and luck, in both places. There are certain species in common of which I am particularly fond, because they commute between the ACT and Tasmania. In the ACT, the silvereyes (ssp. *lateralis*) that show a peach-coloured chest are said to be the Tasmanian ones. Similarly, some grey fantails are said to make the journey between the two places. I am intrigued by the fact that such tiny, delicate birds can withstand the rigours of crossing Bass Strait, and puzzled as to why they would depart Tasmania in winter to come to an even colder winter in the ACT. Swift parrots

Swift parrot, ACT. Photo: David Dedenczuk

are perhaps the loveliest and most special Tasmanian bird species that make their way from Tasmania to the mainland, including the ACT, every winter. This is an endangered species, so it was wonderful to see over two dozen of them turn up to one of the local nature reserves, Callum Brae, in 2021. The arrival of the swifties in Canberra resulted in quite a few regional birders making their way to the humble, and often overlooked, Callum Brae woodland, and some fantastic photographs were taken. Perhaps as a result of all the attention, the ACT swift parrots soon relocated to a copse of eucalypts next to a hamburger outlet in Tuggeranong, where the human beings had other priorities. There are many differences in the avifauna, too. The birds of semi-arid western and semi-tropical northern NSW make their way to the ACT much more than they do to Tasmania. Wild budgerigars periodically appear in the ACT. Wild emus are to be found in the ACT (especially in the lovely Cotter Reserve), whereas they can no longer be found in Tasmania. Tasmanian emus shared a similar, and even harsher, fate than the eastern grey kangaroos there, being completely exterminated by the British colonists.

I have learnt that the mainland has much to offer, even if its natural beauty is not as concentrated or spectacular as it is in Tasmania. On the mainland, I have learnt to appreciate its vastness and antiquity. One can drive west for five hours from the ACT, and still be only half way across the state of NSW. Never again shall I consider Hobart as being a long way from Launceston. On the mainland, and in my excursions outside of the ACT (when lockdowns permit), I have grown an appreciation for the arid, the flat and heavily eroded. I have learnt that mainlanders do not know that they are mainlanders, and mainlanders for their part, now recognise the many attractions of Tasmania, including as a refuge from increasingly hot summers. As a Tasmanian, I now see my island home even more clearly, by living, for the time being, away from it. By living in Canberra, I have come to see that Tasmania's natural world has many unique elements but is also an extension of that seen on the mainland.

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Record of a Tasmanian population of the common trilobite cockroach *Laxta granicollis* (Blaberidae: Perisphaeriinae) from Deal Island, north-eastern Bass Strait

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Introduction

Tasmania's cockroach fauna is poorly known with around 20 recognised native and introduced species (Semmens et al. 1992; Rentz 2014). Even well-known, large and colourful species have recently been found to constitute new endemic species, such as the recently described *Polyzosteria yingina* (Henry et al. 2021). In recent years, the Natural Sciences staff of the Queen Victoria Museum and Art Gallery (QVMAG) have been actively sampling cockroaches from across Tasmania. Specimens and high-resolution images have been supplied to Australia's foremost cockroach authority, Dr David Rentz, who has identified new genera and undescribed species of *Calolampra*, *Platyzosteria, Temnelytra, Ellipsidion* and *Balta* in QVMAG samples. In addition, poorly known and previously undocumented Tasmanian species of *Choristima* have been identified (D. Rentz pers. comm.; Fearn 2017). Also, it may be that the warming climate, coupled with increasing volumes of freight movements across Bass Strait, has made it easier for introduced populations of invasive cockroaches to establish in Tasmania (Fearn & Rainbird 2017).

The subfamily Perisphaeriinae comprises 18 genera worldwide, two of which occur in Australia – *Neolaxta* and *Laxta*. The genus *Laxta* contains 13 species that are distributed from far north Queensland south to Victoria and west to south-west Western Australia (Rentz 2014; Atlas of Living Australia (ALA) 2021a). There are also undescribed species present in collections (Rentz 2014). Taxonomic keys to the Perisphaeriinae are provided by Roth (1992) and Rentz (2014).

Laxta species are dimorphic with long, narrow, fully winged males (Plate 1) and broadly ovoid wingless females (Plate 2). Both sexes are dorsoventrally flattened allowing them to squeeze into relatively tight gaps under bark and rocks. They are nocturnal, spending the day in concealment (often in groups) and emerging at night to feed on dead wood, bark and possibly lichen and dead grass. In suitable habitat these cockroaches can be common to abundant and are often found under bark on both living and dead trees (Rentz 2014; S. Fearn unpublished data).

The common trilobite cockroach *Laxta granicollis* Saussure, 1862 is common throughout south-eastern Australia from the southern Queensland border to south-eastern South Australia (Rentz 2014; ALA 2021b). They are often under the bark of eucalypts throughout their range but also under slabs of rock in some habitats (Rentz 2014).

While *Laxta granicollis* occurs on the southern Victorian coastline, this species has not previously been collected from the Bass Strait islands. However, there is one unidentified *Laxta* specimen in the Waite Insect and Nematode Collection at the University of Adelaide, reputedly from Tasmania but with no collection data (ALA 2021b). In this paper we describe the first collection record of *Laxta granicollis* from Deal Island, Tasmania, as well as notes on the species' habitat preferences.

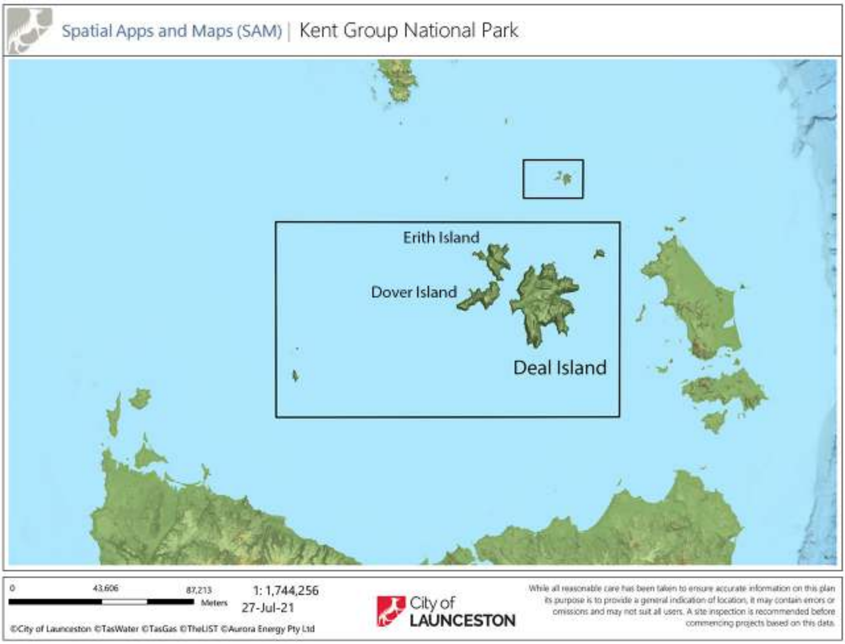

Figure 1. Kent Island National Park, north eastern Bass Strait.

Deal Island

Deal Island (39^0 28'S, $147^0$21'E) is a 1576-hectare granite island in northern Bass Strait. It is the largest island in the Kent Group, which lies between Flinders Island and Wilsons Promontory, Victoria. The Kent Group comprises three main islands (Erith, Dover and Deal), the much smaller North East Isle as well as the islets Judgement Rocks and South West Isle (Fig. 1; Brothers et al. 2001; Tasmanian Parks and Wildlife Service (TPWS) 2021).

Deal Island has a long history of European occupation and disturbance and is therefore locally highly modified, with many introduced plants and animals such as rabbits, rats and cats (Brothers et al. 2001; Harris & Davis 1990, 1995). The cutting of trees for construction and firewood, regular burning and grazing of both cattle and sheep have had significant impacts on the island's natural values. Parts of the island were still under grazing leases as recently as the 1990s (TPWS 2021). Because of the island's position and height, a lighthouse was built, of which construction began in 1846, and it became operational in 1848. The presence of the lighthouse ensured a continuous human presence on the island until it was replaced with two smaller automated lights on North East and South West islands in 1992. Deal Island is considered an important part of Tasmanian cultural heritage, since it includes a number of significant historic sites such as the lighthouse and the superintendent's residence (now used as a museum), grave sites, infrastructure from the lighthouse era and various shipwrecks located around the shores of the islands. There are also an airstrip (closed), roads, a jetty, two houses and a dam (Brothers et al. 2001; TPWS 2021). Deal Island is now occupied most of the time by Parks and Wildlife Service volunteer caretakers.

The flora and vertebrate fauna of Deal Island is reasonably well documented (Brothers et al. 2001; Harris & Davis 1990, 1995) with specific zoological expeditions made to the island as early as the 19th century (Le Souef 1891). Yet, new vertebrate records may still be possible (Wapstra & Doran 2007). Collections of invertebrates, however, appear to have been ad hoc and the authors are not aware of any systematic attempts to document the invertebrate fauna of the island.

Laxta specimens from Deal Island

A single female *Laxta* was collected among firewood at the caretaker's residence above East Cove in December 2017 by three of the authors (Widdowson family) and donated to QVMAG. The senior author was aware that no registered voucher specimens of *Laxta* cockroaches from anywhere in the Tasmanian region were present in any public Australian entomological collections (ALA 2021a). In June 2020, a further 20 specimens were collected by the Widdowson family from *Allocasurinae* woodland habitats above East Cove comprising nine females, seven larvae and, crucial for taxonomic identification, four males (QVM.12.2020.1953-1972; Plate 2). Based on the literature and

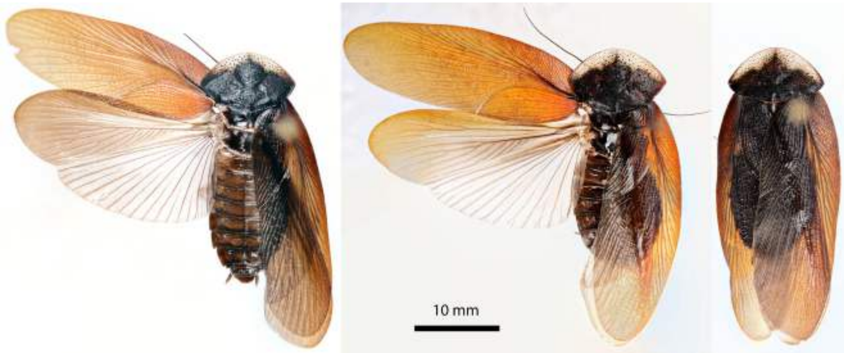

Plate 1. Male *Laxta granicollis* from Canberra, ACT (left;QVM.2021.12.2062) and Deal Island, Bass Strait (middle-right QVM.2020.12.1968-69). Photo: David Maynard

Plate 2. Female *Laxta granicollis* from Deal island, Bass Strait. Dorsal (left) and ventral. QVM.2020.12.1953. Photo: David Maynard

comparisons with *Laxta granicollis* from ACT (QVM.2017.12.1765-66, 2062; Plate 1), the cockroaches were determined to be *L. granicollis*. The collection location (south-east Australia) and the habitat (woodland and coastal habitat) add weight to the identity (Rentz 2014; ALA 2021b).

All the specimens collected to date have been associated with raised, splitting but still attached bark on recently fallen drooping she-oak *Allocasuarina verticillata* (Lam.) L.A.S. Johnson, or under exfoliated sheets of granite on granite outcrops in *A. verticillata* dry woodland (Plates 3 & 4). Both habitats are consistent with known micro-habitat preferences of the species on mainland Australia (Rentz 2014).

Discussion

The presence of *Laxta granicollis* on a small Bass Strait island poses the question, how did it get there? It is possible that its distribution, prior to the end of the last Glacial Maximum (around 14,000 years ago; Lambeck & Chappell 2001), reached at least as far south as the Kent Group (Fig. 1). Prior to 14,000 years ago the sea level was low enough to connect Tasmania to Victoria by a land bridge. This would have allowed the species to extend its range naturally through suitable habitat. After this date the rising sea cut the land bridge, and by about 11,500 years ago the Kent Group was isolated (Lambeck & Chappell 2001).

The Kent Group probably represents the southern-most (possibly natural) extension of this species range. Speculations on the biogeography of the species must be qualified by acknowledging the limitations of the data. Museum records may not give a true picture of the distribution of this species in Bass Strait due to low sampling effort.

It is unclear why, under this naturally-occurring distribution scenario, the species did not progress further south whilst the land bridge still existed. Perhaps it was due to the presence of unsuitable habitat such as marshland south of the Kent Group (see Lambeck & Chappell 2001) that the flightless *Laxta* females were incapable of crossing. Flinders Island today has extensive suitable habitat for *Laxta* but, as mentioned earlier, this genus has never been recorded from anywhere else in the Tasmanian region. The most recent attempt to document the invertebrate fauna of Flinders Island was an Australian Biological Resources Study (Bush Blitz) run from 18 to 29 March 2014 with no *Laxta* identified.

An alternative explanation for the presence of *L. granicollis* on Deal Island would be its accidental introduction, as has occurred on Norfolk Island. A population of *L. granicollis* was identified on Norfolk Island, 1400 km east of Australia, in 1996. It apparently arrived there in timber or plant importations (Walker & Hangay 2002). While the present authors suggest that it is unlikely that the Deal Island population represents an introduction, it cannot be ruled out at this time, particularly in light of the long history of European visitation, including large volumes of

Plate 3. Specimens of *Laxta granicollis* were collected under splitting bark on recently fallen *Allocasuarina verticillata*. Photo: Justin Widdowson

Plate 4. *Laxta granicollis* were found sheltering under thin granite exfoliations such as that in the middle foreground. Photo: Justin Widdowson

building materials and other freight, particularly during construction of the lighthouse and dwelling in the 1800s.

Key to the status of the *Laxta* population on Deal Island will be an understanding of its genetic similarity to mainland populations – is there evidence of 14,000 years of genetic divergence? There is an apparent north-south cline in this species with thoracic granulation, size and overall darkness increasing in the southern portion of the range (Deal Island specimens appear to reflect this pattern) leading Roth (1992) to suggest that cryptic new taxa may be present in some populations. Given its apparently generalist trophic ecology of consuming dead plant material as well as being able to utilise rock exfoliations for shelter, the presence of this species cannot be ruled out anywhere in the Kent Group without proper sampling. The discovery of *Laxta granicollis* on other islands in the Kent Group, especially those without a history of European occupation, would be powerful evidence that they represent a natural, isolated population due to sea level rise at the end of the last glacial cycle.

Acknowledgements

Thanks to QVMAG Librarian Andrew Parsons for obtaining some obscure references and the two zoological reviewers of *The Tasmanian Naturalist* for constructive comments on the manuscript.

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An affair with a beach wolf: *Tetralycosa oraria* (L. Koch, 1876) (Arachnida: Lycosidae)

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Our fieldwork takes us far and wide, from lakes and montane tarns to rainforest, rivers and Tasmania's glorious coastline. This particular journey culminated at Petal Point, near Cape Portland, where we hunkered down in coastal scrub at the edge of a landscape besieged by leviathan towers topped with machines reminiscent of a scene from a science fiction novel. As always, upon choosing a likely campsite we set about a thorough ground search to locate any nearby myrmecine ant colonies, as they can prove to be a challenge in close proximity to an open camp. Search complete, our only obvious close neighbour living in the ground was a large female garden wolf spider, *Tasmanicosa godeffroyi* (L. Koch, 1865), or so we thought!

Afternoon shadows had begun to lengthen by the time our tarps were erected, groundsheet laid out and the wood stove was sharing a warm glow as the jacket potatoes roasted. A glass of cold wine in hand, we sat soaking up the ambience, when our attention was drawn to a movement, ever so slight, on the sand near a stove leg. As we watched enthralled, two diminutive legs appeared and slowly raised a silken cover, so well camouflaged with sand crystals as to be invisible. The owner of the dwelling remained just inside the opening, but was enticed out with the offering of a tiny grasshopper nymph. So swiftly was the morsel taken that we only caught a fleeting glimpse of a grey blur that disappeared down the hole. It was not until the following evening that we were able to clearly see and indeed photograph the speedy arachnid; its hunger overpowered its fear as it tenaciously grasped a small tabanid fly held by Chris. This patient game of enticement continued for several long minutes and we thought she had lost interest, but with renewed effort she burst from the burrow and bounded to the offering, allowing us the chance to capture an identifiable image of the beach wolf spider, *Tetralycosa oraria* (L. Koch, 1876) (Plate 1).

The days were warm and sunny but with periods of gusty wind, which seemed to not affect the locals; broad-back weevils, *Leptopius duponti* (Boisduval, 1835), grazed and mated on the foliage of *Acacia sophorae* (Plate 2) and we also noted the presence of the jewel beetle, *Melobasis innocua* (Thomson, 1879) (Plate 3). Blue sand wasps, *Bembix furcata* Erichson, 1842, were constantly burrowing and stocking their larders, and we were graced by the presence of a fine robber fly, *Zosteria* sp. Daniels, 1987, that perched on our guy rope whilst scanning

Plate 1. Beach wolf spider, *Tetralycosa oraria*, accepting a tabanid

Plate 2. Broad-back weevils, *Leptopius duponti*

Plate 3. Jewel beetle, *Melobasis innocua*

Plate 4. Heliotrope moth, *Utetheisa pulchelloides*

Plate 5. Tachinid fly, *Microtropesa nigricornis*

for prey or the presence of an interloper. A superb example of the salt and pepper moth, *Utetheisa pulchelloides* Hampson, 1907 (Plate 4), was photographed on the underside of a *Bursaria spinosa* leaf, and after many failed attempts we managed to secure an image of the spectacular tachinid fly, *Microtropesa nigricornis* Macquart, 1851 (Plate 5).

An anomalous find was a small colony of nocturnal sugar ants, *Camponotus consobrinus* (Erichson, 1842), a species we normally associate with trees, nesting either inside trees or in the ground underneath, but this colony was beneath a sawn timber section on gravelly substrate at the storm-tide zone east of Boobyalla Beach, with no trees in sight. In the same area we observed a very active tiger snake, *Notechis scutatus humphreysi* Worrell, 1963, diligently searching for prey in the heathland; a recently shed skin of a much smaller individual was located nearby on the pathway.

Our fishing attempts were continually thwarted by the gusty onshore wind, which was of sufficient strength to stall our bait in mid-air despite the heavily weighted rig, so we contented ourselves with the entertaining antics of the soldier crabs, *Mictyris longicarpus* Latrielle, 1806, foraging on the recently exposed sandy expanse.

Wedge-tailed eagles, *Aquila audax fleayi* Condon & Amadon, 1954, and white-bellied sea eagles, *Haliaeetus leucogaster* (Gmelin, 1788), were almost constantly present. These majestic raptors soared along the coast, often dangerously close to the rotating blades of the imposing turbines, prompting us to contemplate the likely number of fatal collisions.

Despite many failed attempts, we finally had to say farewell to our campsite without having successfully photographed the garden wolf spider, which taunted us from a safe distance, but was elusive until the very end. A complete list of the invertebrate fauna recorded over the two November days is presented in Table 1.

Table 1. List of invertebrate species recorded at Petal Point

Species	Common name	Family
ARACHNIDA		
Backobourkia heroine	Orb weaver	Araneidae
Tasmanicosa godeffroyi	Garden wolf spider	Lycosidae
Tetralycosa oraria	Beach wolf spider	Lycosidae
COLEOPTERA		
Eleale sp.	Clerid beetle	Cleridae
Curculionid x2	Weevils	Curculionidae
Leptopius duponti	Broad-back weevil	Curculionidae
Melobasis innocua	Jewel beetle	Buprestidae
Harmonia conformis	Common spotted ladybird	Coccinellidae
Micraspis frenata	Striped ladybird	Coccinellidae
DIPTERA		
Leskiini undetermined genus (nr. Toxocnemis)	Tachinid fly	Tachinidae
Microtropesa nigricornis	Tachinid fly	Tachinidae
Scaptia sp.	March fly	Tabanidae
Zosteria sp.	Robber fly	Asilidae
HEMIPTERA		
Acanthosomatidae sp.	Shield bug	Acanthosomatidae

Table 1 continued

Omyta centrolineata	Gum tree shield bug	Pentatomidae
HYMENOPTERA		
Camponotus consobrinus	Nocturnal sugar ant	Formicidae
Iridomyrmex spp. x 2	Meat ants	Formicidae
Myrmecia pilosula	Jack jumper	Formicidae
Bembix furcata	Blue sand wasp	Sphecidae
Paralastor emarginatus	Potter wasp	Eumenidae
Vespula germanica	European wasp	Vespidae
LEPIDOPTERA		
Erebidae sp.(larva)	Tussock moth	Erebidae
Euproctis sp.	Tussock moth	Erebidae
Psychidae (shelter)	Bag moth	Psychidae
Pterolocera sp. (larva)	Anthelid moth	Anthelidae
Utethesia pulchelloides	Salt and pepper moth	Erebidae
ODONATA		
Austrolestes annulosus	Blue ringtail (damselfly)	Lestidae
Hemicordulia tau	Tau emerald (dragonfly)	Hemicorduliidae
ORTHOPTERA		
Schizobothrus flavovvittatus	Disappearing grasshopper	Acrididae
DECAPODA		
Mictyris longicarpus	Soldier crab	Mictyridae

The second record of an Eastern Yellow Wagtail *Motacilla tschutschensis* in Tasmania

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The first Eastern Yellow Wagtail in Tasmania was sighted, photographed and reported on 30 October 2008, by Graeme Chapman at Bluff Hill Point in western Tasmania. This report is on a recent sighting with photographs of the species in eastern Tasmania.

On Monday 12 July 2021, Heidi Krajewsky and I drove up to Freycinet Peninsula. We were volunteering for the twice-annual waterfowl survey of the Ramsar-listed Moulting Lagoon, which was to be held on the following day. This survey is done by PWS rangers, DPIPWE staff and volunteers. Most counters meet on the evening before to catch up and are organised into teams for counting at various sites all around the lagoon. I was teamed up with the ranger, Shannon McDougall. He and I dropped off the canoe with a team of counters, before driving to our allocated site at the end of Flacks Road. We had been asked to count birds in the entire area between Pelican Rocks and the mouth of the lagoon, near Swanwick. On arrival at Pelican Rocks, carrying my camera, telescope and binoculars, I climbed over the stile and headed towards the rocks. I immediately noticed a small bird hopping around on the marshland. I commented to Shannon that the bird looked like a wagtail; however, when it joined a group of Goldfinches on the marshland, I chastised myself that it must be a male Greenfinch instead. Fortunately, I asked Shannon to wait while I crept towards the bird and took photographs. At about 50 m distance, I was still unsure of its identity. From then onwards, Shannon and I counted all the birds on and around the lagoon for the rest of the day, finishing at Swanwick to collect the other team, who had arrived with the canoe. We all returned to the ranger's headquarters to report in with our survey results. Heidi had already arrived after having finished her count earlier, and she asked if I had seen anything interesting. On showing her my photo of the yellow bird (Plate 1), she immediately recognised it as a Yellow Wagtail. I ran to the ranger's tea rooms, where everyone was unwinding from the day, and told them the news before dashing out the door with Heidi, who wanted to see the bird for herself. As the light was already starting to fade, she decided not to collect her camera and we went straight to where the wagtail had been. Luckily the bird was still there and Heidi had a good look. By coincidence, Paul Brooks was on his way north and was able to join us there to see the bird as well. We posted my photograph onto

Plate 1. Eastern Yellow Wagtail at Moulting Lagoon

a birding group website and it was immediately positively identified by Dr Rohan Clarke. Our birding friends around Australia were all excited. There was some debate whether it was an Eastern or Western Yellow Wagtail, but Rohan determined it to be an Eastern Yellow Wagtail in breeding plumage. Before returning to our cabin, Heidi and I celebrated with a glass of bubbly and half a dozen oysters as we watched the sunset from the balcony of Freycinet Lodge.

The following morning we returned to the site and there was a group of about 12 Tasmanian birders already lined up with cameras, telescopes and sound recording equipment. Fortunately, the bird reappeared and flew over the group numerous times, calling, allowing flight shots and good sound recordings of its high-pitched call. The wagtail's flight was highly undulating as it flew between wet depressions in the marshland. Eventually it disappeared and everybody returned home. The wagtail was reported again the following day by another observer, but has not been seen again since.

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Flower wasps, Thynnidae – an opportunistic observation

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I have always been fascinated by coupling pairs of wasps 'on the wing' though they are mostly observed resting on vegetation. Occasionally I have found the wingless female on a track; the observation of cf. *Catocheilus apterus–hyalinatus* complex wasps was made in the Peter Murrell Reserve and caused me to delve further into their behaviour.

Flower wasps were placed in the family Tiphiidae, but what was previously a subfamily is now a family in its own right, Thynnidae. This particular family is characterised by having all wingless females. Those I have found and photographed here include *Tachynomyia abdominalis* (Plate 1), cf. *Catocheilus apterus–hyalinatus* complex and *Aeolothynnus westwoodi* (Plate 2) (all in the subfamily Thynninae) and *Diamma bicolor* (the bluebottle 'ant', in the subfamily Diamminae) (Plate 3). Flower wasps are found in Australia, South America, Lord Howe Island, New Guinea, the Solomon Islands, New Caledonia, Sulawesi, the Philippines and North America. The *Insects of Tasmania* website, which has very recently been upgraded, I have found an essential reference for identifying all insects. The direct URL for Flower Wasps is listed in the references.

Males and females are quite different. Males are winged, larger than the females, and dark though often with bright yellow markings. They are responsible for feeding the females. Females, in contrast, are wingless and so of course flightless, and mostly small and dark. They have modified front legs for digging or burrowing. The exception is *Diamma bicolor*, which we know as the 'bluebottle ant', which is the large, brilliantly metallic blue-coloured female (Plate 3).

Flower wasps are solitary; adults feed on nectar or insect exudates. Following mating, the female burrows into the ground in search of scarab beetle larvae in the soil (or mole cricket larvae, in the case of *Diamma bicolor*). First, the female paralyses her prey with a sting (beware!), then lays a single egg in or on the larva. She returns to the surface and repeats this process perhaps three times, over a period of weeks. The eggs hatch and the larvae parasitise the host initially, then pupate inside the living larva, which remains alive until the wasp is ready to emerge as an adult.

Let me return to my observation. My attention was drawn to a male wasp rushing about in a sandy location, next to

Plate 1. *Tachynomyia abdominalis* found in my vegie patch. Note the bearded head of the male used to hold the regurgitate nectar; also, the droplet between the first and second legs of the male. I did not witness the female feeding on this but believe it may be nectar intended for her.

Plate 2. *Aeolothynnus westwoodi*, found on *Tetragonia implexicoma* (bower spinach) at Taroona

Plate 3. *Diamma bicolor* or 'bluebottle ant' is really a female flower wasp, the largest and most colourful. They parasitise mole crickets; the adults feed on nectar.

a major track. I assumed it was hunting for prey. Stopping to watch, I was amazed when it began tugging at a piece of wood and pulled out a hidden female (Plate 4)! Their coupling began almost immediately on the ground right in front of me. Was it pheromones which led to his finding? A further complication was the attraction of numerous ants crawling both on the wasps and me (as I was on my belly to take photographs). Initially the female was behind, attached to the male in coupling (*in copula*); she then made her way underneath him until they were face to face, still attached (Plate 5). A red gooey mass was coming from the male's mouth, attracting the ants, too! The pair appeared to be 'kissing', the red goo being passed from the male to the female, which looked as though she were combing it into her 'mouth' (Plate 6). I was enthralled! This continued for some time. She then became disengaged from the male (still at the mercy of the ants, Plate 7) and presumably continued to search for her host larvae underground (according to my research). This whole event took about 20 minutes.

Research (Harris 2020) has explained much of this, though I still have numerous questions such as: do the ants play a role?

As adult flower wasps are nectar feeders, they need to visit flowers. Flying males can do this but need to transport the females to feed, which they do while mating/coupled tail to tail. In captivity this coupling has sometimes lasted up to two days (Brown & Phillips 2014). It is thought they also feed on the secretions of scale insects, leafhoppers and aphids, and nectar. There appear to be different methods of assisting the female to feed on nectar. He may carry her to flowers and position her so that she can feed independently, or he may deposit nectar droplets for her to reach, or he may present regurgitated nectar as a 'nuptial gift', which is what I was so lucky to observe! Flower wasps are regarded as important pollinators, including of some orchids, using sexual mimicry. There are about 600 described species of flower wasps in Australia, with around 2000 species in collections. Many questions remain about the wasps' food sources and their role as pollinators – a job for field naturalists!

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Plate 4. Male flower wasp in the cf. *Catocheilus apterus–hyalinatus* complex, finding a female (here from under a piece of wood). Observed in Peter Murrell Reserve.

Plate 5. Flower wasps coupling. Regurgitate is visible at the male's 'mouth', attracting an ant. Ants are also on the female, which is making her way to the male's mouth.

Plate 6. The female now receiving the 'nuptial gift'. She has small eyes, with no ocelli. They are still joined.

Plate 7. After 20 or so minutes the female is abandoned to dig and seek scarab beetle larvae to parasitise.

Short note: A possible example of imperfect Batesian mimicry in the carrion-beetle *Ptomaphila lacrymosa* (Coleoptera: Silphidae)

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Henry Bates was a nineteenth-century English naturalist and a contemporary of Charles Darwin and Alfred Wallace. Having spent a decade studying and collecting insects in the Amazon basin, he published his ideas outlining the way that some of his otherwise defenceless butterflies gained protection from predators through closely mimicking the appearance of other, unpalatable species. The model species advertised its distastefulness through aposematic (warning) combinations of contrasting colours – usually red, yellow and/or black; and the mimic adopted those same colours, effectively playing bluff. This form of mimicry – which is one of the most widespread and best-known – now bears Bates' name in his honour. Examples of Batesian mimicry can be found amongst most insect groups as well as other animal groups in which some, but not all, species are unpalatable or poisonous, such as frogs. While most examples are colour-based, others are based on movement or other behavioural traits. There is even acoustic Batesian mimicry among some moths aimed at avoiding predation by bats. The other main form of mimicry common among insects and frogs – Mullerian mimicry – differs from Batesian mimicry in that it entails the evolution of similar 'honest' warning signals among groups of distasteful or otherwise best-avoided species that share common predators; the more species participate in the mimicry ring, the more the warning signal is amplified and the better protected they all are.

Not all mimics bear a perfect resemblance to their models: such species are called

– wait for it – imperfect mimics. For instance, it seems that the beautiful patterns on the wings of some butterflies aren't there just for our delectation, but are better interpreted in the context of imperfect mimicry of millipedes, salamanders, frogs, snakes, falcons, spiders, hornets, bats, caterpillars, wolves and owls (Howse 2014). The strategy carries a risk of the 'dishonesty' being caught out, and there are many theories as to why they bother if they can't fool their potential predators all of the time. One is that the deception only has to give the predator cause for hesitation, giving the mimic vital extra time to flee. Another is that the mimicry is still only in the process of evolving: come back in another half a million years and it might by then be perfect, if the trait continues to be selected for. It's also possible that we humans perceive mimics' degree of mimicry differently from how their predators do, and that for the predators, the deception is more convincing.

It's in the context of imperfect Batesian mimicry that we offer this possible Tasmanian example. Last March, we were both involved in a Bush Blitz at Stony Head on Tasmania's north-east coast. While searching for snails among some small, crumbly logs in woodland beside one of the gravel roads, one of us (KB) came across a carrion-beetle, *Ptomaphila lacrymosa*, that was uncharacteristically torpid, perhaps because of cold weather. When the beetle was picked up and then placed on the road for a closer look, it landed on its back and for a while remained motionless. It then began to move, but instead of attempting to turn itself over and run off, it performed an unusual series of movements that involved

Plate 1. Carrion-beetle *Ptomaphila lacrymosa*, in 'imperfect mimicry' mode. Photo: S. Grove

Plate 2. Devil's coach-horse beetle *Creophilus erythrocephalus,* in 'back-off' mode. Photo: S. Grove

curling and extending its abdomen to reveal orange-coloured terminal segments. At the same time, it curled its head and antennae forwards, allowing the orange-coloured apical segments of its antennae to make contact with the tip of its abdomen (Plate 1). It stayed in this position for a number of seconds, occasionally flinching its antennae and jerking its abdomen in unison.

This behaviour and appearance was startling to a human, and we can imagine that a potential predator, such as a bird, antechinus or quoll, would also have been given cause for hesitation. But it seemed to us to go beyond merely startling and into the realm of mimicry. The models, we suggest, are the devil's coach-horse beetles, *Creophilus erythrocephalus* and *C. lanio*. These lithe, active and common predators have orange heads contrasting with black bodies; they have a liking for the same carrion habitat as *Ptomaphila lacrymosa* (see Grove 2020 for further details); and – tellingly for models in the Batesian sense – they are capable of disabling or deterring would-be predators with a combination of big jaws at the front end and noxious chemicals emanating from the rear end. To ward off potential predators, all they have to do is to stand erect, menacingly lower their heads to emphasise that redness (a contrasting black eye-spot in the centre of the red probably helps too), and raise their tails, rather in the manner of a skunk (Plate 2). The would-be predator will usually get the message and back off or move on.

We cannot say conclusively that this is what was going on, but to us it seems the most parsimonious explanation for the carrion-beetle's strange behaviour. Perhaps if our beetle had been warmer and less taken off-guard it might not have bothered, since if it played the dishonest mimicry card too often, its predators would probably cotton on; but having an evolved ability to act in this way in an emergency would surely be advantageous. If nothing else, it would explain the odd colouration of its terminal abdominal and apical antennal segments.

Acknowledgements

We thank the ABRS Bush Blitz organisers and the ADF Stony Head range staff for facilitating our participation in the Stony Head Bush Blitz; and we thank Alastair Richardson for helpful feedback on an earlier version of this short note.

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Obituary

Marking the passing of a passionate naturalist

Chris Peter Spencer

30 March 1957 – 20 August 2021

It is difficult to pinpoint exactly when Chris P Spencer became a naturalist and conservationist, but I do know that he was infected by a deep-seated childhood curiosity and wonder about nature. As a young lad, Chris would sit for hours on a footpath or in the paddock patiently observing nature, in his home town of Liffey at the foothills of the Western Tiers. By the age of five, Chris was known to borrow his sister's nail polish and use a single horse-tail hair to carefully mark ants in a trail, to determine where they were going and how far they travelled. At a similar age he marvelled at the ability of his two-legged captive rehabilitated huntsman to regrow its legs after being severely injured by a family member rushing to escape the spider clinging to the shower curtain.

As a boy, he took an unusual spider in to QVMAG for identification during one of his family's monthly visits to Launceston. At first he was dismissed by a museum receptionist, but his chance hallway encounter with Robert 'Bob' Green led to a wonderful relationship which inspired the young Chris to explore, identify and learn more about the world of fauna. While Chris assisted the museum in the process, Bob encouraged Chris to collect unusual specimens for QVMAG. Bob would also loan museum books to the young Chris, who would greedily devour the information presented and then swap these texts and new collected specimens for more texts on his next visit.

Instilled with a strong sense of compassion and justice, at the age of seven Chris would soon become the family spokesman for the 'little people', convincing his father to set aside an area in the paddock for the protection of habitat for invertebrates, reptiles and frogs. Formal education had its limitations and Chris left school at a young age. At first working for his family in road construction, he quickly became the camp cook for a team of 10 to 15 men at the age of 14, all of whom appreciated his culinary talents; then, later, he worked in the family forest-harvesting business. Following several family tragedies, Chris dropped out of society for a number of years but was not idle; rather, he continued to read profusely, including on such varied topics and genres as poetry, autobiographies, history and, most importantly, fauna, all whilst continuing to pursue his obsession of observing nature. His bookshelves hold testament to this insatiable thirst for knowledge; I expect he possessed one of the most comprehensive private libraries on avifauna, vertebrates and invertebrates in Tasmania.

Once he re-joined the Liffey community, Chris gained employment at the Liffey tearooms and gallery, where he and Simon Fearn created wonderful natural history exhibitions and Chris rehabilitated, bred and exhibited various raptor species; he was the first person ever to have bred masked owls. In his off-time Chris collected a variety of invertebrates, creating the beginnings of what would become impressive pinned and wet invertebrate collections that are now destined for TMAG.

After years of working in a native plant nursery and tour-guiding, Chris eventually landed a job as technical officer with the ABC's Natural History Unit in the early 2000s, during the filming of two documentaries, one on Tasmanian devils and the other on platypus and echidna. His firsthand knowledge and understanding of Tasmanian fauna and animal behaviour was gratefully appreciated and utilised during the filming. A lengthy stint as a technical officer at the Forest Practices Authority (2004–2012) allowed him to share his expertise with staff, forest industry representatives and PhD students alike, and this was where he met his future partner and collaborator, Karen. This meeting, and the sharing of a deeply-held passion for invertebrates (and fauna more generally), would result in the mutually beneficial exchange of knowledge and collaboration on numerous research projects and the production of over 30 scientific publications. While some of this research took years to complete, Chris would doggedly pursue each project until it came to fruition. Despite some of the investigations being unsuccessful, all were considered learning opportunities.

We lost Chris on the morning of 20 August 2021. In the end, an aggressive, rapidly spreading cancer took him all too cruelly from those who loved him and from others who appreciated his ability to enthusiastically dispense knowledge and to inspire. I wish to thank those kind people who have made contact to share their fond memories of Chris's passionate nature, cheeky commentary and wealth of knowledge, and to express their deep sadness at the incredible loss of this true naturalist and entomological legend. While this may mark the end of an era, with many musings drafted and research projects yet to be completed, expect there to be further articles from Spencer and Richards to be published in *The Tasmanian Naturalist* for a number of years to come.

Karen Richards

Book reviews

Beachcombing: A Guide to Seashores of the Southern Hemisphere

by Ceridwen Fraser

Published in New Zealand by Otago University Press 2021 and in Australia by CSIRO Publishing

Paperback, 116 pages

ISBN: 9781486314898

Reviewed by Lynne Maher

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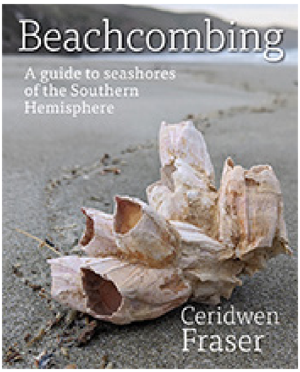

When asked if I would like to review this book, I had to commend the match of person and subject. I have long enjoyed beachcombing and exploring rock platforms and looked forward to reading this book with anticipation of another useful volume that would inform foreshore forays.

The book cover tells us –

Ceridwen Fraser grew up in Australia and spent childhood summers poking around rockpools along the New South Wales south coast. She developed a deep attachment to the ocean and the fascinating critters that live in and around it, and decided at the age of 11 to become a marine biologist. She has worked in Belgium and Australia and today is an associate professor in the Marine Science Department at the University of Otago, New Zealand.

The contents of the book are comprised of an eclectic mix of information, some of which is quite peripheral to what I would have expected of a volume entitled '*Beachcombing*'.

The author starts with a chapter titled 'Looking after our beaches', which addresses the predictable matters of taking care and being aware of causing distress or damage to the coastal and intertidal life there, as well as care of middens. The book's first diversion occurs on the second page of the chapter, with passing reference to the last ice age and sea level rises, and some beach-related words from four indigenous languages across the Southern Hemisphere.

A section on tides and currents leads into flotsam and jetsam with stories of messages in bottles, references to the disappearance of Malaysian Airlines flight MH370 and large numbers of rubber duckies overboard, and the way that distribution of flotsam contributes to our understanding of tides and currents. Discarded rubbish gets a mention with the admonition that we all have a responsibility to reduce this, in particular plastics.

The author's deep interest in kelp

surfaces in a number of places with the introduction of material on this topic that is much more in depth than that on other topics.

She touches on assorted phenomena associated with currents and tides, including the left/right variation in the orientation of the sails of *Physalia* and *Velella*, crustacean tides, bioluminescence and sea foam.

A chapter on 'Beach treasure' touches on ambergris, the formation and nature of sand, and fossils.

The chapter 'From the shallows' introduces the reader to some of the life in the intertidal and subtidal zones and again the author's deep interest in kelp comes into play with a lot of information including the subtle differences between the different *Durvillea* species and diversions into some recipes involving seaweeds. It seems her interest in shells is considerably less, so if you want to identify anything other than a handful of species, I'd advise Simon Grove's *The Seashells of Tasmania: A Comprehensive Guide* or Margaret Richmond's *Tasmanian Sea Shells* volumes, although these are much harder to come by. Other phyla are touched upon in this chapter but if the reader is seeking some real help on identifying the range of life and beach-washed specimens that might be found on Tasmania's foreshores, I would recommend *Between Tasmanian Tide Lines – A Field Guide*, produced a while back by the Tasmanian Marine Naturalists Association Incorporated and available from the Field Naturalists website. Edgar's *Australian Marine Life* and Dakin's *Australian Seashores* are also very helpful resources for identification of specimens from beach and rock platform explorations.

Returning to *Beachcombing*, the author continues, touching on life in the deep sea environment; seabirds (specifically shearwaters and penguins), but not the shorebirds that we might see on our beaches; marine mammals; seed etc. dispersal by currents – including another quite in-depth section on kelp, kelp rafting and learnings from DNA analysis of it. She finishes up with a brief section on the issues challenging and changing our beaches.

As I read the book, I spent time pondering the author's target audience, since the content and style varies from addressing the beginner to introducing some terminology I had not encountered before. It is inconsistent in the level of information on the various topics introduced, and in at least one case introduces an inaccuracy, referring to sea slugs as nudibranchs (while all nudibranchs can be termed sea slugs, not all sea slugs are nudibranchs). I have come to the conclusion that the book is best read at home, by someone who has had little experience of walking beaches or has previously shown little interest in what is found on beaches.

Did the book meet my expectations? It did not. I would not recommend it as a useful volume to take along on beachcombing expeditions; any of the books referred to above would be much more useful.

Bird Talk: An Exploration of Avian Communication

by Barbara Ballentine and Jeremy Hyman

CSIRO Publishing, with Quarto Publishing & Cornell University Press, 2021

Hardback, 192 pages

ISBN: 9781486315307

Reviewed by Els Wakefield

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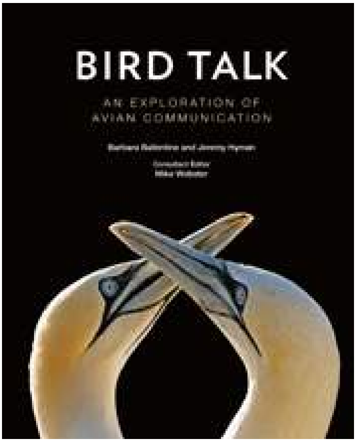

This stunning book has a matt black cover featuring two gannets.

The authors deliver a well-researched series of explanations, descriptions and arguments relating to the various methods by which birds communicate, based on recent studies.

The book is easy to follow with a summary at the start of each new chapter in heavy print. The main text is paler and not so easy to read, but the contents are well presented and clear, flowing well from one topic to the next. Topics include male–female communication, territoriality and dominance, parent–offspring communication, warning signals, group life, and communication in a noisy world.

Throughout the book, there are pictures of birds to illustrate various aspects of the text and the photography is superb. Top-quality photos have been sourced from various photographers and include birds from around the world. I enjoyed the use of arrows to identify the photos that the captions relate to.

I found the book fascinating and difficult to put down. I learnt that research on olfaction in birds, which is a relatively new area of study, has demonstrated that Crested Auklets emit a tangerine smell that is detectable to anybody within 1 km of the colony. The main source of this smell comes from the uropygial gland and is spread across their feathers by preening. Higher quantities of odorant may indicate the ability of adults to repel ectoparasites; it is also correlated with crest size in males and with immune function in both males and females. By sniffing each other's necks, adults may be acquiring information about their immunocompetence.

I also learnt that our own Purple Swamphen, which is closely related to New Zealand's Pukeko, appears to use the bright red frontal shield of the bill as a badge of status, and that its size can change quickly according to the bird's rank in the group.

An interesting adaptation to living in an urban environment is demonstrated by the Common Blackbird, which has been shown to sing louder at higher frequencies than at lower frequencies, thus raising its voice above the noise in the city.

In this book there are so many well-described new discoveries about communication between birds around the world that it is inspiring to observe our own birds more closely. I highly recommend this book.

PooFlip: Life-size guide to the scats of Tasmanian mammals

by Rob Wiltshire and Jane Burrell

University of Tasmania, Tasmanian Museum & Art Gallery (2018)

Foldable, illustrated, laminated chart

Reviewed by Don Hird

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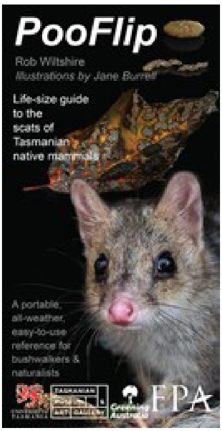

Having a pictorial guide to the scats of Tasmanian mammals can only contribute to increasing knowledge of and interest in this faunal group. Moreover, because so many of the extant species are common, this guide can be used by visitors and locals alike, almost anywhere in Tasmania. At so many places in Tasmania, scats of pademelon, Bennett's wallaby and the common wombat will be evident and readily distinguishable.

Some newcomers may be surprised that the smaller pademelon produces a larger scat than its macropod relative and the cuboid scat of the wombat. On the other hand, in studying potoroos for some eight years, I seldom saw scats, neither from animals that I was marking and releasing in a population ecology study, nor in their general habitat. Few people seem to realise that potoroos and bettongs, while also macropods, occupy their own sub-group and do not browse or graze on green leaves like the other macropods, usually known as wallabies and kangaroos. Potoroo scats are small, dark and sticky, resembling a streak of Vegemite, in my experience. This reflects their diet of underground fungal fruiting bodies, sometimes called truffles or hypogeal fungi. This is similar for bettongs with regard to diet, but these energetic marsupials are more vagile. Both of these species are believed to be important in disseminating the spores of hypogeal fungi, which are in turn vital to healthy forests, although the detailed science underlying this is, not unusually, in its infancy. The conical diggings of each differ in detail and in my experience are usually much more evident than their scats in the wild.

For mammals and many other animals, scats are more than a means of voiding waste. Many walkers in Tasmania would have noticed that wombats not only produce cuboid scats, but that they also often place them on a log or rock, with a likely inference that this serves as a place marker for individuals, possibly including territory. Something that cannot yet be included in a guide like this is a 'Smell Flip' that wombats and, of course, dogs are so attuned to. Cat lovers and urban gardeners will know that cat scats are usually buried. Some beetles accumulate their excreta as a shield in what is known as 'repugnatorial defence', but no self-respecting marsupial that I know of would come at that!

Even a glance at this *PooFlip* will arouse further curiosity and speculation. Could those bone fragments and the hair in devil scats indicate devils' prey species? Yes, of course. Again, comparing the Bennett's wallaby and pademelon scats, the coarse fibrous residues in the former grazer are different to the smoother-surfaced scats of the pademelon, which is more of a browser than a grazer.

Lastly, the careful use of resources such as the *PooFlip* can potentially assist in mammal survey documentation, in which Tasmania is lamentably deficient in comparison to, say, Victoria, where often this will be in detail. Despite lobbying for attention to the status of the platypus and potoroo on King Island, both species appear to have been ignored over many years by government authorities responsible for wildlife matters. Although much of the basic biology of Tasmanian mammals is yet to be discovered, the *PooFlip* should encourage enthusiasts to investigate this further.

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The Tasmanian Naturalist publishes articles on all aspects of natural history and the conservation, management and sustainable use of natural resources, with a focus on Tasmania and Tasmanian naturalists. These can be either in a formal or informal style. Articles need not be written in a traditional scientific format unless appropriate for the content. A wide range of types of articles is accepted. For instance, the journal will publish articles that:

- summarise or review relevant scientific studies, in language that can be appreciated by field naturalists;
- stimulate interest in, or facilitate in identifying, studying or recording particular taxa or habitats;
- record interesting observations of behaviour, phenology, natural variation or biogeography;
- stimulate thinking and discussion on points of interest or contention to naturalists;
- put the study of natural history today into context through comparisons with past writings, archives, etc.;
- review recent publications that are relevant to the study of Tasmanian natural history.

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