OTWAY BIOSCAN

Great Otway National Park

July 2018–June 2019

OTWAY BIOSCAN
Great Otway National Park

July 2018–June 2019

Edited by
Genefor Walker-Smith
and **Kate Phillips**

We acknowledge the Traditional Owners and Custodians of the land on which this Bioscan was conducted and pay our respects to Elders past and present.

CONTENTS

Species Lists

Executive Summary

On December 19, 2015, lightning strikes ignited two bushfires in the Barwon Otway Region, one near Delaneys Road and the other near Jamieson Track. In the early stages, these fires, which became known as the Wye River–Jamieson Track fire, were largely controlled and contained but the combination of strong winds, heat, and dry conditions resulted in the fire jumping containment lines on December 25 and by Boxing Day 98 houses in Wye River and 18 in Separation Creek had been destroyed.

The Otway Ranges are characterised by steep terrain and complex gully systems that are difficult to access and thus difficult to defend from fire. The Wye River–Jamieson Track fire lasted for 34 days and approximately 2500 hectares of land was burned, including areas within the Great Otway National Park.

Bushfires often have devastating direct and indirect consequences for people living and working in fire affected areas. In addition to the loss of homes and belongings, businesses are often affected by a reduction in the number of tourists visiting the region. This may be due, in part, to the loss of tourist infrastructure (e.g. holiday rentals) or the perceived loss of nature and natural beauty.

As part of the Wye River Recovery Project, a collaboration between Museums Victoria (MV) and Parks Victoria (PV) was established and the Otway Bioscan project was born. In spite of the devastating effects of the 2015/16 fires, the Great Otway National Park (GONP) remains an area of important biological, geological and cultural value and the main aim of the Otway Bioscan was to further investigate, discover and showcase (to locals and tourists) the national park's rich and resilient environment.

From September 2018 to March 2019 MV and PV staff, scientists and volunteers carried out a series of biological surveys within the GONP. The groups covered included birds, freshwater fish, insects (i.e. aquatic species, moss bugs and moths), small mammals, reptiles and amphibians. In addition, geology and palaeontology pilot surveys were conducted in the western part of the park.

The combined expertise of MV and PV staff resulted in the collection of important data that adds to our knowledge and understanding of the biological diversity within the park, which in turn contributes to conservation management. In addition, the rich imagery, data and knowledge captured during these surveys will be a shared resource that PV can use to promote the natural values of the Otway Region. The Otway Bioscan incorporated a range of opportunities for community participation and engagement. These events allowed for knowledge transfer and exploration of the natural world at a local level, while at the same time building and strengthening community relationships, particularly in the Wye River and Separation Creek areas.

Objectives

The major objectives of the Otway Bioscan were:

- To improve ecosystem knowledge and understanding of biodiversity values of the GONP.
- To encourage community involvement.
- To provide opportunities to establish citizen science initiatives.
- To support the recovery of fire-affected communities.
- To work collaboratively to provide opportunities for knowledge sharing and skills transfer, and identify avenues for future collaboration.

Project Benefits

The Otway Bioscan has the potential to benefit Parks Victoria, Museums Victoria, local communities, local businesses, the scientific community and the environment. Some specific benefits are listed below.

Economic: This project enhanced the knowledge of biodiversity assets in the GONP. This knowledge has the potential to assist PV in relation to the allocation and targeting of PV resources.

Social: This project engaged local communities and provided access to expert advice and skills (MV and PV). This project will help to increase community understanding of the environment, which may, in turn, assist in creating a shared vision for the management of the GONP.

Environmental: Through an increased understanding of the environment, PV will be able to better inform park planning and management, with an emphasis on the long-term preservation of biota.

Scope

The scope of the project focused on the expertise of Museums Victoria's staff, with agreement between PV and MV. The details of the investigations undertaken during this project can be found in this report.

Deliverables

- Species lists for the areas surveyed
- Distribution of biodiversity data and images, via *MV's Collections On-line* website and the Atlas of Living Australia, with attribution to 'The Museums Victoria–Parks Victoria Great Otway National Park Bioscan'.
- Three hundred high and low-resolution digital images and associated, relevant metadata. Photo subjects include species encountered, natural habitats and other features found within the park.
- Three to four minutes of professionally produced video footage. For example, a short documentary promoting the survey highlights and the natural assets of the GONP.
- Ten 1-page narratives containing biodiversity/biological/geological information that could be used for PV promotional material.
- A final written report, which consolidates the work carried out during the Otway Bioscan.
- Three public engagement events, including at least one in the Wye River/Separation Creek/Kennett River area.

Participants

Museums Victoria Staff

Anna McCallum (frogs)
Ben Healley (photography)
Brigette Bell (small mammals)
Chris Rowley (snails)
Claire Keely (public engagement)
Dermot Henry (tektites)
Dani Measday (public engagement)
Dianne Bray (freshwater fish)
Erich Fitzgerald (palaeontology and geology)
Genefor Walker-Smith (project leader, final report)
Heath Warwick (photography & image management)
Jane Melville (reptiles and amphibians)
Joanne Sumner (reptiles and amphibians)
John Broomfield (photography)
Julian Finn (aquatic invertebrates & photography)
Kate Phillips (final report and public engagement)
Karen Rowe (birds)
Katie Date (frogs)
Ken Walker (bees and moss bugs)
Kevin Rowe (small mammals)
Kylea Clarke (reptiles and amphibians)
Maggie Haines (reptiles and amphibians)
Maik Fiedel (reptiles and amphibians)
Mark Nikolic (birds and moths)
Martin Gomon (freshwater fish)
Melanie Mackenzie (public engagement)
Nish Mohamed Nizar (birds and moths)
Richard Marchant (aquatic invertebrates)
Ricky-Lee Erickson (reptiles and amphibians)
Robert Zugaro (photography and videography)
Rod Start (photography)
Rolf Schmidt (palaeontology and geology)
Sakib Kazi (small mammals)
Simon Hinkley (moths)
Steph Versteegen (small mammals)
Stephen Dixon (photography and videography)
Steve Sparrey (preparator)
Tim Ziegler (palaeontology and geology)

Museums Victoria Volunteers, Honouries and Research Associates

Cathy Powers (moths)
Dean Hewish (moths)
Marilyn Hewish (moths)
Matthew McGee (freshwater fish)
Molly Watchorn (small mammals)
Peter Marriott (moths)
Rudie Kuiter (freshwater fish)

Other Volunteers

Andrew O'Grady (reptiles and amphibians)
Caroline Dong (reptiles and amphibians)
David Mules (moths and lacewings)
Frank Pierce (moths and lacewings)
Ken Harris (moths and lace-wings)
Till Ramm (reptiles and amphibians)

Parks Victoria Staff

Jani Demetrious
Katrina Lovett
Kieran Lieutier

INTRODUCTION

The Great Otway National Park (GONP, Fig. 1) was established in 2005 and is the product of amalgamation of the former Otway National Park and Melba Gully State Park, most of Angahook-Lorne State Park and Carlisle State Park, a number of former State forest areas, many smaller reserves and other areas of public land. It is approximately 103,185 hectares. The Otways, as the broader area is affectionately known, stretches from Anglesea in the east to Princetown in the west.

On December 19, 2015, lightning strikes ignited two bushfires in the Otways, one near Delaneys Road and the other near Jamieson Track. In the early stages, these fires, which became known as the Wye River–Jamieson Track fire, were largely controlled and contained but the combination of strong winds, heat, and dry conditions resulted in the fire jumping containment lines on December 25 and by Boxing Day, 98 houses in Wye River and 18 in Separation Creek had been destroyed (IGEM, 2016).

The Otway Ranges are characterised by steep terrain and complex gully systems that are difficult to access and thus difficult to defend from fire. The Wye River–Jamieson Track fire lasted for 34 days and approximately 2500 hectares of land was burned, including areas within the Great Otway National Park (IGEM, 2016).

Coastal villages and towns border the national park in many areas and the winding Great Ocean Road enables thousands of tourists to enjoy amazing views along one of the world's most scenic drives. Tourism is an important part of the economy of the Otways, with more people visiting the Twelve Apostles than Uluru and the Great Barrier Reef combined (Great Ocean Road Taskforce 2018) and the Wye River–Jamieson Track fire could not have come at a worse time for local businesses. The period between Christmas and New Year is the busiest for Great Ocean Road towns like Lorne and Apollo Bay. For example, during this time Lorne's population usually swells from 1600 to 16,000, with more than $200 million pumped into the economy of towns within the Surf Coast Shire and the Otway–Colac Shire (Booker 2015) but it was suggested that

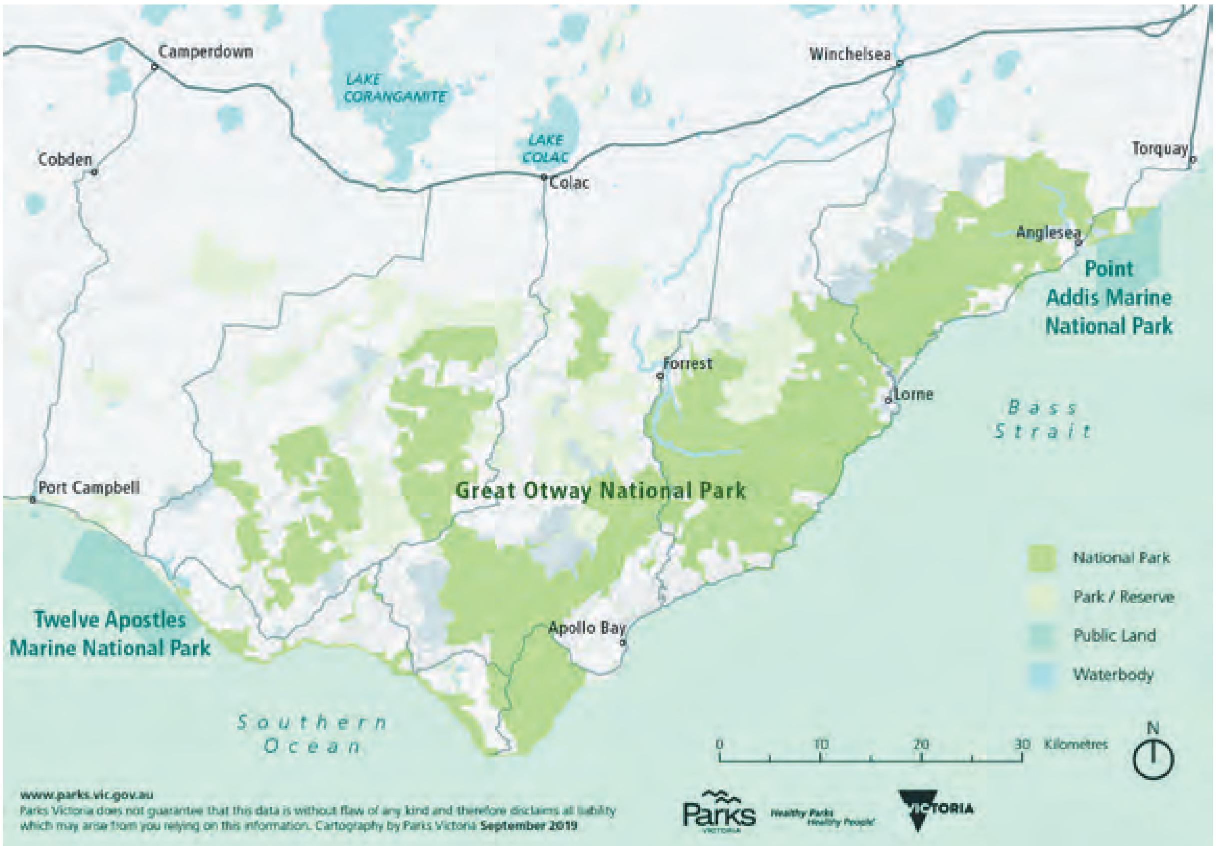


Figure 1. Great Otway National Park. Map by Parks Victoria, reproduced with permission.

there would be a 30% drop in business in these two shires after the Christmas day fire, as holiday makers chose to stay away (Kayler-Thomson, cited in Booker, 2018). This choice may have been due, in part, to the loss of tourist infrastructure (e.g. holiday rentals) but it may also have been due to a perceived loss of natural beauty in the region.

This down-turn in visitor numbers seems to have been short-lived. The vast majority of visitors to the Great Ocean Road region are Victorian, with the number of domestic overnight stays increasing by an average of 11% over the past five years (2014–2018). The number of international visitors to the region has also climbed, increasing by an average of 22% over the same five-year period (see the Great Ocean Road Taskforce's Independent Co-Chairs Final Report, August 2018).

The Twelve Apostles, magnificent waterfalls, and the chance to see koalas, king parrots and cockatoos in their natural environment seem to be promoted as the main visitor attractions, but the Great Otway National Park has so much more to offer.

A diverse range of habitats can be found in the Otways, including rocky shores, coastal heathland and dense forest. Vegetation varies from highly diverse low-growing heathlands, to tall, wet sclerophyll forests with giant Mountain Ash trees, Messmate, Blackwood and temperate rainforests with Myrtle Beech (or Southern Beech) trees and tree ferns. The national park also is home to a myriad of animal species whose beauty is often unrecognised and rarely seen, unless you are intentionally looking.

As part of the Wye River Recovery Project, a collaboration between Museums Victoria (MV) and Parks Victoria (PV) was established and the Otway Bioscan project was born. In spite of the devastating effects of the 2015/16 fires, the Great Otway National Park remains an area of important biological, geological and cultural value, thus the main aim of the Bioscan was to further investigate, discover and showcase (to locals and tourists) the national park's rich and resilient environment.

During the Otway Bioscan Museums Victoria and Parks Victoria planned to research some of the lesser-known animal groups found in the national park and bring to life some of the amazing stories coming out of this research, through narratives and rich imagery. It was hoped these stories and images would help to enhance the visitor experience (both in the 'real-world' and in the digital realm) and provide land managers with information that may assist with conservation and land-use decisions.

From September 2018 to March 2019 MV and PV staff, scientists and volunteers carried out a series of biological surveys within the GONP. The groups covered included birds, freshwater fish, insects (i.e. aquatic species, moss bugs and moths), small mammals, reptiles and amphibians. In addition, geology and palaeontology pilot surveys were conducted in the western part of the park.

The combined expertise of MV and PV staff resulted in the collection of important data that adds to our knowledge and understanding of the biological diversity within the park, which in turn contributes to conservation management. In addition, the rich imagery, data and knowledge captured during these surveys will be a shared resource that PV can utilise to promote the natural values of the Otway Region. The Otway Bioscan incorporated a range of opportunities for community participation and engagement. These events allowed for knowledge transfer and exploration of the natural world at a local level, while at the same time building and strengthening community relationships, particularly in the Wye River and Separation Creek areas.

First Peoples in the Otways

The Maar are the First Peoples of the Otway region. Prior to the arrival of Europeans in the late 1840s the Maar Nation contained more than 200 clan groups but this number was decimated as Europeans took over the First Peoples land (EMAC, 2015).

The area designated as the Great Otway National Park is in Gadubanud Country. The Gadubanud People are said to have had at least five language groups: Bangura gundidj, Guringid gundidj, Ngalla gundidj, Ngarowurd gundidj and Yan Yan Gurt (Clark 1990: cited in Niewójt 2009).

Prior to the arrival of Europeans the Gadubanud country had a wealth of potential food sources available from the highly productive wetlands, rivers, estuaries and open forests, as well as in areas cleared and cultivated by the Gadubanud people (Niewójt 2009).

The rocky shores provided shellfish during the warmer months and eels were caught in the Barwon River marshes when the fierce winter weather and big seas made collecting shellfish from local rockpools too difficult and dangerous. On the land, the Gadubanud hunted possums, kangaroos and wallabies, caught native rats, mice, reptiles, frogs and birds, and collected eggs (Niewójt 2009).

Areas of forest were burnt to facilitate passage through the bush and to create areas where native yams (the Murnong Yam, *Microseris lanceolata*) could be cultivated. The seeds, dispersed by the wind, would readily colonise cleared ground and the tubers could also be transplanted from one area to another. According to Gott (1982: cited in Niewójt 2009) there are at least 218 plant species with edible roots that were included in the diet of Victorian First Peoples.

There are few written records of Gadubanud language or of Gadubanud Creation or Dreaming stories but the 2014 book, *Nyernila*, includes the story of Pirt Koorrook as told by Gadubanud Custodians, including both the Gadubanud language version and the English translation (see VACL 2014). Pirt Koorrook was a female devil spirit who took the form of a woman. While female devil spirits were believed to haunt various parts of the country, there were none so celebrated for their great size as those frequenting the forests of Cape Otway ranges (VACL 2014).

Top: Tall forest, Triplet Falls, Great Otway National Park. Photographer: John Broomfield | Source: Museums Victoria. **Above:** Southern Brown Bandicoot, *Isoodon obesulus*. Photographer: Heath Warwick | Source: Museums Victoria.

It is worth stopping to reflect on the fact that at least 1600 generations of Koori people have lived in Victoria (Broome 2005) and over this time, substantial changes occurred within the natural environment. Sea levels along the Victorian coast only stabilised to near current heights approximately 6,000 years ago. Prior to this time, a period global warming caused the sea level to rise between 100 and 150 metres, over 15,000 years. Approximately 9000 years ago rising seas flooded the Victorian coastline, resulting in the formation of Bass Strait and Port Phillip Bay, and a one fifth reduction in the land mass (Broome 2005). Compared to today's coastline, the previous coastline was more than five kilometres away to the southwest. As a consequence, there was a slow but dramatic alteration to traditional territories (Broome 2005) and possibly a change in food supply. The First Peoples continuous, unbroken record of survival, adaptation and knowledge is a testament to human ingenuity and culture.

Right: Fern frond, Lake Elizabeth. Photographer: John Broomfield | Source: Museums Victoria. **Below:** Helena Gum Moth, *Opodiphthera helena*, Great Otway National Park. Photographer: Ken Harris | Source: Museums Victoria.

The history of the Otways in the 'Age of the Reptiles'

From about 550 million years ago, the continent of Australia was joined to Antarctica, South America, Africa, India, Arabia and Madagascar as part of a giant landmass, called the supercontinent Gondwana. Enormous geological upheaval during the 'Age of the Reptiles' (late Mesozoic Era, Fig. 2) saw Australia begin to split from Antarctica and drift northwards. The Earth's crust thinned, stretched and weakened at the junction between the continents, forming a vast east-west volcanic valley (Fig. 3). Australia is today still drifting north at a rate of six centimetres per year: equivalent to the rate that fingernails grow.

This southern Australian 'rift valley' was filled by river channels kilometres wide, bounded by billabongs, lakes and saturated floodplains. A whole record of that landscape—sand and mud, plants and trees, and the animals living within it—washed into those rivers, to be quickly buried. Today, we find that sand and mud as sandstone and mudstone; the plants have been compressed into black coal seams; and those animals—dinosaurs, pterosaurs, mammals, fish, insects, turtles and crocodiles—are found as fossils along Victoria's coast.

These southern rift basins are of major economic importance because they host some of Australia's principal oil, gas and coal reserves. Layers of sedimentary rock extending from the surface up to three kilometres deep, known as the Otway

Era (Ma = million years ago: all ages are approximate)	**Period**	**Epoch**	**Former terminology**	**Notes**
Cenozoic	Quaternary	Holocene		We are currently in the Holocene Epoch
		Pleistocene		
	Neogene	Pliocene	Tertiary	
		Miocene		
	Paleogene	Oligocene		
		Eocene		
The Cenozoic Era began 66 Ma		Paleocene		
Mesozoic	Cretaceous			The Mesozoic is also known as the "Age of the Reptiles"
	Jurassic			
The Mesozoic Era began 252 Ma	Triassic			The breakup of Gondwana began approximately 140 Ma, in the early Cretaceous Period.
Paleozoic	Permian			
	Carboniferous			
	Devonian			
	Silurian			
	Ordovician			
The Paleozoic Era began 541 Ma	Cambrian			

Figure 2. Geological Time Chart. Based on the 2019 chart from the International Commission on Stratigraphy (http://stratigraphy.org/ICSchart/ChronostratChart2019-05.pdf). Note, this chart is not to scale.

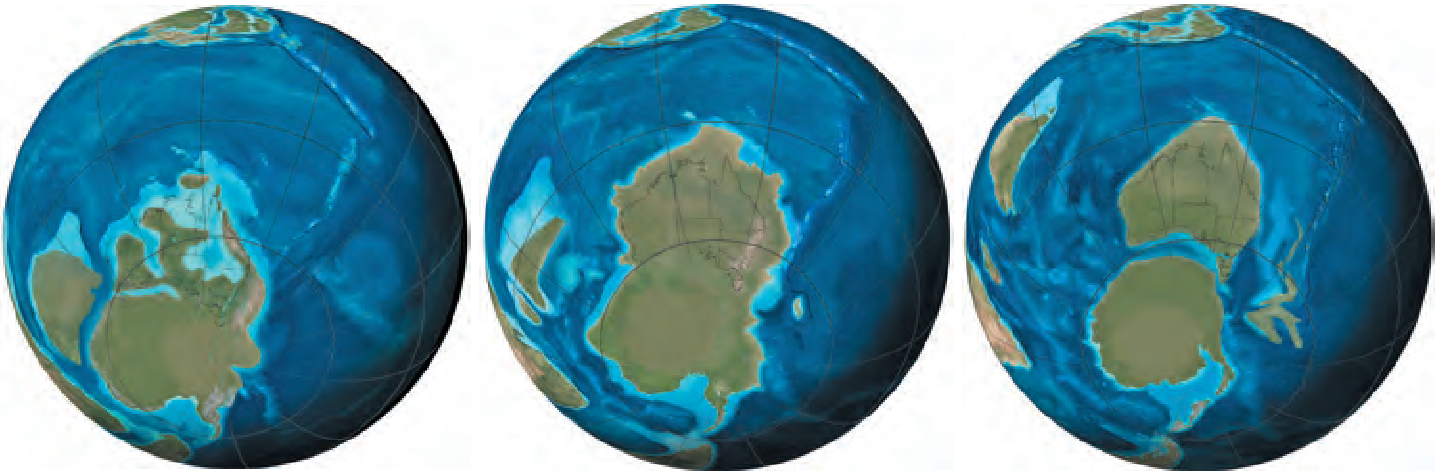


Figure 3. The globe 120, 90 and 65 million years ago showing the gradual break up of Gondwana. First India separates then Australia begins to separate. Creator: Ron Blakey | Source: Colorado Plateau Geosystems.

Group, include Jurassic and Cretaceous sandstones, mudstones and shales, rich with carbon from fossilised plants. These rock layers provide intriguing clues about the animals and plants of this area during the time of the dinosaurs.

The dinosaurs in this area during the Late Cretaceous lived at palaeolatitudes of between 60°S and 65°S, well within the Antarctic Circle, where it is possible that they experienced a three month-long winter with cool temperatures (+8°C to –6°C) and 24-hour darkness. There were no ice sheets around at the time, but it is likely that winter ice occurred in the area. The only other places in the world where dinosaurs lived at such high latitudes were northern Canada and Alaska.

Many species of dinosaur found in Victoria are not known from anywhere else, but most belong to groups with relatives elsewhere in Australia and on the then-connected Gondwanan continents. Wallaby-sized plant-eating 'bird-footed' dinosaurs, or ornithopods, were most common, eating low vegetation on river floodplains (e.g. see Fig. 4). They were in turn hunted by lightly built, agile, grasping predatory dinosaurs, known as megaraptorids. Pony-sized armoured ankylosaur dinosaurs were rare in the landscape, and had close relatives along Australia's eastern coast. Uniquely, crocodile-sized amphibians, known as temnospondyls, survived in Victoria's rivers a full 50 million years after their relatives went extinct in the rest of the world.

The plants associated with the dinosaur faunas included familiar trees, such as Norfolk Pine and Myrtle Beech. These towered over an understory of ferns, horsetails and club mosses (lycopods). Amongst these would also have been the early ancestors of today's flowering plants, extending further southwards as global climate warmed in the late Cretaceous.

North and south of the main valley channel, quiet lakes supported fish and insects, whose fossil remains are found in East Gippsland at Koonwarra. The siltstones and mudstones have yielded exceptionally preserved fossils, with patterns of colour intact. Even the delicate feathers of birds and dinosaurs, floating onto the lake's surface, have been preserved with microscopic detail.

The end of the Mesozoic era and the extinction of dinosaurs (except birds) 66 million years ago is marked by a fossil layer called the Cretaceous/Palaeogene boundary (or sometimes the KT-boundary). No Cretaceous/Palaeogene boundary has been discovered in any Australian outcrops, though it may have been intersected in drill cores. At Point Margaret near Princetown, a gap of tens of millions of years marks the boundary (unconformity) between Cretaceous sandstones and the overlying Paleocene conglomerate (Fig. 5).

Early Cretaceous rocks can be seen at the surface scattered across Victoria, where the geologic process of uplift has pushed them to the surface. Most reports imply these blocks were pushed upwards around 100 million years ago, before the separation of Australia and Antarctica. However, black coal found near Lorne was buried up to a depth of 750 metres deep by around 55 million years ago. Further, Victoria's present-day rocks were forming in ocean environments as late as 15 million years ago on the Aire Coast. These lines of evidence suggest local depressions (basins) persisted much longer.

The cliffs and shore platforms at Artillery Rocks (Fig. 6) are formed from late Early Cretaceous (Aptian-Albian) river sandstones, known to geologists as the Eumeralla Formation. They are mostly sandstones, sometimes featureless (massive), and sometimes showing the

Figure 4. Model of the dinosaur Qantassaurus in a forest in Victoria. Photographer: Jon Augier | Source: Museums Victoria.

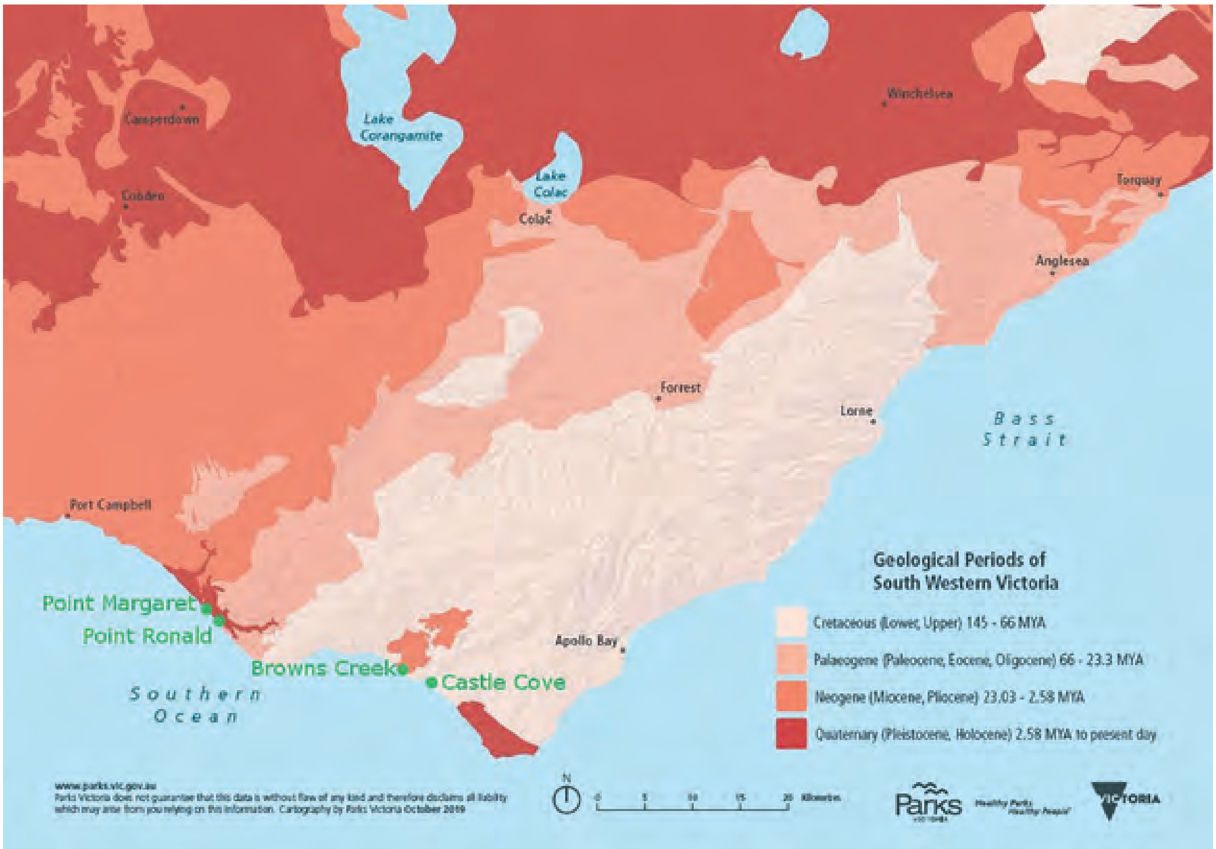


Figure 5. Rock outcrops in the Otway region. Map reproduced with the permission of Parks Victoria. Creator: Parks Victoria | Source: Parks Victoria.

layers (bedding) from when they were deposited. They often include ripped-up fragments of muddy riverbeds, thin coal seams, and where animals' remains were washed in to rivers, fossils can also be found.

Much of the sand and mud carried by those Cretaceous rivers was volcanic in origin—particles of lava, ash grains, and crystal feldspar from volcanoes then erupting to the south and east.

The original feldspathic sands and silt were deposited in a floodplain that emptied into the gradually opening rift valley between Australia and Antarctica at the time. When freshly exposed, the rocks are all greenish-grey. However, more differences become apparent as they break down in the open air. Layers formed from larger sand grains stick around longer, producing shelves and jutting outcrops. Mineralised 'cement' binds the sand grains, preserving some layers more strongly than others. Iron particles turn from grey to orange-red as they interact with oxygen in the air, essentially forming rust (ferric oxide) in the rocks (Fig. 6e).

Several minerals, mainly calcium carbonate (calcite), iron carbonate and iron sulphide, sometimes with magnesium and manganese, became concentrated soon after sediments were laid down. As the sediments turned into rock, these concentrations took the form of iron-rich spheres called 'cannon ball concretions', some as small as marbles and others a metre across (Fig. 7).

These concretions tend to only occur in some beds—coarser-grained sandstones leave more space (porosity) between the grains for mineral-rich fluids to flow. Over time, softer rock is washed away by ocean waves, causing the 'cannon balls' to stand out on pedestals (Fig. 7), cupolas and contorted surfaces.

A characteristic particularly evident on these platforms is the development of a pitted honeycomb-like surface, known to geologists as 'tafoni' (Fig. 8). The exact cause of tafoni is uncertain—it may be as simple as the growth of salt crystals formed on rock surfaces by the constant sea spray.

Figure 6. Artillery Rocks, Great Ocean Road: **a.** the view down to the rock platform at Artillery Rocks; **b.** rock formations; **c.** ferric oxide (i.e. rust) in the rocks. Photographer: Rodney Start | Source: Museums Victoria.

Figure 7. Cannon ball formations at Artillery Rocks. Photographer: Rodney Start | Source: Museums Victoria.

References

Booker, C. 2015. *Victorian bushfires: Millions estimated lost as tourists desert Lorne and Apollo Bay*. The Age, December 28, 2015. https://www.theage.com.au/national/victoria/victorian-bushfires-millions-estimated-lost-as-tourists-desert-lorne-and-apollo-bay-20151227-glvgjb.html

Broome, R. 2005. *Aboriginal Victorians – a history since 1800*. Allen and Unwin, Crows Nest NSW. 467 pp.

Clark, I.D. 1990. *Aboriginal Languages and Clans: An Historical Atlas of Western and Central Victoria, 1800–1900*, Monash Publications in Geography No 37, Department of Geography and Environmental Science, Monash University, Melbourne. 448 pp.

EMAC - Eastern Maar Aboriginal Corporation. 2015. *Eastern Maar. Meerreengeeye ngakeepoorryeeyt*. The Country Plan. North Melbourne. 48 pp. Also see: http://easternmaar.com.au/wp-content/uploads/2012/10/EM_CountryPlan_FINAL.pdf

Great Ocean Road Taskforce. 2018. Independent Co-Chairs Final Report, Great Ocean Road Taskforce. *Protecting our iconic coast and parks. Governance of the Great Ocean Road, its land and seascapes*. https://www.planning.vic.gov.au/__data/assets/pdf_file/0029/394346/GreatOceanRoad_FinalReport_web.pdf

Gott, B. 1982. Ecology of root use by the Aborigines of Southern Australia. *Archaeology in Oceania* 17(1): 59–67.

IGEM — Inspector-General for Emergency Management, Victoria. 2016. *Review of the initial response to the 2015 Wye River–Jamieson Track fire*. https://www.igem.vic.gov.au/sites/default/files/embridge_cache/emshare/original/public/2017/07/3d/304a66bd0/Publication%20-%20Review%20of%20the%20initial%20response%20to%20the%202015%20Wye%20River%20-%20Jamieson%20Track%20fire.PDF

Niewójt, L. 2009. Gadubanud society in the Otway Ranges, Victoria: an environmental history. *Aboriginal History* 33: 175–199.

VACL— Victorian Aboriginal Corporation for Languages. 2014. *Nyernila – Listen Continuously – Aboriginal Creation Stories of Victoria*. Arts Victoria, Melbourne. 82 pp. Also see: https://cv.vic.gov.au/media/3046/nyernila-listen-continously-2015.pdf

Figure 8. Examples of 'honeycomb weathering' or 'tafoni' at Artillery Rocks. Photographer: Rodney Start | Source: Museums Victoria.

REPORTS

01

BIO-ACOUSTIC SURVEYS OF BIRDS ACROSS BURNT AND UNBURNT SITES

Report Author: Karen Rowe
Survey Team: Karen Rowe, Mark Nikolic, Nish Nizar, Genefor Walker-Smith, Heath Warwick

Introduction

Automated acoustic recorders are rapidly becoming an important tool in the assessment and monitoring of vocally active species across different geographic and temporal scales (Brandes 2008, Furnas and Callas 2014, Laiolo 2010). Large volumes of audio data can be collected with little effort and the resulting environmental soundscapes can be interrogated to address a range of research questions, from the detection of individual species to the summary of the acoustic output within a community (Sueur and Farina 2015). In addition, the collected audio files can be preserved in perpetuity to serve as a verifiable record of a species' presence or to be used for further enquiry as new research questions, technologies, and priorities emerge (e.g. Krause and Farina 2016).

At the community level, summarising acoustic data can be achieved by generating *acoustic indices* from soundscape recordings, providing an indication of species richness at a given site, as well as seasonal and daily activity patterns (Sueur et al. 2014, Fuller et al. 2015). These indices can be particularly powerful for addressing questions about species richness and diversity patterns across ecological and disturbance gradients including elevation, urbanisation and fire, as well as changes in the landscape over time (Depraetere et al. 2012, Pieretti and Farina 2013, Burivalova et al. 2017, Jorge et al. 2018). More recently, acoustic indices have been used as a way to document soundscapes in a broader sense, by summarising inherent characteristics of habitats and the components that comprise the soundscape (e.g. Towsey et al. 2014, Bradfer-Lawrence et al. 2019). More than 60 different soundscape indices have been developed, each representing a different component of a soundscape (Sueur et al. 2014, Bradfer-Lawrence et al. 2019). In particular, three indices, Acoustic Complexity Index (ACI; Pieretti et al. 2011), Acoustic Diversity Index (ADI; Villanueva-Rivera et al. 2011), and Number of Frequency Peaks (NP; Gasc et al. 2013), have been demonstrated in multiple studies to represent known species richness patterns across different ecological gradients and also to diagnostically classify soundscapes based on habitat type (Sueur et al. 2008a, Pieretti et al. 2015, Mammides et al. 2017, Nielsen 2018). For each index, higher values are associated with greater species richness of vocal animals and lower values for fewer species and more sounds driven by non-biological sources (e.g. wind, rain). In this study, we explore whether these patterns hold across a disturbance gradient from a recent fire within the Otway Ranges, Victoria.

During the summer of 2015–16, dry conditions led to a series of lightning strikes and spot fires within the Otways, centred on Wye River to the south and Separation Creek to the north (IGEM 2016). By the time the fire was fully contained on 21 January 2016, a total of 2500 hectares had burned to varying degrees across the area. As part of the Museums Victoria–Parks Victoria Otway Bioscan, in 2018–2019 we undertook a pilot project to explore differences in the acoustic activity of burnt and unburnt sites across the Otway Ranges by summarising soundscapes using three different acoustic indices, ACI, ADI and NP. Considering the reduction in vegetative structure within burnt sites, we predicted less activity of vocal animals and increased non-biological sounds (e.g. wind) in burnt sites compared with unburnt sites, resulting in overall lower index values. Given that wildlife communities were also likely to differ in species composition, we also predicted diagnostically different daily patterns between burnt and unburnt sites.

Methods

Survey sites

We selected four sites (Kennett River, Grey River, Wye River and Cumberland River), each consisting of two survey points a minimum of 50 metres apart to minimise the likelihood the same vocalising individuals would be detected by two different recorders (Fig. 1, Darras et al. 2018). Surveys were conducted during summer (two sites, four survey points) and autumn (two sites, four survey points) in areas burned in 2015 (summer only) and in unburnt sites (summer and autumn).

Figure 1. Map of Otway Bioscan audio survey sites in relation to the 2015 Wye River fire. Sites (Kennett River, Grey River, Wye River and Cumberland River) each consist of two survey points (OTWSM01–08). Audio surveys were conducted in summer (square) or autumn (circle) in burnt (red) or unburnt (green) habitats.

Audio recordings

We used four different automated digital field audio recorders (Bioacoustic Audio Recorder, Frontier Labs) fitted with a single omnidirectional microphone to record ambient sounds between 10–22,000 hertz. At each survey point, a single recorder was attached to a tree with a lashing strap at approximately chest height with the microphone pointing downward (Fig. 2). GPS coordinates (WGS 84) were recorded, as well as general habitat information, at each survey point (forest type, burn status; Table 1). Each recorder was programmed to record for 10 minutes every 20 minutes throughout the day and all files were saved as 16-bit.wav files. Recorders were collected after a minimum of two weeks in the field. All audio files have been archived at Museums Victoria and will be made publically available online through Museums Victoria's online collections (https://collections.museumvictoria.com.au/).

Table 1. Survey points and site information

Site id	General locality	Specific location	Latitude (°S)	Longitude (°E)	Elevation (m)	General habitat description	Burn category	Surveyed season
OTWSM01	Wye River	0.7 km W junction Morley Ave and Sturt Ct	38.63978	143.88268	149	burnt forest, adjacent to power line easement	burnt	summer
OTWSM02	Kennett River	powerline track 1.5 km WSW junction Grey River Rd and Hawdon Ave	38.67467	143.84622	180	unburnt cleared land	unburnt	summer
OTWSM03	Wye River	0.6 km W junction Morley Ave and Sturt Ct	38.63958	143.88419	142	burnt forest, adjacent to power line easement	burnt	summer
OTWSM04	Kennett River	powerline track 1.5 km WSW junction Grey River Rd and Hawdon Ave	38.67438	143.84573	179	unburnt, cleared land	unburnt	summer
OTWSM05	Grey River	4.1 km WNW junction Hawdon Ave and Grey River Rd	38.65934	143.8147	248	wet forest with tree ferns	unburnt	autumn
OTWSM06	Cumberland River	0.6 km NNW junction Cumberland Track and Great Ocean Road	38.56977	143.94611	44	open, tall forest	unburnt	autumn
OTWSM07	Grey River	Grey River Picnic Area	38.65957	143.81604	249	wet forest with tree ferns	unburnt	autumn
OTWSM08	Cumberland River	0.6 km NNW junction Cumberland River and Great Ocean Road	38.57019	143.94629	39	open woodland with tall eucalypts, and understory species	unburnt	autumn

Figure 2. Bioacoustic audio recorder deployed at Cumberland River (OTWSM06) to capture environmental sounds. Photographer: Rodney Start | Source: Museums Victoria.

Acoustic analysis

All audio data files were processed and analysed by Museums Victoria. Three different acoustic diversity indices were calculated (Acoustic Complexity Index (ACI), Number of Frequency Peaks (NP), and Acoustic Diversity Index (ADI)) using the R programming language (v. 3.4.3, R Core Team 2019) and the 'seewave' (v. 1.6.7, Sueur et al. 2008b) and 'tuneR' (v. 1.3.2, Ligges et al. 2018) packages. For all recordings, we restricted our soundscape analyses to only include only those sounds between 100–10,000 hertz to target the frequency range of most vocalising animals (including birds and frogs) and to minimise the influence of low frequency noise on index values (sounds below 100 Hz are primarily human-based). We calculated an index value for each 10 minute recording and then calculated a single value for each day of recording, represented by the 95th percentile value, which captures a maximum index value while minimising the impact of outlier values. These daily index values were used in subsequent statistical analyses. As only unburnt sites were surveyed in autumn, we present values from the autumn surveys but restricted our statistical analyses to only include summer surveys.

Statistical analyses

We tested for an effect of burn history (burnt or unburnt) on each acoustic index using a linear mixed effects model using the 'lme4' package (v. 1.1-13, Bates et al. 2015) in R. To account for a possible random effect of survey points and sites on index values, we compared the burn history model with an alternative model that also included survey points nested within sites as a random effect. Alternative models (including an intercept only model) were compared using ANOVA and models with delta (Δ) AICc values greater than 4 were retained as the top model(s) to evaluate statistical significance (Burnham and Anderson 2004). Significance of fixed effect terms (burn category) were tested using Chi-square tests. To compare differences in index values between seasons (unburnt sites only) we used the Welsh independent t-test. All values are presented as means ± 95% confidence intervals.

Results

A total of 1124 hours of recordings were collected across the eight survey points, with an average of 140 hours per site (Table 2). For four sites (OTWSM03, 05, 07, and 08) the recorders failed to record the full 14 days due to battery power loss.

The results of our mixed models indicated there were significant differences in index values between burnt and unburnt sites for two acoustic indices — NP and ADI (Fig. 3). For both indices, the top model included only burn history (Table 3). For both NP and ADI, index values were significantly lower in the burnt site than in the unburnt site (NP: burnt = 11.4, 9.6–13.1 95% CI, unburnt = 24.3, 22.7–25.9 95% CI, $X^2 = 63.01$, $p < 0.0001$; ADI: burnt = 1.63, 1.47–1.81 95% CI, unburnt = 1.97, 1.88–2.05 95% CI, $X^2 = 11.30$, $p = 0.0007$). There were no overall differences between burnt and unburnt sites for ACI (66.4, 65.0–67.7 95% CI vs. 67.4, 66.6–68.2 95% CI, $X^2 = 1.75$, $p = 0.19$). However, daily patterns in acoustic index values for all three indices differed between unburnt and burnt sites (Fig. 4).

Index values were similar in summer and autumn for all three indices (NP: summer = 24.3, autumn = 24.4, $t = 0.056$, $p = 0.96$; ACI: summer = 67.4, autumn = 68.8, $t = 1.50$, $p = 0.14$; ADI: summer = 1.97, autumn = 1.99, $t = 0.40$, $p = 0.69$).

Table 2. Acoustic survey information

Site id	Survey start date	Survey duration (days)	No. of recordings	Recording duration (hrs)
OTWSM01	28-Nov-18	14	910	151.5
OTWSM02	27-Nov-18	14	888	148.0
OTWSM03	28-Nov-18	13	904	149.7
OTWSM04	27-Nov-18	14	910	151.2
OTWSM05	04-Mar-19	13	889	147.9
OTWSM06	05-Mar-19	20	1358	226.0
OTWSM07	04-Mar-19	6	321	53.4
OTWSM08	05-Mar-19	9	578	96.2

Above: Flame Robin, *Petroica phoenicea*. Photographer: Heath Warwick | Source: Museums Victoria.

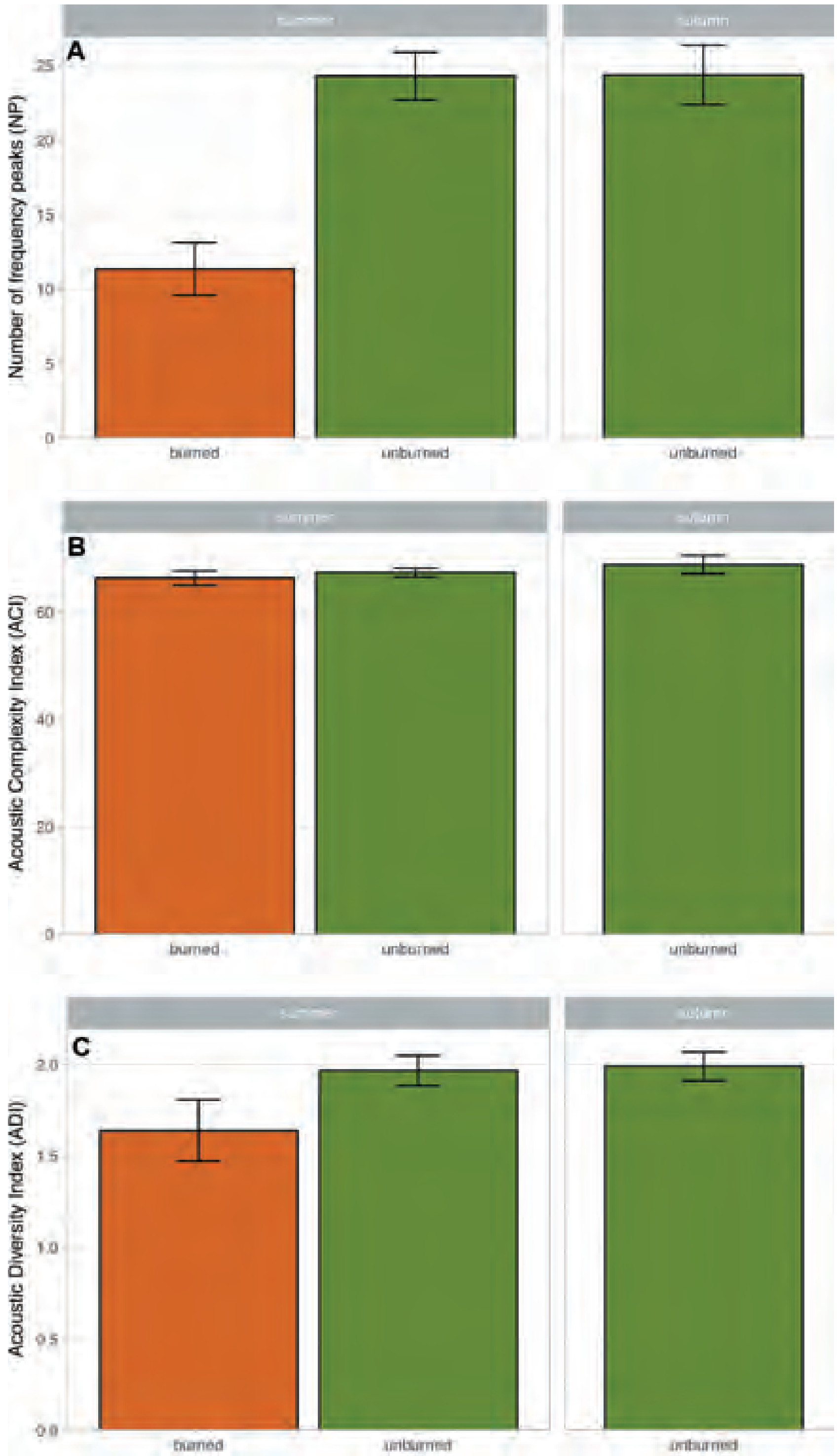


Figure 3. Differences in acoustic index values (**A:** number of frequency peaks, **B:** acoustic complexity index, **C:** acoustic diversity index) between burnt (orange) and unburnt (green) sites in summer and autumn (unburnt sites only). Height of bar represents average daily 95th percentile value ± 95% confidence intervals.

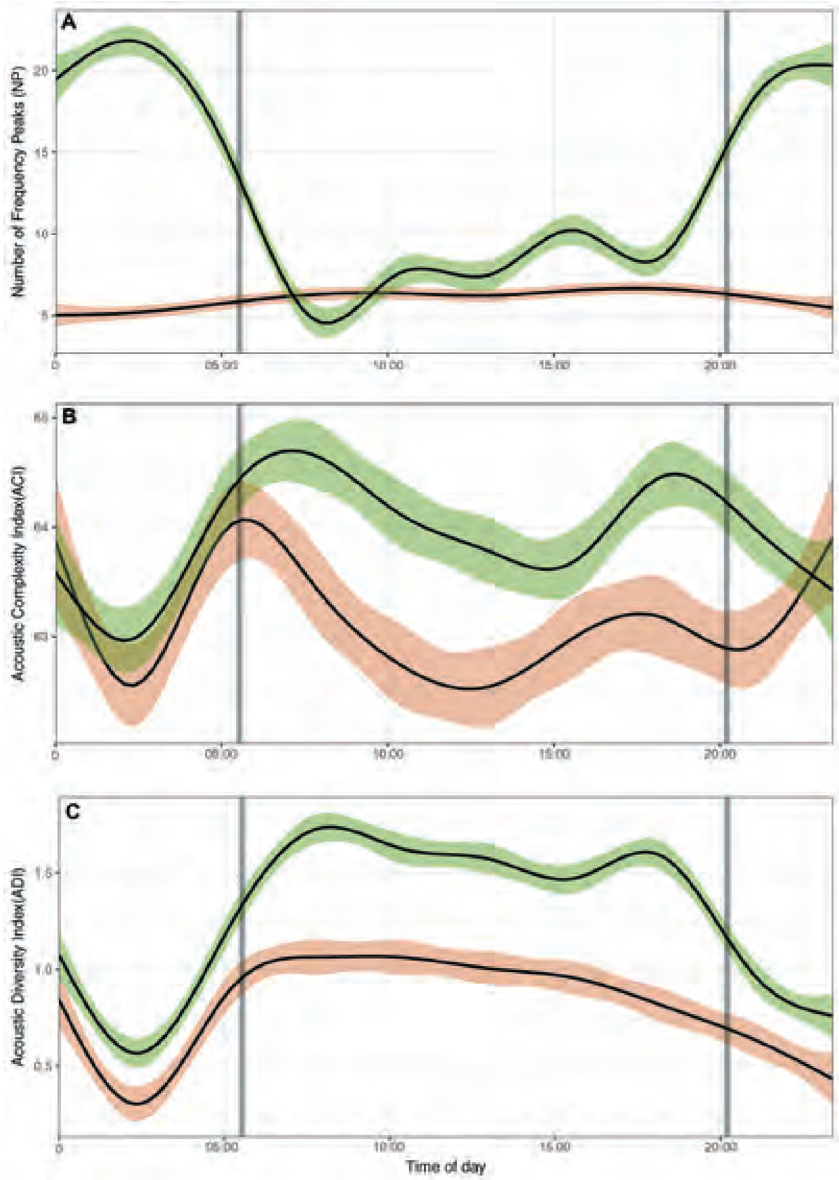


Figure 4. Variation in acoustic index values (**A:** number of frequency peaks, **B:** acoustic complexity index, **C:** acoustic diversity index) throughout the day between burnt (orange) and unburnt (green) sites from summer surveys only. Lines represent smoothed 95th percentile values averaged across days within time periods (10-min. recordings) ± 95% confidence intervals.

DID YOU KNOW?

Acoustic recorders are becoming an important tool for monitoring vocally active species such as frogs and birds partly due to the development of small and inexpensive recording devices.

Right: Gang-gang Cockatoo, *Callocephalon fimbriatum*. Photographer: Wayne Longmore | Source: Museums Victoria.

Table 3. Results of Akaike Information Criterion (AIC) model selection for the three acoustic indices (Number of Frequency Peaks, NP; Acoustic Complexity Index, ACI; and Acoustic Diversity Index (ADI)). Bolded models indicate the top models in the study (Δ AICc < 4) and significance of the effect of burn category on index values. See text for details of methods and model selection.

Acoustic index	Model	AICc	Δ AICc	Weight	Chi-square	P value
NP	**burn**	**325.5**	**0.0**	**0.9**	**63.01**	**< 0.0001**
	burn + survey | site	329.5	4.0	0.1	0.00	1
	intercept	386.5	61.0	0.0		
ACI	**intercept**	**278.4**	**0.0**	**0.5**		
	burn	**278.6**	**0.3**	**0.4**	**1.75**	**0.19**
	burn + survey | site	282.6	4.2	0.1	0.07	0.96
ADI	**burn**	**44.3**	**0.0**	**0.9**	**11.30**	**< 0.001**
	burn + survey | site	48.3	4.0	0.1	0.00	1
	intercept	53.5	9.3	0.0		

Discussion

Acoustic indices calculated from audio recordings were able to capture marked differences between unburnt and burnt sites within the Otway Ranges, even with a small sample size. Of the three indices tested in this study, number of frequency peaks (NP) and acoustic diversity index (ADI) were consistently and significantly lower in burnt sites than in unburnt sites. In particular, NP was markedly reduced overall and daily patterns of acoustic activity were suppressed in burnt habitats. Combined, these results suggest acoustic indices have the potential to capture unique and diagnosable soundscape differences across a fire-affected landscape.

Index values between summer and autumn were consistent among unburnt sites from different locations, suggesting a persistence of unburnt habitat soundscapes through time. Although burnt habitats were not surveyed in autumn in this study, this result for unburnt habitats suggests acoustic indices may be capable of capturing unique and consistent differences between burnt and unburnt habitats that could potentially be used to classify habitats based on fire history as well as tracking habitats as they recover. Surveys across seasons in burnt and unburnt habitats, as well as in habitats experiencing different fire severities could illustrate whether this pattern holds.

Exploring spectrograms of the collected recordings revealed fewer 'unique' sounds in burnt habitats, suggesting acoustic index values may reflect species richness within sites for this study. This anecdotal evidence warrants further exploration of the audio data in order to identify which species are present in each habitat, confirming whether acoustic index values are correlated with species richness for this area. If this is the case, acoustic indices could be used as a non-invasive and rapid method to estimate bird diversity, in lieu of repeated on-the-ground surveys (Sueur et al. 2014). This approach could be particularly useful as a means of tracking changes in diversity over time as habitats revegetate and species assemblages shift.

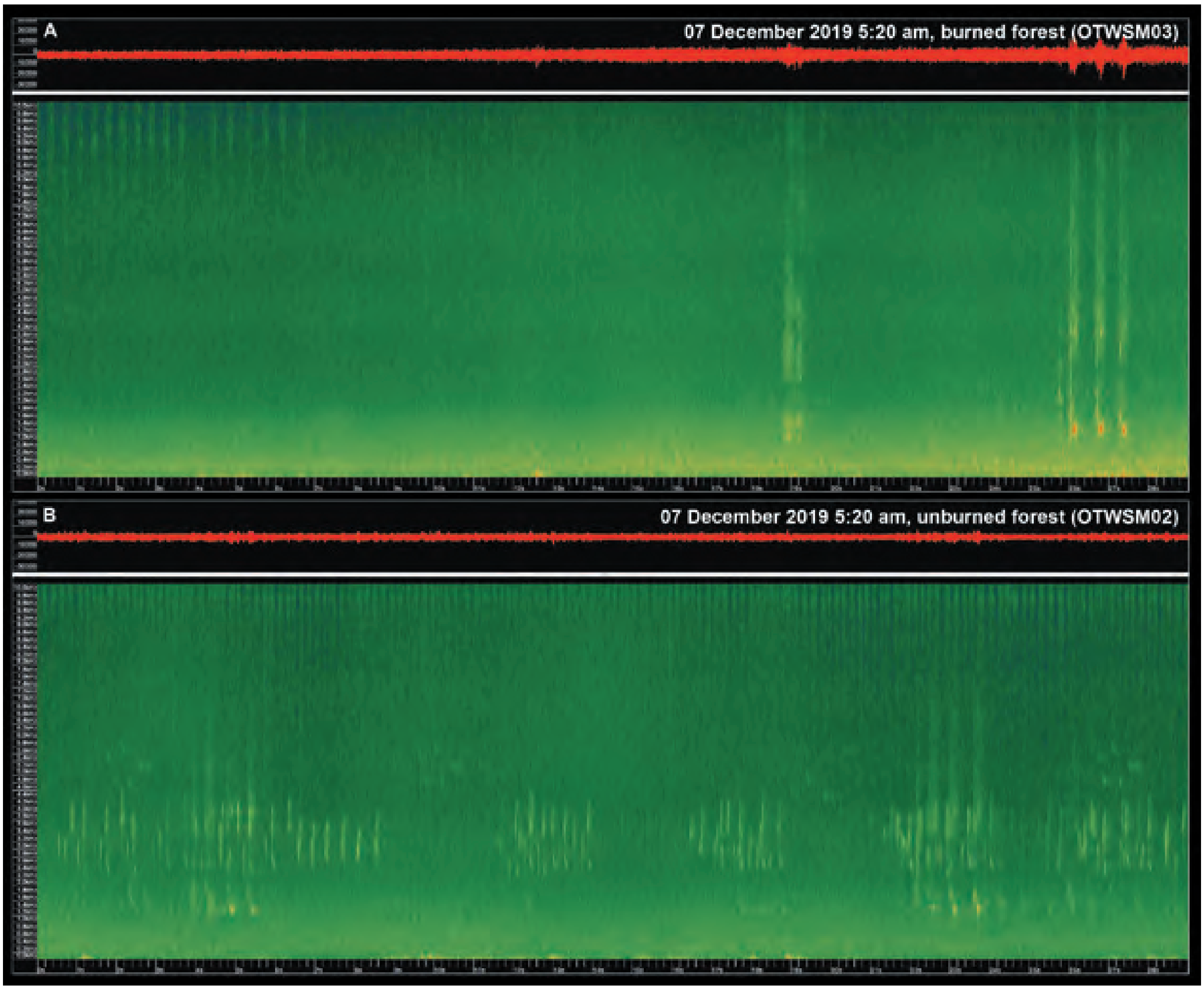


Figure 5. Spectrograms of audio clips collected on 7 December 2019 at 5:20 am from (**A**) OTWSM03 (burnt) and (**B**) OTWSM02 (unburnt) sites.

In addition to the detection of fewer species in the spectrograms from burnt sites, we also noted more non-biological sounds associated with wind, dominating the lower frequencies (< 1000 Hz). Higher intensity low frequency sounds are more common in open and anthropogenic habitats (e.g. Fuller et al. 2015, Turgeon et al. 2017) and acoustic indices that capture this effect (e.g. NP) could be useful as a means of identifying the impacts of burnt habitats. However, low frequency 'noise' may be masking the calls of species that occupy lower frequencies, for instance nocturnal birds (e.g. owls), which could bias estimates of species richness from the acoustic index values. Further work exploring the presence of wildlife sounds within these lower frequencies would help to address this potential bias and should be taken into consideration when evaluating the relationship between acoustic index and species richness values.

In this study we focused on frequencies that were likely to detect birds and frogs (100–10,000 Hz) and restricted our analyses to this frequency range. Other species of animals, for example insects, often vocalise outside this range (>10,000 Hz), specific animal groups may vocalise within narrower frequency ranges (e.g. frogs), and some birds call at very low frequencies (less than 100 Hz). In this case, complimentary analyses including only the frequency range of species or groups of species of interest could provide more information on their presence between burnt and unburnt sites.

Above left: Laughing Kookaburra, *Dacelo novaeguineae*. Photographer: Heath Warwick | Source: Museums Victoria. **Above right:** Sulphur-crested Cockatoo, *Cacatua galerita*. Photographer: Heath Warwick | Source: Museums Victoria.

Future work and recommendations

Initial results from this study suggest acoustic indices calculated from soundscapes could provide novel insight into the health and status of habitats across the Otway Ranges region. Future work should focus on acoustic survey data collection to confirm these initial findings, including a greater number of survey sites and across a larger gradient of fire severities. Repeated surveys that span seasons would also be useful to determine more detailed differences between burnt and unburnt sites, for example to see whether the differences in dawn choruses are found only in summer or throughout the year.

One of the most important outcomes of acoustic surveys is that recordings can be further interrogated to determine which species differ between sites and can be referred to as a benchmark at a later date to compare how the sites change over time. In this case, we recommend the accessioning of future audio survey recordings continue to be deposited in a publically available and online accessible database (e.g. Museums Victoria's Online Collections, Atlas of Living Australia) as new methods and research questions emerge.

Acknowledgements

Field data collection was carried out by Karen Rowe, Mark Nikolic, Nish Nizar and Genefor Walker-Smith, with additional field assistance from Rodney Start and Heath Warwick (Museums Victoria). Advice on research focus was provided by Katrina Lovett and Jani Demetrious (Parks Victoria).

This research was carried out under DELWP National Parks Act Research Permit number 10008862.

References

Bates, D., Maechler, M., Bolker, B., and Walker, S. 2015. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software* 67(1): 1–48. doi:10.18637/jss.v067.i01.

Bradfer-Lawrence, T., Gardner, N., Bunnefeld, L., Bunnefeld, N., Willis, S.G., and Dent, D.H. 2019. Guidelines for the use of acoustic indices in environmental research. *Methods in Ecology and Evolution*, 2019(June): 2041–210X.13254. https://doi.org/10.1111/2041-210X.13254

Brandes, T.S. 2008. Automated sound recording and analysis techniques for bird surveys and conservation. *Bird Conservation International* 18(S1): S163–S173. https://doi.org/10.1017/S0959270908000415

Burivalova, Z., Towsey, M., Boucher, T., Truskinger, A., Apelis, C., Roe, P., and Game, E.T. 2017. Using soundscapes to detect variable degrees of human influence on tropical forests in Papua New Guinea. *Conservation Biology* (online), pp. 1–29. https://doi.org/10.1111/cobi.12968

Burnham, K.P., and Anderson, D.R. 2004. Multimodel inference: understanding AIC and BIC in model selection. *Sociological Methods and Research* 33: 261–304.

Darras, K., Furnas, B., Fitriawan, I., Mulyani, Y., and Tscharntke, T. 2018. Estimating bird detection distances in sound recordings for standardizing detection ranges and distance sampling. *Methods in Ecology and Evolution* 9(9): 1928–1938. https://doi.org/10.1111/2041-210X.13031

Depraetere, M., Pavoine, S., Jiguet, F., Gasc, A., Duvail, S., and Sueur, J. 2012. Monitoring animal diversity using acoustic indices: Implementation in a temperate woodland. *Ecological Indicators* 13(1): 46–54. https://doi.org/10.1016/j.ecolind.2011.05.006

Fuller, S., Axel, A.C., Tucker, D., and Gage, S.H. 2015. Connecting soundscape to landscape: Which acoustic index best describes landscape configuration? *Ecological Indicators* 58: 207–215. https://doi.org/10.1016/j.ecolind.2015.05.057

Furnas, B.J., and Callas, R.L. 2014. Using automated recorders and occupancy models to monitor common forest birds across a large geographic region. *The Journal of Wildlife Management* 79(2): 325–337. https://doi.org/10.1002/jwmg.821

Gasc, A., Sueur, J., Pavoine, S., Pellens, R., and Grandcolas, P. 2013. Biodiversity sampling using a global acoustic approach: contrasting Sites with microendemics in New Caledonia. *PLoS ONE* 8(5): e65311. https://doi.org/10.1371/journal.pone.0065311

IGEM. 2016. Inspector-General for Emergency Management Department of Justice and Regulation. *Review of the initial response to the 2015 Wye River–Jamieson Track fire*. Victorian Government, Melbourne, Victoria. 51 pp.

Jorge, F.C., Machado, C.G., da Cunha Nogueira, S.S., and Nogueira-Filho, S.L.G. 2018. The effectiveness of acoustic indices for forest monitoring in Atlantic rainforest fragments. *Ecological Indicators* 91: 71–76. https://doi.org/10.1016/j.ecolind.2018.04.001

Krause, B., and Farina, A. 2016. Using ecoacoustic methods to survey the impacts of climate change on biodiversity. *Biological Conservation* 195: 245–254. https://doi.org/10.1016/j.biocon.2016.01.013

Laiolo, P. 2010. The emerging significance of bioacoustics in animal species conservation. *Biological Conservation* 143: 1635–1645.

Ligges, U., Krey, S., Mersmann, O., and Schnackenberg, S. 2018. tuneR: Analysis of Music and Speech. URL: https://CRAN.R-project.org/package=tuneR

Mammides, C., Goodale, E., Dayananda, S.K., Kang, L., and Chen, J. 2017. Do acoustic indices correlate with bird diversity? Insights from two biodiverse regions in Yunnan Province, south China. *Ecological Indicators* 82: 470–477. https://doi.org/10.1016/j.ecolind.2017.07.017

Nielsen, S. 2018. *Acoustic indices as rapid assessments of avian species richness under natural field conditions in a biodiversity hotspot.* University of Melbourne, MSc Thesis. 55 pp.

Pieretti, N., Duarte, M.H.L., Sousa-Lima, R.S., Rodrigues, M., Young, R.J., and Farina, A. 2015. Determining temporal sampling schemes for passive acoustic studies in different tropical ecosystems. *Tropical Conservation Science* 8(1): 215–234.

Pieretti, N., and Farina, A. 2013. Application of a recently introduced index for acoustic complexity to an avian soundscape with traffic noise. *The Journal of the Acoustical Society of America* 134(1): 891–900. https://doi.org/10.1121/1.4807812

Pieretti, N., Farina, A., and Morri, D. 2011. A new methodology to infer the singing activity of an avian community: The Acoustic Complexity Index (ACI). *Ecological Indicators* 11(3): 868–873. https://doi.org/10.1016/j.ecolind.2010.11.005

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.URL https://www.R-project.org/.

Sueur, J., Aubin, T., and Simonis, C. 2008a. seewave: a free modular tool for sound analysis and synthesis. *Bioacoustics* 18: 213–226.

Sueur, J., Pavoine, S., Hamerlynck, O., and Duvail, S. 2008b. Rapid Acoustic Survey for Biodiversity Appraisal. *PLoS ONE* 3(12): e4065. https://doi.org/10.1371/journal.pone.0004065

Sueur, J., and Farina, A. 2015. Ecoacoustics: the Ecological Investigation and Interpretation of Environmental Sound. *Biosemiotics* 8(3): 493–502. https://doi.org/10.1007/s12304-015-9248-x

Sueur, J., Farina, A., Gasc, A., Pieretti, N., and Pavoine, S. 2014. Acoustic indices for biodiversity assessment and landscape investigation. *Acta Acustica United with Acustica* 100(4): 772–781. https://doi.org/10.3813/AAA.918757

Towsey, M., Zhang, L., Cottman-Fields, M., Wimmer, J., Zhang, J., and Roe, P. 2014. Visualization of long-duration acoustic recordings of the environment. *Procedia Computer Science* 29(Krause 2008): 703–712. https://doi.org/10.1016/j.procs.2014.05.063

Turgeon, P J., Wilgenburg, S.L. Van, and Drake, K.L. 2017. Microphone variability and degradation: implications for monitoring programs employing autonomous recording units. *Avian Conservation and Ecology* 12(1): 9. https://doi.org/10.5751/ACE-00958-120109

Villanueva-Rivera, L.J., Pijanowski, B.C., Doucette, J., and Pekin, B. 2011. A primer of acoustic analysis for landscape ecologists. *Landscape Ecology* 26(9): 1233–1246. https://doi.org/10.1007/s10980-011-9636-9

02 FRESHWATER FISHES

Report Author: Martin Gomon
Survey Team: Martin Gomon, Dianne Bray, Rudie Kuiter, Matthew McGee and Kieran Lieutier (PV)

Introduction

Aquatic environments within and adjacent to the Great Otway National Park range from clear upland springs and runoff driven tributaries to fully marine coastal environments that are subject to strong hydrographic conditions and climatic influences. Fishes occurring in coastal and estuarine waters are in general, wider-ranging and much better known than freshwater species, which are often isolated, having far fewer interconnected populations.

During the Otway Bioscan fish collection efforts were confined to the tributaries on the southern side of the Otway Range. Freshwater discontinuities on the south-eastern part of the range are attributable to the coastal flowing nature of creeks and streams, which exhibit little lateral cross over. Studies such as those by Raadik (2014) have demonstrated that coastal drainages have a greater likelihood of supporting short-range endemics than the more widely interconnected inland systems.

Historical efforts to document the freshwater fish species found in this part of the park are reflected in material lodged in the Museums Victoria fish collection, which contains 158 registered freshwater specimen lots from the area between Wongara and Aireys Inlet. These collections contain five native species and one introduced species. The native species are the Southern Shortfin Eel, *Anguilla australis* Richardson, 1841, the Climbing Galaxias, *Galaxias brevipinnis* Günther, 1866, the Common Galaxias, *Galaxias maculatus* (Jenyns, 1842), the Trout Galaxias, *Galaxias truttaceus* Valenciennes, 1846 and the Congolli, *Pseudaphritis urvillii* (Valenciennes, 1832), while the introduced species is the Brown Trout, *Salmo trutta* Linnaeus, 1758.

Methods

Six freshwater drainages on the southern slopes of the Otway ranges (Cumberland River, Erskine River, Grey River, Jamieson River, Little Sheoak Creek and St George River) were surveyed during a seven-day period (18–24 November 2018) using hand nets, seine nets and bait traps (Table 1). Where possible, each drainage was ascended from near the coast toward the headwaters, periodically sampling along the way. Only the St George River was sufficiently broad and deep to prevent direct access in its lower reaches, necessitating reliance on bait traps. The Erskine River was sampled above and below the falls.

Table 1. Sites sampled during the Otway Bioscan.

Otway drainage	Event code	Date sampled	Precise locality	Latitude (°S)	Longitude (°E)	Elevation (m)
Cumberland River	OTB 2018 142	20/11/2018	just above Sheoak Picnic Ground at end of trail off Garvie Track	38.5652	143.9311	115
Cumberland River	OTB 2018 143	20/11/2018	at boulder river crossing near end of walking trail off Garvie Track (track begins ~2 km above Sheoak Picnic Ground)	38.5675	143.9311	186
Grey River	OTB 2018 140	19/11/2018	upstream from picnic ground on Grey River Rd, from bridge to ~200 m upstream	38.6586	143.8136	257
Grey River	OTB 2018 141	19/11/2018	upstream from picnic ground on Grey River Rd, from bridge to ~200 m upstream	38.6586	143.8136	257
Jamieson River	OTB 2018 144	21/11/2018	~30 m stretch sampled upstream and downstream of first crossing on walking trail from campground on Great Ocean Road	38.5958	143.9167	25
Jamieson River	OTB 2018 145	21/11/2018	pool ~15 m upstream first crossing on walking track from campground on Great Ocean Road	38.5958	143.9167	25
Jamieson River	OTB 2018 148	23/11/2018	pool ~15 m upstream from first crossing on walking track from campground on Great Ocean Road	38.5958	143.9167	25
Little Sheoak Creek	OTB 2018 147	23/11/2018	just downstream of large pool with large cave/rock overhang	38.5622	143.9167	232
St George River	OTB 2018 149	23/11/2018	very large pool just upstream of bridge on Great Ocean Road	38.5539	143.9761	10

Climbing Galaxias, *Galaxias brevipinnis*. Photographer: Rudie Kuiter, Aquatic Photographics | Source: Museums Victoria.

Results

Four fish species were collected during the Bioscan: the Southern Shortfin Eel, *Anguilla australis*, the Climbing Galaxias, *Galaxias brevipinnis*, the Common Galaxias, *Galaxias maculatus* and the Trout Galaxias, *Galaxias truttaceus*. A fifth species, tentatively identified as the exotic Brown Trout, *Salmo trutta*, was observed in the Grey River but not collected. All three Galaxias species were found in the Jamieson River and no fish were collected from the Erskine River. Table 2 shows the number and species of fish found at each site.

Discussion

The three *Galaxias* species are the dominant fishes in these systems and share a similar trophic niche. The Climbing Galaxias was easily the most abundant, occurring in every stream where fish were caught, no doubt due to its ability to overcome obstacles, like extreme shallows and waterfalls, climbing over obstructions with the aid of their specialised pectoral fins.

Table 2. The number of fish collected during the Otway Bioscan.

		Fish species					
Otway drainage	**Event code**	Southern Shortfin Eel *Anguilla australis*	Climbing Galaxias *Galaxias brevipinnis*	Common Galaxias *Galaxias maculatus*	Trout Galaxias *Galaxias truttaceus*	Brown Trout *Salmo trutta*	**Total no. of fish**
Cumberland River	OTB 2018 142	-	3	-	-	-	3
Cumberland River	OTB 2018 143	1	-	-	-	-	1
Erskine River	N/A	-	-	-	-	-	0
Grey River	OTB 2018 140	-	5	-	-	1*	6**
Grey River	OTB 2018 141	-	3	-	-	-	3
Jamieson River	OTB 2018 144	-	5	1	3	-	9
Jamieson River	OTB 2018 145	-	10	-	-	-	10
Jamieson River	OTB 2018 148	-	-	1	3	-	4
Little Sheoak Creek	OTB 2018 147	-	3	-	-	-	3
St George River	OTB 2018 149	2	-	-	-	-	2
TOTAL no. fish collected →		3	29	2	6	1*	41**

*Observational record, no fish collected; **Includes one fish not collected

Southern Shortfin Eel, *Anguilla australis*. Photographer: David Paul | Source Museums: Victoria.

All native species found in this survey have broad geographical distributions and marine stages in their life cycle. Fishes that live part of their life in freshwater, and another part of their life in saltwater are termed diadromous and there are about 33 species of diadromous fishes in Australia (Miles et al. 2014). The Common Galaxias (*Galaxias maculatus*), the Southern Shortfin Eel (*Anguilla australis*) and the Congolli (*Pseudaphritis urvillii*) spend most of their life in freshwater but migrate to estuaries or the sea to breed. The Climbing Galaxias (*Galaxias brevipinnis*) and the Trout Galaxias (*Galaxias truttaceus*) migrate between freshwater and seawater, but not for the purpose of reproducing. The larvae hatch from eggs laid in freshwater and are carried out to sea soon after where they feed and grow in the marine waters for up to six months before returning to the freshwaters where they continue to feed, become adults and reproduce. One consequence of these native fishes having a marine stage in their life cycle is that their populations are refreshed via marine early stage recruits. This provides them with a means to re-populate rivers. If the species is reduced or eliminated from one river due to a temporary disturbance or pollution event, it is possible for the species to return to that river from the sea. This process provides these diadromous species with some resilience in the face of short term river impacts, unlike obligate freshwater species.

Top: Common Galaxias, *Galaxias maculatus.*
Bottom: Spotted Galaxias, *Galaxias truttaceus*.
Photographer: Rudie Kuiter, Aquatic Photographics | Source: Museums Victoria.

Conclusion

Drainages sampled, apart from the lowermost reaches of the Saint George River, were seemingly little affected by human activities and numbers of individuals encountered implied reasonably healthy populations. These waters may never have contained obligate freshwater species but it is hard to be sure because of the paucity of records prior to the mid-1960s. Alternatively their absence may be due to the presence of trout, which are known to be extremely successful predators on native freshwater fauna. In other Victorian coastal-draining rivers trout are known to have caused the localised extinction of native fish species.

Acknowledgements

Rudie H. Kuiter provided invaluable assistance with the hand-net collection of fishes in shallow streams and creeks and the photography of fishes captured. Kieran Lieutier, Ranger, Parks Victoria, assisted with the choice of sampling sites and guided the team to remote areas of the park. Matthew McGee participated with hand-net collecting. Museums Victoria members of other teams provided insights to access of some of the rivers.

This work was carried out under Animal Care and Ethics permit no. MV AEC 16003 and Victorian Fisheries Authority Permit no. RP 1349.

References

Miles, N.G., Walsh, C.T., Butler, G., Ueda, H., and West, R. J. 2014. Australian diadromous fishes – challenges and solutions for understanding migrations in the 21st century. *Marine and Freshwater Research* 65: 12–24.

Raadik, T.A. 2014. Fifteen from one: a revision of the *Galaxias olidus* Günther, 1866 complex (Teleostei, Galaxiidae) in south-eastern Australia recognises three previously described taxa and describes 12 new species. *Zootaxa* 3898(1): 1–198.

03 FRESHWATER INSECTS

Survey team and report authors:
Richard Marchant and Julian Finn

Introduction

Several interesting groups of insects—the mayflies, stoneflies and caddisflies—spend their lives in two phases. During the longer early phase they live in freshwater and then emerge into the air for their adult phase to mate and disperse. Because they spend their young life in freshwater environments they are indicators of the health of rivers and streams and have been used as 'bio-indicators' as some species have been found to be more sensitive to environmental changes such as pollution and sedimentation than others. However it is often difficult to identify species. So an integral part of this survey was capturing high quality images for identification and doing the necessary work to connect the larval and adult phases of each species.

Between October 2018 and April 2019, we surveyed the aquatic insect communities at six river sites in the southern Otway Ranges (Table 1). The main aim was to make a preliminary assessment of aquatic insect biodiversity of the mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera).

A further aim was to determine whether the aquatic insects in the Wye River had been affected by a bushfire in December 2015, which burnt part of its catchment. This was achieved by comparing the community at Wye River with that at several other nearby sites, principally the Cumberland River.

During the 2000s one of us (RM) conducted monthly sampling at Cumberland River for two species of larval caddisfly, together with light trapping of adults during the warmer months. These samples provided larval specimens of many of the common aquatic insects, particularly those of the mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera). These groups are considered to be those most sensitive to the various man-made disturbances of running waters and collectively are called the EPT taxa (after the first letter of each order). Adult specimens of caddisflies had also been collected during the 2000s, but only the two species whose larvae had been surveyed were examined in any detail.

During the current work we concentrated on the adult EPT taxa, but also took larval samples at most sites. In the limited time available, identification of adults was considered the most efficient way of quickly acquiring knowledge of the EPT composition of these southern Otway streams. However, this is only a preliminary assessment of EPT diversity and a number of visits in different seasons over several years are needed before a comprehensive picture can emerge.

Methods

Adults

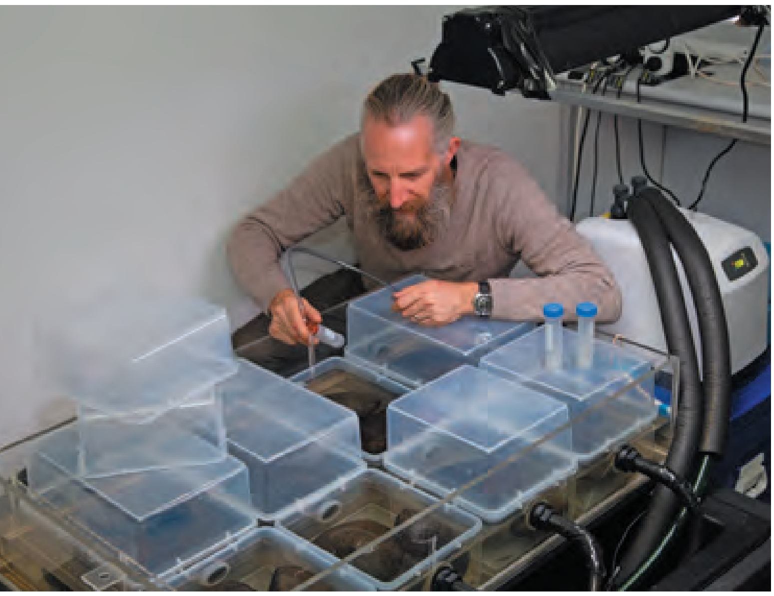
Two methods provided all of our records. During visits (between October 2018 and April 2019) photographs of adult insects that had emerged onto rocks in the river channel were taken using macrophotography during the day (Nikon D810 Digital SLR Camera, Nikon 105mm f/2.8G Micro-Nikkor Lens) (Fig. 1). After several photos had been taken of each specimen, the adult was captured using a pooter (Fig. 2) and preserved in 70% ethanol. This proved very productive during daylight and provided specimens from each of the EPT groups at nearly all sites; stonefly adults were not caught at the Kennett and St George rivers. Preserved specimens were identified using existing keys, under low magnification. Thus each photographed specimen could be examined in detail and in most cases this led to an identification. Many of the species we dealt with have rarely been photographed in the field before. Photos of identified specimens provided information about colour, wing patterns and size. Photos and specimens were registered in the museum's collection

Figure 1 (bottom). Julian Finn photographing live adult specimens at Wye River. A digital SLR camera, macro lens and lens-mounted close-up flashes were used to produce images of sufficient magnification and resolution to enable species identification.
Figure 2 (below). Julian Finn using a pooter to collect adult insects at Wye River. A pooter is a small suction device that allows an individual insect to be drawn through a bent glass tube into a collection vial, propelled by an inhaled breath of the collector.
Photographer: Rodney Start | Source: Museums Victoria.

database. During our last two visits to Cumberland River (Table 1) we also used UV lights at night to attract insects and were able to photograph several species (Fig. 3) that we had not observed during the day.

The second method of obtaining adults relied on specimens emerging from an indoor aquarium at the museum. Larvae collected in the field were kept in artificial streams where they could continue to feed and develop. Stream water was circulated continuously from a 250 litre reservoir to a clear tank (positioned above the reservoir) in which cobbles from Cumberland River were isolated in eight lidded containers (Fig. 4). Each container received a constant flow of water through mesh covered holes cut in the sides. Water temperature was maintained at 19°C. Fluorescent tubes illuminated the aquarium for 14 hours each day. Adults emerged into the air space between the water and the lid, from where they were removed and photographed using the same camera as used in the field. We collected cobbles with larvae attached on three occasions between October and March and each collection usually provided emerging adults (Fig. 5) for 4–6 weeks. In this way we were able to collect species we had not observed in the field, as well as more specimens of those that we had observed. The aquarium was checked almost every day for emerged adults and it provided us with many more specimens than we collected in the field. For Cumberland River we thus achieved a more comprehensive list of EPT species than we could at the other sites.

Figure 3 (above). Adult caddisfly *Plectronemia australica* (Polycentropodidae) in flight, attracted to UV light at night, Cumberland River, March 2019. Photographer: Julian Finn | Source: Museums Victoria.
Figure 4 (below). Julian Finn tending the aquarium at Melbourne Museum. The containers with cobbles from Cumberland River are sitting in a clear tank. Stream water is pumped to this tank from a reservoir positioned below; inlet hoses can be seen at the lower right. The white box on the far right cools the water in the reservoir. The timer-activated light above the aquarium maintains the natural daylight cycle. A pooter is being used to catch adults. Photographer: Rodney Start | Source: Museums Victoria.



Larvae

Larvae were sampled at three of the six sites: Kennett River and Wye River (October 2018); Grey River (March 2019). Data on larval EPT species was also available for Cumberland River from the work done by one of us (RM) during the 2000s. All samples were taken with a hand net (200-micron mesh) by disturbing the stream bed (either by hand or by foot) immediately upstream of the net and allowing the current to sweep specimens and other material into the net. The contents of the net were poured into white trays and live specimens picked out with pipettes or forceps for 30–40 minutes. The aim of this process was to remove several specimens of every species present, rather than to remove all individuals observed, thus giving a species list for each site. This process is termed live picking and results in collections consisting mostly of 'clean' specimens, rather than specimens buried in fine sediment and organic matter, which make picking and handling them very time consuming. Specimens were preserved in 70% ethanol and identified later under low magnification.

Figure 5. Adult mayfly *Austrophlebioides pusillus* (Leptophlebiidae) imago, emerging from sub-imago skin, Melbourne Museum aquarium, January 2019. Photographer: Julian Finn | Source: Museums Victoria.

Results

A total of 26 adult EPT species (Table 2) were recorded from the Cumberland River, more than at any other site (where 2–10 species were recorded). Undoubtedly, this reflects the higher number of visits to this site as well as the fact that extra species (6) were detected for this site from the aquarium, a source which was not available for the other sites. Several visits were made to Wye River and Grey River (Table 1), but only single visits to the remaining sites, thus explaining their low numbers of species. At least 2–3 species in each EPT group occurred at several sites. With further collecting this number would increase and many of the species would be found widely in the southern Otways. None of the species detected as adults are rare and all are generally widespread in south-east Australia. The specimens reported here as *Dinotoperla hirsuta* may be an undescribed species, but this has yet to be confirmed.

At Cumberland River most adults occurred over a number of visits (Table 3) suggesting long emergence periods for many species. Some taxa were not detected in the field but only from the aquarium e.g. *Oecetis complexa*, *Helicopsyche heacota*, *Hampa patona*, *Austrophlebioides pusillus*. This demonstrates the usefulness of raising live specimens in controlled conditions. At the very least it enabled us to record species we had not observed in the field. The UV lights on the last two trips generally revealed the same species as shown in Table 2 but included several taxa not seen during the day: *Ecnomus russelius*, *Aphilorheithrus stepheni*, *Notalina* sp. (female), *Paranyctiophylax* sp.

The species detected at the Wye River did not suggest that this river, whose catchment was burnt in 2015, was obviously disturbed. The species at the Wye River were a subset of those that occurred at the Cumberland River. However a number of those missing from the Wye River as adults were present as larvae (see below), suggesting that the difference in diversity was not as great as suggested by the data in Table 2 and that further collecting of adults would record many of these species.

The larval sampling (Table 4) showed rather similar communities of EPT species at each of the four sites examined. Again, more species (20) were found at the Cumberland River, but undoubtedly this resulted from the much greater sampling effort at this site compared with that at the other sites (where 14–17 species occurred). Not all the larval taxa were able to be identified to a named species. These uncertainties indicate that the larval taxonomy is still incomplete (those where codes are substituted for species names) or that the specimens collected were too small for a confident identification. As with the adults, all larval taxa are widespread in south-east Australia. The only

Table 1. Sites sampled in the southern Otways.

Site (River)	Latitude (°S)	Longitude (°E)	Elevation (m)	Dates sampled	Dates sampled	Dates sampled	Dates sampled	Dates sampled
Cumberland	38.57008	143.89641	10	24-Oct-18	18, 19, 20-Nov-18	12-Dec-18	02, 3, 4-Mar-19	27-Apr-19
Wye	38.63563	143.88652	9	25-Oct-18	19-Nov-18	3-Dec-18	4-Mar-19	
Grey	38.65926	143.81586	235	25-Oct-18		3-Dec-18	4-Mar-19	
Kennett	38.66748	143.85340	10	25-Oct-18				
St George	38.55285	143.97021	34	25-Oct-18				
Barham	38.75109	143.62054	53			3, 4-Dec-18		

The Grey River. Photographer: Nish Nizar | Source: Museums Victoria.

exception is *Eusthenia nothofagi* (a eustheniid stonefly found only at the Grey River) which is endemic to the Otway ranges. It is closely related to *E. venosa*, which is widely found in the rest of Victoria.

Photos of the adults of the different orders (Plates 1–7) show differences in colour, wing pattern, antennal length and size. These characteristics can be used to distinguish and identify live specimens in the field. The three orders themselves are readily distinguished by overall shape and size. At this stage it is premature to suggest that adult EPT can be reliably identified solely by photos. A much larger area of the Otways would need to be sampled before a comprehensive set of photos could be produced. However, our work shows a clear potential for rapid photo surveys of EPT diversity.

Discussion

The high diversity of EPT taxa at the Cumberland River and the fact that diversity was probably comparable at the other sites (if differences in sampling effort are accounted for) indicate water quality was unimpaired at any of the sites. The recent bushfire in the catchment of the Wye River had not obviously reduced diversity of EPT taxa. One of the consequences of fire in a catchment is that subsequent rain can wash fine sediment uncovered by the fire into the river. The upstream end of the reach examined on the Wye had indeed been burnt by the fire, but there was no indication of increased sedimentation on the river bed. The Wye River is narrower and has less discharge than the Cumberland (5 metres versus 10–12 metres), but like the Cumberland consists of pools and riffles. Thus, the same sorts of stream habitats are available and it is likely that further sampling of the Wye would reveal more of the EPT species recorded in the Cumberland.

The Victorian EPA has sampled stream and river sites throughout Victoria for freshwater macroinvertebrates. The EPA has a single sampling site in the southern Otways at Cumberland River, (near where we took our samples) which was sampled six times from 1990 to 2000. The EPA list of EPT species from this site is very similar to ours. We recorded nine of their 13 species of Trichoptera, four of their five species of Plecoptera and four of their seven species of Ephemeroptera. The EPA, however, did not record the trichopteran *T. palpata*, which we found abundantly as larvae (it was also abundant in the 2000s); nor the ephemeropteran *Ulmerophlebia* sp of which we recorded two species. Other discrepancies are probably the result of differences in taxonomic discrimination between the EPA and us.

Table 2. Adult EPT species identified from rivers in the southern Otway ranges.

Family	Species	St George	Cumberland	Wye	Kennett	Grey	Barham
Ephemeroptera taxa							
Baetidae	*Centroptilum* sp.		●				
	Offadens sp.		●				
Leptophlebiidae	*Atalophlebia albiterminata*		●	F			
	Austrophlebioides pusillus		●				
	Nousia fuscula	○	●	●	○	○	●
	Ulmerophlebia annulata		●	F			
	Ulmerophlebia pipinna					F	
Plecoptera taxa							
Eustheniidae	*Cosmioiperla kuna*		●	○		○	
Gripopterygidae	*Dinotoperla eucumbene*		●				
	Dinotoperla hirsuta.		●	●			●
	Illiesoperla mayi		●				●
	Riekoperla rugosa		●				●
Trichoptera taxa							
Atriplectidae	*Atriplectides dubius*		●				
Calamoceratidae	*Anisocentropus bicoloratus*		●				
Conoesucidae	*Hampa patona*	○	●		○		
Glossosomatidae	*Agapetus kimminsi*		●				
	Agapetus pontona			○			●
Helicopsychidae	*Helicopsyche heacota*		●				
Hydrobiosidae	*Apsilochorema gisbum*		●	○			
	Ulmerochorema membrum		●				
Hydropsychidae	*Asmicridea edwardsi*		●	●			
	Cheumatopsyche modica		F	●			
Hydroptilidae	sp.		F				
Leptoceridae	*Oecetis complexa*		●				
Philopotamidae	*Chimarra australica*		●	●	○		●
	Hydrobiosella gibbera					●	
Philoreithridae	*Kosrheithrus tillyardi*		●				
Polycentropodidae	*Plectrocnemia australica*		●				
Tasimiidae	*Tasimia palpata*		●				
Total number of species		**2**	**26**	**10**	**3**	**4**	**6**

● Male specimens collected and photographed
F Only female specimens collected and photographed
○ Specimens photographed, not collected

Table 3. Monthly occurrence of EPT taxa at Cumberland River plus occurrence in field or aquarium.

		2018			2019				Location	
Family	**Species**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Field**	**Aquarium**
Ephemeroptera taxa										
Baetidae	*Centroptilum* sp.				●					●
	Offadens sp.			●						●
Leptophlebiidae	*Atalophlebia albiterminata*						●		●	
	Austrophlebioides pusillus	◊	●	●	●	●	●			●
	Nousia fuscula	●	●	●	●		●	○	●	●
	Ulmerophlebia annulata			●			●	●	●	
Plecoptera taxa										
Eustheniidae	*Cosmioiperla kuna*			●					●	
Gripopterygidae	*Dinotoperla eucumbene*						●		●	
	Dinotoperla hirsuta.		●	●	●				●	●
	Illiesoperla mayi						●		●	
	Riekoperla rugosa		●						●	
Trichoptera taxa										
Atriplectidae	*Atriplectides dubius*						●		●	
Calamoceratidae	*Anisocentropus bicoloratus*		●				●		●	●
Conoesucidae	*Hampa patona*						●			●
Glossosomatidae	*Agapetus kimminsi*		◊				●		○	●
Helicopsychidae	*Helicopsyche heacota*		●	●	●					●
Hydrobiosidae	*Apsilochorema gisbum*						●	●	●	●
	Ulmerochorema membrum				●			F	F	●
Hydropsychidae	*Asmicridea edwardsi*						●		●	
	Cheumatopsyche modica		F		F				F	F
Hydroptilidae	sp.							F		F
Leptoceridae	*Oecetis complexa*		●	●	●	●				●
Philopotamidae	*Chimarra australica*	●	●	●			●		●	
Philoreithridae	*Kosrheithrus tillyardi*							●	●	
Polycentropodidae	*Plectrocnemia australica*						●		●	
Tasimiidae	*Tasimia palpata*	◊	●	●	●		●	●	●	●

● Male specimens collected and photographed
F Only female specimens collected and photographed
○ Specimens photographed, not collected
◊ Specimens collected, not photographed

Table 4. Larval EPT taxa identified at rivers in the Otways.

Family	Species	Cumberland	Wye	Kennett	Grey
Ephemeroptera taxa					
Baetidae	*Centroptilum* sp.				●
	Offadens hickmani	●	●	●	●
Caenidae	*Tasmanocoenis* sp.	●			
Leptophlebiidae	*Austrophlebiodes pusillus*	●	●	●	●
	Atalophlebia sp.		●	●	
	Atalophlebia albiterminata	●			●
	Ulmerophlebia annulata	●	●		●
	Nousia sp. AV1				●
Plecoptera taxa					
Eustheniidae	*Cosmioperla kuna*	●	●		
	Eusthenia nothofagi				●
Gripopterygidae	*Dinotoperla fontana*	●	●	●	
	Dinotoperla eucumbene				●
	Dinotoperla thwaitesi				●
	Illiesoperla mayi	●	●	●	
	Trinotoperla montana	●	●	●	
	Riekoperla rugosa	●	●		
Trichoptera taxa					
Calamoceratidae	*Anisocentropus bicoloratus*	●	●	●	
Conoesucidae	*Hampa patona*	●		●	
	Tamasia sp. AV1				●
Ecnomidae	*Ecnomus tillyardi*	●		●	
Glossosomatidae	*Agapetus* sp.	●	●	●	
Helicopsychidae	*Helicopsyche heacota*	●			●
Hydrobiosidae	*Taschorema complex*	●	●	●	
Hydropsychidae	*Asmicridea* sp.	●			●
	Cheumatopsyche sp.	●	●		
Hydroptilidae	*Orthotrichia aberrans*			●	
Leptoceridae	*Oecetis* sp.		●		
	Triplectides ciuskus			●	●
	Triplectides australis		●		
Philopotamidae	*Chimarra australica*	●	●		
Philorheithridae	*Aphilorheithrus* sp. AV3				●
Tasimiidae	*Tasimia palpata*	●	●	●	●
Total number of species		**20**	**17**	**14**	**15**

Plate 1. Mayflies (Ephemeroptera) from the southern Otway ranges. Body length in mm.
a. *Centroptilum* sp. (Baetidae), female, imago, NMV EPH35, 6.6 mm. **b.** *Offadens* sp. (Baetidae), female, imago, NMV EPH36, 4.9 mm. **c-d.** *Atalophlebia albiterminata* (Leptophlebiidae): c. male, sub-imago; d. male, imago, NMV EPH117, 10.0 mm. **e-h.** *Austrophlebioides pusillus* (Leptophlebiidae): e. male, sub-imago, NMV EPH66, 7.1 mm; f. male, imago, NMV EPH68, 9.1 mm; g. female, sub-imago, NMV EPH53, 8.5 mm; h. female, imago, NMV EPH65, 9.9 mm. Photographer: Julian Finn | Source: Museums Victoria.

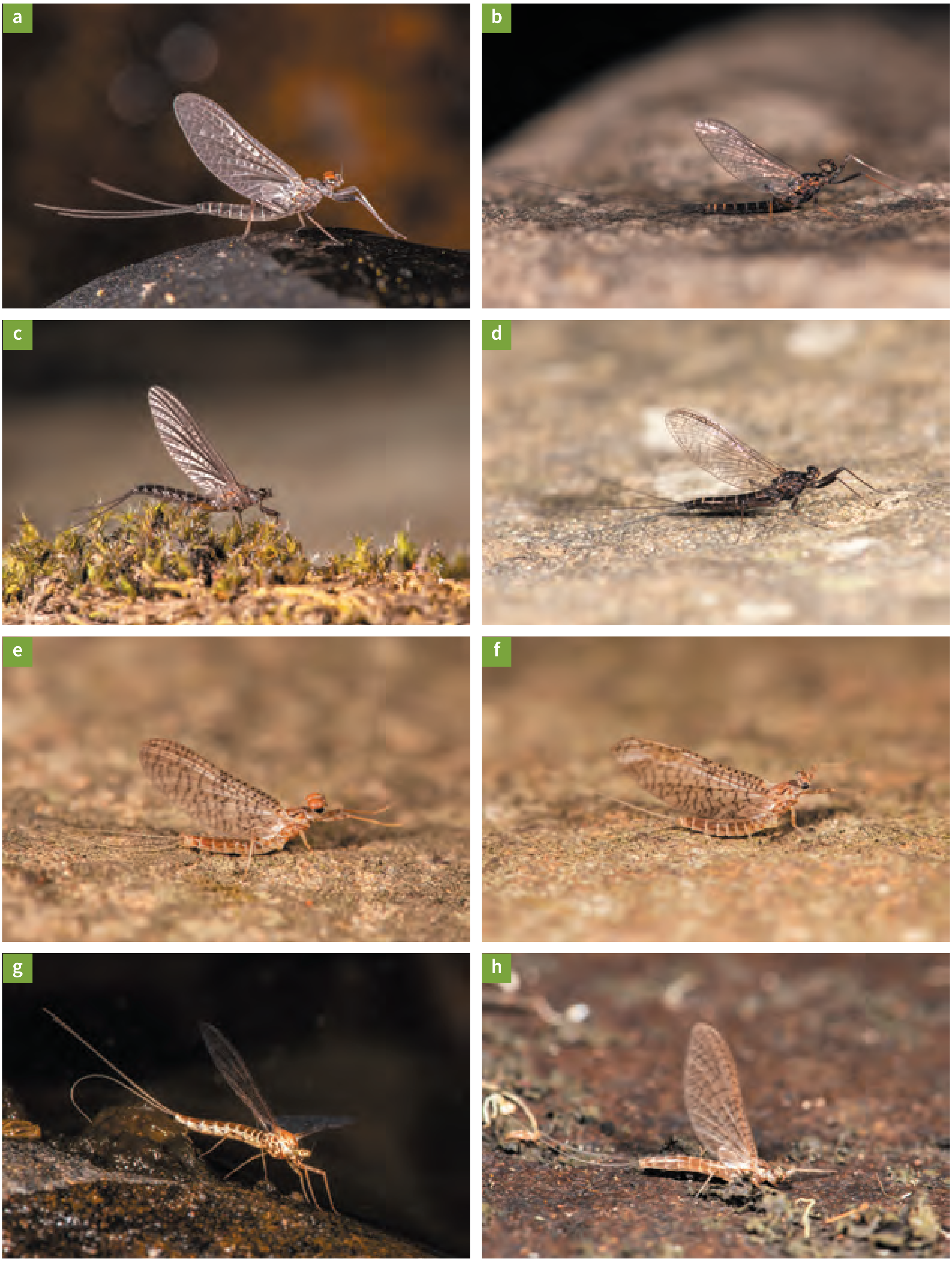


Plate 2. Mayflies (Ephemeroptera) from the southern Otway ranges. Body length in mm.
a-d. *Nousia fuscula* (Leptophlebiidae): a. male, sub-imago, NMV EPH119, 6.2 mm; b. male, imago, NMV EPH139, 5.4 mm; c. female, sub-imago, NMV EPH159, 7.7 mm; d. female, imago, NMV EPH97, 6.8 mm. **e-g.** *Ulmerophlebia annulata* (Leptophlebiidae): e. male, sub-imago, NMV EPH129, 6.7 mm; f. female, sub-imago, NMV EPH131, 7.9 mm; g. female, imago, NMV EPH111, 11.8 mm. **h.** *Ulmerophlebia pipinna* (Leptophlebiidae), female, sub-imago, NMV EPH123, 8.4 mm. Photographer: Julian Finn | Source: Museums Victoria.

Plate 3. Stoneflies (Plecoptera) from the southern Otway ranges. Body length in mm.
a. *Cosmioiperla kuna* (Eustheniidae), shed larval skin, NMV PLE19, 22.3 mm. **b.** *Dinotoperla eucumbene* (Gripopterygidae), female, NMV PLE38, 6.7 mm. **c-e.** *Dinotoperla hirsuta* (Gripopterygidae): c. male, NMV PLE25, 7.2 mm; d. female, NMV PLE24, 7.5 mm; e. male, NMV PLE29, 7.6 mm. **f.** *Illiesoperla mayi* (Gripopterygidae), female, NMV PLE37, 15.0 mm. **g-h.** *Riekoperla rugosa* (Gripopterygidae): g. male, NMV PLE34, 5.2 mm; h. female, NMV PLE35, 6.5 mm. Photographer: Julian Finn | Source: Museums Victoria.

Plate 4. Caddisflies (Trichoptera) from the southern Otway ranges. Body length in mm.
a. *Atriplectides dubius* (Atriplectidae), male, NMV TRI55435, 12.7 mm. **b-c.** *Anisocentropus bicoloratus* (Calamoceratidae): b. male, NMV TRI55322, 10.2 mm; c. female, NMV TRI55315, 10.3 mm. **d-e.** *Hampa patona* (Conoesucidae): d. male, NMV TRI55492, 6.6 mm; e. female, NMV TRI55485, 6.8 mm. **f-g.** *Agapetus kimminsi* (Glossosomatidae): f. male, NMV TRI55498, 4.3 mm; g. female, NMV TRI55490, 3.9 mm. **h.** *Agapetus pontona* (Glossosomatidae), male, NMV TRI55316, 5.2 mm. Photographer: Julian Finn | Source: Museums Victoria.

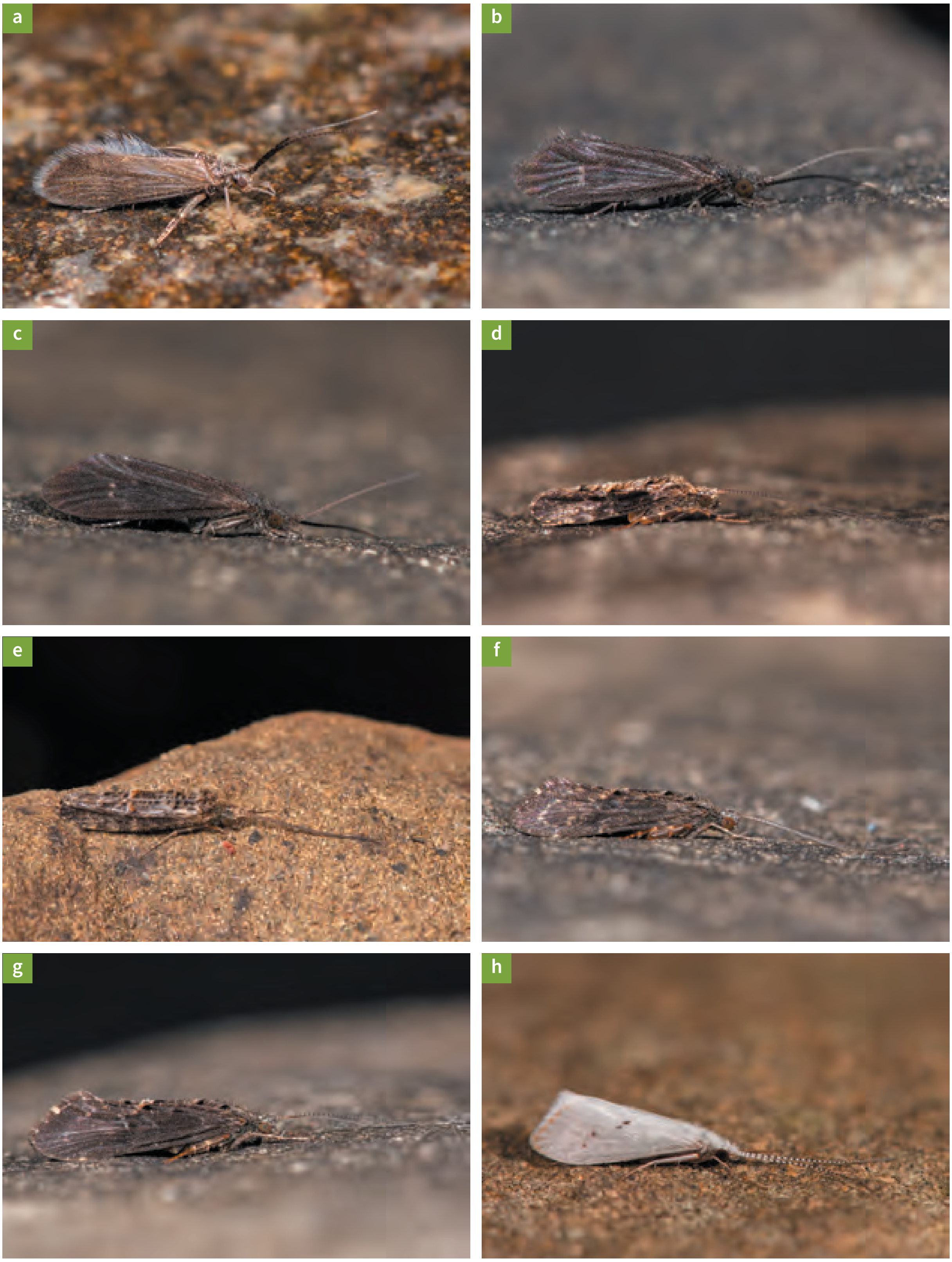


Plate 5. Caddisflies (Trichoptera) from the southern Otway ranges. Body length in mm. *Agapetus pontona* (Glossosomatidae): **a.** female, NMV TRI55320, 5.0 mm. *Helicopsyche heacota* (Helicopsychidae): **b.** male, NMV TRI55371, 5.8 mm; **c.** female, NMV TRI55351, 6.2 mm. *Apsilochorema gisbum* (Hydrobiosidae): **d.** male, NMV TRI55491, 8.2 mm; **e.** female, NMV TRI55453, 9.3 mm. *Ulmerochorema membrum* (Hydrobiosidae): **f.** male, NMV TRI55392, 7.4 mm; **g.** female, NMV TRI55391, 8.5 mm. *Asmicridea edwardsi* (Hydropsychidae): **h.** male, NMV TRI55459, 8.5 mm. Photographer: Julian Finn | Source: Museums Victoria.

Plate 6. Caddisflies (Trichoptera) from the southern Otway ranges. Body length in mm.
a-b. *Cheumatopsyche modica* (Hydropsychidae): a. male, NMV TRI55394, 9.2 mm; b. female, NMV TRI55396, 8.6 mm. **c.** Hydroptilidae, female, NMV TRI55523, 3.4 mm. **d-e.** *Oecetis complexa* (Leptoceridae): d. male, NMV TRI55409, 7.3 mm; e. female, NMV TRI55403, 6.6 mm. **f-g.** *Chimarra australica* (Philopotamidae): f. male, NMV TRI55450, 6.6 mm; g. female, NMV TRI55442, 6.6. mm. **h.** *Hydrobiosella gibbera* (Philopotamidae). Photographer: Julian Finn | Source: Museums Victoria.

Plate 7. Caddisflies (Trichoptera) from the southern Otway ranges. Body length in mm.
a. *Kosrheithrus tillyardi* (Philoreithridae), male, NMV TRI55442, 16.3 mm. **b-c.** *Plectronemia australica* (Polycentropodidae): b. male, NMV TRI55460, 8.5 mm; c. female, NMV TRI55463, 8.1 mm. **d-e.** *Tasimia palpata* (Tasimiidae): d. male, NMV TRI55431, 6.5 mm; e. female, NMV TRI55428, 7.7 mm. Photographer: Julian Finn | Source: Museums Victoria.

Acknowledgments

We would like to thank Rob Zugaro (Videographer, Museums Victoria) for filming our work in the field. We would also like to thank Rodney Start for taking photos of us at work in the field and in the lab at Melbourne Museum.
This research was conducted under DELWP National Parks Act Research Permit number 10008713.

Adult caddisfly *Asmicridea edwardsi* (Hydropsychidae) in flight, attracted to UV light at night, Cumberland River, March 2019. Photographer: Julian Finn | Source: Museums Victoria.

04 MOSS BUGS (PELORIDIIDAE)

Report Author: Ken Walker
Survey Team: Ken Walker and Nish Nizar

Introduction

Peloridiidae, commonly known as moss bugs, are a small and ancient group of insects. They belong to the Order Hemiptera that is characterised by having a piercing, tube-like mouthpart.

Moss bugs of the Peloridiidae are a small group of cryptic and mostly flightless insects measuring between 2–4 millimetres in body length. There are 37 species known worldwide of which nine species occur in Australia and of these, only four species are found in Victoria. A timescale analysis of the moss bugs suggests that they evolved in the late Jurassic (about 153 million years ago). They originated in the area now known as Patagonia (Chile and Argentina) and later spread to the continent now called Australia. At this time all these continents were part of the single large continent Gondwana.

Peloridiids have a unique association with Nothofagus (Myrtle Beech or Southern Beech) forest. Moss bugs live by sucking sap from the mosses and liverworts that grow only around the bases of Nothofagus trees. This explains their modern distribution. Both moss bugs and beech forest have similar distributions in eastern Australia, New Zealand, New Caledonia and Patagonia (Chile and Argentina) reflecting the ancient connections in Gondwana.

Methods

Sites

This investigation sampled several well-known Nothofagus sites in the Great Otway National Park collecting moss from around the bases of Nothofagus trees.

Table 1. Sites sampled.

Site (River)	Latitude (S°)	Longitude (E°)	Date sampled
Beauchamp Falls	38.6469	143.6119	10–11 Oct 2018
Hopetoun Falls	38.6684	143.5679	10–11 Oct 2018
Triplet Falls	38.6713	143.4934	10–11 Oct 2018
Melba Gully	38.6921	143.3688	10–11 Oct 2018

Collecting

Moss from around the base of Nothofagus trees was collected using a hand trowel. These moss samples were placed in two-litre glass jars to ensure the moss did not dry out.

Twelve moss samples were placed into individual Tullgren funnels.

These funnels are a metal cylinder about 30 centimetres wide and 50 centimetres high (Fig. 1). At the bottom of the funnel is a wire mesh on which we placed the moist, recently collected moss. Below this mesh, the funnel narrows to a small opening where we placed a small plastic collecting vial. At the top of the funnel is a heat generating light bulb. The moss samples were left in the funnels with the heating bulb for two days before examination.

Over the two days the heat from the light bulb slowly dried out the moss from the top down. As the moss dried, the moss bugs and other invertebrates moved to the bottom of the moss. Finally even the bottom of the moss eventually dried out and the invertebrates left the moss and fell down through the narrowed tube into the collecting vial below.

Figure 1. Tullgren funnels were used to separate invertebrates from moss samples. Photographer: John Broomfield | Source: Museums Victoria.

DID YOU KNOW?

In nature, invertebrates generally fall into two major categories. One group has bright, vibrant colours that strongly advertise their presence. This group contains species that are either highly poisonous or non-poisonous mimics trying to fool predators that they are indeed poisonous and best not to eat. The other group, which is the majority of the invertebrate world, use cryptic colours to camouflage themselves as a means to hide from predators and prey. This second group of invertebrates are difficult to find in the wild. You often need to disturb them to even notice their presence.

While 70% ethanol is usually placed into the Tullgren collecting tube, on this occasion moistened paper was used instead in order to keep the invertebrate fauna alive for filming. The invertebrates were placed into petri dishes for examination and filming. Finally they were placed into vials with 70% ethanol for addition to the museum's collection.

Results

Peloridiidae (*Hemiodoecus acutus*) was collected at Melba Gully. This consisted of two Peloridiidae specimens—one adult and one nymph.

No Peloridiidae were found at the other three sites sampled.

A Museums Victoria film crew accompanied the scientific team and fully documented the survey from collection of the moss samples to separation of the invertebrates from the moss.

It was the first time live Peloridiidae have been filmed under the microscope capturing detailed images of the moss bugs behaviour and movement. Moss Bugs do not need to be agile or fast movers. This is exactly what we observed in the live specimens. Movements were almost 'staccato', deliberate and methodical. Such movement can also be predicted from the body armament of the bug. The entire dorsal surface of Moss Bugs is covered with a thick, reticulate patterned cuticle that does not allow the body to flex. The body shape and movement is designed for a sedentary life feeding in Nothofagus moss. Since Moss Bugs are not very mobile, they make excellent keystone species as indicators of continental break-up and drift. The other invertebrates collected from the moss sample including insects, mites and arachnids were also filmed live.

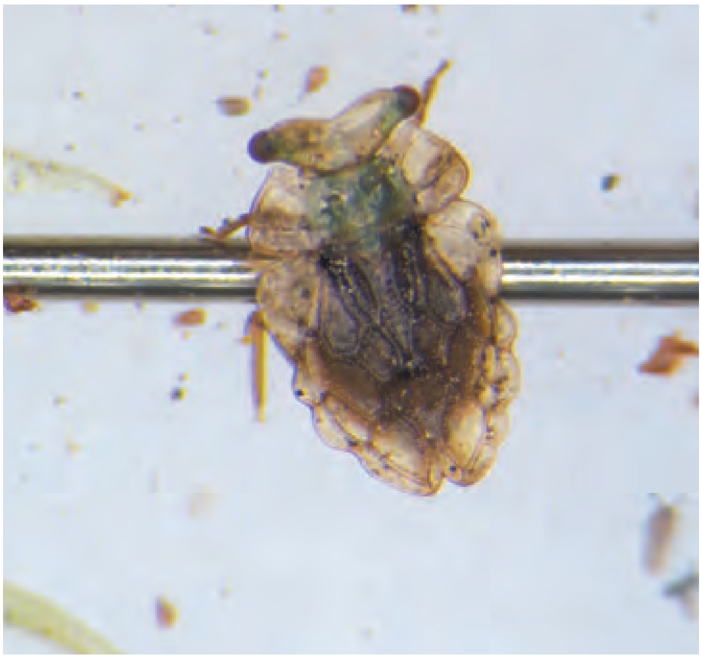
Discussion

Previous sampling for Peloridiidae in 1992–1994 (by Ken Walker) found abundant peloridiids at all sites listed above. As a similar sampling technique was used in this survey, the team were surprised that they only found two peloridiid specimens—one adult and one nymph—at one site. This is a concern but without follow up sampling it is not clear if these low specimen numbers are a sampling artifact or indeed shows a significant decline in the peloridiid population in the Great Otway National Park. Ideally this sampling should be repeated next year and compared with these results.

Peloridiidae may be affected by the effects of climate change in southern Victoria. If these forests significantly dry, the beech forests will decline, along with their incumbent moss and reliant moss bugs. However nothing can be claimed on this relationship at present without a more comprehensive study.

Acknowledgements

This research was conducted under DELWP National Parks Act Research Permit number 10008886.



Left: A live adult Moss Bug as viewed under the microscope. https://www.facebook.com/melbournemuseum/videos/914404565624814/. Photographer: Stephen Dixon | Source: Museums Victoria. **Above:** Ken Walker collecting moss. Photographer: John Broomfield | Source: Museums Victoria.

05 MOTHS

Report Author: Marilyn Hewish
Survey team: Peter Marriott (PM), Marilyn Hewish (MH), Cathy Powers (CP), Ken Harris (KH), David Mules (DM), Frank Pierce (FP), Dean Hewish (DH), Genefor Walker-Smith, Nish Nizar and Mark Nikolic.

Introduction

A series of Bioscan biodiversity surveys has been conducted by Museums Victoria (MV) and Parks Victoria (PV) in various Victorian national parks since 2011. As part of this programme, Lepidoptera survey teams from the Entomological Society of Victoria and Museums Victoria have carried out intensive moth and butterfly surveys. These surveys have produced important information on Lepidoptera, particularly moths, including new species for the state and significant range extensions (e.g. Hewish et al. 2014a). The Otway Bioscan provided these teams with the opportunity to continue their important survey work and add to the list of species found in the Otways. In addition they asked two questions: Was there a difference in the moth fauna between burnt and unburnt sites? Has the moth fauna changed over the last 100 years?

The earliest moth surveys known for the Otway Ranges were carried out by avid naturalist George Lyell. Lyell was born in Ararat (Victoria) in 1866 and lived in Gisborne for most of his life: he died in 1951 (Neboiss 1986). Lyell collected moths from Lorne in February and March 1906, 1907, 1909 and 1911, presumably while on his summer holidays. In 1932 Lyell began to donate his Lepidoptera collection to Museums Victoria and by 1946 the museum received the last of his moth cabinets (Hewish 2014).

Since 1991, some of us (MH, PM, KH) and Axel Kallies (AK) have led moth surveys in the Otway Ranges and its surrounds. More than 25 sites and a variety of habitats have been visited, with surveys in all seasons. All species lists have been kept in a database for research purposes. The results of these surveys indicate that the moth fauna of the Otway Ranges is abundant, diverse and scientifically interesting. Several species were new records for Victoria when they were discovered (e.g. *Glyphipterix gypsonota*). The Otways appears to be an area of biogeographical overlap, with species showing connections to Tasmania and the eastern and western mainland states. *Glyphipterix gypsonota* and an undescribed species of *Neumichtis* are known from Tasmania and have been found in the Carlisle Heath (MH, PM and AK, pers. obs.). Small populations were probably left isolated there when Tasmania was cut off by flooding of the Bass Strait land-bridge about 12,000 years ago. The Otways also connects with the wet heathland and forest in the coastal strip along eastern and south-eastern Australia. An undescribed moth in the genus *Dinophalus* was known only from Queensland and New South Wales before it was found at Bald Hills near Anglesea (MH, pers. obs.). This is still the only Victorian record (Marriott 2012b). A connection with moth populations in South Australia and Western Australia is indicated by a record of an undescribed *Euloxia* species at Cape Otway (Marriott 2012b). Some species show a disjunct distribution including the Otways and the Victorian Alps. Geometridae *Conosara castanea* and *Aeolochroma mniaria* occur along the Otway coast in wet forests and heathlands, and in similar habitats in the Victorian Alps (Hewish et al. 2014b, Marriott 2012b).

Bioscan surveys were conducted in the Great Otway National Park from spring 2018 to autumn 2019. During preparatory discussions, Lepidoptera team leader Peter Marriott and PV staff Katrina Lovett and Jani Demetrious formulated three projects for investigation: the effect of wildfire on moth populations; comparing George Lyell's records from Lorne in the early 1900s with the Bioscan results; and compiling a comprehensive list of the Otways moth fauna from all surveys known to the authors.

The Bioscan surveys therefore offered the opportunity to investigate new sites in the Otway Ranges, to add to the already large species list and to pursue particular projects of historical and ecological interest.

Methods

Light-traps

Light traps (250-watt mercury-vapour lights shining on vertical white sheets (Fig. 1) and a Hitachi 8-watt long-wave ultraviolet light on a smaller sheet) were used to attract moths in three series of surveys: 29–31 October 2018, 26–27 November 2018 and 21–23 March 2019. The light traps were set up at dusk, checked through the night and early morning, and shut down at sunrise. Each moth species was photographed. Where possible, significant specimens were collected and lodged as voucher specimens in the Museums Victoria Entomology Collection.

Table 1. Survey sites, locations, dates and observers.

Dates	Location	Latitude (S°)	Longitude (E°)	Habitat	Recorders
October 2018					
29–30	Wye River, Grey River Rd	38.67452	143.84562	Open forest, unburnt	PM, KH, DM
29–30	Wye River, Bird Track (Tk)	38.63968	143.88275	Open regrowth forest*	MH, CP, DH
30–31	Wye River, Grey River Rd	38.67452	143.84562	Open forest, unburnt	MH, CP, DH
30–31	Wye River, Bird Tk	38.63968	143.88275	Open regrowth forest*	PM, KH, DM
31–01 Nov	Grey River Picnic Area (PA)	38.65903	143.81591	Tall wet forest	PM, MH, CP, KH, DM, DH
November 2018					
26–27	Grey River PA	38.65903	143.81591	Tall wet forest	PM, MH, CP, KH, DM, DH, FP
27–28	Carlisle Heath, Rapier Ridge Tk	38.56271	143.44054	Heathland, scattered trees	KH, DM, FP
27–28	Carlisle Heath, Old Carlisle Rd	38.55399	143.43043	Heathland, scattered trees	PM, MH, CP, DH
March 2019					
21–22	Blanket Leaf PA (Lorne)	38.51672	143.93921	Tall wet forest	PM, MH, CP, DH
21–22	Sheoak PA (Lorne)	38.55528	143.94411	Tall wet forest	KH, DM, FP
22–23	Blanket Leaf PA (Lorne)	38.51672	143.93921	Tall wet forest	KH, DM, FP
22–23	Sheoak PA (Lorne)	38.55528	143.94411	Tall wet forest	PM, MH, CP, DH
23–24**	Sheoak PA (Lorne)	38.55528	143.94411	Tall wet forest	PM, MH, CP, DH, KH, DM, FP

*burnt in wildfire in Dec 2015; **finished at midnight

Sites

All sites visited on the Bioscan surveys were within the Great Otway National Park. They ranged along the coastal strip from Wye River north-east to Lorne and inland to Grey River Picnic Area and the Carlisle Heath (Table 1). No surveys were carried out in rainforests (e.g. Myrtle Beech or Nothofagus forests).

For the study on moths' responses to wildfire, the Wye River unburnt and burnt sites were chosen by the PV staff, Katrina Lovett and Jani Demetrious. For comparison, one team surveyed the unburnt site and another team the burnt site on the first night. On the second night, the teams swapped sites. Thus each site had two surveys on consecutive nights, each conducted by a different team. Apart from their fire history, the sites were similar in habitat and aspect. The wildfire passed through the burnt site on 25 December 2015, and so the surveys were conducted approximately three years after the fire. More detailed descriptions of the sites are given below.

Unburnt site, Grey River Road

This was a ridge easement bordered by forest with a dense and varied understorey. The moth sheets were oriented roughly north-west and north, facing downslope. Surveys here were done using two mercury vapour lights and one ultraviolet light on 29–30 October 2018 (PM, KH, DM) and one mercury-vapour light on 30–31 October 2018 (MH, CP, DH).

Burnt site, Bird Track (3-year-old regrowth)

This was a ridge track bordered by forest with an understorey dominated by a dense regrowth of eucalypt saplings of even age (three years). Visual observations indicated that the numbers and variety of other shrubby plants was reduced, crowded out by the eucalypts. The sheets were oriented roughly north-west, facing downslope. Surveys were done using one mercury-vapour light on 29–30 October 2018 (MH, CP, DH) and two mercury-vapour lights and one ultraviolet light on 30–31 October 2018 (PM, KH, DM).

Moth lists from the Bioscan sites near Lorne (Sheoak Picnic Area, Blanket Leaf Picnic Area) were used for comparison with George Lyell's historical species lists. When collecting at home in Gisborne, Lyell used to walk in the forests as far out as Bullengarook and the Pyrete Range. He therefore ranged up to four to five kilometres away from the town though his specimen labels all bear the location "Gisborne" (Garnet and Burns 1951, Jean Benson unpublished notes: see Hewish 2014). Similarly, we have assumed his specimens labelled "Lorne" could have been collected in the forest within a radius of about five kilometres, which encompasses Blanket Leaf and Sheoak Picnic Areas. Even if he did not visit those particular sites, they are representative of the extensive areas of wet forest in that region.

Identifying the species photographed and collected

If species had been previously encountered by the authors, they could be found among more than 1000 species covered in the *Moths of Victoria* book series (Hewish et al. 2014b, 2016, Kallies et al. 2015, Marriott 2011, 2012a, 2012b, 2015, Marriott et al. 2017) or among Victorian moth photographs (more than 2900 species) in a personal computer database maintained by one of us (PM). For unrecognised species, searches were undertaken in the Museums Victoria collection and the Australian National Insect

Figure 1. Light traps (i.e. white sheets and lights) set up at Sheoak Picnic Area. Photographer: Heath Warwick | Source: Museums Victoria.

Collection (ANIC; through E.D. Edwards, reference photographs taken by the authors, and the CSIRO/ANIC website Australian Moths Online). Other sources used were reference books (Common 1990, 1994, 1997, 2000, Horak and Komai 2006, Matthews 1999, Robinson and Nielsen 1993, Simonsen 2018) and reputable internet sites (e.g. Australian Moths Online: Atlas of Living Australia; BOLDSYSTEMS Public Data Portal; BOLD SYSTEMS Taxonomy Browser).

Peter Marriott and Cathy Powers co-ordinated the identification process and preparation of the species lists. Nomenclature follows the Australian Faunal Directory website (AFD).

Analysis

For comparison of the unburnt and burnt Wye River sites, species lists for each site were made. However, quantitative estimates of numbers of individuals for each species were not possible because of the high numbers of moths, movement over the sheets and, probably, movement away and back again. However, numbers were estimated for the large and conspicuous Helena Gum Moth, *Opodiphthera helena*.

The species lists in consecutive surveys at each site were combined. This compensated for the differing numbers and types of light traps, observer differences and variation in weather on the two nights. Because of the limited sampling, no statistical analysis was justified (R. Marchant, pers. comm.).

George Lyell's historical records from Lorne

George Lyell collected in the Lorne area in February and March in 1906, 1907, 1909 and 1911. He donated the specimens to the museum, along with the rest of his collection, in the years between 1932 and 1946 (Hewish 2014). Identifications and label data from those specimens, which had previously been registered in the museum's database, were extracted and additional Lyell records were compiled by searching the museum's drawers of moth specimens (W. Moore). From this data a list of 190 species was compiled, excluding those for which a current valid name could not be identified in the *Checklist of the Lepidoptera of Australia* (Nielsen et al. 1996) or the Australian Faunal Directory website.

Above: Moth, *Spilosoma glatignyi* Photographer: Cathleen Powers | Source: Museums Victoria. **Top:** Moth, *Abantiades labyrinthicus*. **Opposite top:** Moth, *Spilosoma glatignyi*. **Opposite middle:** Moth, *Abantiades latipennis*. Photographer: Heath Warwick | Source: Museums Victoria. **Opposite bottom:** Moth, *Trigonistis asthenopa*. Photographer: Cathleen Powers | Source: Museums Victoria .

Results and discussion

Species diversity

During the Bioscan, 468 moth species were recorded. Of these, 380 could be identified to species level. A further 23 are known to lepidopterists but they have not been formally named. In the book series *Moths of Victoria*, they have been assigned a species number. The remaining 65, mainly small species, have not been identified. Many of these may also be unnamed.

Significant findings include:

- species possibly new to science
- range extensions
- species which are rare or uncommon in Victoria
- heathland and wet forest species with specialised habitat requirements and localised distributions in Victoria.

These findings were significant at national, state and regional levels.

The lists for individual surveys ranged from 121 species (Wye River burnt site, 31 October 2018) to 54 (Sheoak Picnic Area, 21 March 2019). The species recorded at the greatest number of sites during this Bioscan were: *Persectania ewingii* (Noctuidae) (13); *Halone sejuncta* (Erebidae) (11); *Spilosoma glatignyi* (Erebidae) (11); and *Agrotis porphyricollis* (Noctuidae) (10). These species are widespread in the southern half of Victoria and have extended flight times (Marriott et al. 2017; PM and MH pers. comm.). They were recorded in the October, November and March surveys.

The rich diversity of species recorded during this Bioscan is most likely due to the variety of habitats sampled and the extended survey period.

Habitat use

Some species have preferences for particular habitats and examples are given below.

In past surveys, *Austrocidaria erasta* (Geometidae) and *Idiodes prionosema* (Geometridae) have been recorded in the cool temperate rainforest (i.e. Maits Rest) (Marriott 2011, Hewish et al. 2016). While no rainforest sites (i.e. Myrtle Beech forests) were visited during this Bioscan, these species were found at Grey River Picnic Area, the most sheltered and dampest of the wet forest areas we surveyed.

During the Bioscan, *Aeolochroma mniaria* (Geometridae) and *Conosara castanea* (Geometridae) were found only in the wet forest at Blanket Leaf

Picnic Area and previous surveys have shown they favour this type of habitat (Marriott 2012b, Hewish et al. 2014b). These two species have a disjunct distribution in Victoria, occurring along the coast in wet forests and heathlands and in the Victorian Alps, in structurally similar habitats. The Bioscan surveys revealed another species with a similar disjunct range, formerly known only from the Victorian Alps (Marriott 2012b), *Oenochroma barcodificata* (Geometridae) was discovered in the Carlisle Heath.

As their common name indicates, the Heath Moths, *Dichromodes* species (Geometridae), prefer heathland or wooded heath (Marriott 2012b). During the Bioscan, *D. ainaria*, *D. atrosignata*, *D. euscia* and *D. stilbiata* were only found at the Rapier Ridge Track site and the Old Carlisle Road site, in the Carlisle Heath.

The list from the burnt forest was characterised by the large number of species in the family Geometridae. The results are given in more detail and analysed in the section of this report titled '*Moths and wildfires*'.

Interesting observations

After autumn rains, many of the larger moths in the family Hepialidae emerge simultaneously from their buried pupae and fly in large numbers (Kallies et al. 2015). At Blanket Leaf Picnic Area on 21 March 2019, light rain and mist enveloped the survey site all night. The Hepialidae *Abantiades labyrinthicus*, *A. latipennis* and *Oxycanus sirpus* came to the sheets in large numbers. *Oxycanus sirpus* is described as widespread but uncommon in Victoria (Kallies et al. 2015). It is unusual to see them in numbers but Axel Kallies (pers. comm.) noted they have been unusually common in southern Victoria in 2019.

Noteworthy records

Two records were of species unknown to the author and the other Bioscan participants. Neither moth was recognised by moth expert Ted Edwards (from the Australian National Insect Collection, ANIC), Marianne Horak (an authority on the family Tortricidae, ANIC) and Axel Kallies, experienced Victorian lepidopterist. These authorities suggested both moths may be species that are new to science, and agreed one belonged in the family Tortricidae and identified the other as a species of *Chrysolarentia* (family Geometridae).

Though the Otway Ranges and surrounds have received considerable attention from collectors and photographers since the early 1900s, the Bioscan revealed a further 123 species that were not previously known from the area. That is to say, 27% of the moths seen during the Bioscan were new records for the Otways and thus, represented range extensions in Victoria.

Table 2 shows a selection of these new records. Several were extensions to the west from their formerly known ranges in eastern Victoria (e.g. *Euproctis limbalis*, *Nola phaeogramma*, *Maxates calaina*, *Maxates* sp. (1), *Oenochroma vetustaria*, *Casbia celidosema*, *Picromorpha pyrrhopa* and *Agrotis ipsilon*). The Otways is the first large area of reserved coastal forest west of the Dandenongs. It may be the western limit of these species' distribution, though some forest species are known to reach the Grampians (Hewish et al. 2014a).

Museums Victoria volunteer, Marilyn Hewish, photographing a moth. Photographer: Heath Warwick | Source: Museums Victoria.

Table 2. Selected new records for the Otway Ranges obtained during the Bioscan, spring 2018 and autumn 2019.

Family/subfamily	Species	Bioscan site	Date	Previously known Vic. range
Erebidae/Lymantriinae	*Euproctis limbalis*	Carlisle Heath, Rapier Ridge Tk	27 Nov 2018	Westwards to Melbourne suburbs[1]
Geometridae/Ennominae	*Casbia celidosema*	Blanket Leaf PA	21, 22 Mar 2019	Westwards to Brisbane Ranges[3]
Geometridae/Ennominae	*Picromorpha pyrrhopa*	Carlisle Heath, Rapier Ridge Tk	27 Nov 2018	Westwards to Mt Donna[3]
Geometridae/Geometrinae	*Maxates calaina*	Wye River unburnt forest, Grey River Rd	30 Oct. 2018	Westwards to Gembrook[2]
Geometridae/Geometrinae	*Maxates* sp. (1)	Wye River burnt forest, Bird Tk	30, 31 Oct 2018	Westwards to Marysville[2]
Geometridae/Larentiinae	*Chloroclystis metallospora*	Wye River burnt forest, Bird Tk	30 Oct 2018	Holey Plains SP SW of Sale[5]
Geometridae/Larentiinae	Genus *Chrysolarentia* – probably a new species	Sheoak PA	23 Mar 2019	Not known
Geometridae/Larentiinae	*Microdes melanocausta*	Blanket Leaf PA	21 Mar 2019	Central Vic., e.g. Werribee Gorge, Eppalock, Mt Baw Baw[5]
Geometridae/Larentiinae	*Microdes* sp. (1)	Grey River PA, Blanket Leaf PA	31 Oct 2018, 21 Mar 2019	Scattered records in Vic., Gembrook, Brucknell[5]
Geometridae/Oenochrominae	*Oenochroma barcodificata*	Carlisle Heath, Old Carlisle Rd, Rapier Ridge Tk	27 Nov 2018	Vic. Alps e.g. Falls Creek[2]
Geometridae/Oenochrominae	*Oenochroma vetustaria*	Carlisle Heath, Rapier Ridge Tk	27 Nov 2018	Westwards to Tynong North[2]
Geometridae/Oenochrominae	*Taxeotis intermixtaria*	Carlisle Heath, Old Carlisle Rd, Rapier Ridge Tk	27 Nov 2018	Scattered records in Vic., Melbourne area, Grampians[2]
Noctuidae/Noctuinae	*Agrotis ipsilon*	Sheoak PA, Blanket Leaf PA	22, 23 Mar 2019	Westwards to Wilsons Prom.[4]
Noctuidae/Noctuinae	*Agrotis radians*	Wye River unburnt and burnt forest	29, 30 Oct 2018	Scattered records in Vic., Big Desert, Gippsland Lakes, Melbourne area[4]
Nolidae/Nolinae	*Nola phaeogramma*	Sheoak PA	23 Mar 2019	Westwards to Gisborne[1]
Tortricidae	Probably a new species	Blanket Leaf PA	21 Mar 2019	Not known

[1]Marriott 2015, [2]Marriott 2012b, [3]Hewish et al. 2016, [4]*Moths of Victoria*, Part 9, in prep., [5]Marriott 2011,

Microdes melanocausta, *Microdes* sp. (1), *Taxeotis intermixtaria* and *Agrotis radians* were known to be patchily distributed in Victoria in a variety of habitats. Records from the Otways reveal range extensions and fill in gaps in distribution.

However, the most striking extension is that of *Oenochroma barcodificata*, previously thought to be restricted to the Alps in Victoria (Marriott 2012b). Now that it is known from the Otways, it appears to fall into the group of species that have a disjunct distribution in wet habitats in the Victorian Alps and along the coast. Thus far, the Bioscan record is the only known coastal record, but further work in wet forests and heathlands may reveal other locations.

Rare moth species in this list include *Agrotis ipsilon*, which is known in Victoria from six records and *Chloroclystis metallospora*, which is known from three specimens recorded in Holey Plains State Park, near Sale.

Moths and wildfires

In comparisons between the unburnt site (Grey River Rd) and the site burnt three years previously (Bird Track), the sampling was limited and the results preliminary. Nevertheless, some interesting results emerged. More moth species were recorded at the burnt site (132: species counts from two nights at this site combined) compared to the unburnt site (113: combined total for two nights), which showed that the regenerating woodland was able to support a fauna as diverse as that found in the areas that had not been burnt. However, the site specificity and species overlap revealed that the sites differed considerably in the suite of species present. From a total of 175 species (in 23 families), 70 (40%) were detected at both sites; 43 (25%) at the unburnt site only; and 62 (35%) at the burnt site only. The majority of the additional species at the burnt site were from the family Geometridae.

Most families were represented by only a few species and at the family level differences between the sites are hard to discern. However there was a clear difference for the family Geometridae: 42 species at the burnt site and 27 at the unburnt site (Table 3). In confirmation, geometrid moths made up a moderately high proportion of the species unique to the burnt site (20 species, 32%). There were fewer geometrid

Table 3. Number of species in each Lepidoptera family at unburnt and burnt sites.

Family	Species at unburnt site	Species at burnt site
Anthelidae	1	3
Cosmopterigidae	2	2
Cossidae	2	1
Crambidae	2	5
Depressariidae	1	1
Elastichidae	1	1
Erebidae	15	15
Gelechiidae	3	1
Geometridae	27	42
Gracillariidae	1	1
Lasiocampidae	2	2
Noctuidae	9	10
Nolidae	5	3
Notodontidae	3	2
Oecophoridae	27	21
Plutellidae	1	1
Pterophoridae	1	1
Pyralidae	2	6
Saturniidae	1	1
Thyrididae	0	1
Tineidae	1	1
Tortricidae	6	10
Yponomeutidae	0	1

moths among the species unique to the unburnt site (5 species, 12%).

The 20 geometrid species found exclusively at the burnt site were:

Ennominae (subfamily) — *Didymoctenia exsuperata*, *Ectropis calida*, *Nisista serrata*, *Nisista* sp. 2, *Nisista* sp. 4 (species numbers from Hewish et al. 2014b), *Psilosticha attacta*, *Scioglyptis chionomera*

Larentiinae (subfamily) — *Chloroclystis filata*, *Chloroclystis metallospora*, *Epicyme rubropunctaria*, *Eucymatoge scotodes*, *Microdes* sp. 4 and *Microdes* sp. 5 (Marriott 2011), *Xanthorhoe anaspila*

Sterrhinae (subfamily) — *Scopula optivata*, *Idaea probleta*

Geometrinae (subfamily) — *Heliomystis electrica*, *Maxates* sp. 1 (Marriott 2012b), *Prasinocyma semicrocea*

Oenochrominae (subfamily) — *Gastrophora henricaria*.

Over the two nights, the numbers of Helena Gum Moths, *Opodiphthera helena* (Geometridae) at the light-traps also differed at the two sites: up to seven individuals on one sheet, at one time, at the burnt site but no more than two individuals together on the sheet at the unburnt site.

In assessing the suitability of a habitat for different moth species, it is probably more important to consider the needs of the larvae (i.e. caterpillars) than the adults, as a species can become established in an area only when breeding occurs. The larvae require suitable food-plants. Larvae of many Geometridae species are foliage-feeders. Of the 20 Geometridae species that were found only in the burnt woodland, five feed on eucalypt and/or wattle foliage, especially new growth (*D. exsuperata*, *G. henricara*, *H. electrica*, *N. serrata* and *P. semicrocea*) (Common 1990, Hewish et al. 2014b, 2016, Marriott 2011, 2012b). In woodland regenerating after fire, the extensive epicormic growth and dense stands of eucalypt saplings provide ample food. The young, soft foliage may attract females ready to lay eggs because it provides suitable food for their larvae. Like many Geometridae species, Helena Gum Moths (*O. helena*) larvae also feed on eucalypt foliage (Marriott 2012a). More individual Gum Moths were found at the burnt site than the unburnt site. They may also be taking advantage of young, eucalypt regrowth.

A smaller difference was seen in the family Oecophoridae, though in this case there were more species in the unburnt site (27 versus 21). Many oecophorid species are associated with eucalypt forests and woodlands, where the larvae feed in leaf litter. There are several litter-feeding species among the oecophorid genera that were unique to the unburnt woodland: for instance, *Thema* species, *Philobota* species and *Stathmopoda* species (Common 1990). In a wildfire, litter would be destroyed along with the larvae living in it, but as it builds up during regeneration, oecophorid moths would presumably return. Litter-feeding Oecophoridae larvae are important in recycling nutrients and maintaining forest health. They also prevent the excessive build-up of leaf litter, thus reducing the intensity of fires (Zborowski and Edwards 2007).

Thus it appears that the response of moth species to fire depends on the needs of the larvae. Recovery develops as an increase in species numbers, but they are not necessarily the same species that were present before the fire. Three years after the Wye River–Jamieson Track fires raged through area, we have detected a fundamental change in the suite of species present at the burnt sites we surveyed, and this may change further as regeneration progresses. It is presumed the composition of moth species at the burnt sites will, over time, come to resemble that of the unburnt woodland.

An article on this work has been published in the *Victorian Entomologist* (see Hewish et al. 2019).

Comparison with George Lyell's records, 1906–1911

George Lyell's records from Lorne in the early 1900s were compared with those from Bioscan surveys conducted near Lorne (Blanket Leaf PA, Sheoak PA) on 21–23 March 2019. Records could be matched across the two sets of surveys only for those moths that could be assigned currently valid species names (Nielsen et al. 1996; Australian Faunal Directory 2019). George Lyell's records with invalid and untraceable names and Bioscan records of undescribed or unidentified species were therefore omitted.

Label data from George Lyell's surveys near Lorne indicate that he collected moths on 5 February to 9 March 1906, 1 February to 1 March 1907, 26 February to 28 March 1909 and 13 February to 14 March 1911. Survey effort varied between years. Specimens were collected on six nights in 1906, 13 nights in 1907, two nights in 1909 and 14 nights in 1911: a total of 35 nights. The final species tally was 190 (Museums Victoria EMu database and W. Moore's search of MV collection).

In comparison, five Bioscan surveys at Blanket Leaf PA and Sheoak PA near Lorne on 21–23 March 2019 yielded a total of 175 named species. The Bioscan surveys therefore recorded a slightly lower number of species than Lyell's surveys, but they were recorded over a much shorter survey period. This suggests the Bioscan surveys were more efficient in accumulating records of moth species.

The two species lists indicate that the area near Lorne supported a rich moth fauna in 1906–1911, and also in 2019. The major families were similar in the two sets of surveys (Table 4). The most species-diverse families were Crambidae, Erebidae, Geometridae, Noctuidae, Oecophoridae and Tortricidae. Some information on George Lyell's study methods can be gleaned from particular species on his list. Several moths that are specialists of rainforests, wet sclerophyll forests and damp gullies were shared between Lyell's surveys and the Bioscan: e.g. *Furcatrox australis*, *Conosara castanea*, *Casbia melanops*, *Aeolochroma mniaria*, *Chrysolarentia bichromata*, (*Trigonistis*) *asthenopa* and *Abantiades labyrinthicus* (Hewish et al. 2014b, Hewish et al. 2016, Kallies et al. 2015, Marriott 2011, 2012b, Marriott et al. 2017). This indicates Lyell and the Bioscan team searched in similar wet forest habitats inland from Lorne. Lyell also recorded *Idiodes prionosema*, another species with a preference for rainforest and wet forest,

Table 4. Number of species in each Lepidoptera family — comparison of George Lyell's records with Bioscan surveys.

Family	No. of species–Lyell	No. of species–Bioscan
Anthelidae	1	1
Carposinidae	2	1
Cosmopterigidae	2	0
Crambidae	16	14
Depressariidae	4	0
Erebidae	9	19
Gelechiidae	3	3
Geometridae	57	70
Gracillariidae	1	0
Hepialidae	1	4
Hypertrophidae	1	0
Lasiocampidae		4
Lecithoceridae	1	0
Limacodidae		1
Noctuidae	9	14
Nolidae	2	7
Notodontidae	0	3
Oecophoridae	36	18
Oenosandridae	0	3
Psychidae	4	1
Pterophoridae	1	0
Pyralidae	4	2
Roeslerstammiidae	1	0
Sphingidae	1	0
Tineidae	4	3
Tortricidae	27	7
Xyloryctidae	2	0
Zygaenidae	1	0

but the Bioscan team found this only at the Grey River Picnic Area, about 20 kilometres from Lorne.

However, there were major differences between the two sets of species lists. Of the 318 moth species recorded overall by Lyell and the Bioscan team, 47 (15%) were found by both Lyell and the Bioscan participants, 128 (40%) by the Bioscan only and 143 (45%) by George Lyell only. Since only 15% of the species' records were shared, there appears to be a marked difference in species composition between the two sets of surveys.

Lyell's list features two day-flying moths, *Eutrichopidia latinus* and *Phalaenoides tristifica*, indicating that he collected opportunistically by day. The Bioscan team concentrated on night-collecting. Lyell found only one species from the family Hepialidae, *Abantiades labyrinthicus*, but the Bioscan team found unusually large numbers of three species after autumn rain. Perhaps Lyell did not collect on wet autumn nights when hepialids emerge from their pupae in numbers. Many of the families represented only in the Lyell list (Table 4) comprised small moth species: e.g. Cosmopterigidae, Gracillariidae, Hypertrophidae, Lecithoceridae, Pterophoridae, Roeslerstammiidae and Zygaenidae.

As with the species comparison, there were differences in the family composition (Table 4). Lyell recorded more families (24) than the Bioscan surveys (18). The combined lists of Lyell and the Bioscan contained 28 families in total and of these, 14 (50%) were found in both sets of surveys, 10 (36%) by Lyell only and 4 (14%) during the Bioscan only. The differences between the families was most marked in the Erebidae (Lyell, nine species versus Bioscan, 19), Oecophoridae (36 species versus 18) and Tortricidae (27 species versus 7).

Though the two sets of surveys appear to show different species and family compositions, they may not represent real differences in the moth populations between the early 1900s and 2019. Interpretation of the results is difficult because of uncertainties about Lyell's collecting sites and differences in methodology.

Collecting sites: We know George Lyell's specimen labels marked "Gisborne" encompassed an area of up to a five kilometre radius around the town

Top: Museums Victoria volunteers, Cathy Powers & Marilyn Hewish, reviewing a moth photo. Photographer: Heath Warwick | Source: Museums Victoria. **Middle:** Emperor Gum Moth, caterpillar, *Opodiphthera eucalypti*. Photographer: David Paul | Source: Museums Victoria. **Bottom:** Moth, *Azelina biplaga*. Photographer: Heath Warwick | Source: Museums Victoria.

(Hewish 2014). We have therefore assumed that some "Lorne" specimens may have been collected outside Lorne. However Lyell's actual collecting sites are not known. We know he visited wet forests, but he may have visited several areas and different habitats, which would increase his potential list of families and species.

Nightly survey coverage: Jean Benson (pers. comm., in Hewish 2014) wrote that George Lyell walked in the forest at night when collecting. The Bioscan team collected at a stationary light. Therefore George Lyell would have covered a greater distance in each survey, with the possibility of encountering different habitats and species.

Collecting methods: George Lyell was said to use a "lamp" but no details were given on the type used. The impression is given that the lamp was used to light his way and illuminate the moths and larvae, rather than to attract them. Portable electric lamps would have been available in the later years of George Lyell's collecting career (1888–1946). In any case, it would have been much fainter than the bright mercury-vapour lights used by the Bioscan team. These use a frequency optimal for attracting moths and can probably bring them in from a considerable distance in the line of sight.

However, some moths are not attracted to bright lights and may even avoid them (Zborowski and Edwards 2007). These would be poorly represented in the Bioscan list, but George Lyell would have been able to find them.

The Bioscan team concentrated on night collecting, but the day-flying noctuids *Phalaenoides tristifica* and *Eutrichopidia latinus* on Lyell's list indicate he collected during the day.

George Lyell also regularly collected larvae and raised them through to emergence of the adults (Hewish 2014) and this may have provided a further source of species for his list.

Seasonal collecting: George Lyell's surveys were carried during late summer and early autumn, in each of the years he visited Lorne. Most moths have restricted flight times, and the suite of moths present at each site changes as the year progresses. Therefore with extended collecting periods, a greater variety of moths can be found. The Bioscan was held over three nights, 21 to 23 March 2019, and provided only a restricted snapshot of the moths present during that short period in autumn.

Comprehensive list of moth species for the Great Otway National Park and surrounds

A comprehensive list of moths species (1141 species from 48 families) was compiled using data from Bioscan surveys, George Lyell's records and surveys led by the author and other Bioscan participants (PM, MH, KH) and Axel Kallies. The Otway sites surveyed included coastal and inland locations and a variety of habitats (rainforest, wet forest, dry forest and coastal and inland heath), and all seasons were covered. These sites included:

- **Lyell's surveys from 1906 to 1911:** Lorne and Forrest.
- **Surveys from 1991 to 2019, led by PM, MH, KH and AK:** Hurst Rd (Eumeralla), Eumeralla Scout Camp, Bald Hills Road (Anglesea), Point Addis, No. 2 Road (west of Anglesea), Distillery Creek Picnic Area (Aireys Inlet), Shelly Beach, Elliot Road (west of Marengo), Lorne, Cumberland River, Apollo Bay, Maits Rest, Great Ocean Road (6 km west of Apollo Bay), Kennett River, Cape Otway, Aire River, Wensleydale (two sites), Yaugher (near Forrest), Lake Elizabeth (near Forrest, two sites), Melba Gully, Carlisle Heath (three sites), Timboon, Brucknell and Johanna.
- **Bioscan surveys 2018 to 2019:** Wye River (two sites), Carlisle Heath (two sites), Grey River, Sheoak Picnic Area and Blanket Leaf Picnic Area.

A booklet with photos of more than 850 species of Lepidoptera, known from the Great Otway National Park, has been produced (i.e. Marriott et al. 2019). One aim of the publication is to highlight the diversity of moths and aid naturalists, photographers and others with identification of local species.

Conclusions and recommendations

This study shows that the Great Otway National Park and its surrounds support a moth fauna that is abundant and diverse. The extensive species list probably reflects the survey effort put in since 1906, the variety of distinct habitats and the large area of undisturbed, natural vegetation in the park. Continued protection of this large, connected area as a designated national park is important for the survival of moth populations large enough to be viable in the long-term.

There is considerable scope for further discoveries. The comprehensive list we have compiled from the Otway

Ranges is unlikely to be complete. Many sites have been surveyed only once and there is little information on seasonal differences in moth populations. Information on day-flying moths and larvae is sparse. Even though there have been several surveys since 1906, the Bioscan project recorded 125 moths not previously known from the Otways, including at least two species that appear to be new to science. There may be other Otways moth species that demonstrate biogeographical overlap with the fauna of Tasmania, southern Victoria to the east and west, and the Victorian Alps. The fire study was limited but still indicated that changes in the family composition of the moth fauna occurred in the course of forest regeneration. This study can be built on in future, for example, longer term studies which survey the fauna directly after a bushfire and at intervals as the bushland is regenerating.

No rainforest sites were sampled during the Bioscan, though Maits Rest and Melba Gully have been visited in the past. Cool temperate rainforest is of conservation significance in Victoria as it has a patchy and restricted distribution and it supports a specialist suite of moths, rarely found in other habitats (MH, pers. obs.). Monitoring of these moths in the park should continue. The coastal heathlands at the Eumeralla Scout Camp and the inland heathlands of the Carlisle Heath have been sampled frequently since 1991 (PM, MH, AK) but their moth faunas have never been directly compared. This may make an interesting study.

Fire regimes, weed and pest control, extensions of access tracks into remote areas, construction and tourist development should be managed as far as possible to protect the national park as a whole, and particularly patches of cool temperate rainforest.

Acknowledgments

We would like to thank

- Museums Victoria and Parks Victoria for the opportunity to take part in this work, for generous support and for funding the study
- the Entomological Society of Victoria for their support
- the pre-survey and field organisers of the Bioscan, Genefor Walker-Smith (MV), Jani Demetrious (PV) and Katrina Lovett (PV) for access, assistance and valuable support throughout the study
- Simon Hinkley, Mark Nikolic, Nish Nizar, Heath Warwick for assistance and company in the field
- Heath Warwick and Rob Zugaro (MV photographer and videographer)
- Axel Kallies, Ted Edwards and Marianne Horak for assistance with identification
- Stephen Williams for information on larval food-plants
- Richard Marchant for advice on data analysis
- Wendy Moore for searching the museum collection for specimens taken by George Lyell at Lorne
- Eumeralla Scout Camp, Brucknell Scout Camp, Trevor and Priscilla Pescott, and John and Pam Newman for access to their properties at Anglesea, Brucknell, Yaugher and Wensleydale respectively
- Museums Victoria and the ANIC, Canberra (CSIRO), for access to their reference collections
- Ken Walker (Snr Curator MV), Peter Lillywhite, Catriona McPhee, Simon Hinkley, Claire Keeley and Genefor Walker-Smith (Collection Mangers MV) and Ted (E.D.) Edwards and Marianne Horak (ANIC) for their generous assistance.

This research was conducted under DELWP National Parks Act Research Permit number 10008543.

References

Atlas of Living Australia. Accessed Nov. 2018 to January 2019. http://www.ala.org.au

Australian Faunal Directory. Australian Biological Resources Study, Canberra. Accessed Nov. 2018 to January 2019. http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html

Australian Moths Online - CSIRO/ANIC. Accessed Nov. 2018 to January 2019. http://www1.ala.org.au/gallery2/main.php

BOLDSYSTEMS Public Data Portal. Accessed Nov. 2018 to January 2019. http://www.boldsystems.org/index.php/Public_BINSearch?searchtype=records

BOLDSYSTEMS Taxonomy Browser. Accessed Nov. 2018 to January 2019. http://www.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=113

Common, I.F.B. 1990. *Moths of Australia*. E.J. Brill: Leiden, The Netherlands. 535 pp.

Common, I.F.B. 1994. Oecophorine Genera of Australia I: The Wingia Group (Lepidoptera: Oecophoridae). *Monographs on Australian Lepidoptera Volume 3*. CSIRO Publishing: Collingwood, Victoria. 390 pp.

Common, I.F.B. 1997. Oecophorine Genera of Australia II: The Chezala, Philobota and Eulechria Groups (Lepidoptera: Oecophoridae). *Monographs on Australian Lepidoptera Volume 5*. CSIRO Publishing: Collingwood, Victoria. 407 pp.

Common, I.F.B. 2000. Oecophorine Genera of Australia III: The Barea Group and Unplaced Genera. *Monographs on Australian Lepidoptera Volume 8*. CSIRO Publishing: Collingwood, Victoria. 469 pp.

Garnet, J.R., and Burns, A.N. 1951. George Lyell, 1866–1951. *The Victorian Naturalist* 68: 53–54.

Hewish, M. 2014. Biographical notes on George Lyell, Victorian lepidopterist. *Victorian Entomologist* 44/5: 96-102 and 44/6: 121–128.

Hewish, M., Harris, K., Lewis, and Hewish, D. 2014a. Lepidoptera. Pp 79–93 in: *Grampians Bioscan 2012*. Museum Victoria unpublished report to Parks Victoria.

Hewish, M., Marriott, P., Edwards, T., Kallies, A., and Williams, S. 2014b. *Moths of Victoria. Part 5. Satin Moths and Allies Geometroidea* (A). Entomological Society of Victoria: Melbourne, Victoria. 36 pp.

Hewish, M., Marriott, P., Edwards, T., Kallies, A., Williams, S., and Byrne, C. 2016. *Moths of Victoria. Part 7. Bark Moths and Allies*. Geometroidea (D). Entomological Society of Victoria: Melbourne, Victoria. 36 pp.

Hewish, M., P. Marriott, C. Powers, K. Harris, D. Mules and D. Hewish. 2019. Moth fauna (Lepidoptera) near Wye River, Victoria: comparison between an unburnt site and a site burnt in a wildfire. *Victorian Entomologist* 49(3): 56–64.

Horak, M., and Komai, F. 2006. Olethreutine Moths of Australia (Lepidoptera: Tortricidae). *Monographs on Australian Lepidoptera Volume 10*. CSIRO Publishing: Collingwood, Victoria. 522 pp.

Kallies, A., Marriott, P., and Hewish, M. 2015. *Moths of Victoria. Part 6. Ghost Moths Hepialidae and Allies*. Entomological Society of Victoria: Melbourne, Victoria. 36 pp + CD.

Marriott, P. 2011. *Moths of Victoria. Part 3. Waves, Carpets and Allies Geometroidea* (C). Entomological Society of Victoria: Melbourne, Victoria. 36 pp + CD.

Marriott, P. 2012a. *Moths of Victoria. Part 1.* (2nd ed). *Silk Moths and Allies Bombycoidea.* Entomological Society of Victoria: Melbourne, Victoria. 32 pp + CD.

Marriott, P. 2012b. *Moths of Victoria. Part 4. Emeralds and Allies Geometroidea* (B). Entomological Society of Victoria: Melbourne, Victoria. 36 pp + CD.

Marriott, P. 2015. *Moths of Victoria. Part 2.* (2nd ed.). T*iger Moths and Allies Noctuioidea* (A). Entomological Society of Victoria: Melbourne, Victoria. 36 pp + CD.

Marriott, P., Edwards, T., Kallies, A., Hewish, M., and Williams, S. 2017. *Moths of Victoria. Part 8. Night Moths & Allies Noctuoidea* (B). Entomological Society of Victoria: Melbourne, Victoria. 36 pp + CD.

Marriott, P., Hewish, M., Harris, K., Powers, C., Mules, D., Pierce, F., and Hewish, D. 2019. *Great Otways National Park Lepidoptera.* Entomological Society of Victoria: Melbourne, Victoria. 44 pp.

Matthews, M. 1999. Heliothine Moths of Australia. *Monographs on Australian Lepidoptera Volume 7*. CSIRO Publishing: Collingwood, Victoria. 320 pp.

Neboiss, A. 1986. Lyell, George (1866–1951). *Australian Dictionary of Biography* Volume 10. Melbourne University Press, Melbourne. 680 pp. Also *National Centre of Biography, Australian National University*, http://adb.anu.edu.au/biography/lyell-george-7265/text12589, accessed online 17 November 2019.

Nielsen, E.S., Edwards, E.D., and Rangsi, T.V. (eds). 1996. Checklist of the Lepidoptera of *Australia. Monographs on Australian Lepidoptera. Volume 4.* CSIRO Publishing: Collingwood, Victoria. 529 pp + CD.

Robinson, G.S., and Nielsen, E.S. 1993. Tineid Genera of Australia (Lepidoptera). *Monographs on Australian Lepidoptera Volume 2.* CSIRO Publishing: Collingwood, Victoria. 344 pp.

Simonsen, T.J. 2018. Splendid Ghost Moths and Their Allies: A Revision of Australian *Abantiades*, *Oncopera*, *Aenetus*, *Archaeoaenetus* and *Zelotypia* (Hepialidae). *Monographs on Australian Lepidoptera Volume 12*. CSIRO Publishing: Clayton South, Victoria. 312 pp.

Zborowski, P., and Edwards, T. 2007. A Guide to Australian Moths. CSIRO Publishing: Collingwood, Victoria. 224 pp.

06

REPTILES AND AMPHIBIANS

Report Author: Jane Melville
Field team: Andrew O'Grady, Caroline Dong, Jane Melville, Joanna Sumner, Kylea Clarke, Maggie Haines, Maik Fiedel, Ricky-Lee Erickson and Till Ramm

Introduction

The Anglesea Heath, at the eastern extent of the Otways region in Victoria, is particularly important in terms of unique environments, as it is an isolated patch of relatively intact coastal heathland. The Anglesea Heath is the richest and most diverse vegetation community in Victoria, with about 25% of Victoria's plant species occurring in this small area. These heaths also support a highly diverse fauna with 29 mammal species and over 100 bird species having been recorded (Parks Victoria 2006). Despite the importance of the Anglesea Heath as one of the state's most species-rich habitats, there is little information about the reptiles and amphibians that occur there.

Prior to this study, the collections of Museums Victoria only held two reptile and 24 frog specimens from the Anglesea Heath: Mountain Dragon, *Rankinia diemensis* (1), Blotched Blue-tongue Lizard, *Tiliqua nigrolutea* (1), Eastern Banjo Frog, *Limnodynastes dumerilii* (9) and the Southern Toadlet *Pseudophryne semimarmorata* (15). Most of these specimens were collected before the 1970s and only one was collected after the year 2000. The museum also had no tissue samples from any herpetofauna (reptiles and amphibians) from these heathlands.

Despite the lack of information, it was suspected species of conservation interest may be found in the Anglesea Heath. It was not known if the Mountain Dragon, *Rankinia diemensis*, would still be found in these heathlands, 40 years after the only museum specimen had been collected.

Mountain Dragons occur in Tasmania, New South Wales and Victoria (Fig. 1). The form of *Rankinia diemensis* living in the Grampians in Victoria, is listed as critically endangered due to local habitat loss, but the species is not threatened in the rest of its range.

Mountain Dragons are usually found on the ground in dry sclerophyll forests but have also been recorded in coastal heaths. They eat insects and breed in summer, with the females laying between two and nine eggs in a burrow. *Rankinia diemensis* is one of the few dragon lizard species where the females are larger than males (Melville and Wilson 2019).

Mountain Dragons are known to occur in the heathlands near the *Eumeralla* scout camp in Anglesea (Ng et al. 2014). This is a naturally isolated population with the nearest other population being in the Wombat State Forest, north-west of Melbourne. Genetic work by Museums Victoria researchers has provided evidence to support the recognition of the '*Eumeralla*' population as an important conservation unit (Ng et al. 2014).

During the Bioscan, herpetofauna surveys focussed on the Anglesea Heath. There was a preliminary survey in October 2018 to select suitable sites for trap-lines and an intensive six-day survey in spring (5–10 November 2018). The aims of the six-day survey were to:

1. Document reptile and amphibian species present and the preferred habitat of these species.
2. Collect tissue samples, blood smears (for blood parasite screening) and skin swabs (amphibians only — to test for chytrid fungus) of herpetofauna caught in the field. The collection of tissue samples is particularly important for the documentation of species diversity.
3. Collect voucher specimens to provide a baseline record of species in this under-sampled region of Victoria.
4. Assess the presence of Mountain Dragons (*Rankinia diemensis*).

Methods

Site selection

Pitfall trap-lines were set at five sites across the extent of heath habitat in the Anglesea Heath (Fig. 2 and Table 1). Pitfall traps were not placed in surrounding woodlands and wetlands, however active searches took place in these habitats (Table 2).

Collection methods

At each of the five pitfall-trap sites, two trap-lines were set at right angles to each other (Fig. 3a). Trap-lines consisted of a drift fence approximately 30 centimetres high and 20 metres long that was made of mesh fly-screen and held in place with tent pegs (Fig. 3b). An average of seven buckets (bucket depth 41 cm, diameter 28 cm) and eight funnel traps (Fig. 3c: also

Table 1. Pitfall trap-line locations in the Anglesea Heath. Also refer to figure 2.

Site number	Site name	Latitude (°S)	Longitude (°E)
1	No. 2 Track	38.41500	144.12420
2	Alcoa Boundary Track	38.38250	144.15810
3	Bald Hills Rd	38.38111	144.12833
4	Haggarts Track	38.36778	144.13560
5	Shiney Eye Track	38.37972	144.18530

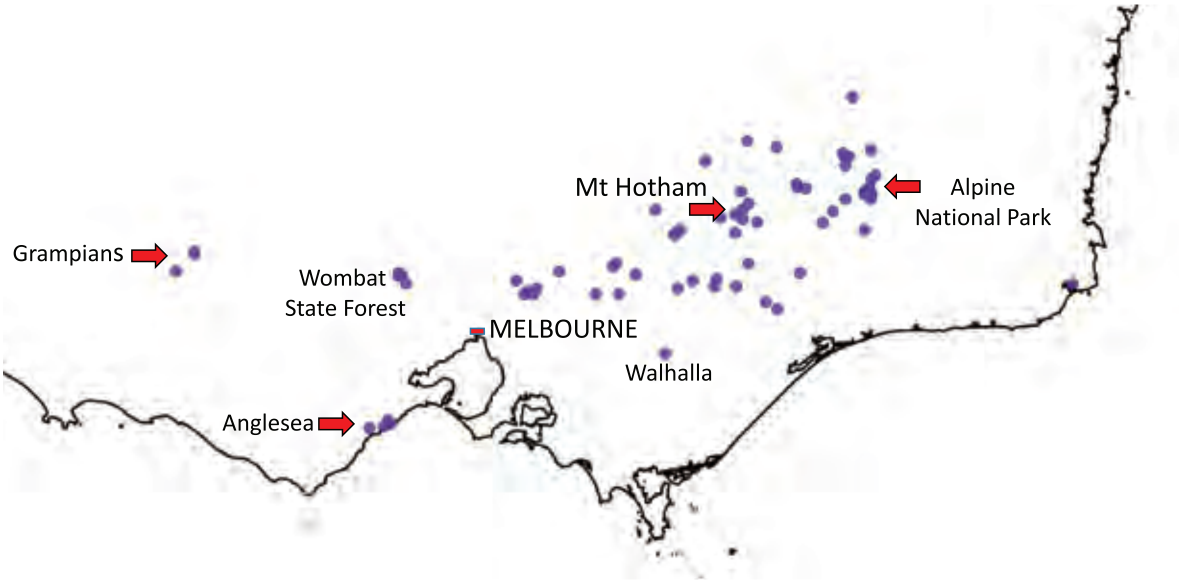


Figure 1. Distribution of the Mountain Dragon, *Rankinia diemensis*. Map generated via the Atlas of Living Australia. Blue dots are occurrence records based on data from specimens held in the collections of Museums Victoria.

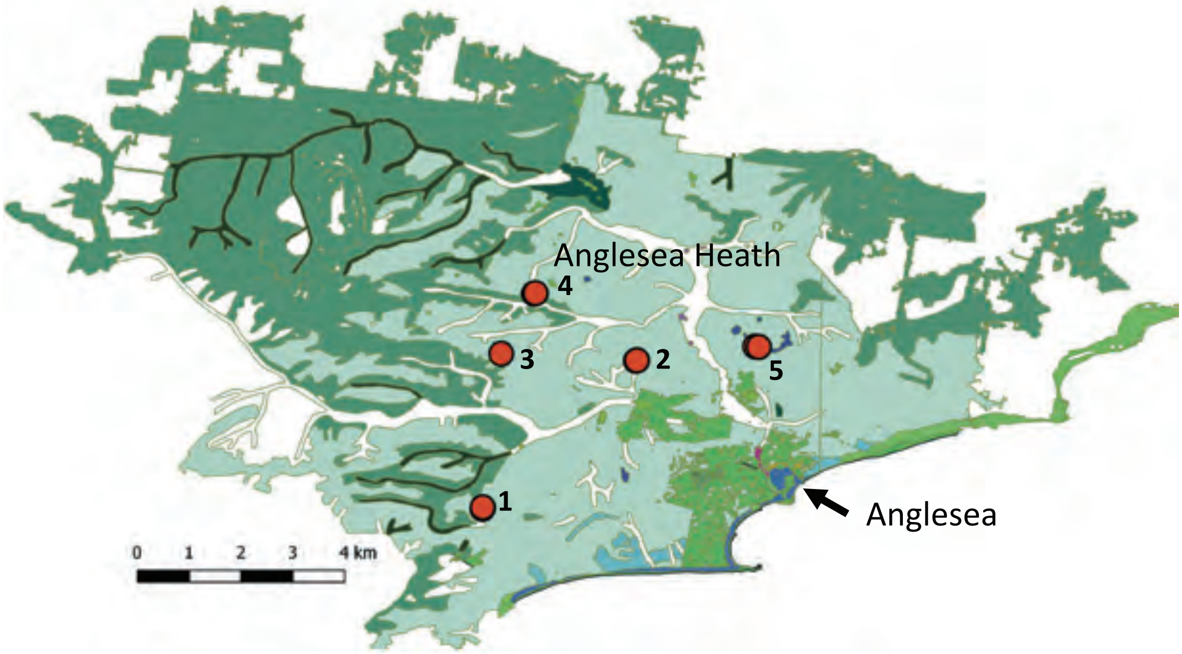


Figure 2. Map of pitfall trap-line sites in the Anglesea Heath. Numbers correspond to site numbers listed in Table 1. Colours on the map depict different vegetation types: light green is heath, bright green is sclerophyll forest/woodlands and dark green is riparian. Vegetation mapping data from Department of Environment, Land, Water & Planning, Victoria, 2018.

Table 2. Sites surveyed during the Otway Bioscan.

Site	Habitat type	Pitfall trap	Active search	Latitude (°S)	Longitude (°E)
Alcoa Boundary Track	heath	yes	yes	38.38250	144.15810
Alcoa Boundary Track	heath	yes	yes	38.38250	144.15833
Bald Hills Rd	heath	yes	yes	38.38111	144.12833
Coalmine Rd	heath	no	yes	38.40194	144.14528
Gum Flats Rd	dam (waterbody)	no	yes	38.34917	144.13555
Forest Hill Rd	woodland	no	yes	38.37361	144.20610
Forest Hill Rd	woodland	no	yes	38.37778	144.20720
Haggarts Tk	heath	yes	yes	38.36500	144.11780
Haggarts Tk	heath	yes	yes	38.36750	144.13530
Haggarts Tk	heath	yes	yes	38.36778	144.13560
Haggarts Tk	heath	yes	yes	38.36778	144.13580
Haggarts Tk	heath	yes	yes	38.37361	144.20390
No. 2 Track	heath	yes	yes	38.41500	144.12420
Shiney Eye Tk	heath	yes	yes	38.36472	144.19750
Shiney Eye Tk	heath	yes	yes	38.36556	144.18970
Shiney Eye Tk	heath	yes	yes	38.36583	144.18890
Shiney Eye Tk	heath	yes	yes	38.37389	144.18690
Shiney Eye Tk	heath	yes	yes	38.37944	144.18440
Shiney Eye Tk	heath	yes	yes	38.37972	144.18530
Shiney Eye Tk	heath	yes	yes	38.38028	144.18640

known as yabby traps) were set along each drift fence. Buckets were placed in holes dug deep enough to ensure the rim of the bucket was at ground level (Fig. 3b). These trap-lines were set up with the assistance and permission of Parks Victoria. Lizards, snakes and frogs were also found via active searching and were either captured in the hand, in a net, or by using a dental floss slip-noose on the end of an extendable fishing pole.

All herpetofauna caught via these methods were measured, photographed in-hand, weighed and sexed. Tissue samples were also collected and blood smears were taken from the tissue sampling sites (to later test for blood parasites).

Tissue sampling was: toe clip (frogs), tail tip (lizards) scale clip (snakes). Animals were then released at the point of capture within 10 minutes. Once an animal was caught, all other activity ceased and the entire field team focussed on processing that animal, in order to minimise handling time. A number of reptiles and amphibians were retained as voucher specimens and have been lodged in the collections of Museums Victoria (see Table 4). All reptiles and frogs were identified on capture, with the additional use of field guides when needed (Wilson & Swan 2003, Cogger 2014).

Figure 3. Survey methods: **a.** Trap-lines set at right angles to each other; **b.** Drift fence and white bucket; **c.** funnel traps, one on each side of the fence and protected by shade-cloth. Photographer: Ben Healley | Source: Museums Victoria.

Table 3. Species observed in the Anglesea Heath and the number of voucher specimens collected at each survey location.

Common name	Species	Alcoa Boundary Tk	Bald Hills Rd	Coalmine Rd	Gum Flats Rd	Haggarts Tk	No. 2 Track	Shiney Eye Tk	TOTAL
Frogs (see Fig. 4)									
Brown Tree Frog	*Litoria ewingii*	-	-	4	1	-	-	-	**5**
Common Froglet	*Crinia signifera*	2	-	1	4	-	-	-	**7**
Eastern Banjo Frog*	*Limnodynastes dumerilii*	3	-	2	1	-	-	1	**7**
Dragon Lizards (agamids) (see Fig. 5)									
Jacky Lizard	*Amphibolurus muricatus*	-	-	-	-	-	-	1	**1**
Mountain Dragon	*Rankinia diemensis*	-	-	-	-	2	-	-	**2**
Skinks (see Fig. 6)									
Blotched Blue-tongue Lizard**	*Tiliqua nigrolutea*	-	-	-	-	-	-	-	**0**
Common Garden Skink***	*Lampropholis guichenoti*	-	-	-	-	-	-	1	**1**
Eastern Three-lined Skink	*Acritoscincus duperreyi*	4	2	-	-	1	-	1	**8**
White's Skink	*Liopholis whitii*	-	-	-	-	2	-	-	**2**
Snakes (see Fig. 7)									
Eastern Brown Snake	*Pseudonaja textilis*	-	-	-	-	-	-	-	**0**
Tiger Snake	*Notechis scutatus*	-	-	-	-	-	-	2	**2**
TOTALS		**9**	**2**	**7**	**6**	**5**	**0**	**6**	**35**

*also known as Pobblebonk; ** also known as Blotched Blue-tongued Lizard; *** also known as Pale-flecked Garden Sunskink,

Table 4. Species and number of samples collected during the Bioscan (5–10 November 2018). Note, more than one tissue sample was collected from some specimens. Also see Figs 4–7.

Taxon	Common names	Voucher specimens	Tissue samples	Blood smears
Agamids (Dragon Lizards)				
Amphibolurus muricatus	Jacky Dragon	1	5	1
Rankinia diemensis	Mountain Dragon	2	2	1
Skinks				
Acritoscincus duperreyi	Eastern Three-lined Skink	8	28	5
Lampropholis guichenoti	Common Garden Skink	1	1	0
Liopholis whitii	White's Skink	2	3	2
Tiliqua nigrolutea	Blotched Blue-tongue Lizard	0	1	0
Snakes				
Notechis scutatus	Tiger Snake	2	2	2
Pseudonaja textilis	Eastern Brown Snake	0	1	0
Frogs				
Litoria ewingii	Brown Tree Frog	5	5	5
Crinia signifera	Common Froglet	7	7	2
Limnodynastes dumerilii	Eastern Banjo Frog	7	10	7

Figure 4. Frogs seen in the Anglesea Heath during the Otway Bioscan: **a.** Eastern Banjo Frog, *Limnodynastes dumerilii*; **b.** Common Froglet, *Crinia signifera*; **c.** Brown Tree Frog, *Litoria ewingii*. Photographers: David Paul (a), Till Ramm (b–c) | Source: Museums Victoria.

Figure 5. Dragon Lizards seen in the Anglesea Heath during the Otway Bioscan: **a.** Jacky Lizard, *Amphibolurus muricatus*; **b.** Mountain Dragon, *Rankinia diemensis*. Photographers: Till Ramm (a), David Paul (b) | Source: Museums Victoria.

Figure 6. Skinks seen in the Anglesea Heath during the Otway Bioscan: **a.** Blotched Blue-tongue Lizard, *Tiliqua nigrolutea*; **b.** Common Garden Skink, *Lampropholis guichenoti*; **c.** Eastern Three-lined Skink, *Acritoscincus duperreyi*; **d.** White's Skink, *Liopholis whitii*. Photographers: Mark Norman (a), David Paul (b, d), Till Ramm (c) | Source: Museums Victoria.

Figure 7. Snakes seen in the Anglesea Heath during the Otway Bioscan: **a.** Eastern Brown Snake, *Pseudonaja textilis*; **b.** Tiger Snake, *Notechis scutatus*. Photographers: John Broomfield (a), Ben Healley (b) | Source: Museums Victoria.

Results and Discussion

Survey results

Immediately prior to and during the survey period (5–10 November 2018) the weather was not ideal for reptile activity. There was heavy rain, cool temperatures and overcast days. Despite weather conditions, we confirmed the presence of eight species of reptiles and three species of amphibians in the Anglesea Heath (Table 3). Tissue samples were collected from 59 animals (Table 4). The species captured in pitfall traps or funnel traps were the Mountain Dragon, *Rankinia diemensis* (one juvenile in pitfall), the Eastern Three-lined Skink, *Acritoscincus duperreyi*, the Common Froglet, *Crinia signifera* and the Eastern Banjo Frog, *Limnodynastes dumerilii*. Other species were hand captured and were not observed in the vicinity of the trap-lines (i.e. Brown Tree Frog, *Litoria ewingii*; Jacky Lizard, *Amphibolurus muricatus*; Common Garden Skink, *Lampropholis guichenoti*; White's Skink, *Liopholis whitii*; Tiger Snake, *Notechis scutatus*). Two specimens were salvaged as roadkill (Eastern Brown Snake, *Pseudonaja textilis* and Blotched Blue-tongue Lizard, *Tiliqua nigrolutea*).

We observed a distinct difference between the species seen and trapped in the heath vegetation and those observed in surrounding eucalypt woodlands or wetlands (Figs 8 and 9). Mountain Dragons (*Rankinia diemensis*), the Eastern Three-lined Skink (*Acritoscincus duperreyi*) and the Eastern Banjo Frog (*Limnodynastes dumerilii*) were only found in the treeless heath habitats, while White's Skink (*Liopholis whitii*) were observed along track edges in sandy soils at the boundary between woodlands and heath. The other skink and dragon species and the snakes were located within the eucalypt woodlands. The Brown Tree Frog (*Litoria ewingi*) was found around wetlands and the Common Froglet (*Crinia signifera*) was collected from both wetlands and in the heath, possibly indicating it is a habitat generalist.

Mountain Dragons (*Rankinia diemensis*)

Our survey confirmed the presence of Mountain Dragons in the Anglesea Heath. One juvenile dragon was captured in a pitfall bucket (site 4, Haggarts Track: Fig. 9a) and an adult was hand captured basking on the middle of the track adjacent to this site. This site (site 4) was on a high ridge, with scattered stands of small eucalypts and a sandy soil. A third animal (probably an adult) was seen on the track near site 4 but was not captured.

It is possible Mountain Dragons were only observed at one site because the inclement weather conditions might have limited activity at other sites. However, it is also possible that within the Anglesea Heath, this species only occurs in particular habitats and aspects (e.g. northern sunny slopes). It should be noted that no Mountain Dragons were observed in the adjacent woodlands but Jacky Lizards (*Amphibolurus muricatus*) were observed at multiple locations around the perimeter of the heathlands. These results, together with those of Ng et al. (2014) suggest Mountain Dragons in the Anglesea area are restricted to heath vegetation and are possibly selecting a particular micro-environment within that habitat type. Further survey work is required to better understand the habitat requirements of Mountain Dragons.

The Mountain Dragons found in the Anglesea area are unique amongst Victorian populations as they inhabit coastal heathlands, instead of upland forests.

Previous genetic research on the *Eumeralla* Mountain Dragons revealed this population has probably been isolated for thousands of years (Ng et al. 2014). Volcanic activity may have led to this isolation from populations further north, with genetic results indicating an isolation event during the Holocene (Ng et al. 2014). Most of the volcanoes north of Anglesea are believed to have erupted in the Holocene or late Pleistocene (Joyce 1988). The *Eumeralla* population is of conservation interest because it is located on the fringe of a popular coastal town, where it may be threatened by residential development, human disturbances, altered fire regimes and predation by domestic dogs and cats (Clemann 2003).

Mountain Dragon, male and gravid female, *Rankinia diemensis*. Photographer: David Paul | Source: Museums Victoria.

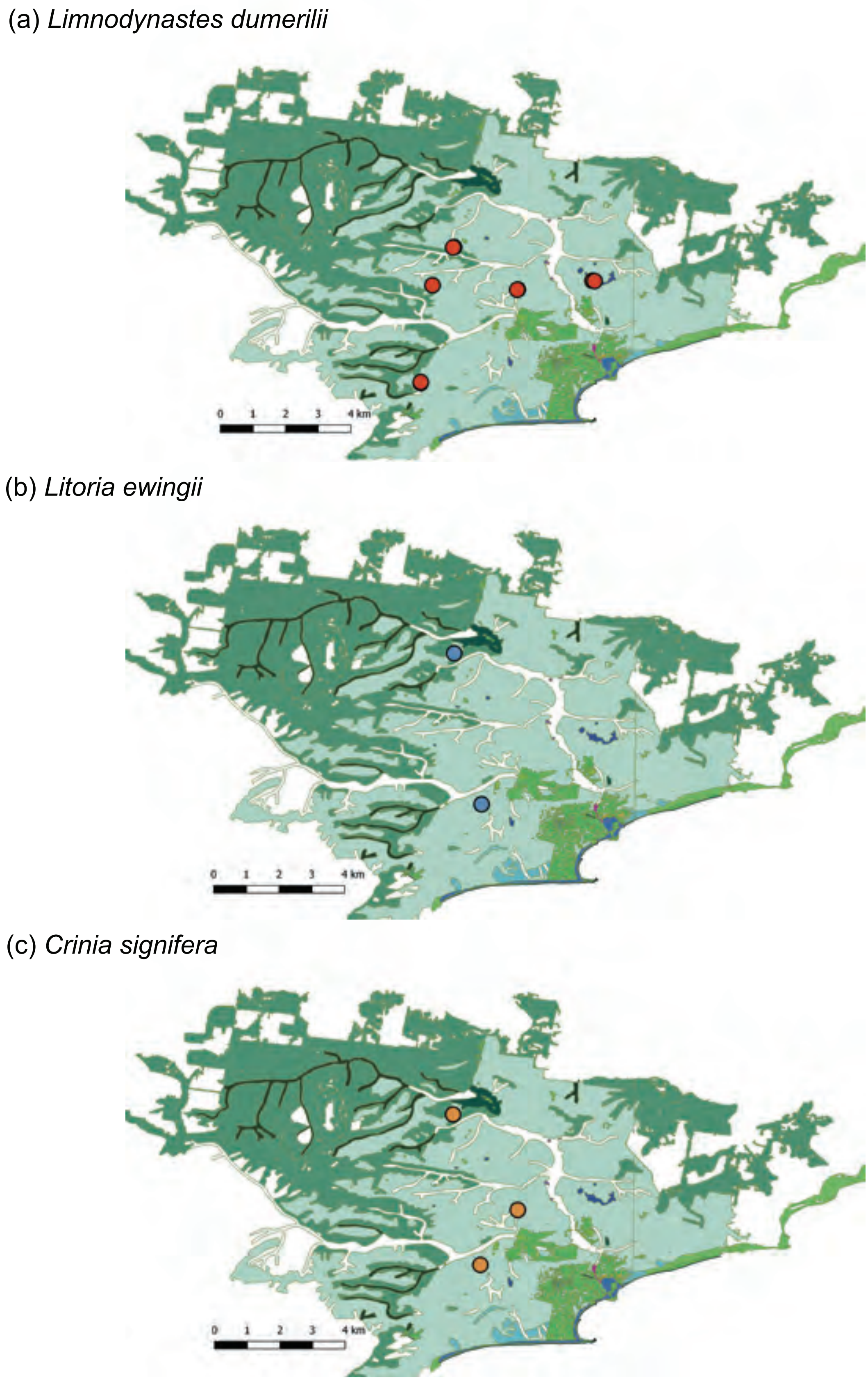


Figure 8. Map of collection sites for frogs: (a) *Limnodynastes dumerilii*; (b) *Litoria ewingii*; and (c) *Crinia signifera*. Colours on the map depict different vegetation types: light green is heath, bright green is sclerophyll forest/woodlands and dark green is riparian vegetation. Vegetation mapping data from Department of Environment, Land, Water & Planning, Victoria, 2018.

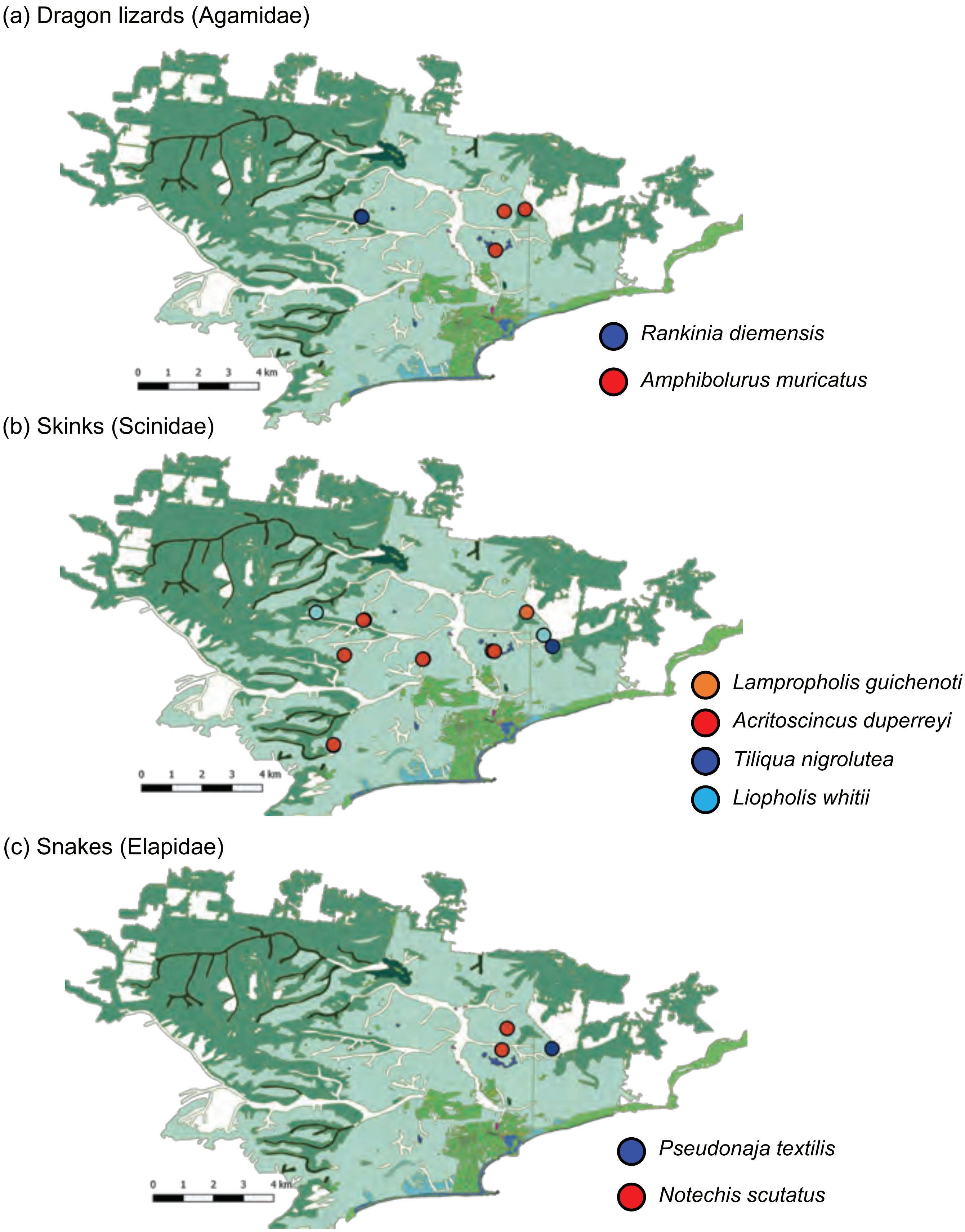


Figure 9. Map of collection sites for reptiles: (a) agamid (dragon) lizards; (b) skinks; and (c) snakes. Colours on the map depict different vegetation types: light green is heath, bright green is sclerophyll forest/woodlands and dark green is riparian vegetation. Vegetation mapping data from Department of Environment, Land, Water & Planning, Victoria, 2018.

Conclusions

The Anglesea Heath is a unique environment, as it is an isolated patch of relatively intact coastal heathland, with a diverse vegetation, and diverse mammal and bird communities (Parks Victoria 2006). Our Bioscan survey provides an initial snapshot of herpetofauna diversity of this area and our results suggest the heath habitat supports a reptile and amphibian fauna that is distinct from that found in the surrounding eucalypt woodlands.

Our results also show the importance of pitfall trap-lines as a survey method, in combination with active searching, in the heathlands. Most species were either found with active searches or pitfall trapping, so both methods are important in reptile and frog surveys. We recommend that future surveys of the Anglesea Heath employ a combination of survey methods.

The tissue samples and the voucher specimens collected during the Bioscan will contribute to continuing efforts to measure genetic diversity within species and help clarify taxonomic diversity in species complexes. Our work highlights the need for further surveys in the Anglesea Heath in order to more fully assess species diversity, occurrences and ecological requirements.

Finally, we confirmed the presence of Mountain Dragons (*Rankinia diemensis*) at one site in the Anglesea Heath. This species is of conservation interest and additional research to determine the full extent of this species in the Anglesea Heath, including its micro-habitat requirements, is a priority.

Acknowledgements

The herpetology team would like to thank staff from the Parks Victoria Anglesea office for advice and assistance with fieldwork including Katrina Lovett, Michael Gerl and Felix Marshall.

This research was conducted under DELWP National Parks Act Research Permit number 10008869.

References

Clemann, N. 2003. The Mountain Dragon *Tympanocryptis diemensis* (Gray, 1841): a complex issue (with notes on the conservation of the 'Anglesea' Mountain Dragon). *Monitor* 11: 8.

Cogger, H., 2014. *Reptiles and amphibians of Australia*. CSIRO Publishing: Melbourne, Victoria. 1064 pp.

Department of Environment, Land, Water & Planning, Victoria. 2018. NV2005_EVCBCS: *Native Vegetation – Modelled 2005 Ecological Vegetation Classes* (*with Bioregional Conservation Status*). Biodiversity and Ecosystem Services, Victoria.

Joyce, E.B. 1988. Newer volcanic landforms. Pp. 419–426 in: Douglas, J.G. and Ferguson, J.A. (eds), *Geology of Victoria*. Geological Society of Australia, Victorian Division: Melbourne.

Melville, J.E. and Wilson, S.K. 2019. *Dragon Lizards of Australia: Evolution, Ecology and a Comprehensive Field Guide*. Museums Victoria Publishing, Melbourne, Australia. 400 pp.

Ng, J., Clemann, N., Chapple, S.N., and Melville, J., 2014. Phylogeographic evidence links the threatened 'Grampians' Mountain Dragon (*Rankinia diemensis*) with Tasmanian populations: conservation implications in south-eastern Australia. *Conservation Genetics* 15(2): 363–373.

Park Victoria. 2006. Parks Victoria Notes: Anglesea Heath. Parks Victoria.

Wilson, S. and Swan, G., 2003. *A Complete Guide to the Reptiles of Australia.* Reed New Holland: Sydney. 480 pp.

07

SMOKY MOUSE REMOTE CAMERA MONITORING

Report authors: Sakib Kazi and Kevin Rowe
Survey team: Sakib Kazi, Steph Versteegen, Brigette Bell, Molly Watchorn and Kevin Rowe

Introduction

The endangered Smoky Mouse (*Pseudomys fumeus*) is a small rodent endemic to south-eastern Australia. It is one of the most elusive Australian mammals with few records across its patchy distribution, with no reliable estimates of population sizes (probably <1000 individuals), and with many instances of sites where the species is recorded but not consistently detectable. For example, while first recorded in Victoria in 1933, the species was not captured in the ACT and NSW until 1986 and 1994, respectively. The basis for their patchy distribution is not known as Smoky Mice live in a wide range of habitats (dry sclerophyll forest, wet forest, subalpine heath, and coastal heath) and have a broad diet (seeds, fruit, fungi, and arthropods). The historical distribution of the Smoky Mouse included the Otways and Grampians of western Victoria, the Great Dividing Range from northeast of Melbourne to the ACT, coastal far East-Gippsland, and the Nullica region of NSW (Fig. 1). However, populations in the ACT have not been detected since the 1980s and recent records of the species in Victoria are restricted to the Grampians and Central Highlands (from the Yarra Ranges to the NSW border). Key threatening processes for the Smoky Mouse include habitat loss and fragmentation, increased threats of bushfires leading to fewer suitable shelter sites for predator avoidance, and the introduction of feral predators. However, the causes of their decline and the threats to their persistence remain poorly understood. The only captive breeding colony for the Smoky Mouse was established recently by the New South Wales Office of Environment and Heritage, and so survival of the species depends largely on its poorly documented wild populations.

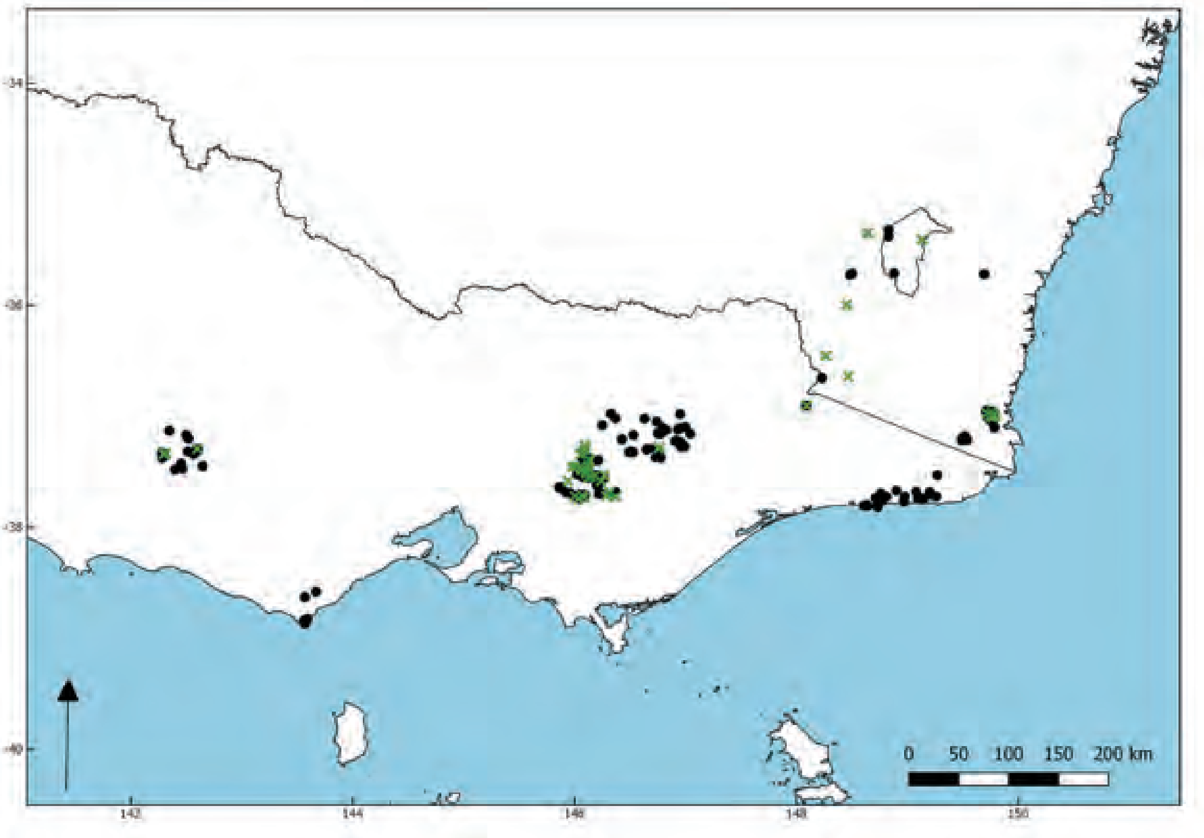


Figure 1. Smoky Mouse occurrence records across Australia. Black circles represent records prior to 2000, green crosses represent records post-2000.

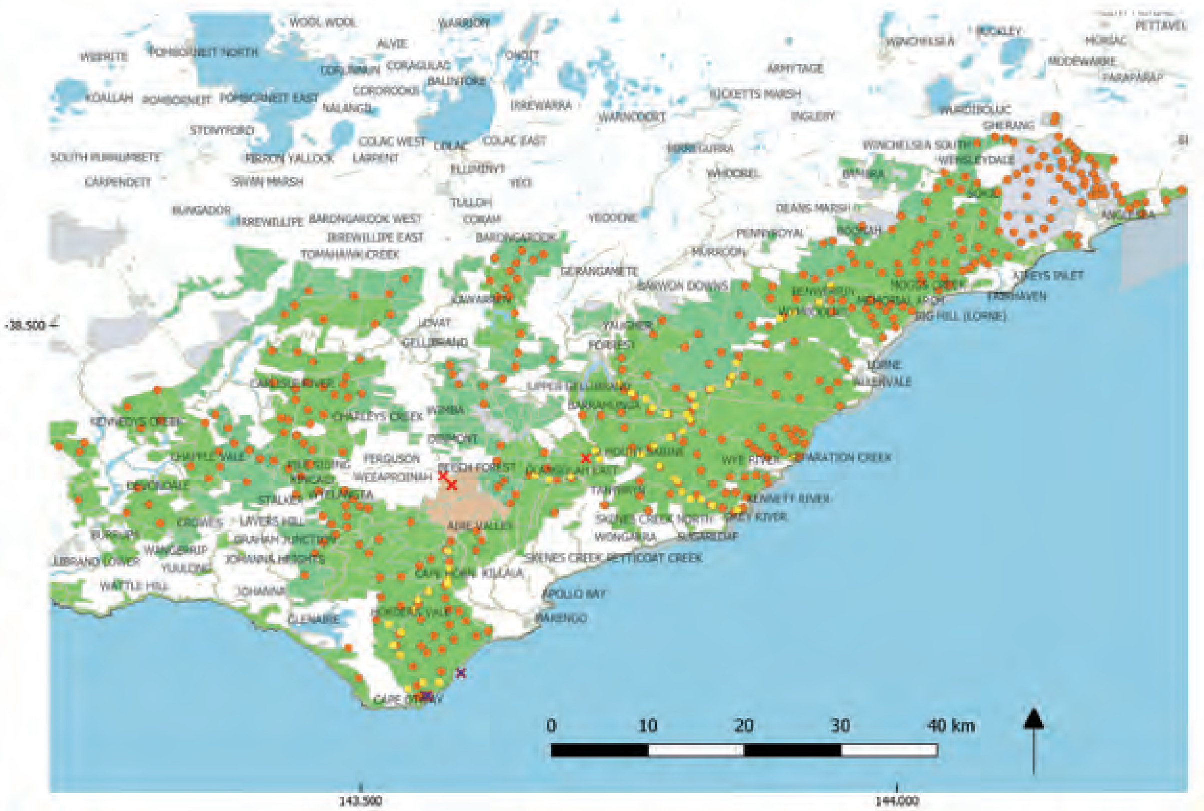


Figure 2. Parks Victoria Otway Ark camera sites (orange circles) and MV Bioscan camera sites (yellow circles). Historical Smoky Mouse occurrences are denoted by coloured crosses.

Figure 3. Camera and bait station arrangement.

Smoky Mice were last recorded in the Otway region in 1985; specifically, at Cape Otway. Monitoring efforts since then have failed to detect the species at historical occurrence sites (Fig. 2) or elsewhere in the national park. These efforts include Parks Victoria's ongoing Otway Ark camera trapping program (Fig. 2) and targeted camera trapping by the Arthur Rylah Institute. Our Bioscan research aimed to set camera traps (configured to photograph small mammals) across the Otway region at sites not currently included in Parks Victoria's ongoing Otway Ark camera trapping program.

Methods

Camera setup

Fifty cameras were deployed for a two-week period in October 2018. Three models of remote sensing camera were used in this deployment: Reconyx HC550 Hyperfires (32 cameras), Reconyx WR6 Ultrafires (eight cameras) and Reconyx HF2 Pro Whites (10 cameras). All models use passive infrared (IR) sensors to detect motion in the field of view, record white flash images and were configured to take three photographs for each motion trigger. White flash cameras are essential for differentiating Smoky Mice from other native rodents, such as Bush Rats (*Rattus fuscipes*). Passive IR sensors detect changes in the IR signature in the field of view, such as an organism's movement. The collection of three photographs, taken in rapid succession (per trigger), can aid identification of quick-moving animals such as small mammals.

Figure 4. Bait station with tea strainers containing a mixture of oats, peanut butter, golden syrup and vanilla.

Figure 5. Comparison of black-and-white photographs and white flash photographs. A and B are Smoky Mice, C and D are Bush Rats (D was captured on camera at site O24 during the Bioscan).

DID YOU KNOW?

Cameras can detect when small mammals are near with temperature-sensitive triggers. Taking three colour photos with a flash helps scientists distinguish between similar looking species. Placing the food bait 15 centimetres off the ground encourages the animals to rear up on their hind legs and gives an identifiable view.

Smoky Mouse, *Pseudomys fumeus*. Photographer: David Paul | Source: Museums Victoria.

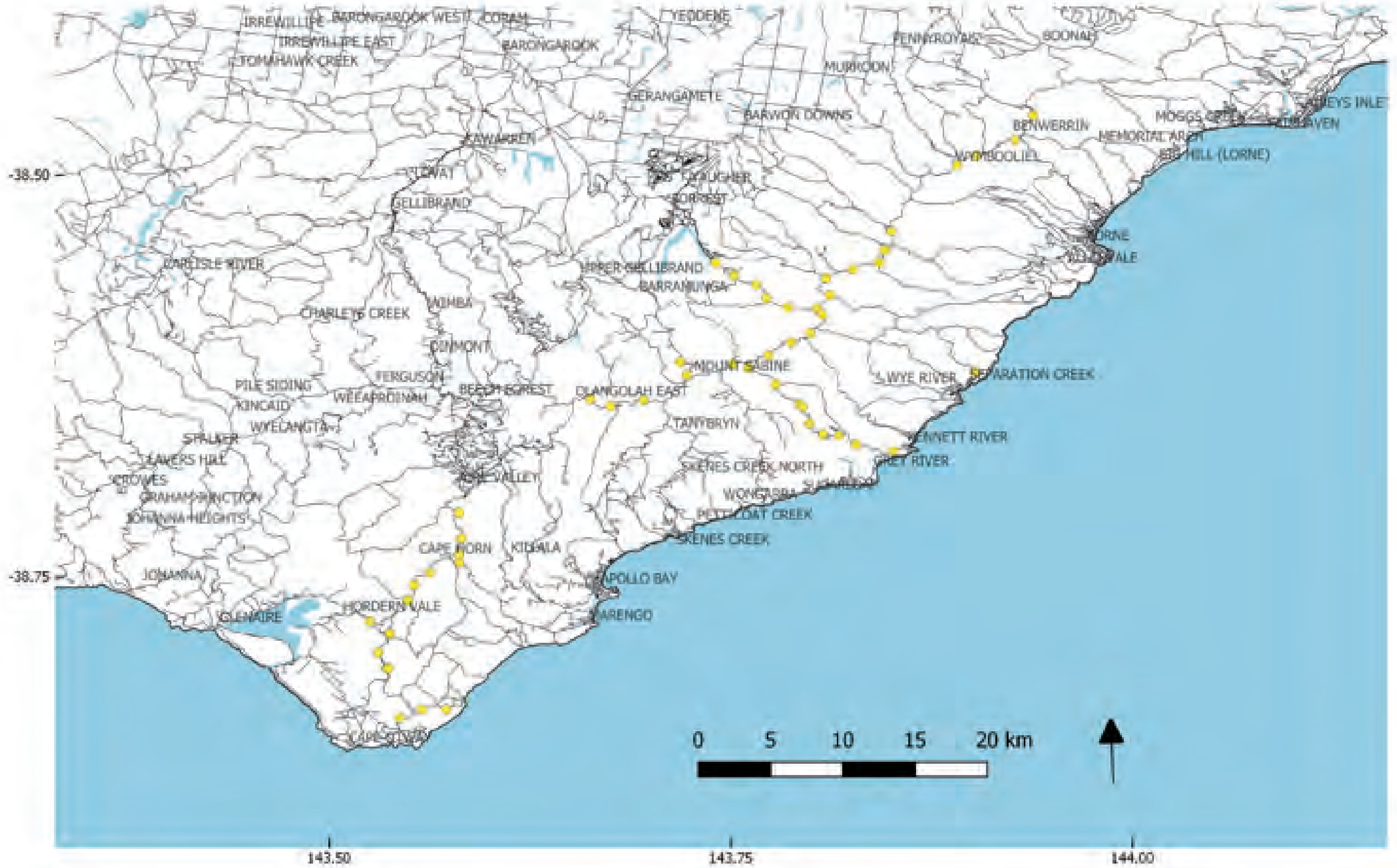


Figure 6. Map of Otway camera trap deployment locations (yellow circles).

Cameras were fixed to trees and faced a bait station, which consisted of a metal cage containing tea strainers full of oats, peanut butter, golden syrup and vanilla essence (Fig. 4). The cage was fixed to a plastic stake and positioned 15 centimetres above the ground. The bait station was placed 70 centimetres from the camera (Fig. 3). Vegetation between the camera and bait station was removed to ensure photographic clarity. The elevated bait station encourages small mammals to rear up on their hind legs, allowing a dorsal view of the body to be captured by the camera. Images taken at this angle enable better differentiation of species and maximise the likelihood of discerning diagnostic external features. Identification of Smoky Mice is relatively straight-forward because of their ash-grey (smoky) coat colour and their long, dorso-ventrally bicoloured tail. Tail and coat colouration are the two easiest methods of discerning smoky mice from other native rodents. Black-and-white photographs taken by infrared cameras are inadequate in differentiating smoky mice from bush rats, thus infrared cameras (i.e. cameras which do not use white flash) were not used in this survey (see Fig. 5).

Camera deployment and sites

Fifty cameras were deployed across fifty sites in the Great Otway National Park and the Otway Forest Park (Fig. 6). Sites were within 100 metres of roads and were on public land. Due to road closures and track conditions, precise locations of past Smoky Mouse occurrences were inaccessible, and cameras were deployed to cover a broad area outside of sites in the Otway Ark camera trapping program. Deployment-site habitat types ranged from drier coastal heath in Cape Otway to wet forests in the Otway Range; both these habitat types are known to support Smoky Mice elsewhere in Victoria (although Smoky Mice no longer occur in coastal heath). Cameras were set from 1–4 October 2018 and retrieved from 15–18 October 2018, and thus were operational for approximately two weeks.

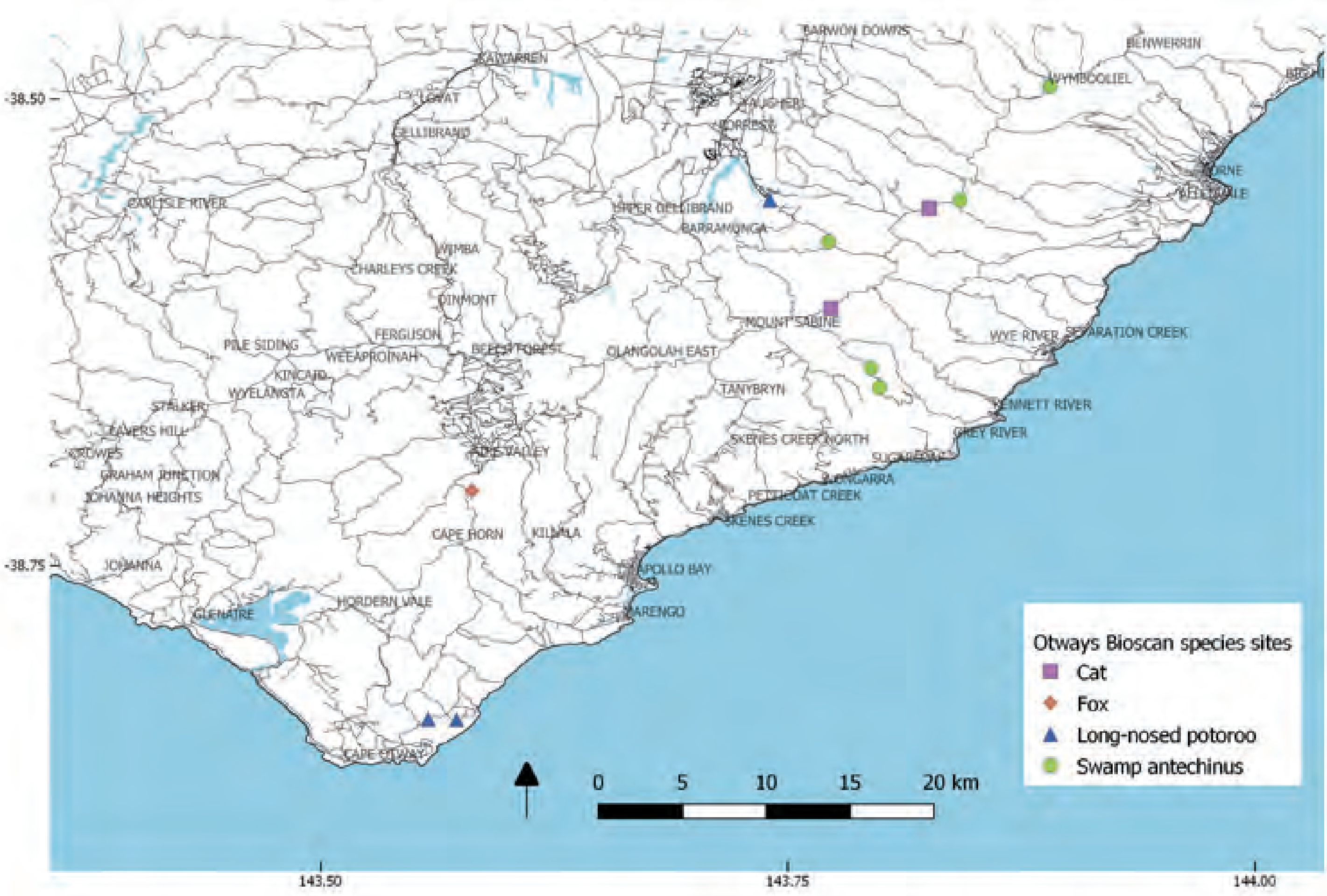


Figure 7. Map of locations with detections of cats, foxes, Long-nosed Potoroos and Swamp Antechinus.

Results

Cameras were deployed for a total of 688 trap nights and took 29,820 photographs. Smoky Mice were not detected on any cameras. Small mammals accounted for most photographs (23,325 or 78.3% of all photos taken), with Bush Rats and Agile Antechinus being the most common and widespread species (Table 1). Feral cats and foxes were the only non-native species photographed. Cats appeared on two cameras and foxes on one (Fig. 7). The Swamp Antechinus (*Antechinus minimus maritimus*) and the Long-nosed Potoroo (*Potorus tridactylus*) were the only two species of conservation concern that were detected (Fig. 8). Both are listed as near threatened on the 2013 DELWP Advisory List (see also Action Plan for Australian Mammals 2012).

Table 1. List of species captured on remote cameras, with number of photographs taken and number of occurrence sites.

Species	No. photos	No. cameras
Cat (*Felis catus*)	63	2
Fox (*Vulpes vulpes*)	6	1
Agile Antechinus (*Antechinus agilis*)	1,203	14
Bush Rat (*Rattus fuscipes*)	18,146	46
Dusky Antechinus (*Antechinus mimetes*)	981	5
Long-nosed Bandicoot (*Perameles nasuta*)	81	4
Long-nosed Potoroo (*Potorus tridactylus*)	42	3
Short-beaked Echidna (*Tachyglossus aculeatus*)	342	5
Smoky Mouse (*Pseudomys fumeus*)	0	0
Swamp Antechinus (*Antechinus minimus*)	924	5
Swamp Rat (*Rattus lutreolus*)	1,116	3
Swamp Wallaby (*Wallabia bicolor*)	510	7
Unidentified skink	6	2
Unidentified bird	5,160	41
Total animals tagged	**28,580**	
Total setup/retrieval/false trigger	1,240	
Total photos taken	**29,820**	

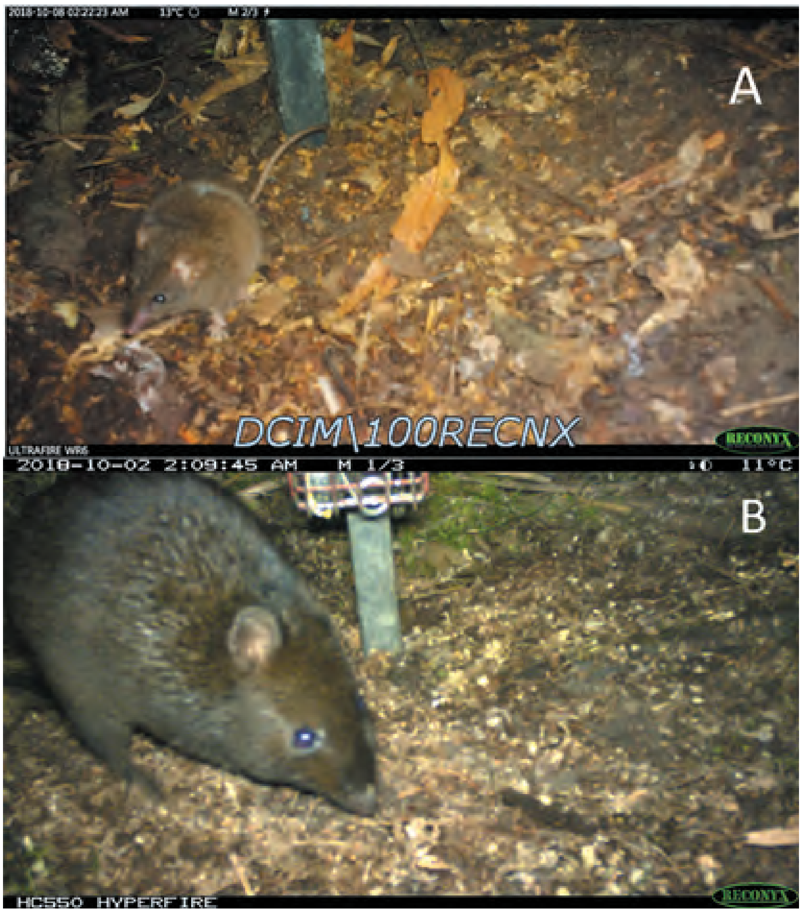


Figure 8. Swamp Antechinus (A) and Long-nosed Potoroo (B) captured on Bioscan cameras.

Discussion

Our deployment of 50 remote cameras failed to detect Smoky Mice in the Otway region, consistent with all other efforts to detect the species in the Otways since 1985. However, several areas in geographic proximity to historical Smoky Mouse records or with potentially suitable habitat remain unsurveyed for the presence of Smoky Mice in the Otway Region. Our deployment was limited by road closures and track conditions, which prevented access to locations of past occurrence and that were identified by our team as priorities for surveys (Fig. 9).

Museums Victoria Smoky Mouse camera trapping in the Victorian Central Highlands in 2018 and 2019 indicates that Smoky Mice are detectable with our camera set-up, but that dense deployment of cameras (i.e. at 200 metre intervals) may be necessary to detect Smoky Mice along roads where they are present. Given the patchy distribution of the species, broadly dispersed cameras may fail to detect Smoky Mice. Future monitoring efforts in the Otways should aim to deploy cameras at a higher density and target areas of historical occupation and potentially suitable habitat, much of which is located along difficult-to-access tracks in the Otways. When possible, cameras should be set along roads near the most recent records in Cape Otway, which were inaccessible during this study, especially along management tracks to the east of Lighthouse Rd and to the south of the Hordern Vale area (Fig. 9).

Acknowledgments

This research was conducted under DELWP National Parks Act Research Permit number 10007934.

References

DEWLP advisory list 2013. https://www.environment.vic.gov.au/__data/assets/pdf_file/0014/50450/Advisory-List-of-Threatened-Vertebrate-Fauna_FINAL-2013.pdf

Woinarski, J.C.Z., Burbidge, A.A. and Harrison, P.L. 2014. *The action plan for Australian mammals 2012; with maps and database management for terrestrial species by Damian Milne*. CSIRO Publishing, Collingwood, Victoria. 1038 pp.

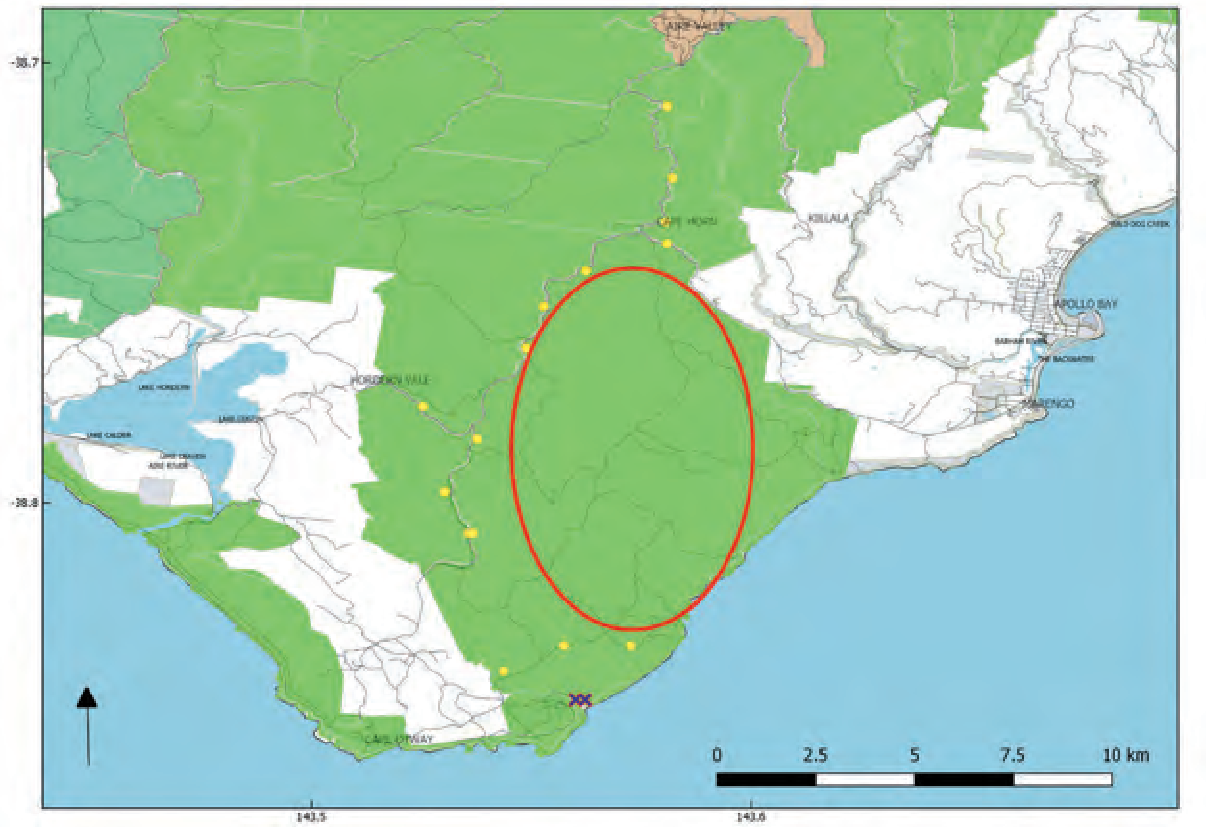


Figure 9. Roads unable to be accessed during the Bioscan and recommended for future small mammal camera trap deployments (area outlined in red). Bioscan cameras are denoted by yellow circles and historical Smoky Mouse records are denoted by purple crosses.

08

PALAEONTOLOGY

Report Authors: Erich Fitzgerald and Rolf Schmidt
Survey Team: Erich Fitzgerald, Rolf Schmidt and Tim Ziegler

Introduction

The mass extinction event at the end of the Cretaceous Period, 66 million years ago, extinguished approximately 75% of all life on Earth. This was a turning point in the history of our planet, spelling doom for all dinosaurs, apart from the ancestors of modern birds, as well as many marine organisms. It is also the boundary between the Mesozoic Era (so-called 'Age of Reptiles') and the Cenozoic Era (the 'Age of Mammals') in which we currently live. The first two-thirds of the Cenozoic Era, is known as the Paleogene Period. The Paleogene Period lasted from 66 million years ago to 23 million years ago. Pivotal climatic and geographic change occurred during this time, shaping Australia's landscapes, flora and fauna into what we see today.

- The Cenozoic Era (and the Paleogene Period) began 66 million years ago.
- Paleocene–Eocene Thermal Maximum occurred 56 million years ago. This was when the global average temperature spiked at 14°C warmer than present and there was intense ocean acidification.
- Eocene Climatic Optimum happened 53–41 million years ago. This was when the global average temperature reached a long term high of 10–12°C warmer than present, and the Earth was ice-free at both poles.
- In the Early Oligocene, 33 million years ago, South America finished separating from Antarctica, there was global cooling of about 4–6°C, and the Antarctica ice sheet started to form.
- The Antarctic Circumpolar Current was established 33–24 million years ago, after Australia fully separated from Antarctica.
- Late Oligocene Warming occurred 25 million years ago. This was a time when global average temperature increased to about 7°C warmer than present.

These shifts in the global environment draw a long-term trend of stepped global cooling from Greenhouse to Icehouse Earth and were the backdrop to some major events in the evolution of the marine environment. Notable here are: the recovery of marine ecosystems following the Cretaceous–Paleogene mass extinction 66 million years ago; the early evolution of penguins, including gigantic species taller than the modern emperor penguin during the Paleocene and Eocene epochs; the evolution of whales (cetaceans) from land mammals and their increasing specialization to life in water between 53 and 36 million years ago; and the rapid diversification of fully aquatic cetaceans between 34 and 23 million years ago, which gave rise to today's whales and dolphins.

How these events played out in Australia is poorly known: largely due to limited onshore outcrops of marine sedimentary rocks that are 60–28 million years old. The only region in Australia with the potential to shed light on all of these critical moments, is the Great Otway National Park, Victoria.

Until now, there has never been systematic exploration of the Great Otway National Park to search for fossils of Paleocene–early Oligocene penguins, whales and associated biota.

Aims

The key objective of this project was to perform geological and palaeontological reconnaissance of key field localities in the Great Otway National Park and determine the prospects for discovery of fossils of penguins, whales and associated macroinvertebrates, dating from the Paleocene–Early Oligocene (approximately 60–28 million years ago).

The aims of the project were to perform preliminary assessment of the geology and macropalaeontology of:

1. The Eocene–Oligocene coastal section at the Castle Cove locality.
2. The Late Eocene section at the Browns Creek east and West coastal gully sections.
3. Paleocene–Eocene coastal sections between the mouth of the Gellibrand River and Pebble Point.
4. Identify the type locality of the first fossil whale described from Australia, *Parasqualodon wilkinsoni* (McCoy, 1866), and collect additional geological data on this locality and determine the prospects for discovery of additional fossil whale specimens from this locality.

Methods

The existing Museums Victoria Palaeontology Collection and published literature were consulted in order to identify target geological outcrops within the Great Otway National Park. Field localities (Fig. 1 and Table 1) were surveyed in a small field party, with fossils and small associated sediment samples collected using hand tools (i.e. geological hammer and chisel: Fig. 2). All vertebrate fossils collected were designated with 'EF2019' field specimen catalogue numbers, where 'EF' denotes 'Erich Fitzgerald' and '2019' denotes the year 2019 in which the specimens were collected.

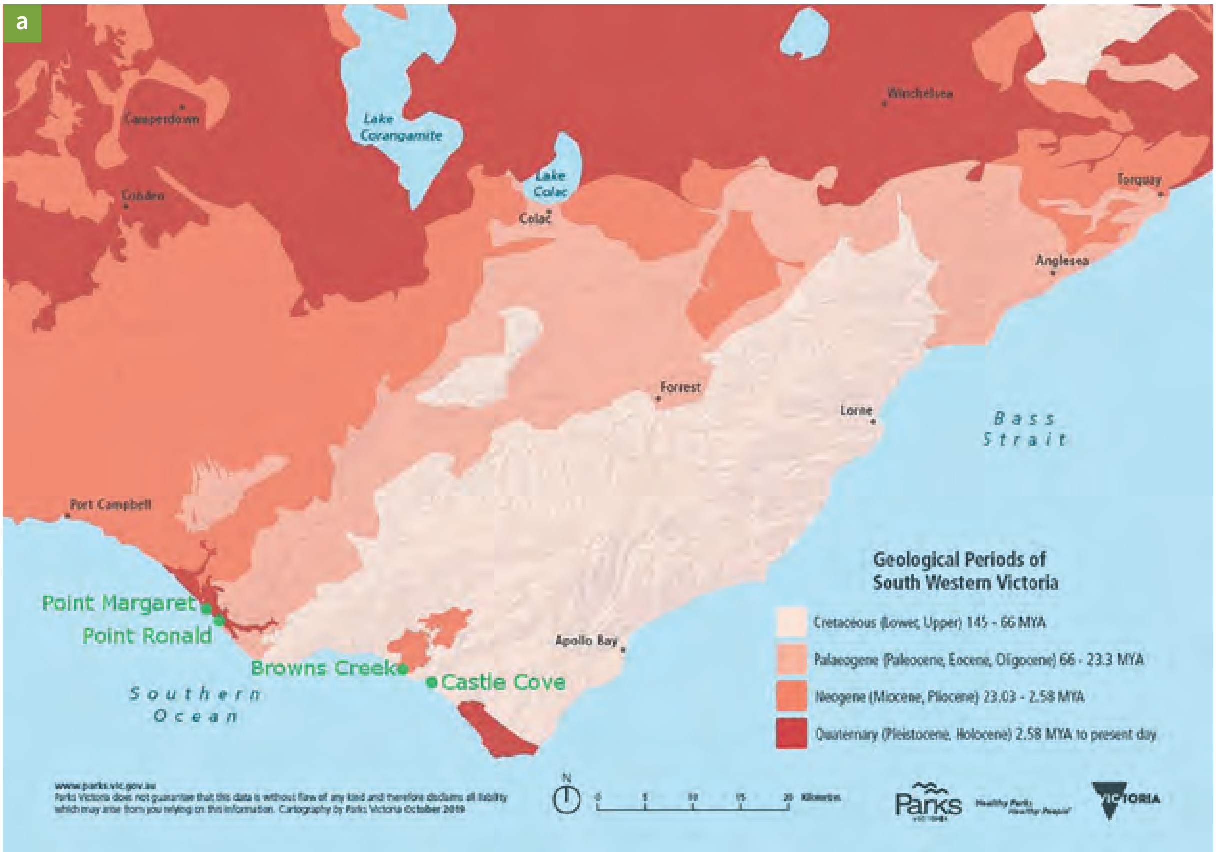


Figure 1. a. Map of field locations visited during the Bioscan. Map used with the permission of Parks Victoria; **b.** Cliffs at Castle Cove, preserved dinosaur-aged rocks (blue-grey, background) and younger, marine limestones (orange, foreground).

Table 1. Field sites. Also see figure 1.

Site no.	Date visited	Locality	Latitude (°S)	Longitude (°E)	Rock unit	Geological age of rock
1	25-Mar-2019	Castle Cove	38.78294	143.42833	Castle Cove Limestone	Early Oligocene
2	25-Mar-2019	Browns Creek	38.72480	143.17580	Browns Creek Formation	Late Eocene
3	26-Mar-2019	Pt Margaret	38.72480	143.17580	Paleocene Pebble Pt Formation	Paleocene
4	28-Mar-2019	SE of Pt Ronald	38.72860	143.17950	Lower Eocene Dilwyn Formation	Lower Eocene
5	27-Mar-2019	SE of Castle Cove	38.79138	143.43777	Calder River Limestone	Late Oligocene
6	28-Mar-2019	Castle Cove	38.78316	143.42861	Castle Cove Limestone	Early Oligocene

Results

Although we had selected five locations (see Table 1: N.B. there were two sites selected at Castle Cove) to visit, bad weather and storm surges, which increased the height of the low tides, prevented us from visiting all of these places.

On day one of fieldwork we reached our Castle Cove site (Fig. 1) and successfully extracted a shark tooth from the limestone (Fig. 3, Table 2). Attempts to access rocky outcrops at Browns Creek were aborted as torrential rain created waterfalls and unstable cliffs, and made safe access to the site impossible.

On the second day of our survey we accessed Point Margaret via Old Coach Road, from the Wattle Hill end. We searched the beach outcrop of Palaeocene Pebble Point Formation and in the boulders of this formation we discovered isolated shark teeth. We did not collected these, because they were too hard to extract, and because noting their presence was enough information. Due to the strong onshore swell, plans to proceed prospecting southeast towards Pebble Point were aborted.

We also attempted to visit an area south-east of Point Ronald. At the mouth of the Gellibrand river we accessed the beach but we did not proceed beyond

Figure 2. Museums Victoria palaeontologist Erich Fitzgerald using a geological hammer and a chisel to extract a fragment of whale bone from rock at site 5, south-east of Castle Cove.

Figure 3. a–b. Fossil shark tooth, found at Castle Cove.

the first headland, southeast of the river mouth, due to a higher than expected tide. The target strata of lower Eocene Dilwyn Formation, which was below the 'Rivernook' property, were therefore inaccessible.

On day three we visited an area south-east of Castle Cove. We accessed this site via the Great Ocean Walk, turning off the trail at 38.790744°S, 143.437525°E and then following a rough wallaby track down to beach. This locality was initially assumed to be 'AW3' of Wilkinson (1865) based on the labelling of his coastal section. It was of particular interest as this would make it the type locality of the archaic toothed whale *Parasqualodon wilkinsoni* (McCoy, 1866)—the first fossil whale described from Australia. However, we realised the 'site' code used by Wilkinson referred not to a locality but rather a sediment horizon. Wilkinson interpreted the Calder River Limestone, which outcrops on the beach immediately below the Castle Cove car park (which he also labelled 'AW3'), to reoccur at this locality, and he interpolated there to be an eroded syncline that connected the two. However, this cannot be, as the beds at both localities dip in the same direction (south-east), and the lithologies and fossils of the two horizons, while superficially similar, are distinctly different.

This is a fundamental discovery, as it appears many researchers over the past 150 years have misinterpreted the meaning of 'AW3', which might cast doubt over the locality details in some published research (e.g. Carter 1958). We therefore measured a detailed stratigraphic section of this outcrop (at 38.79138 °S, 143.43777°E) which appears to consist of the upper Browns Creek Formation grading into Castle Cove Limestone over 20 metres in this location (Fig. 4).

Within the Upper Oligocene Calder River Limestone, we collected a small fragment of whale rib and a fish spine (Fig. 5), as well as invertebrate fossils and bulk rock samples (see Table 2).

On the final day of our survey we returned to Castle Cove and continued to search the Lower Oligocene Castle Cove Limestone. Here we discovered and collected additional two shark teeth (Table 2).

Table 2. Fossils collected during Otways Bioscan. Refer to table 1 (above) for details of site numbers.

Specimen No.	Fossil	Taxon	Rock unit	Geol. age	Site no.	Locality
EF2019-13	shark tooth	Elasmobranchii	Castle Cove Limestone	Early Oligocene	1	Castle Cove
EF2019-14	whale rib fragment	Cetacea	Calder River Limestone	Late Oligocene	5	SE of Castle Cove
EF2019-15	fish spine	Actinopterygii	Calder River Limestone	Late Oligocene	5	SE of Castle Cove
EF2019-16	shark tooth	Elasmobranchii	Castle Cove Limestone	Early Oligocene	6	Castle Cove
EF2019-17	shark tooth	Elasmobranchii	Castle Cove Limestone	Early Oligocene	6	Castle Cove
-	9 bulk samples	-	Calder River Limestone	Late Oligocene	5	SE of Castle Cove
-	brachiopod	-	Calder River Limestone	Late Oligocene	5	SE of Castle Cove
-	5 bulk samples	-	Castle Cove Limestone	Early Oligocene	1	Castle Cove
-	echinoid	?*Eupatagus*	Castle Cove Limestone	Early Oligocene	1	Castle Cove
EF2019-03	bivalve	-	Castle Cove Limestone	Early Oligocene	1	Castle Cove

Figure 4. Museums Victoria palaeontologists Erich Fitzgerald and Rolf Schmidt measuring a stratigraphic section at site 5, east of Castle Cove.

Figure 5. Fossils found at site 5, east of Castle Cove: **a–c.** Whale bone fragments; **d.** a fish bone.

Discussion

Two fundamental advances in knowledge arose from this reconnaissance fieldwork.

1. The first Early Oligocene vertebrate fossils from Victoria were recorded from the Castle Cove Limestone at Castle Cove––several small shark teeth. This proves the potential of the Castle Cove Limestone to yield at least shark teeth and potentially small teeth and bones of other vertebrates. This makes the Castle Cove Limestone rather important because marine sedimentary rocks from the Early Oligocene (approximately 34–28 million years ago) are globally rare in outcrop, as they were largely eroded away following a substantial sea level fall in the mid-Oligocene. Thus, fossil evidence of marine faunal evolution from the early Oligocene is globally rare, making even limited fossil vertebrate evidence from Castle Cove globally important.
2. The geology of the Upper Oligocene Calder River Limestone was elucidated through the first detailed measurement of a section of this rock unit. The potential for the recovery of vertebrate fossils from the Calder River Limestone was realised through discovery of two small bones. However, we were unable to confirm exactly which outcrop of Calder River Limestone, southeast of Castle Cove, represents the type locality of the historically important fossil whale *Parasqualodon wilkinsoni*.

Conclusions and recommendations

In general, aims one and four of this project were met. We were unable to meet aims two and three due to the inaccessibility of the relevant field localities for the duration of our fieldwork. Nonetheless, some conclusions can be drawn from this preliminary work, including recommendations for further research.

1. The Castle Cove Limestone is rich in macroinvertebrate fossils and small vertebrate fossils—at least shark teeth––can be recovered from the outcrop of this unit at Castle Cove. Castle Cove Limestone is the only onshore outcrop of fossiliferous Early Oligocene marine sediments in Victoria, and one of the few fossil-rich Early Oligocene exposures in Australia. This makes further systematic collecting of macrofossils, especially vertebrates, from this rock unit scientifically important.
2. The potential of the Calder River Limestone to yield vertebrate fossils has been proven by this work. However, substantially more research could be undertaken to establish the age, depositional environment and palaeontology of this unit, including whether it is stratigraphically equivalent to the Upper Oligocene Clifton Formation.
3. Confirmation of the type locality of the historically important fossil whale *Parasqualodon wilkinsoni* eluded this work. It may not be possible to further constrain the exact type locality for this fossil.
4. The potential for the upper Eocene Browns Creek Clay to yield penguin and/or whale fossils remains unknown. It is recommended that the Browns Creek gully sections be systematically prospected for vertebrate fossils as the opportunity arises.
5. One fragment of fossil penguin bone in the existing Museums Victoria Palaeontology Collection hints at the potential for the Rivernook Beds of the lower Eocene Dilwyn Formation to yield penguin fossils. It is anticipated that future prospecting of the Dilwyn Formation will result in the discovery of additional penguin fossils.

References

Carter, A.N. 1958. Tertiary Foraminifera from the Aire District, Victoria. *Geological Survey of Victoria Bulletin* 55: 1–76.

McCoy, F. 1866. *Notes sur la zoologie et la palaeontologie de Victoria*. Masterman, Melbourne, 35 pp.

Wilkinson, C.S. 1865. *Report on the Cape Otway country*. Report of the Director of the Geological Survey of Victoria for the Period from June 1863 to September 1864, with Appendices 1864–5: 21–28.

Acknowledgements

This research was conducted under the following permits: DELWP Consent for use of Crown Land no. 0700258/0700242 and DELWP Research Permit no. 10008133.

NARRATIVES

The narratives are written as a resource for public interpretation. Parks Victoria staff can use them as a basis for park notes, interpretive signage or public presentations.

Some narratives have a detailed section first, followed by a more general, interpretive piece.

ARTILLERY ROCKS

The area known as Artillery Rocks lies on the coast between Jamieson Creek and Separation Creek. The location takes its name from the 'cannon ball' rock formations that can be found along the cliffs and on the rock platforms. A variety of other geological features and weathering structures can also be viewed at this location.

The Otway Coast is part of an ancient rift valley that formed approximately 140 million years ago, as mainland Australia began separating from Antarctica. At this time, active volcanoes in the east spewed out large quantities of lava and volcanic ash. Large amounts of these erupted feldspathic sands and ash washed into westward flowing river systems, and then drained into flood plains that emptied into the gradually opening rift. Over a period of approximately 15 million years, more than 3300 metres of volcanic sediment was deposited in this Gondwanan rift valley. Millennia passed, and the land masses we now know as Australia and Antarctica continued to move apart, finally separating completely approximately 34 million years ago.

On top of these volcanic sediments, marine sediments were laid down in the region as the sea-level rose and fell in line with interglacial and glacial periods. The last interglacial period occurred approximately 125,000 years ago and at this time sea-level was 4–6 metres above what we see today. In contrast, at the peak of the last ice age, around 22,000 to 20,000 years ago, sea-levels were up to 120 metres lower than now. The current interglacial period began approximately 11,700 years ago and continues today.

The area's geological history, the climate, the weather and the sea have all contributed to the fascinating formations found at Artillery Rocks.

The rock-platform at Artillery Rocks has been created by the pounding force of the waves, while the characteristic honey-comb rock is believed to be caused, in part, by salt crystals expanding within the sandstone and mudstone. This action, termed "salt plucking", causes the breakdown of the natural cementing of the sand and mud grains.

Cannon ball concretions and pedestals are some of the other unusual rock features found at Artillery Rocks. While there is no definite answer to how they formed, a few features are shared in common with similar ball concretions found elsewhere in the world. The ball-shaped concretions develop before the sediment has turned to rock, when calcite-rich groundwater flows through permeable layers and crystallises in certain spots. These sediment layers remain preserved in the cannon balls, and often allow them to crack perfectly through the middle. Usually this occurs around a piece of bone or shell, which acts like the nucleus or core of the sphere, however, this appears not to be the case at Artillery Rocks, as broken cannon balls show no internal features or fossils. The cannon ball concretions can sometimes be seen sitting on pedestals, which are actually just the remains of the softer, less erosion-resistant sandstone, which used to surround the entire sphere.

Another rock feature that can be seen at Artillery Rocks is "jointing". Jointing is where the rocks appear to have parallel cracks that sometimes give the platform a "tessellated" appearance. These joint lines are breaks in the rock created by tectonic pressure.

Some extra notes

Visitors need to be aware that 'freak' waves may unexpectedly flood parts of the shore platform, especially where narrow channels in the rocks funnel them.

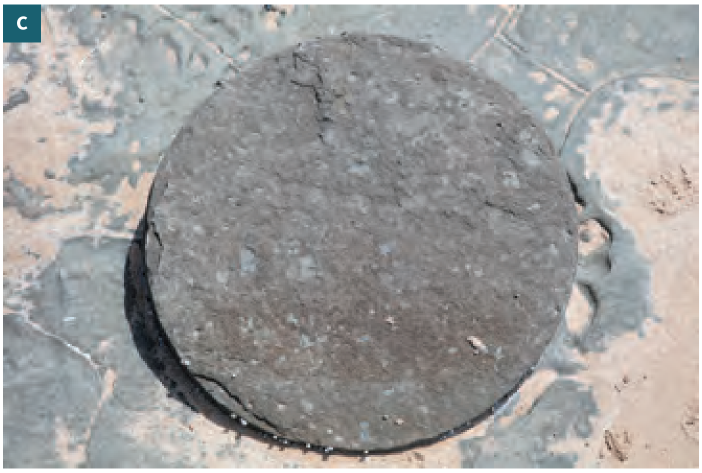
Rolf Schmidt

Artillery Rocks: **a.** Embedded cannon ball and honey-comb weathered rock; **b.** Cannon ball concretion on a sandstone pedestal; **c.** Lower section of a cannon ball concretion after the top half has eroded away; **d.** Example of 'jointing' in rocks, which creates 'tessellated' platform (image not taken at Artillery Rocks); **e,** Narrow channel at Artillery Rocks with cannon ball formation on either side; **f.** Warning sign at Artillery Rocks. Photographer: Rodney Start | Source: Museums Victoria.

a

b

c



d

e

f


Artillery Rock
WARNING
Strong Currents
Unexpected Large Waves
Submerged Rocks
Slippery Rocks
NO LIFESAVING SERVICE
Artillery Rocks
Access Stairs

FANTASTIC FOSSILS

Fossil Dinosaur Claw

This is the fossilised claw of a carnivorous (meat-eating) dinosaur. It was found at Cape Otway, Victoria in 2014 by John Wilkins, Alan M Tait, and Lesley Kool during fieldwork by a Museums Victoria-led team of researchers and volunteers.

This claw is very similar to the claw of *Australovenator wintonensis*, a theropod dinosaur found in Queensland and described in 2009. We think this claw is from a dinosaur closely related to *Australovenator*, if not from the same species. Both Victorian and Queensland dinosaurs would have been alive about 100 million years ago, during the Cretaceous period.

The *Australovenator* skeleton from Queensland includes a lower jaw, teeth, parts of the forelimbs and hindlimbs, and ribs. From these, scientists could tell it was a bipedal (two-legged) carnivorous, theropod dinosaur that would have been about two metres tall at the hip and around six metres long, making it quite a small predator.

The Museums Victoria claw is obviously from a carnivore, being rather sharp. In life it would have been even longer and sharper as the bone would have been covered by a horny sheath. This would have been attached at the groove running down the side of the claw that can be seen in the photos.

The name *Australovenator* means 'southern hunter' from the Latin words *austral* meaning south and *venator* meaning hunter.

Prehistoric Otway Ranges (Interpretive sign)

The rocks you are standing on, and have been driving past in road cuttings, were originally laid down 120 million years ago as sediments in a giant rift valley that formed between Australia and Antarctica, when the supercontinent Gondwana began splitting into the separate continents we know today.

Volcanoes were active all along the eastern coast. Rocks and ash from these volcanoes washed into the flood plain. These sediments contained the remains of plants, dinosaurs and early mammals, which became fossilised. Over time, layers of fossil plants became black coal when they were buried and compressed by more layers of sediment.

Dinosaurs and early mammals of this time lived at latitudes of between 60°S and 65°S, which is well within the Antarctic Circle. Winter darkness would have lasted for three months and conditions were cool (+8°C to –6°C). There were no ice sheets but it is likely winter ice occurred in the area. Northern Canada and Alaska are the only other places on earth where dinosaurs lived in Polar Regions.

Reference

Stephen F. Poropat, Matt A. White, Patricia Vickers-Rich & Thomas H. Rich (2019) New megaraptorid (Dinosauria: Theropoda) remains from the Lower Cretaceous Eumeralla Formation of Cape Otway, Victoria, Australia, Journal of Vertebrate Paleontology, DOI: 10.1080/02724634.2019.1666273

Rolf Schmidt

Fossilised dinosaur claw, found at Cape Otway. The claw came from a meat-eating dinosaur that is probably closely related to *Australovenator*, which lived 110 million years ago. It was a two-legged, theropod dinosaur, about two metres tall, and would have hunted smaller dinosaurs such as *Leaellynasaura*. Claw approx. 17 cm. Photographer: Benjamin Healley | Source: Museums Victoria.

FRESHWATER INSECTS: THE CADDISFLY (TRICHOPTERA)

Caddisflies have aquatic larvae (an immature stage in the life cycle) which are often enclosed within a case made from mineral (e.g. sand), or organic matter (e.g. leaves or twigs). Some larvae do not construct cases but are usually found within a silken retreat; some are free-living. The adults resemble small dark-winged moths. Most bodies of fresh water have Caddisflies but the largest number of species is found in rivers and streams. The larval life cycle varies from a few months to a year but these details are not well known for Victoria. The adults live for much shorter periods and are responsible for reproduction and dispersal.

One common form of Caddisfly has quite large larvae (up to 25 mm long) with feathery gills attached to the abdomen. They live in retreats, part of which is modified as a net. The larvae are only found in running water usually in areas with strong currents. These larvae rely on their net to trap small algae and invertebrates which they then eat. Other common Caddisfly larvae are quite small (less than 8 mm long) and live in dome-shaped stone cases commonly on the surface of rocks in the main channel of streams and rivers. These larvae eat algae, which they scrape from the surface of rocks.

A very common form of Caddisfly larva in Victoria lives in cases made of sand grains, hollowed twigs or plant material. These occur in streams, rivers, temporary streams, ponds, lakes, saline lakes and estuaries. The larvae are often found amongst detritus or on aquatic plants, and usually in still or slow-flowing water. Most species eat detritus and algae; a few are predators on other invertebrates.

Caddisfly, *Tasimia palpata* (family Tasimiidae) from the Cumberland River: **a.** case of a larva; **b.** adult. Photographer: Julian Finn | Source: Museums Victoria. **Below:** Adult, Caddisfly *Hydrobiosella gibbera* (family Philopotamidae), from the Grey River. Photographer: Julian Finn | Source: Museums Victoria.

FRESHWATER INSECTS: THE MAYFLY (EPHEMEROPTERA)

The Mayfly's immature or nymphal stage is fully aquatic and they are commonly found in rivers, streams and lakes. The nymphs are elongate and have gills along the side of the abdomen and three filaments or tails arising from the tip of the abdomen. The adults are very short lived (a few hours to a few days) and do not feed; they are merely a reproductive phase. The nymphs live from a few months up to a year before they emerge as adults. Thus the nymph is the longest lived stage.

Some nymphs are flattened with plate-like gills on the abdomen. These usually live on the surface of rocks and are most abundant in upland streams. They feed by scraping algae from the surface of the submerged rocks. Other nymphs are common in the still waters of ponds or stream banks and have much more delicate gills characterised by long filaments. They are often found among aquatic plants or in the crevices of submerged logs. They eat leaf and wood material as well as other organic detritus. Finally some nymphs are robust with a cylindrical body and spiny rigid gills that anchor individuals beneath rocks. These are usually found in stony upland streams in areas with good flow. Their mouths are modified for filter feeding on fine particulate organic material and algae; hairs on the legs assist in this process.

After hatching from the nymphs, the adults often swarm over water bodies. This enables males and females to encounter one another and mate. The ripe female then sheds her eggs into the water and the life cycle begins again. Fly-fishermen imitate both the adults and nymphs when they tie artificial flies.

Mayfly: **a.** nymph, *Offadens* sp. (family Baetidae) from the Cumberland River; **b.** adult, *Austrophlebioides pusillus* (family Leptophlebiidae) from the Cumberland River. Photographer: Julian Finn | Source: Museums Victoria.

FRESHWATER INSECTS: THE STONEFLY (PLECOPTERA)

Stonefly nymphs, the immature phase of this group of insects, are common in rivers and streams and can be recognised by the two thin tails emerging from the tip of the slender abdomen. Most species also possess abdominal gills. Adults fly or crawl near the water's edge but are very inconspicuous and not nearly as long-lived as the nymph. Many species in southern Australia take at least a year to grow from an egg to a mature nymph ready to emerge. These insects are characteristic of cool flowing waters at high altitudes and only a few species are found in the warmer lowland rivers.

Large green nymphs (up to 38 millimetres long) with filamentous beaded gills on first few abdominal segments are widespread but never numerous in Victorian streams, usually in the faster flowing regions. These nymphs are carnivorous and eat small aquatic insects. They may spend 2–3 years as nymphs before emerging as adults. The most abundant stoneflies in Victoria are small brown nymphs characterised by a tuft of gills between the two tails at the tip of the abdomen. They are usually found clinging to the underside of stones. They eat a variety of organic detritus or algae; a few prey on other aquatic invertebrates.

In Victoria one group of stoneflies is confined to mountain tops. The nymphs of this group are large and colourful but are not readily seen as they burrow quite deeply into creek beds. The adults, which are present during autumn, are quite conspicuous because they are vividly coloured and large. If global warming proceeds as predicted and mountain tops become warmer places than they currently are, then this group of insects may not be able to survive as they are never found at lower, warmer altitudes.

Richard Marchant

Stonefly, *Dinotoperla fontana* (family Gripopterygidae): **a.** nymph from the Wye River; **b.** adult from the Barham River. Photographer: Julian Finn | Source: Museums Victoria.

FROGS

Be quiet…listen carefully. The best way to learn about frogs is to listen for their calls. There are ten species of frog that can be found in the south-west region of Victoria. Each species has their own distinct call, and you will hear different species at different times of the year according to their breeding season. Did you know that only the male frogs call, and they do this to attract a female mate?

Frogs live near water, such as streams, rivers, dams and creeks. Still water is required to lay their eggs, which will grow into tadpoles and then become adult frogs. Frogs are carnivores and eat insects, some eat lizards and even other frogs.

Here are some frogs you might hear:

Brown Tree Frog, *Litoria ewingii*

Southern Brown Tree Frogs are excellent climbers and are very agile. They are often found in large numbers around water bodies. These frogs call year-round, often after rain, from the ground, in low vegetation or floating in the water.

Call: "Creeeee-cree-cree-cree-cree", rapid, harsh, first note longest.

Pobblebonk, *Limnodynastes dumerilii*

Also known as a Banjo Frog, this species burrows in the soil. People sometimes find them when digging in the garden. Their eggs form a large, white, floating raft in still water. Males mainly call from spring to autumn (September to March). Calling is particularly intense after heavy rainfall.

Call: "Bonk… bonk… bonk", similar to a banjo string being plucked.

Common Froglet, *Crinia signifera*

The Common Eastern Froglet is eastern Australia's most common and widespread frog species. Males can be heard calling all year round and will call both day and night.

Call: "Crick, crick, crik, crik, crick", sound a bit like crickets chirping.

Eastern Smooth Frog, *Geocrinia victoriana*

Eastern Smooth Frogs lay eggs in gelatinous masses in damp places, such as under bark, in wet wheel ruts or puddles. Their tadpoles require water and take up to eight months to develop into frogs. Males call in summer and autumn.

Call: "Waaaarrrrrkkk pip pip pip pip pip".

Vanishing frogs

Frogs are in trouble globally, with up to 40% of species facing extinction. Of the 30 species of frog found in Victoria, half of them are endangered. The threats frogs are facing include habitat destruction and fragmentation, climate change and disease.

The primary cause of decline for many frog species is infection with the amphibian chytrid fungus. Frogs' permeable skin makes them particularly sensitive to pollutants and pathogens, which is why they are considered bio-indicators.

The increasing frequency of bushfires, as a result of climate change, is an additional threat to frogs. Bushfires may not only reduce the abundance of species but also the genetic diversity of populations.

Helping frogs

Limit the spread of the deadly chytrid fungus by sticking to paths. Create your own frog-friendly habitat at home to attract local species. Never handle frogs or move them from their home.

Learn more

Get the free *Museums Victoria Field Guide App* to learn about all 30 Victorian frog species and listen to their calls.

Anna McCallum and Katie Date

Opposite top: Brown Tree Frog, *Litoria ewingii*. **Middle:** Common Froglet, *Crinia signifera*. Photographer: David Paul | Museums Victoria. **Bottom:** Pobblebonk, *Limnodynastes dumerilii*, Great Otway National Park. Photographer: Till Ramm | Museums Victoria.

GLOW-WORMS

Australia is home to amazing native plants and animals. Surely amongst the smallest but most interesting are the glow-worms — predatory, bioluminescent insects that are not worms at all. Australia has eight species of glow-worm with another species occurring in New Zealand where it can be found in spectacular concentrations in places like the Waitomo caves.

Despite their common name, glow-worms are not worms but flies, more specifically, what are commonly called fungus gnats from the family Keroplatidae. The term glow-worm applies to the larval or immature phase, which looks a bit like a small, thin worm. The adult fly resembles a small mosquito but they don't bite.

The predatory larval glow-worms measuring only a couple of centimetres construct a tube in which they reside and later pupate before emerging as an adult fly. Surrounding this tube, the larvae hang a number of silk threads to which they attach drops of mucous that they exude from their mouth.

The glow-worms are amongst a varied group of organisms ranging from fish to fungi that display bioluminescence, which is the production and emission of light by a living organism. In the case of the glow-worms, a chemical reaction in the body of the larva results in a blue-white light being emitted from the posterior end of the larva. In the darkness, other invertebrates can be attracted to this light but don't see the glow-worms dangling, sticky snares. The prey taken in the curtain of sticky drops can be pulled up to the glow-worm's tube to be consumed. In the event that the snares catch prey that is too big, the glow-worms can sever the thread.

In environments where wind disturbance is minimal, such as caves, the threads can reach up to 40 centimetres in length. In areas exposed to the elements, the threads tend to be much shorter, as long threads could become tangled in the wind.

These insects are very sensitive to drying out so they live in damp or sheltered areas like rainforests, caves, old mines, gullies and even old railway tunnels. In a cave or mine situation where the glow-worms are attached to the roof they can resemble a starry night sky. Changes in humidity in caves can result in the loss of colonies.

Victoria has three species of glow-worms found in areas such as Gippsland, Mt Buffalo and the Otways. It is thought that the species found at Mt Buffalo is endemic to that area, as is the species found in the Otways (*Arachnocampa* (*Campara*) *otwayensis*) where it occurs in areas like Melba Gully and Grey River.

Glow-worms are also sensitive to chemicals, smoke, fire and even noise. If you find a colony of glow-worms, it is best not to talk too loudly or shine your torch directly on them. If disturbed the glow-worms can turn off their light for up to 15 minutes. They will light up again once they feel the threat has passed but while their light is off no food is being attracted to their traps.

Simon Hinkley

Top: Glow-worms, *Arachnocampa (Campara) otwayensis*, Grey River. Photographer: Heath Warwick | Source: Museums Victoria. **Above:** Glow worms, *Arachnocampa (Campara) otwayensis*, Grey River. Photographer: David Paul | Source: Museums Victoria.

LAND MOLLUSCS: SLUGS – HAVE YOU SEEN THIS SLUG?

The Black Slug, *Arion ater* is an introduced slug that is generally considered not to be a good world traveller. Its presence in Australia had previously been recorded only from a few localities, generally confined to gardens and cultivated areas. The species was regarded as not established in Australia, however since 2001, the museum has received a number of enquiries regarding the appearance of large black slugs, sometimes in massive numbers. Subsequent reports indicate that small populations of *Arion ater* have become established in the Dandenong and Otway Ranges. It is thought their distribution is limited to very moist environments and that widespread distribution is unlikely due to the dry climate in Australia. *Arion ater* is a garden pest in Britain and Europe where they cause damage to seedlings in spring. Their diet includes living and dead vegetation, fungi, manure and even dead animals.

Chris Rowley

Black Slug, *Arion ater*. Photographer: David Paul | Source: Museums Victoria.

LAND MOLLUSCS: SNAILS – BE CAREFUL WHAT YOU SQUASH!

Otway Black Snail, *Victaphanta compacta*, Great Otway National Park. Photographer: John Broomfield | Source: Museums Victoria.

Most introduced snails and slugs are thought of as pests since they like to feed on flowers and vegetables. Some are major agricultural pests of crops and pasture. However not all snails and slugs are pests. The Otway Ranges are home to a number of native species, which play an important role in the ecology of our forests and bushland. Some are classified as endangered and need our help to protect them. In fact, four species of land snails native to the Otway Ranges are listed as 'threatened' under the Victorian Flora and Fauna Guarantee Act 1988.

They are:

Allocharopa erskinensis
Erskine River Pinwheel Snail

Geminoropa scindocataracta
Splitters Falls Pinwheel Snail

Pernagera gatliffi
Gatliff's Pinwheel Snail

Victaphanta compacta
Otway Black Snail

Of the threatened species, the most obvious and frequently encountered is the Otway Black Snail, *Victaphanta compacta*. This snail is quite striking with its thin, black, glossy shell measuring up to 25 millimetres in diameter. The Otway Black Snail occurs only in the wet sclerophyll and beech forests of the Otway Ranges where they live under rocks, logs and moist leaf litter. They are a carnivorous snail belonging to the family Rhytididae and are amongst the largest species of carnivorous snails found in southern Australia. Their diet includes other snails, slugs, earthworms and insect larvae.

The remainder of the species listed as 'threatened' are less than 3mm in diameter and are much harder to see.

Chris Rowley

MOSS BUGS – TIME LORDS OF THE OTWAY FORESTS

"Study the past if you would define the future." – Confucius

Among the forests of the Great Otway National Park, lives a creature that is a window to our past biodiversity, our fossil record and evidence of the original makeup of the Southern Hemisphere continents. You will rarely see it, but to know it is there links you with a time over 200 million years ago when Australia was part of a super continent called Gondwana. At that time, Gondwana included India, Australia, South Africa and South America as one single land mass. These Otway creatures provide evidence for the formation of Gondwana but more importantly to its eventual breakup about 100 million years ago when the continents separated into Australia and South America as well as several Pacific Islands. This special Victorian Otway creature is truly one of the great time travellers of Australia.

Peloridiidae commonly known as moss bugs are a small and ancient group of insects. They belong to the Order Hemiptera that is characterised by having a piercing, tube-like mouthpart called a proboscis or a beak. Most other insect groups have chewing mouthparts. Hemiptera is one of the success stories of insects with about 80,000 species named worldwide and about 7000 known from Australia. Its members suck either plant or animal juices - such as the predatory Assassin bugs. And did you know that bed bugs, which suck our blood, are also Hemipterans?

Moss bugs of the Peloridiidae are a small group of cryptic and mostly flightless insects measuring between 2 to 4 millimetres in body length. Today, we know of 37 species worldwide of which nine species occur in Australia and of these, only four species are found in Victoria. A timescale analysis of the moss bugs suggests that they were around in the late Jurassic (about 153 million years ago). They originated in the area now known as Patagonia (Chile and Argentina) and later spread to the continent now called Australia – remember, at that time these areas were all physically joined together.

Peloridiids have a unique association with the ancient forest tree Nothofagus or beech forest. Moss bugs live by sucking sap from the mosses and liverworts that grow only around the bases of Nothofagus trees.

Curiously, though not surprisingly, both moss bugs and beech forest have similar distributions in eastern Australia, New Zealand, New Caledonia and Patagonia (Chile and Argentina). So, how does a flightless, minute bug and a rainforest tree currently occur on continents on both sides of and on islands across the Pacific Ocean? The answer is simple – they were once all together on the same land mass called Gondwana.

Finding moss bugs is not an easy task. We travelled to a number of well-known Otway National Park Nothofagus locations which included: Beauchamps Falls, Hopetoun Falls, Triplet Falls and Melba Gully. Here we located some of the tall, gnarly and very old Nothofagus trees whose bases were covered in moss. We collected small samples of this moss which was stored in airtight containers to ensure the moss did not dry out.

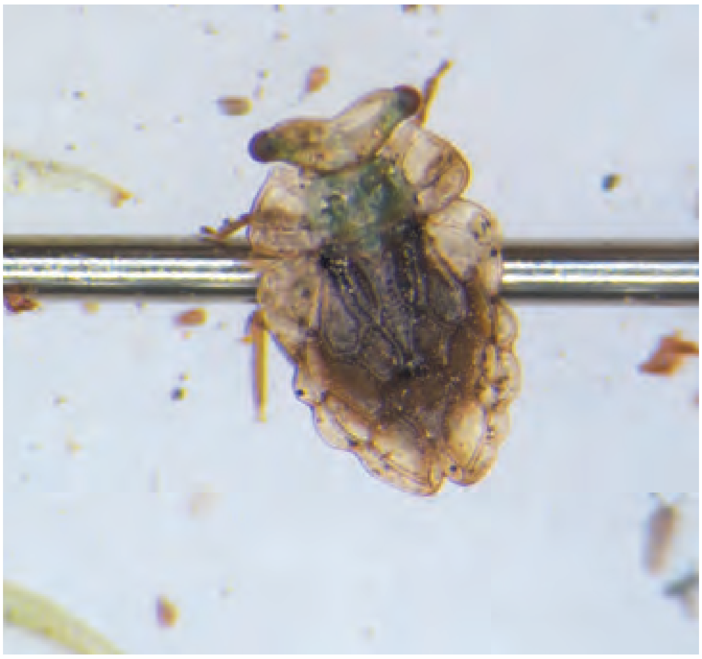
Back at the Museum, we placed the collected moss samples into metal containers that look very similar to milk churns called Tullgren funnels. These funnels are basically a metal cylinder about 30 centimetres wide and 50 centimetres high. At the bottom of the funnel is a wire mesh on which we placed the moist and recently collected moss. Below this mesh, the funnel narrows to a small opening where we placed a small plastic collecting vial. At the top of the funnel is a heat generating light bulb. We used 12 separate Tullgren funnels to filter our collected moss samples.

The idea behind these Tullgren funnels is that the heat from the light bulb slowly dries out the moist moss from the top down. As the moss dries, the moss bugs move to the bottom of the moss. As even the bottom of the moss eventually dries out, the moss bugs leave the moss and fall down through the narrowed tube into a collecting vial below. This is an excellent way to sample fauna from moss, compost or leaf litter. We collected an absolute 'Zoo' of microscopic insects, spiders, mites and other invertebrates – the diversity we collected from moss or litter samples cannot not be seen or examined when still in the moist moss sample.

Usually, the collecting tube below the funnel contains 70% alcohol so that we can immediately preserve the collected specimens. However, for these recent Nothofagus extractions, I placed a piece of moistened tissue paper at the base of the collecting vial to keep the collected specimen alive. We filmed the entire process of visiting the Otway forests, finding old Nothofagus trees, collecting moss, placement of the moss into the Tullgren funnels and turning on the heat lights. The results were spectacular. We collected live moss bugs, both an adult and a nymph, which for the first time were filmed walking around – it was magic to see these *Otway Time Travellers* walking around in a very slow and methodical way (see https://www.facebook.com/melbournemuseum/videos/914404565624814/).

Nature is full of clues to its past. The trick is knowing how to read what you see today and interpret its significance to the past. Peloridiidae may be the canary in the coal mine for the Otway Forests. If these forests significantly dry, the beech forests will die as will their incumbent moss along with their reliant moss bugs. My hope is that in 100 or perhaps even 1000 or 10,000 years' time, the beech forests and their moss bugs will still be around for exploration, people's wonderment, biodiversity and still there for anyone wanting to find our unique *Otway Forest Time Travellers*.

Ken Walker



Top right: A live adult Moss Bug as viewed under the microscope. https://www.facebook.com/melbournemuseum/videos/914404565624814/. Photographer: Stephen Dixon | Source: Museums Victoria. **Right and below:** Myrtle Beech tree, *Nothofagus cunninghamii*. Photographer: John Broomfield | Source: Museums Victoria.

MOTHS: GEORGE LYELL AND THE MOTHS OF THE OTWAY RANGES 100 YEARS AGO

In the first half of the 20th century, George Lyell was well known in the field of Victorian insect studies. He was one of the pioneers of the systematic study of moths and butterflies in Victoria, and between 1932 and 1946, he donated more than 51,000 specimens to Museums Victoria forming the core of the state reference collection. This collection has repeatedly proved its value to the science of Entomology over the last 70 years.

George Lyell's story as a moth collector is connected with the town of Gisborne in central Victoria, where he lived for 60 years. However it is less widely known that he also worked in Lorne. The labels he added to specimens he collected from Lorne show dates from 5 February to 9 March 1906, 1 February to 1 March 1907, 26 February to 28 March 1909 and 13 February to 14 March 1911. It seems likely that he and his wife went to Lorne for their annual summer holiday in those years, spending about a month each time. Wherever he was, Lyell was alert for moths. He collected near Lorne for a total of 35 nights and the final tally was 190 named species.

As a result we have an early historical list of species from the ranges with the original specimens in the museum. In 2019, organisers of the Otway Bioscan survey (Museums Victoria/Parks Victoria) devised a project to compare Lyell's lists with more recent ones from the Lorne area (Blanket Leaf Picnic Area, Sheoak Picnic Area). In March 2019, the Bioscan team found 175 named species over three nights. The comparison was an interesting exercise — although not as simple as it sounded.

We can deduce from Lyell's list from Lorne that there was a rich and varied population of moths in the Otways in the early 1900s. The family composition is similar to that found in recent surveys. Several of Lyell's moths are known to prefer wet forests, a habitat which is protected in the Great Otway National Park near Lorne. It still supports many moth species.

However, there is on the whole little overlap (15%) between Lyell's moth list and the Bioscan list. One likely factor may be changes in preferred survey methods since 1906–1911. We rely on Jean Benson, the granddaughter of Lyell's wife, for her reminiscences on how Lyell collected around his home in Gisborne. He walked alone at night with a fold-up net and lamp in the ranges out to Bullengarook, the Pyrete Range and towards Macedon. Specimens labelled 'Gisborne' could have come from an area of up to 3–4 kilometres in radius around the town. Similarly, many of his Lorne specimens probably came from the surrounding forest. The exact locations are not known. The lamp seems to have been used to light his way and reveal moths. It was probably not large, as he carried it for kilometres through the bush, and it would have been less bright than today's torches. Lyell also studied day-flying moths and collected caterpillars to grow them through to the adult stage, projects which were not part of the Bioscan survey.

In comparison, the 2019 surveys relied on powerful mercury-vapour lights shining on stationary white sheets to attract moths from some distance away. These surveys covered a smaller area and a more restricted habitat range than Lyell's mobile surveys, but would have been more efficient. Lyell would be more likely to find moths with numerous or conspicuous caterpillars, day-flying moths and moths which aren't attracted to lights. Also, his surveys covered a greater time span in each year and included summer species missed during the autumn Bioscan.

Lyell was the pioneer and the work goes on. Since Lyell's time, moth surveys by the Bioscan team and others have raised the species tally in the Otway Ranges to an astounding 1100 plus, proving it be one of the hot-spots for moths in Victoria.

Marilyn Hewish

Portrait of George Lyell, Nada Studio, Sydney, c. 1895.
Source: Museums Victoria Archives .

MOTHS: GHOST MOTHS

After autumn rains, people living in or near the bush in south-eastern Australia may experience a flush of large, brown moths banging at their lighted windows and clustering against walls and doors in the night. The moths may come in dozens or hundreds.

Many people assume these are Bogong Moths (Fig. 1a) because they've heard that Bogong Moths occur in large numbers and enter buildings. However most of these reports refer to the large Ghost Moths in the family Hepialidae (Fig. 1b). While Bogong Moths pass through on their migratory journeys, the irruptions of Ghost Moths relate to the timing of the emergence of the adult moths from their underground pupae. After autumn rain, this emergence can occur simultaneously over a wide area, and suddenly the moths are everywhere. A few nights later, they have disappeared, as the adults have a short lifespan. Their attraction to lights and their large numbers make them obvious to home-owners in a way that many moth species are not.

The main groups of Ghost Moths noticed by the general public are in the genera *Trictena*, *Oxycanus* and *Abantiades* (Fig. 2). These are among some of the largest moths in Victoria, with wingspans up to 150 millimetres. They lay their eggs by dropping them on the ground. When the caterpillars hatch, they tunnel underground where they feed on plant roots. They spin a silk lining for the tunnel and a silk cap for the entrance. Eventually they transform into a protective pupa in a vertical tunnel, inside which they transform into the adult moth. Rain in late summer to early winter triggers the mass emergence of the moths. The adult wriggles the pupa upwards until it breaks the ground surface and then the moth breaks out through the upper end. In grassy areas with little concealing vegetation, the abandoned pupae can be seen sticking out of the ground like large, brown birthday candles on a cake!

Ghost moths get their name because they are large and hover and flutter in the dark around street lights and lighted windows, sometimes in groups. They have shiny wings and the reflected light makes them look silvery white perhaps making people think of ghosts. They're also called rain moths because the adults emerge after autumn rains.

A total of 47 Ghost Moth species are known to occur in Victoria, in habitats ranging from wet forests to dry forests, woodlands and the arid north-west of the state. Many are beautifully coloured in green, pink, orange or purple, but even the brown and grey ones have delicate patterns that reward close attention. The Otway Ranges are particularly rich in Ghost Moths, and surveys in late summer and autumn can reveal large numbers and many species.

Autumn rains can bring out more than one species at once. On a wet night at Melba Gully in May 2009, a survey team set up a sheet and light under a picnic shelter to attract moths. We were inundated by large Ghost Moths, landing on the sheet and the ground, hanging on the posts and walls of the shelter, hanging on to our clothing and hanging on to each other. At least 20 individuals were counted. Identification from the photographs took some time, but they were mainly the Late Oxycanus (*Oxycanus antipoda*) with a few Southern Oxycanus (*O. australis*). Once settled at a light, they tend to remain for the night. Anyone who has tried to remove a Ghost Moth from a sheet, or from their own hair or skin, knows that they are robust creatures and they have a strong and sharp grip.

A mass emergence can reveal Ghost Moth species that are rarely seen. At Blanket Leaf Picnic Area on 21 March 2019, light rain and mist enveloped the survey site all night and numbers of Labyrinthine Ghost Moths (*Abantiades labyrinthicus*), Brown Ghost Moths (*A. latipennis*) and the Heath Oxycanus (*Oxycanus sirpus*) came to the sheets. The Heath *Oxycanus* has been described as uncommon in Victoria.

Some of the small, delicate, Primitive Ghost Moths in the genus *Fraus* can also fly in large numbers on autumn nights. Anglesea Heath is a good hunting ground. Ted's Fraus (*Fraus tedi*) and the Lined Fraus (*F. bilineata*) are both currently restricted in distribution in Victoria, with one population around Anglesea, and the Heath Fraus (*F. pteromela*) can occur in great numbers in the heathland.

So if you if you think you have Bogong Moths at your windows, please take another look. They may be the equally extraordinary Ghost Moths.

Marilyn Hewish

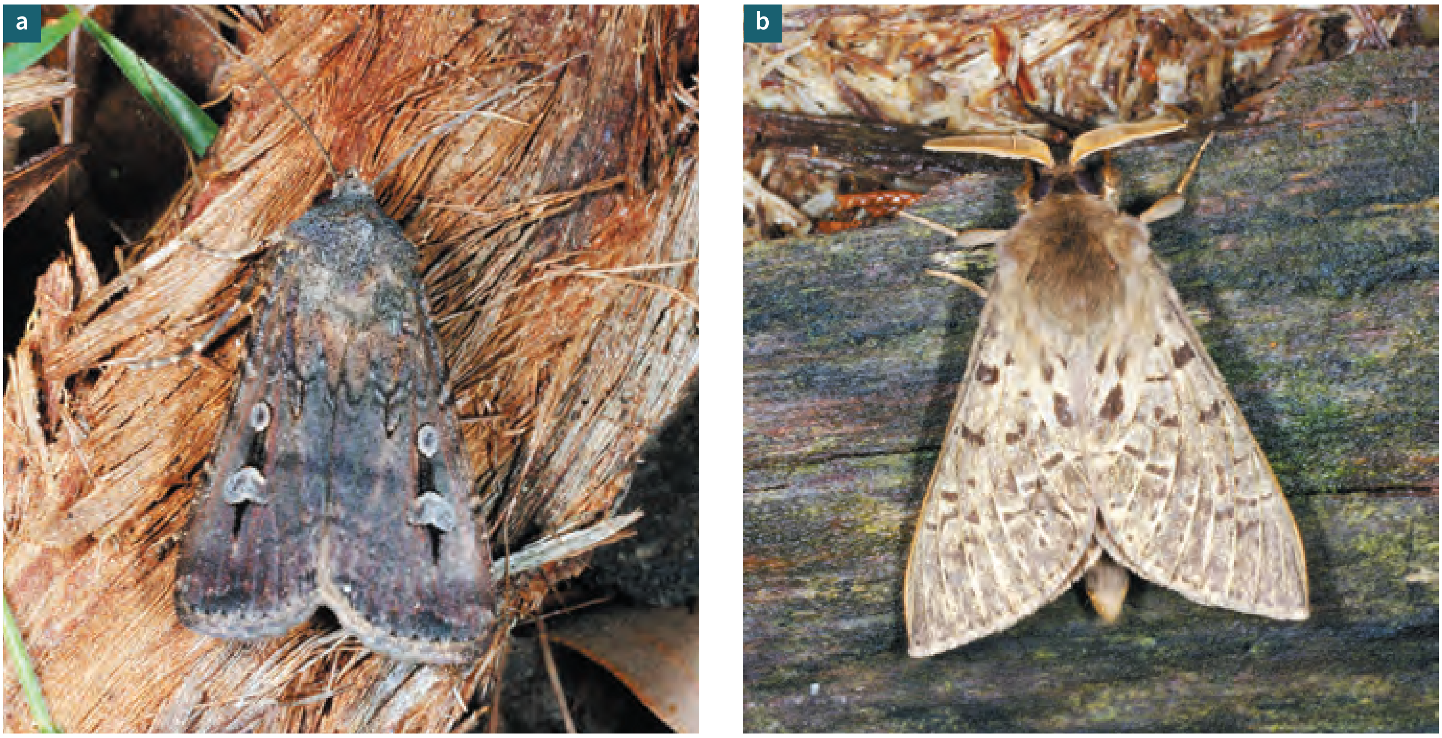


Figure 1. Ghost Moths are often mistaken for Bogong Moths because they can occur seasonally in large numbers. **a.** Bogong Moth, *Agrotis infusa*. **b.** Late Oxycanus, *Oxycanus antipoda*. Photographer: Marilyn Hewish | Source: Museums Victoria.

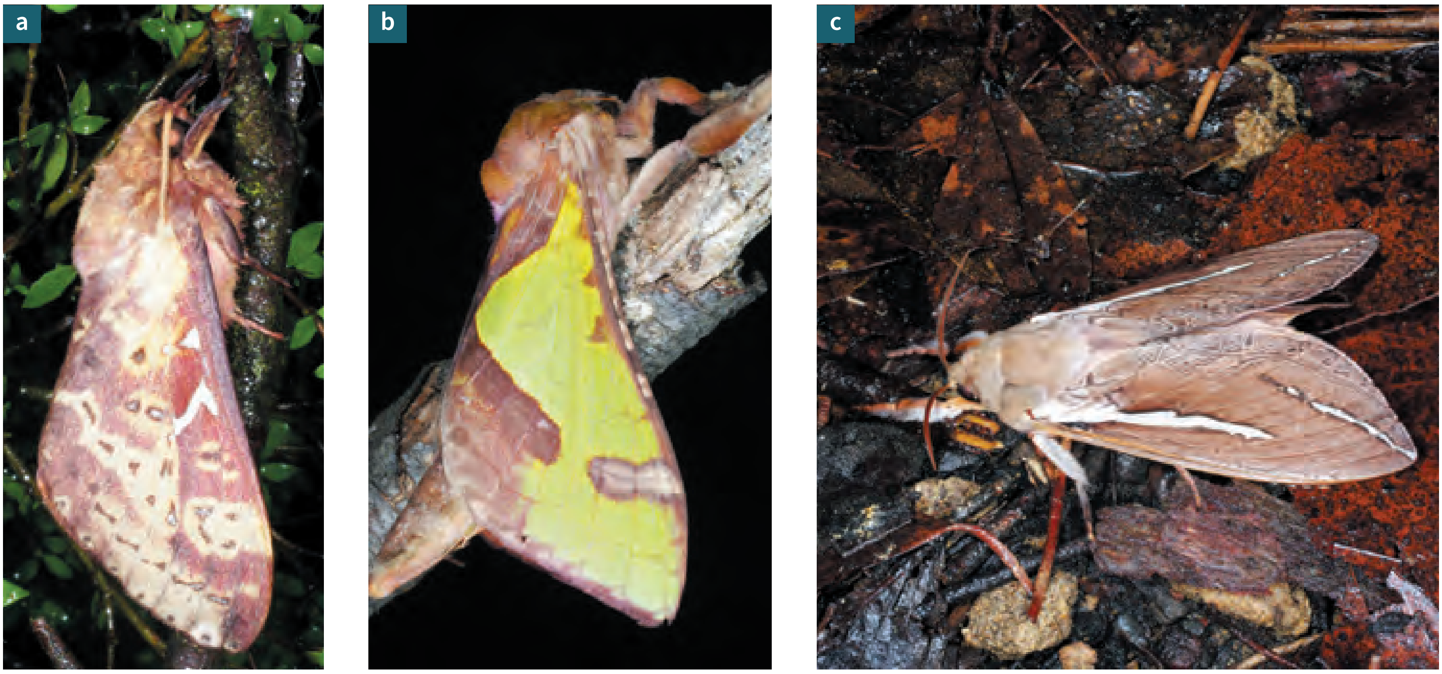


Figure 2. Some of the diversity seen within the Ghost Moths. **a.** Heath Oxycanus, *Oxycanus sirpus* at Blanket Leaf Picnic Area. Considered uncommon in Victoria, but several came to the light on a wet autumn night during the Bioscan. **b.** Splendid Ghost Moth, *Aenetus ligniveren*. **c.** Brown Ghost Moth, *Abantiades latipennis*. Photographer: Marilyn Hewish | Source: Museums Victoria.

MOTHS: THE EFFECT OF FIRE ON MOTHS

Wildfires and controlled burning are currently topics of great interest for landowners, land managers, naturalists and scientists in Victoria. The effect of fire on wildlife and natural habitats is one important aspect of this discussion. Some studies have been carried out on insects and fire, but none has particularly focussed on moths.

Moths are worth studying as they play important roles in natural ecosystems. Their roles in plant pollination have recently been highlighted in studies in Australia and overseas. Moths and caterpillars are an essential part of the food chain, as prey for larger insects, spiders, reptiles, birds and small mammals (especially bats). And caterpillars of some moths live in and feed on leaf litter. They recycle nutrients into the soil in forests and woodlands and keep the leaf litter under control.

In 2018, organisers of the Otway Bioscan survey (Museums Victoria/Parks Victoria) devised a project to compare the moths of a tract of unburnt woodland near Wye River with another area burnt in the wildfire of December 2015. We set up white sheets with bright lights to attract moths and made lists of the species seen at each site.

This was a simple experiment with only one site of each type and two nights surveying. So it was satisfying when we found striking differences between the unburnt and burnt areas. Even more pleasing, the results made sense in reference to what we know of the moths' life histories and woodland regeneration.

It seems reasonable to expect fewer moths at the burnt site, as it had been 'damaged'. The opposite occurred, with 132 species at the burnt site and 113 at the unburnt site. The regenerating woodland was thus still of value to moths. However the species at each site showed marked differences. Only 40% of the total species were common to the burnt and unburnt areas, a relatively small overlap. In particular there were many more species from the family Geometridae at the burnt site (42) than at the unburnt site (27), making up the extra numbers in the burnt woodland. There were 20 geometrid species unique to the burnt site.

In trying to explain this result, we looked at the needs of the caterpillars, as a moth species cannot become established in an area unless it can breed. The caterpillars of geometrids are typically foliage-feeders, preferring eucalypt and wattle leaves. In the burnt woodland three years after fire, the extensive, epicormic growth and dense stands of regenerating eucalypt saplings provided ample food. The young, soft foliage probably attracted females about to lay eggs. After hatching the caterpillars would have plenty of food.

In contrast, there were fewer moths in the family Oecophoridae in the burnt area (21 versus 27). Many oecophorid caterpillars feed on leaf litter, which is destroyed in a fire. Recovery cannot occur until the woodland canopy is restored.

Though it was a simple study, the results were revealing.

1. The woodland supported a rich and diverse moth population three years after a wildfire.
2. Family composition of the moth population changed after wildfire, with more geometrid species and fewer oecophorid species.
3. Recovery was not a simple increase in the species present before the fire.
4. Responses to wildfire appeared to depend on the foods used by the caterpillars.
5. Longer-term fire studies and additional studies on the foods used by caterpillars would be useful.

Marilyn Hewish

MOUNTAIN DRAGONS

Dragon lizards are an amazing group of Australian reptiles, with a few well known and iconic species such as the iconic Frill-necked Lizard, the prickly and strange Thorny Devil from Australia's red centre, and the Bearded Dragons, which are a popular pet worldwide. Overall there are about 100 species of dragon lizards in Australia, many of them are not so well known. One of these is the Mountain Dragon (*Rankinia diemensis*), which occurs from northern coastal New South Wales, down through Victoria, and into Tasmania. This small lizard is unique and amazing in its own way.

Mountain Dragons are the most southerly occurring dragon lizard in Australia, and one of the most southern in the world. They are found from sea-level coastal heaths up to alpine forests and heaths. Their ability to tolerate cold is far greater than any other Australian dragon lizard.

These small to medium-sized dragon lizards are also one of only a couple of Australian dragons where the females are larger than the males. In most dragons, the males are big and brash, holding and defending their territories against rival males. Mountain Dragons are different, the males are small and don't hold territories, while the females are large and probably territorial. It is not known why they have this social system that is unusual for a dragon lizard. However, it is thought that being a large female is an advantage because this species lays eggs. Large females can lay more eggs than smaller females.

Females lay their eggs in spring and early summer, which will then hatch in later summer or autumn. As with most south-eastern Australian lizards, Mountain Dragons are generally not active in winter, lying in wait until the weather warms up in spring.

Mountain Dragons are also quite secretive and mostly ground dwelling. Many dragon lizards will perch off the ground to bask in sunlight or survey their surrounds but Mountain Dragons keep close to the ground, sunning in gaps in the vegetation and dashing to shelter when alarmed.

A more common and widespread species of dragon, the Jacky Lizard, is sometimes mistaken for a Mountain Dragon. These two species are readily distinguishable by a number of features. The inside of a Mountain Dragon's mouth is pink, rather than yellow, and it has a series of prominent spines on the sides of the tail just behind the rear legs, in contrast to a completely spineless smooth tail in the Jacky Lizard.

In Victoria, Mountain Dragons occur in the uplands and alpine areas surrounding Melbourne and east along the Great Divide into New South Wales. There are two isolated populations in Victoria. One in the Grampians National Park – this population is listed as Critically Endangered on the Department of Environment, Land, Water and Planning (DELWP) Advisory List of Threatened Vertebrate Fauna 2013. The other isolated population lives around the township of Anglesea, at the eastern extent of the Otways Region.

The Anglesea population of Mountain Dragons is isolated from the nearest populations to the west of Melbourne by ancient volcanic lava flows. This isolated population is unique amongst Victorian Mountain Dragons as it inhabits coastal heathlands instead of the upland forests where other populations occur.

Mountain Dragons around Anglesea are of conservation interest because research has indicated that they are distinct from other Victorian populations, isolated for thousands of years. At Anglesea they are located in heathlands on the fringe of this popular coastal town where they may be threatened by residential development, human disturbances, altered fire regimes and predation by domestic dogs and cats. Management of intact heathlands and reduction of other threats is important for the conservation of this species.

Jane Melville

Above: Mountain Dragon, male and gravid female, *Rankinia diemensis*. Photographer: David Paul | Source: Museums Victoria. **Right:** Jacky Dragon, *Amphibolurus muricatus*. Photographer: Till Ramm | Source: Museums Victoria.

NATIVE BEES

World-wide there are an estimated 20,000 species of bees and the Australian native bee fauna consists of about 1700 species. Australia has five of the seven world-wide families of bees: Colletidae, Halictidae, Megachilidae, Stenotritidae and Apidae.

All bees are divided into two functional groups – short-tongue and long-tongue bees. Australia has about 300 species of long-tongue bees which prefer to visit flowers with a deep corolla tube where the nectar resources are hidden at the end of a long floral tube. Australia has about 1400 species of short-tongue bees which prefer to visit flowers which expose their floral resources (nectar and pollen) at the top of the flower. Australia is the only continent which has a dominance of short-tongued bees and this is thought to be due to the co-evolution of native bees with the dominant primitive plant family the Myrtaceae which are eucalypts, gums and angophoras, callistemon, melaleuca etc. Flowers of the Myrtaceae plant family offer a broad and shallow cup for their floral resources to visiting bees which is perfect for short-tongue bees.

In general, bees of the world prefer a dry or Mediterranean climate and habitat. Few bees occur in rainforest or wet and damp habitats. Sections of the Great Otway National Park that are dense forest are too damp and are not a suitable habitat for native bees.

Interpretive text

A buzz in the bush

Some of the most important players in the Great Otway National Park are small but mighty. Native bees, flies and beetles act as pollinating agents for flowering plants. They transfer pollen from one plant to another ensuring that seeds form and native plants can reproduce and thrive in their environment. The colour and scent of the flowers let the insects know that they are open and have nectar to reward them for visiting. Flowers catch their attention like a colourful road sign advertising food and drinks does for humans.

In different parts of the national park, the range of flowering plants attract different insect species. Eucalypts have flowers that attract native bees. These native bees have relatively short tongues compared to other bees. The open cup-shaped flowers are shallower than flowers with narrow bells. This illustrates the close association between plant and the insects that feed on them.

Plants such as Tea-trees (*Leptospermum* species) are covered with flowers in spring and this is a good time to look and listen for native insects. You can often catch sight of attractive small beetles and native bees feasting on the nectar.

What bees might I see?

There are 1700 native Australian bee species in Australia! Most are smaller than the introduced European Honey Bee.

Here are some distinctive native bee types to look for on native flowering plants:

- Reed Bees are slender black bees less than 8 millimetres long, some species have a red abdomen
- Blue Banded Bees are mostly 8–13 millimetres long with glittering stripes of blue or whitish hair across their black abdomens
- Teddy Bear Bees are rounded, furry, brown bees 7–15 millimetres long
- Halictine Bees are mostly less than 8 millimetres long and come in an array of glittering colours

Ken Walker and Kate Phillips

Above: Tea-tree, *Leptospermum* sp., Great Otway National Park. Photographer: Benjamin Healley | Source: Museums Victoria. **Right:** Halictine Bee, male, *Lasioglossum (Chilalictus) lanarium*. Photographer: David Paul | Source: Museums Victoria.

NATIVE FISH – OTWAY RIVER TRAVELLERS

Native fish species including Galaxias and Southern Shortfin Eels that live in the coastal flowing streams of the Otway ranges spend part of their lives in freshwater and part in seawater. This migratory lifecycle requires them to be adapted to very different environments but it provides them with opportunities to move into new areas and take advantage of the resources they find there.

The most widely roaming are the Southern Shortfin Eels that breed in deep water areas well off the eastern Australian coastline. Their eggs and larvae are carried by the Eastern Australia Current southward along the coast and then the developing young make their way back into the rivers where they travel upstream to the home waters of their parents. Adult eels usually spend years in these freshwater environments before swimming downstream and offshore to the breeding site for mating. In coastal areas of western Victoria, Freshwater Eels were important resources for indigenous people who developed a sophisticated aqua culture technique that trapped the Eels as a source of food.

The most diverse freshwater fishes in the Otway region belong to the genus *Galaxias*. At least three species occur in the rivers of the Otways: The Common Galaxias (*Galaxias maculatus*), the Climbing Galaxias (*Galaxias brevipinnis*) and the Trout Galaxias (*Galaxias truttaceus*).

In contrast to freshwater eels, Galaxias breed in freshwater. After hatching the young transparent larvae are carried downstream into estuaries and coastal waters. As the young fish grow and develop darker juvenile colour patterns, they make their way back upstream to feed, grow and mature.

The Common Galaxias *Galaxias maculatus*, was thought to live in different parts of the Southern Hemisphere, but recent work on their genetics using DNA techniques suggests that although the fish look the same they may be different species.

The Climbing Galaxias *Galaxias brevipinnis*, though less widely distributed, is considered to occur in New Zealand as well as widely in south-east Australia. It gets its name from the ability of individuals to make their way over vertical obstacles – even waterfalls – to reach the upper extents of streams and creeks where food is more plentiful and competition is less intense.

The Trout Galaxias *Galaxias truttaceaus* is the most attractive of the three but is the least widely distributed, having a range restricted to the coastal streams of Victoria, easternmost South Australia and Tasmania with an isolated population living near Albany, Western Australia.

Martin Gomon

Southern Shortfin Eel, *Anguilla australis*. Photographer: David Paul | Source Museums: Victoria.

SMOKY MOUSE

The endangered Australian native Smoky Mouse (*Pseudomys fumeus*) gets its name from the colour of its coat which is blue-grey. This little rodent is very hard to find because it only occurs in low numbers in scattered populations. It's almost as hard to catch as a wisp of smoke!

However scientists have a few useful tricks which help them find native species and study them in the wild without harming them. Camera traps are commonly used. A tasty bait attracts the animal and the motion triggers a camera to take a flash photograph. Baits made of a mixture of oats, peanut butter, golden syrup and vanilla essence inside a tea strainer work well to attract small mammals.

Smoky Mice live in a wide range of habitats (dry sclerophyll forest, wet forest, subalpine heath, and coastal heath) and have a broad diet (seeds, fruit, fungi, and arthropods). They have litters of three to four young in spring and summer and individuals live for about three years in the wild. They nest in shallow burrows.

Smoky Mice have been found in the Great Otway National Park, but not for many years. The last sighting was in 1985. To try to find them again fifty camera traps were set by Museums Victoria scientists as part of the 2018 Bioscan with Parks Victoria.

Unfortunately, Smoky Mice were not detected but Bush Rats, Swamp Rats, Agile Antechinus, Dusky Antechinus and Swamp Antechinus were all caught on camera. In addition, larger animals were seen – Long-nosed Bandicoots, Long-nosed Potoroos, Short-beaked Echidnas, Swamp Wallabies and two introduced predators: cats and foxes. The presence of these last two might be one of the reasons why no Smoky Mice were found.

There are a few remote pockets of bushland in the national park where Smoky Mice have been sighted in the past which this survey was not able to reach. It is possible that small populations of Smoky Mice still live there and scientists will try once again to capture them on film on a future survey.

Kate Phillips and Kevin Rowe

Bait station with tea strainers containing a mixture of oats, peanut butter, golden syrup and vanilla.

Smoky Mouse, *Pseudomys fumeus*. Photographer: David Paul | Source: Museums Victoria.

TEKTITES

Across the Otways and on the limestone cliff tops along the Port Campbell coastline in western Victoria, centimetre-sized, smooth, black, glassy 'pebbles' can be found. These pebbles are characterised by their unusual shapes, which are classified by their likeness to other objects, such as cores, buttons, ladles, dumbbells, teardrops, canoes, discs and lenses. These strange glassy objects are known as tektites (from Greek τηκτός "tēktos", meaning molten) and locally as 'australites'. The 'perfect button' tektites are perhaps the most intriguing. The smooth surface, concentric patterning and regular, but unusual shape, superficially has the appearance of a manufactured plastic button.

Many theories as to the origins of tektites have been postulated (Henry, 2003). Although known from the 1830s, Charles Darwin made the earliest observations of australites in his book *Geological Observations on the Volcanic Islands Visited during the Voyage of H.M.S. Beagle (1844)*. A tektite was given to him in Sydney in 1836. Darwin named it 'obsidianite', the black glassy appearance reminding him of the volcanic glass obsidian. He related their origins to the large volcanic regions in eastern Australia and western Victoria. From that time on, many theories were put forward to explain their origins, including production in bushfires and fusion of atmospheric dust. By the early 1900s some were suggesting they had an extra-terrestrial origin. A lunar origin became popular, with either a volcano or large meteorite impact on the Moon responsible for their formation. The lunar origin remained in vogue until the Apollo 11 Moon landing, in 1969, when lunar rocks were shown not to have the appropriate chemical compositions to form tektites. It is now widely accepted that tektites have formed through the melting of Earth rocks struck by a large meteorite.

Figure 1. Typical tektite 'perfect' button, 25 mm across, found on Port Campbell cliff. Photographer: Rodney Start | Source: Museums Victoria.

The Victorian tektites are part of the Australasian field, which formed about 790,000 years ago +/- 7000 years (Shoemaker and Uhlherr, 1999) when a large fragment of asteroid, travelling at supersonic speed, smashed into south-east Asia. At the point of impact the asteroid vaporised and the shockwaves generated melted the earth rocks blasting molten rock high into the atmosphere, where it rapidly cooled to form glassy blobs. Some of this glass went into partial orbit and was reshaped through surface melting while re-entering the atmosphere at super speed and rained down across south-east Asia and Australia.

The button tektites must have remained stable in flight through the atmosphere so only the one side, the leading edge, became molten and glassy. Others, such as dumbbells, show the blobs of glass were spinning as they travelled through the atmosphere, causing the glass to be extruded, and sometimes separating into two ladle-shaped pieces.

While no meteorite impact structure has been clearly identified for this impact event we do find clues in the array of tektites which fan-out across south-east Asia. The Australasian tektite field is the largest and youngest known, extending from China through Vietnam, Laos, Cambodia, Thailand, the Philippines, Indonesia and across most of Australia. All the tektites within the Australasian field are of the same age. This means they all formed at precisely the same time in the one impact event, and rained down across south-east Asia like a hailstorm of glass. There are possible source structures identified in Cambodia and off-shore Vietnam. The best-preserved tektites are found along the Port Campbell coast from Princetown through to Flaxman's Hill. They are eroding out of a particular sandstone layer the Hanson Plains Sand, which is exposed in a number of places along the coast and extends inland. Through the Otway National Park tektites have been found along the Gellibrand River; in sand quarries near Chapple Vale and in the Lavers Hill district.

In the 1960s, NASA became very interested in the perfect tektite buttons as it would appear they stayed stable during re-entry of the Earth's atmosphere from outer space. The convex shape of the front of the tektite was used to model the heat shield of the re-entry vehicles of the Apollo lunar missions. For these experiments, several synthetic tektites were made using ceramics and shaped in a high temperature wind tunnels.

NASA was not the first to recognize or use tektites. There is anecdotal evidence of Aboriginal people using tektites as 'magic' stones for medicinal and ceremonial purposes (Bevan and Bindon 1996), as well as using the glassy material for crafting spear points. At Port Campbell there is evidence for the transportation of tektites by aboriginal people (Shoemaker and Uhlherr, 1999).

Interpretive text

A blast from the past: hailstones of glass!

Have you seen these strange, black, glassy pebbles?

Imagine sitting here one sunny afternoon, about 770,000 years ago, when suddenly weirdly-shaped, glassy, black stones started pelting down around you.

These pebbles, known as tektites, have endured an incredible high-speed journey all the way from south-east Asia to here! They were formed by a large asteroid smashing into earth in Asia (possibly Cambodia or Vietnam), melting the local rocks and blasting them into space where they rapidly cooled to form glassy blobs. As they started to fall back to Earth and re-entered the Earth's atmosphere at high speed they were sculpted by friction with the atmosphere. They rained down like glassy hailstones across south-east Asia and Australia. The best preserved tektites are found along the Port Campbell coast and within the Great Otway National Park.

Aboriginal people attributed the stones with special powers for medicinal and ceremonial use, as well as crafting their glassy material into spear points.

These 'perfect button' tektites were used by NASA to develop the heat shield for the re-entry vehicles of the Apollo Moon landing program.

Figure 2. Typical 'cores' and 'dumbbell' tektites from the Port Campbell district. Dumbbell length 90 mm. Photographer: Rodney Start | Source: Museums Victoria.

References

Henry, D. A., 2003: Meteorites and tektites. In: Birch, W. D.. ed. *Geology of Victoria*, pp Geological Society of Australia, Special Publication 23. Geological Society of Australia (Victorian Division) pages 663-669

Bevan, A.W.R. and Bindon, P., 1996: Australian Aborigines and meteorites. *Records of the Western Australian Museum* 18: 93-101.

Shoemaker E.M. & Uhlherr H.R. 1999. Stratigraphic significance of australites in the Port Campbell Embayment, Victoria. *Meteoritics and Planetary Science* 34, 369-384

Dermot Henry

PUBLIC ENGAGEMENT

Public engagement is an essential part of the collaboration between Museums Victoria and Parks Victoria. It is a way of connecting the community with the living species and environments of the Great Otways National Park. It also provides opportunities for local people to share their observations and questions with Bioscan participants and the resulting conversations benefit both.

The area has many aspects which people find fascinating including rare species, fossil relics, webs of living connections, biodiversity hot-spots and historical stories. Feeding people's curiosity gives them motivation to continue to care for the environment in the national park and surrounds.

Community members were invited to share the excitement of discovery and learn more about the natural features at three free events run by the Bioscan teams. The events were for the general public and were advertised to locals and visitors via the Eventbrite website and local community Facebook pages, direct contact with 'Friends' groups and posters in local businesses and information centres. Museums Victoria also promoted the public events via their social media platforms.

Introductory meeting Saturday 17 November 2018, Wye River Surf Life Saving Club

This meeting was to let the community know we were embarking on the project. Genefor Walker-Smith (MV) and Jani Demetrious (PV) gave an overview of the Bioscan project, followed by two speakers on their particular areas of interest: Dr Rolf Schmidt, Collection Manager, Invertebrate Palaeontology, Museums Victoria, spoke about *Otway Coast Geology: Window into a time that changed Australia* and Dr Karen Rowe, Hugh D.T. Williamson Research Fellow, Museums Victoria, spoke about *Listening for Nature: Building capacity and participation in acoustic monitoring for birds*. The event was attended by fifteen people who found it informative and interesting.

'Moth Magic' Saturday 23 March 2019, Sheoak Picnic area, Lorne

Moth magic happens as the sun goes down and as well as attracting a good number of insects this event also attracted about thirty-five *Homo sapiens*!

Three light sheets were set up in the Sheoak Picnic Area. Museums Victoria volunteer and moth expert Peter Marriott gave an introductory talk and once it was dark the participants were able to observe the moths and other insects that visited the sheets. The infectious enthusiasm and deep knowledge of the Bioscan moth team made the night a memorable event for members of the community who participated.

'Discovery Day' Saturday 27 April 2019, Wye River Surf Life Saving Club

There was a buzz of interest and a bubbling up of curiosity at the relaxed settlement at Wye River on Saturday 27 April. The Surf club was transformed into a fascinating array of displays featuring wildlife big and small from the local area.

From when the doors opened at 10am to closing time around 3.30pm, a steady stream of visitors made their way into the club. Most stayed for an hour, some as long as two hours! There were elderly people as singles or couples, many families with babies and young children, and a few adults without children.

A roomful of twelve displays included: lizards, frogs, land insects and spiders, aquatic insects, fossils, moths, national park resources, snails and slugs, birds, local artist-drawn discovery books for children and children's nature-based craft. About ninety people attended.

What people said about the event:

- 'My kids got to learn about some of the native animals in the area.'
- 'I liked the biodiversity on display such as the moths – great close up viewing and chats with experts'
- 'I loved how engaged my kids were with the Museum staff and their exhibits.'
- 'I learned about fossils, little lizards and moths.'
- 'I learned what effects a bushfire can have on waterways.'
- 'I appreciated the great staff who were so informative and obviously loved what they do. I liked to see the specimens both live and dead.'
- 'There is so much more out there than I was aware of. I learned how to catch moths to observe them, that spiders are nocturnal!'


Parks
VICTORIA
Healthy Parks Healthy People

Publications

Book

Great Otway National Park Lepidoptera: A field guide to the moths of the Otways with over 900 colour images Published by Victorian Entomological Society.
ISBN 9780 6483 5922 7

Published Scientific Paper

Hewish, M., P. Marriott, C. Powers, K. Harris, D. Mules and D. Hewish. 2019. Moth fauna (Lepidoptera) near Wye River, Victoria; comparison between an unburnt site and a site burnt in a wildfire. *Victorian Entomologist* 49(3): 56–64.

Acknowledgments

Museums Victoria (MV) would like to thank Parks Victoria (PV) for funding the Otway Bioscan through the Wye River Recovery Project. We would also like to thank Jani Demetrious PV Regional Project Coordinator (Wye River Recovery) for his assistance and support throughout this project. Thanks to Katrina Lovett and the staff at the PV Anglesea office (i.e. West Coast District Office) for providing advice, sharing knowledge and assisting in the field. Thank you to the original PV working group for their input to the project: Sally Lewis (Regional Director, Western Region), Michelle Anstee (Area Chief Ranger, Surf Coast, West Coast District Office), Fiona Smith (Biodiversity Coordinator, Western Regional Management Team), Mark Antos (Manager Science and Effectiveness), John Wright (Team Leader Research Coordinator, Science and Effectiveness), Katrina Lovett (Ranger Team Leader, West Coast District Office), Peter Hay (Ranger Team Leader, West Coast District Office) and Gary Summers (Ranger West Coast). Thank you to Gary Lewis and the Wye River Surf Life Saving Club for allowing MV to use their club rooms as the venue for two of our public engagement events. Thank you to the members of the Victorian Entomological Society who participated in the moth surveys. Thank you to all the museum staff and volunteers who participated in the surveys and public engagement events. The volunteers, in particular, were extremely generous with regards to the many hours of their time they dedicated to this project. Without their participation, knowledge and enthusiasm, large sections of this project, and report, would not have been possible. Finally, MV would like to thank all the members of the Wye River and Separation Creek communities, as well as the other visitors that attended the Bioscan public engagement events. We hope you enjoyed them.

Picture Credits

Page 2–3 David Paul; 9, 18–19, 31 John Broomfield; 25, 30, 90, 131 top left, middle right, bottom right Heath Warwick; 68 Cathy Powers; 96–97 Rodney Start; 131 top right, middle left, bottom left Rob Zugaro

Species List

Species known to occur in the Otway region (excluding birds, moths and native bees, which are listed separately). Basis of records: Bioscan = presence recorded during the Otway Bioscan surveys. Bioscan INS = incidental sightings that occurred during the Bioscan but were not related to a particular survey. ALA = not seen during the Bioscan but records from the Atlas of Living Australia indicate it has been recorded from the Otway region. Only ALA records provided by Australian museums were used to generate this list. Unverified observational data was not used.

Common Name	Species Name	Bioscan or ALA	Native or introduced
Freshwater Fish			
Congolli (or Tupong)	*Pseudaphritis urvillil*	ALA	Native
Eel, Southern Shortfin Eel	*Anguilla australis*	Bioscan	Native
Galaxias, Climbing Galaxias	*Galaxias brevipinnis*	Bioscan	Native
Galaxias, Common Galaxias	*Galaxias maculatus*	Bioscan	Native
Galaxias, Trout Galaxias	*Galaxias truttaceus*	Bioscan	Native
Trout, Brown Trout	*Salmo trutta*	ALA	Introduced
Freshwater Insects (Caddisflies, Mayflies and Stoneflies only)			
Caddisfly	*Agapetus kimminsi*	Bioscan	Native
Caddisfly	*Agapetus pontona*	Bioscan	Native
Caddisfly	*Anisocentropus bicoloratus*	Bioscan	Native
Caddisfly	*Apsilochorema gisbum*	Bioscan	Native
Caddisfly	*Asmicridea edwardsi*	Bioscan	Native
Caddisfly	*Atriplectides dubius*	Bioscan	Native
Caddisfly	*Cheumatopsyche modica*	Bioscan	Native
Caddisfly	*Chimarra australica*	Bioscan	Native
Caddisfly	*Hampa patona*	Bioscan	Native
Caddisfly	*Helicopsyche heacota*	Bioscan	Native
Caddisfly	*Hydrobiosella gibbera*	Bioscan	Native
Caddisfly	*Kosrheithrus tillyardi*	Bioscan	Native
Caddisfly	*Oecetis complexa*	Bioscan	Native
Caddisfly	*Plectrocnemia australica*	Bioscan	Native
Caddisfly	*Tasimia palpata*	Bioscan	Native
Caddisfly	*Ulmerochorema membrum*	Bioscan	Native
Mayfly	*Atalophlebia albiterminata*	Bioscan	Native
Mayfly	*Austrophlebioides pusillus*	Bioscan	Native
Mayfly	*Centroptilum* sp.	Bioscan	Native
Mayfly	*Nousia fuscula*	Bioscan	Native
Mayfly	*Offadens* sp.	Bioscan	Native
Mayfly	*Ulmerophlebia annulata*	Bioscan	Native
Mayfly	*Ulmerophlebia pipinna*	Bioscan	Native
Stonefly	*Cosmioiperla kuna*	Bioscan	Native
Stonefly	*Dinotoperla eucumbene*	Bioscan	Native
Stonefly	*Dinotoperla hirsuta*	Bioscan	Native
Stonefly	*Dinotoperla hirsute?*	Bioscan	Native

Common Name	Species Name	Bioscan or ALA	Native or introduced
Stonefly	*Dinotoperla serricauda*	Bioscan	Native
Stonefly	*Riekoperla rugosa*	Bioscan	Native
Frogs			
Frog, Striped Marsh Frog or Brown Striped Frog	*Limnodynastes peronii*	ALA	Native
Frog, Eastern Banjo Frog or Pobblebonk	*Limnodynastes dumerilii*	Bioscan	Native
Frog, Eastern Smooth Frog	*Geocrinia victoriana*	ALA	Native
Frog, Growling Grass Frog or Southern Bell Frog	*Litoria raniformis*	ALA	Native
Frog, Smooth Frog	*Geocrinia laevis*	ALA	Native
Frog, Southern Brown Tree Frog	*Litoria ewingii*	Bioscan	Native
Frog, Spotted Grass Frog or Spotted Marsh Frog	*Limnodynastes tasmaniensis*	ALA	Native
Frog, Sudell's Frog or Common Spadefoot Toad	*Neobatrachus sudellae*	ALA	Native
Froglet, Common Eastern Froglet	*Crinia signifera*	Bioscan	Native
Toadlet, Bibron's Toadlet	*Pseudophryne bibronii*	ALA	Native
Toadlet, Southern Toadlet	*Pseudophryne semimarmorata*	ALA	Native
Mammals			
Antechinus, Agile Antechinus	*Antechinus agilis*	Bioscan	Native
Antechinus, Dusky Antechinus	*Antechinus swainsonii*	ALA	Native
Antechinus, Swamp Antechinus	*Antechinus minimus maritimus*	Bioscan	Native
Bandicoot, Long-nosed Bandicoot	*Perameles nasuta*	Bioscan	Native
Bandicoot, Southern Brown Bandicoot	*Isoodon obesulus*	ALA	Native
Bat, Large Bent-winged Bat	*Miniopterus orianae*	ALA	Native
Bat, Chocolate Wattled Bat	*Chalinolobus morio*	ALA	Native
Bat, Gould's Long-eared Bat	*Nyctophilus gouldi*	ALA	Native
Bat, Gould's Wattled Bat	*Chalinolobus gouldii*	ALA	Native
Bat, Lesser Long-eared Bat	*Nyctophilus geoffroyi*	ALA	Native
Bat, White-striped Free-tail Bat	*Austronomus australis*	ALA	Native
Bat, Large Forest-bat	*Vespadelus darlingtoni*	ALA	Native
Bat, Little Forest-bat	*Vespadelus vulturnus*	ALA	Native
Bat, Southern Forest-bat	*Vespadelus regulus*	ALA	Native
Cat	*Felis catus*	Bioscan	Introduced
Deer, Fallow Deer	*Dama dama*	ALA	Introduced
Deer, Sambar Deer	*Cervus unicolor*	ALA	Introduced
Dunnart, White-footed Dunnart	*Sminthopsis leucopus*	ALA	Native
Echidna, Short-beaked Echidna	*Tachyglossus aculeatus*	Bioscan	Native
Fox	*Vulpes vulpes*	Bioscan	Introduced
Fruit-bat	*Pteropus poliocephalus*	ALA	Native
Glider, Narrow-toed Feather-tailed Glider	*Acrobates pygmaeus*	ALA	Native
Glider, Sugar Glider	*Petaurus breviceps*	ALA	Native
Glider, Yellow-bellied Glider	*Petaurus australis*	Bioscan INS	Native
Goat (Check)	*Capra hircus*	ALA	Introduced
Kangaroo, Eastern Grey Kangaroo	*Macropus giganteus*	Bioscan INS	Native
Koala	*Phascolarctos cinereus*	Bioscan INS	Native
Mouse, House Mouse	*Mus musculus*	ALA	Introduced
Mouse, New Holland Mouse	*Pseudomys novaehollandiae*	ALA	Native
Mouse, Smoky Mouse	*Pseudomys fumeus*	ALA	Native

Common Name	Species Name	Bioscan or ALA	Native or introduced
Pig	*Sus scrofa*	ALA	Introduced
Platypus	*Ornithorhynchus anatinus*	Bioscan INS	Native
Possum, Common Brushtail Possum	*Trichosurus vulpecula*	ALA	Native
Possum, Common Ringtail Possum	*Pseudocheirus peregrinus*	ALA	Native
Possum, Eastern Pygmy Possum	*Cercartetus nanus*	ALA	Native
Potoroo, Long-nosed Potoroo	*Potorous tridactylus*	Bioscan	Native
Quoll, Spotted-tailed Quoll	*Dasyurus maculatus*	ALA	Native
Rabbit, European Rabbit	*Oryctolagus cuniculus*	ALA	Introduced
Rat, Black Rat	*Rattus rattus*	ALA	Introduced
Rat, Broad-toothed Rat	*Mastacomys fuscus*	ALA	Native
Rat, Bush Rat	*Rattus fuscipes*	Bioscan	Native
Rat, Swamp Rat	*Rattus lutreolus*	Bioscan	Native
Rat, Water Rat	*Hydromys chrysogaster*	ALA	Native
Wallaby, Red-necked	*Macropus rufogriseus*	ALA	Native
Wallaby, Swamp Wallaby	*Wallabia bicolor*	Bioscan	Native
Molluscs (Land Snails and Slugs)			
Slug, Black Slug	*Arion ater*	ALA	Introduced
Slug, Brown Field Slug	*Deroceras panormitanum*	ALA	Introduced
Slug, Cuvier's Semi-slug	*Helicarion cuvieri*	ALA	Native
Slug, Dark-edged Semi-slug	*Helicarion nigra*	ALA	Native
Slug, Grey Field Slug	*Deroceras reticulatum*	ALA	Introduced
Slug, Hedgehog Slug	*Arion intermedius*	ALA	Introduced
Slug, Jet Slug	*Milax gagates*	ALA	Introduced
Slug, Leopard Slug	*Limax maximus*	ALA	Introduced
Slug, Petterd's Humpback Slug	*Cystopelta petterdi*	ALA	Native
Slug, Purple Humpback Slug	*Cystopelta purpurea*	ALA	Native
Slug, Striped Field Slug	*Lehmannia nyctelia*	ALA	Introduced
Snail, Annabell's Pinhead Snail	*Paralaoma annabelli*	ALA	Native
Snail, Cape Otway Pinwheel Snail	*Oreomava otwayensis*	ALA	Native
Snail, Cellar Snail	*Oxychilus cellarius*	ALA	Introduced
Snail, Circular Head Pinwheel Snail	*Pernagera officeri*	ALA	Native
Snail, Coarse-Ribbed Carnivorous Snail	*Tasmaphena ruga*	ALA	Native
Snail, Common Southern Carnivorous Snail	*Austrorhytida capillacea*	ALA	Native
Snail, Dandenong Ranges Pinwheel Snail	*Pillomena dandenongensis*	ALA	Native
Snail, Dyer's Carnivorous Snail	*Prolesophanta dyeri*	ALA	Native
Snail, Erskine River Pinwheel Snail	*Allocharopa erskinensis*	ALA	Native
Snail, European Garden Snail	*Cornu aspersum*	ALA	Introduced
Snail, Flinders Ranges Pinwheel Snail	*Excellaoma retipora*	ALA	Native
Snail, Garlic Snail	*Oxychilus alliarius*	ALA	Introduced
Snail, Gatliff's Pinwheel Snail	*Pernagera gatliffi*	ALA	Native
Snail, Gawler Carnivorous Snail	*Strangesta gawleri*	ALA	Native
Snail, Hall's Pinhead Snail	*Paralaoma halli*	ALA	Native
Snail, Miniscule Carnivorous Snail	*Prolesophanta occlusa*	ALA	Native
Snail, Otway Black Snail	*Victaphanta compacta*	Bioscan INS	Native
Snail, Penola Pinhead Snail	*Magilaoma penolensis*	ALA	Native

Common Name	Species Name	Bioscan or ALA	Native or introduced
Snail, Plump Pinwheel Snail	*Pillomena meraca*	ALA	Native
Snail, Prickle Pinhead Snail	*Paralaoma caputspinulae*	ALA	Native
Snail, Small Pointed Snail	*Prietocella barbara*	ALA	Introduced
Snail, Southern Ambersnail	*Succinea (Succinea) australis*	ALA	Native
Snail, Southern Hairy Red Snail	*Chloritobadistes victoriae*	ALA	Native
Snail, Splitters Falls Pinwheel Snail	*Geminoropa scindocataracta*	ALA	Native
Snail, Tamar River Pinwheel Snail	*Pernagera tamarensis*	ALA	Native
Snail, Tarraville Pinwheel Snail	*Allocharopa tarravillensis*	ALA	Native
Snail, Tiny Pinhead Snail	*Trocholaoma parvissima*	ALA	Native
Snail, Vineyard Snail	*Cernuella virgata*	ALA	Introduced
Snail, White Italian Snail	*Theba pisana*	ALA	Introduced
Reptiles			
Legless Lizard, Striped Legless Lizard	*Delma impar*	ALA	Native
Lizard, Blotched Blue-Tongue	*Tiliqua nigrolutea*	Bioscan	Native
Lizard, Eastern Blue-Tongue	*Tiliqua scincoides*	ALA	Native
Lizard, Jacky Lizard	*Amphibolurus muricatus*	Bioscan	Native
Lizard, Mountain Dragon	*Rankinia diemensis*	Bioscan	Native
Skink, Eastern Three-lined Skink	*Acritoscincus duperreyi*	Bioscan	Native
Skink, Highlands Forest Skink	*Anepischetosia maccoyi*	ALA	Native
Skink, Pale-Flecked Garden Sunskink	*Lampropholis guichenoti*	Bioscan	Native
Skink, Southern Forest Cool-skink	*Niveoscincus coventryi*	ALA	Native
Skink, Southern Water-Skink	*Eulamprus tympanum*	ALA	Native
Skink, Trunk-climbing Cool-skink	*Pseudemoia spenceri*	ALA	Native
Skink, Tussock Cool-skink or Southern Grass Skink	*Pseudemoia entrecasteauxii*	ALA	Native
Skink, Tussock Skink	*Pseudemoia pagenstecheri*	ALA	Native
Skink, Weasel Skink	*Saproscincus mustelinus*	ALA	Native
Skink, White's Skink	*Liopholis whitii*	Bioscan	Native
Snake, Eastern Brown Snake	*Pseudonaja textilis*	Bioscan	Native
Snake, Little Whip Snake	*Parasuta flagellum*	ALA	Native
Snake, Lowland Copperhead	*Austrelaps superbus*	ALA	Native
Snake, Tiger Snake	*Notechis scutatus*	Bioscan	Native
Snake, White-lipped Snake	*Drysdalia coronoides*	ALA	Native
Turtle, Common Long-necked Tortoise (also known as the Eastern Snake-necked Turtle)	*Chelodina longicollis*	ALA	Native

Bird species known to occur in the Otway region, including coastal species

This list is based on records aggregated by the Atlas of Living Australia (https://www.ala.org.au/). These records were provided by: BirdLife Australia (Birdata), eBird Australia and OZCAM (Online Zoological Collections of Australian Museums).

Common Name	Species Name
Avocet, Red-necked Avocet	*Recurvirostra novaehollandiae*
Bee-eater, Rainbow Bee-eater	*Merops (Merops) ornatus*
Bittern, Australasian Bittern	*Botaurus poiciloptilus*
Bowerbird, Satin Bowerbird	*Ptilonorhynchus violaceus*
Bristlebird, Rufous Bristlebird	*Dasyornis (Maccoyornis) broadbenti*
Brolga	*Grus (Mathewsia) rubicunda*
Bronzewing, Brush Bronzewing	*Phaps (Phaps) elegans*
Bronzewing, Common Bronzewing	*Phaps (Phaps) chalcoptera*
Butcherbird, Grey Butcherbird	*Cracticus torquatus*
Chat, White-fronted Chat	*Epthianura (Epthianura) albifrons*
Chough, White-winged Chough	*Corcorax melanoramphos*
Cisticola, Golden-headed Cisticola	*Cisticola (Cisticola) exilis exilis*
Cockatoo, Gang-gang Cockatoo	*Callocephalon fimbriatum*
Cockatoo, Sulphur-crested Cockatoo	*Cacatua (Cacatua) galerita*
Cockatoo, Yellow-tailed Black-Cockatoo	*Calyptorhynchus (Zanda) funereus*
Coot, Eurasian Coot	*Fulica atra*
Corella, Little Corella	*Cacatua (Licmetis) sanguinea*
Corella, Long-billed Corella	*Cacatua (Licmetis) tenuirostris*
Cormorant, Australian Pied Cormorant	*Phalacrocorax (Phalacrocorax) varius*
Cormorant, Black-faced Cormorant	*Phalacrocorax (Anacarbo) fuscescens*
Cormorant, Great Cormorant	*Phalacrocorax (Phalacrocorax) carbo*
Cormorant, Little Black Cormorant	*Phalocrocorax (Phalacrocorax) sulcirostris*
Cormorant, Little Pied Cormorant	*Phalocrocorax melanoleucos*
Crake, Australian Spotted Crake	*Porzana (Porzana) fluminea*
Crake, Baillon's Crake	*Porzana (Porzana) pusilla*
Crake, Spotless Crake	*Porzana (Porzana) tabuensis*
Cuckoo, Brush Cuckoo	*Cacomantis (Cacomantis) variolosus*
Cuckoo, Fan-tailed Cuckoo	*Cacomantis (Vidgenia) flabelliformis*
Cuckoo, Horsfield's Bronze-Cuckoo	*Chalcites basalis*
Cuckoo, Pallid Cuckoo	*Cacomantis (Vidgenia) pallidus*
Cuckoo, Shining Bronze-Cuckoo	*Chalcites lucidus*
Cuckoo-shrike, Black-faced Cuckoo-shrike	*Coracina (Coracina) novaehollandiae*
Currawong, Grey Currawong	*Strepera (Neostrepera) versicolor*
Currawong, Pied Currawong	*Strepera (Strepera) graculina*
Darter, Australasian Darter	*Anhinga novaehollandiae*
Dotterel, Black-fronted Dotterel	*Elseyornis melanops*
Dotterel, Hooded Dotterel (Hooded Plover)	*Thinornis rubricollis*
Dotterel, Red-kneed Dotterel	*Erythrogonys cinctus*
Dove, Rock Dove	*Columba (Columba) livia*
Dove, Spotted Dove	*Spilopelia (Spilopelia) chinensis*
Duck, Australian Shelduck	*Tadorna (Casarca) tadornoides*
Duck, Australian Wood Duck (Maned Duck)	*Chenonetta jubata*

Common Name	Species Name
Duck, Australasian Shoveler	*Anas (Spatula) rhynchotis*
Duck, Blue-billed Duck	*Oxyura australis*
Duck, Chestnut Teal	*Anas (Nettion) castanea*
Duck, Freckled Duck	*Stictonetta naevosa*
Duck, Grey Teal	*Anas (Nettion) gracilis*
Duck, Hardhead (White-eyed Duck)	*Aythya (Nyroca) australis*
Duck, Musk Duck	*Biziura lobata*
Duck, Pacific Black Duck	*Anas (Anas) superciliosa*
Duck, Pink-eared Duck	*Malacorhynchus membranaceous*
Eagle, Little Eagle	*Hieraaetus (Hieraaetus) morpnoides*
Eagle, Wedge-tailed Eagle	*Aquila (Uroaetus) audax*
Eagle, White-bellied Sea-Eagle	*Haliaeetus (Pontoaetus) leucogaster*
Egret, Eastern Cattle Egret	*Ardea (Bubulcus) ibis coromandus*
Egret, Great Egret	*Ardea alba*
Egret, Intermediate Egret	*Ardea (Mesophoyx) intermedia*
Egret, Little Egret	*Egretta garzetta nigripes*
Falcon, Australian Hobby	*Falco (Falco) longipennis*
Falcon, Brown Falcon	*Falco (Ieracidea) berigora*
Falcon, Peregrine Falcon	*Falco (Hierofalco) peregrinus*
Fantail, Grey Fantail	*Rhipidura (Rhipidura) albiscapa*
Fantail, Rufous Fantail	*Rhipidura (Howeavis) rufifrons*
Fantail, Willie Wagtail	*Rhipidura (Sauloprocta) leucophyrs*
Finch, European Goldfinch	*Carduelis carduelis*
Finch, European Greenfinch	*Chloris chloris*
Finch, Red-browed Finch (Red-browed Firetail)	*Neochmia (Aegintha) temporalis*
Firetail, Beautiful Firetail	*Stagonopleura (Zonaeginthus) bella*
Firetail, Diamond Firetail	*Stagonopleura (Stagonopleura) guttata*
Flycatcher, Leaden Flycatcher	*Myiagra (Myiagra) rubecula*
Flycatcher, Restless Flycatcher	*Myiagra (Seisura) inquieta*
Flycatcher, Satin Flycatcher	*Myiagra (Myiagra) cyanoleuca*
Galah	*Eolophus roseicapilla*
Gerygone, White-throated Gerygone	*Gerygone olivacea*
Goose, Cape Barren Goose	*Cereopsis novaehollandiae*
Goose, Magpie Goose	*Anseranas semipalmata*
Goshawk, Brown Goshawk	*Accipiter (Leucospiza) fasciatus*
Goshawk, Grey Goshawk	*Accipiter (Leucospiza) novaehollandiae*
Grassbird, Little Grassbird	*Megalurus gramineus*
Grebe, Australasian Grebe	*Tachybaptus novaehollandiae*
Grebe, Great Crested Grebe	*Podiceps cristatus*
Grebe, Hoary-headed Grebe	*Poliocephalus poliocephalus*
Gull, Pacific Gull	*Larus (Larus) pacificus*
Gull, Silver Gull	*Chroicocephalus novaehollandiae novaehollandiae*
Harrier, Spotted Harrier	*Circus assimilis*
Harrier, Swamp Harrier	*Circus approximans*
Hen, Black-tailed Native-hen	*Tribonyx ventralis*
Heron, Nankeen Night Heron (Rufous Night Heron)	*Nycticorax caledonicus*
Heron, White-faced Heron	*Egretta novaehollandiae*

Common Name	Species Name
Heron, White-necked Heron (Pacific Heron)	*Ardea (Ardea) pacifica*
Honeyeater, Brown-headed Honeyeater	*Melithreptus (Eidopsarus) brevirostris*
Honeyeater, Crescent Honeyeater	*Phylidonyris (Phylidonyris) pyrrhoptera*
Honeyeater, New Holland Honeyeater	*Phylidonyris (Meliomis) novaehollandiae*
Honeyeater, Scarlet Honeyeater	*Myzomela (Myzomela) sanguinolenta*
Honeyeater, Singing Honeyeater	*Gavicalis virescens*
Honeyeater, Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*
Honeyeater, Tawny-crowned Honeyeater	*Gliciphila melanops*
Honeyeater, White-eared Honeyeater	*Nesoptilotis leucotis leucotis*
Honeyeater, White-naped Honeyeater	*Melithreptus (Melithreptus) lunatus*
Honeyeater, White-plumed Honeyeater	*Ptilotula penicillata penicillata*
Honeyeater, Yellow-faced Honeyeater	*Caligavis chrysops chrysops*
Ibis, Australian White Ibis	*Threskiornis moluccus*
Ibis, Straw-necked Ibis	*Threskiornis spinicollis*
Jacky Winter	*Microeca (Microeca) fascinans*
Kestrel, Nankeen Kestrel (Australian Kestrel)	*Falco cenchroides cenchroides*
Kingfisher, Azure Kingfisher	*Ceyx azureus*
Kingfisher, Laughing Kookaburra	*Dacelo (Dacelo) novaeguineae*
Kingfisher, Sacred Kingfisher	*Todiramphus (Todiramphus) sanctus*
Kite, Black Kite	*Milvus migrans affinis*
Kite, Black-shouldered Kite (Australian Kite)	*Elanus axillaris*
Kite, Whistling Kite	*Haliastur sphenurus*
Koel, Eastern Koel (Pacific Koel)	*Eudynamys orientalis cyanocephala*
Lapwing, Masked Lapwing	*Vanellus (Lobipluvia) miles*
Lorikeet, Little Lorikeet	*Parvipsitta pusilla*
Lorikeet, Musk Lorikeet	*Glossopsitta concinna*
Lorikeet, Purple-crowned Lorikeet	*Parvipsitta porphyrocephala*
Lorikeet, Rainbow Lorikeet	*Trichoglossus haematodus moluccanus*
Magpie, Australian Magpie	*Cracticus tibicen telonocua*
Magpie-Lark	*Grallina cyanoleuca cyanoleuca*
Martin, Fairy Martin	*Petrochelidon (Petrochelidon) ariel*
Martin, Tree Martin	*Petrochelidon (Hylochelidon) nigricans*
Miner, Noisy Miner	*Manorina (Myzantha) melanocephala*
Mistletoebird	*Dicaeum (Dicaeum) hirundinaceum hirundinaceum*
Moorhen, Dusky Moorhen	*Gallinula (Gallinula) tenebrosa tenebrosa*
Myna, Common Myna	*Acridotheres tristis*
Needletail, White-throated Needletail	*Hirundapus caudacutus*
Nightjar, White-throated Nightjar	*Eurostopodus mystacalis*
Oriols, Olive-backed Oriole	*Oriolus (Mimeta) sagittatus sagittatus*
Osprey, Eastern Osprey	*Pandion cristatus*
Owl, Australian Masked Owl	*Tyto novaehollandiae novaehollandiae*
Owl, Barking Owl	*Ninox (Hieracoglaux) connivens connivens*
Owl, Eastern Barn Owl	*Tyto (Tyto) javanica*
Owl, Powerful Owl	*Ninox (Rhabdoglaux) strenua*
Owl, Southern Boobook	*Ninox (Ninox) novaeseelandiae boobook*
Owlet-nightjar, Australian Owlet-nightjar	*Aegotheles (Aegotheles) cristatus cristatus*
Oystercatcher, Pied Oystercatcher	*Haematopus longirostris*

Common Name	Species Name
Oystercatcher, Sooty Oystercatcher	*Haematopus fuliginosus fuliginosus*
Pardalote, Spotted Pardalote	*Pardalotus (Pardalotus) punctatus*
Pardalote, Striated Pardalote	*Pardalotus (Pardalotinus) striatus ornatus*
Parrot, Australian King-Parrot	*Alisterus scapularis scapularis*
Parrot, Blue-winged Parrot	*Neophema (Neonanodes) chrysostoma*
Parrot, Eastern Ground Parrot	*Pezoporus wallicus wallicus*
Parrot, Orange-bellied Parrot	*Neophema (Neonanodes) chrysogaster*
Parrot, Swift Parrot	*Lathamus discolor*
Pelican, Australian Pelican	*Pelecanus conspicillatus*
Penguin, Little Penguin	*Eudyptula minor undina*
Petrel, Northern Giant-Petrel	*Macronectes halli*
Petrel, Southern Giant-Petrel	*Macronectes giganteus*
Pigeon, Crested Pigeon	*Ocyphaps lophotes*
Pigeon, Rock Pigeon	*Columba (Columba) livia*
Pigeon, White-headed Pigeon	*Columba (Janthoenas) leucomela*
Pipit, Australian Pipit (Australasian Pipit)	*Anthus (Anthus) novaseelandiae novaseelandiae*
Plover, Double-banded Plover	*Charadrius (Charadrius) bicinctus*
Plover, Hooded Plover (Hooded Dotterel)	*Thinornis cucullatus*
Prion, Fairy Prion	*Pachyptila turtur turtur*
Quail, Brown Quail	*Coturnix (Synoicus) ypsilophora australis*
Quail, Painted Button-quail	*Turnix (Austroturnix) varius*
Quail, Stubble Quail	*Coturnix (Coturnix) pectoralis*
Quail-Thrush, Spotted Quail-Thrush	*Cinclosoma (Cinclosoma) punctatum*
Rail, Buff-banded Rail	*Gallirallus philippensis*
Rail, Lewin's Rail	*Lewinia pectoralis*
Raven, Australian Raven	*Corvus coronoides coronoides*
Raven, Forest Raven	*Corvus tasmanicus tasmanicus*
Raven, Little Raven	*Corvus mellori*
Reed-Warbler, Australian Reed-Warbler	*Acrocephalus (Acrocephalus) australis australis*
Robin, Eastern Yellow Robin	*Eopsaltria (Eopsaltria) australis australis*
Robin, Flame Robin	*Petroica (Littlera) phoenicia*
Robin, Pink Robin	*Petroica (Erythrodryas) rodinogaster*
Robin, Rose Robin	*Petroica (Erythrodryas) rosea*
Robin, Scarlet Robin	*Petroica (Petroica) boodang*
Rosella, Crimson Rosella	*Platycercus (Platycercus) elegans elegans*
Rosella, Eastern Rosella	*Platycercus (Violania) eximius*
Sandpiper, Common Greenshank	*Tringa (Glottis) nebularia*
Sandpiper, Red Knot	*Calidris (Calidris) canutus*
Sandpiper, Red-necked Stint	*Calidris (Ereunetes) ruficollis*
Sandpiper, Sharp-tailed Sandpiper	*Calidris (Erolia) acuminata*
Shearwater, Fluttering Shearwater	*Puffinus (Puffinus) gavia*
Shearwater, Hutton's Shearwater	*Puffinus (Puffinus) huttoni*
Shearwater, Short-tailed Shearwater	*Puffinus tenuirostris*
Shrike-Thrush, Grey Shrike-Thrush	*Colluricincla (Colluricincla) harmonica*
Shrike-Tit, Crested Shrike-Tit	*Falcunculus frontatus frontatus*
Silvereye	*Zosterops lateralis lateralis*

Common Name	Species Name
Silvereye	*Zosterops lateralis westernensis*
Sittella, Varied Sittella	*Daphoenositta (Neositta) chrysoptera chrysoptera*
Skylark, Eurasian Skylark	*Alauda arvensis*
Snipe, Latham's Snipe	*Gallinago (Gallinago) hardwickii*
Sparrow, Eurasian Tree Sparrow	*Passer montanus*
Sparrow, House Sparrow	*Passer domesticus*
Sparrowhawk, Collared Sparrowhawk	*Accipiter (Paraspizias) cirrocephalus*
Spinebill, Eastern Spinebill	*Acanthorhynchus tenuirostris*
Spoonbill, Royal Spoonbill	*Platalea (Platalea) regia*
Spoonbill, Yellow-billed Spoonbill	*Platalea (Platibis) flavipes*
Starling, Common Starling	*Sturnus vulgaris*
Stilt, Banded Stilt	*Cladorhynchus leucocephalus*
Stilt, Australasian Pied Stilt	*Himanotopus himanotopus leucocephalus*
Swallow, Welcome Swallow	*Hirundo neoxena*
Swamphen, Australasian Swamphen	*Porphyrio (Porphyrio) porphyrio melanotus*
Swan, Black Swan	*Cygnus (Chenopis) atratus*
Swift, Pacific Swift (Fork-tailed Swift)	*Apus pacificus*
Tawny Frogmouth	*Podargus strigoides*
Tern, Caspian Tern	*Hydroprogne caspia*
Tern, Greater Crested Tern	*Thalasseus bergii*
Tern, Whiskered Tern	*Chlidonias (Pelodes) hybrida*
Thornbill, Brown Thornbill	*Acanthiza (Acanthiza) pusilla*
Thornbill, Buff-rumped Thornbill	*Acanthiza (Geobasileus) reguloides*
Thornbill, Striated Thornbill	*Acanthiza (Subacanthiza) lineata*
Thornbill, Yellow Thornbill	*Acanthiza (Subacanthiza) nana*
Thornbill, Yellow-rumped Thornbill	*Acanthiza (Geobasileus) chrysorrhoa*
Thrush, Bassian Thrush (Olive-tailed Thrush)	*Zoothera lunulata lunulata*
Thrush, Common Blackbird	*Turdus merula*
Treecreeper, White-throated Treecreeper	*Cormobates leucophaea*
Treecreeper, White-throated Treecreeper	*Cormobates leucophaea leucophaeus*
Triller, White-winged Triller	*Lalage (Lalage) sueurii*
Turnstone, Ruddy Turnstone	*Arenaria interpres*
Wattlebird, Little Wattlebird	*Anthocaera (Anellobia) chrysoptera*
Wattlebird, Red Wattlebird	*Anthocaera (Anthocaera) carunculata*
Whistler, Australian Golden Whistler	*Pachycephala (Pachycephala) pectoralis*
Whistler, Olive Whistler	*Pachycephala (Timixos) olivacea olivacea*
Whistler, Olive Whistler	*Pachycephala (Timixos) olivacea bathychroa*
Whistler, Rufous Whistler	*Pachycephala (Alisterornis) rufiventris*
Woodswallow, Dusky Woodswallow	*Artamus (Angroyan) cyanopterus*
Woodswallow, Masked Woodswallow	*Artamus (Campbellornis) personatus*
Woodswallow, White-browed Woodswallow	*Artamus (Campbellornis) superciliosus*
Wren, Chestnut-rumped Heathwren	*Hylacola pyrrhopygius*
Wren, Southern Emu-wren	*Stipiturus malachurus malachurus*
Wren, Striated Fieldwren	*Calamanthus fuliginosus*
Wren, Striated Fieldwren	*Calamanthus fuliginosus bourneorum*
Wren, Superb Fairy-wren	*Malurus (Malurus) cyaneus cyanochlamys*

Moth species recorded in the Otway region

List based on records held by the Entomology Society of Victoria and maintained by P. Marriott, 2019 (also see Marriott et al. 2019). For simplicity, subfamily names have not been included.

Note: taxonomic research within the Lepidoptera (moths and butterflies) is on-going and often results in changes to species names and movement of species from one genus to another. Sometimes these changes may leave a previously accepted genus name unavailable, without a suitable alternative. In such cases, the names in this list have been put in most recent published (but unavailable) genus name in brackets: e.g. *(Chrysolarentia) plesia*. Where there are multiple unidentified species, which belong to the same genus, these have be represented as: *Leptozestis* spp. (4), i.e. four species of *Leptozestis*.

Superfamily	Family	Species Name
Alucitoidea		
	Tineodidae	
		Tineodes adactylalis
	Anthelidae	
		Anthela acuta
		Anthela connexa
		Anthela ferruginosa
		Anthela nicothoe
		Anthela ocellata
		Anthela repleta
		Chelepteryx chalepteryx
		Chelepteryx collesi
		Chenuala heliaspis
		Munychryia senicula
		Nataxa flavescens
		Pterolocera amplicornis
		Pterolocera leucocera
	Lasiocampidae	
		Entometa apicaliss
		Entometa fervens
		Genduara subnotata
		Opsirhina albigutta
		Pararguda sp.
		Pararguda nasuta
		Pararguda rufescens
		Pinara divisa
		Pinara obliqua
		Porela albifinis
		Porela delineata
		Porela subfasciata
		Porela vetusta
	Saturniidae	
		Opodiphthera eucalypti
		Opodiphthera helena
	Sphingidae	
		Hippotion scrofa
Copromorphoidea		
	Carposinidae	
		Bondia maleficana
		Bondia nigella
		Carposina latebrosa
		Carposina telesia
		Sosineura mimica
Cossoidea		
	Cossidae	
		Culama anthracica
		Culama suffusca
		Endoxyla eucalypti
		Endoxyla lituratus
		Endoxyla secta
		Endoxyla sp.
		Idioses littleri
		Ptilomacra senex
		Sympycnodes epicycla
		Zyganisus caliginosus
Epermenioidea		
	Epermeniidae	
		Epermenia exilis
Gelechioidea		
	Coleophoridae	
		Coleophora alcyonipennella
	Cosmopterigidae	
		Cosmopterigidae sp.
		Labdia bryomina
		Labdia hexaspila
		Leptozestis spp. (4)
		Limnaecia camptosema
		Limnaecia camptosema
		Limnaecia cirrhosema

Superfamily	Family	Species Name
		Limnaecia cirrhozona
		Limnaecia scoliosema
		Limnaecia trissodesma
		Limnaecia trissodesma
		Limnaecia spp. (3)
		Macrobathra alternatella
		Macrobathra arrectella
		Macrobathra baliomitra
		Macrobathra bigerella
		Macrobathra ceraunobola
		Macrobathra chrysotoxa
		Macrobathra myriophthalma
		Macrobathra nephelomorpha
		Macrobathra spp. (2)
		Mimodoxa metallica
		Trachydora centromela
		Trachydora spp. (2)
	Depressariidae	
		(Cryptolechia) coriaria
		Doleromima hypoxantha
		Eclecta aurorella
		Enchocrates glaucopis
		Eutorna eurygramma
	Depressidae	
		Eutorna rubida
	Elachistidae	
		Phylomictis sp.
	Ethmiidae	
		Ethmia eupostica
	Gelechiidae	
		Ardozyga abruptella
		Ardozyga aversella
		Ardozyga bistrigata
		Ardozyga catarrhacta
		Ardozyga chionoprora
		Ardozyga decaspila
		Ardozyga desmatra
		Ardozyga enchotypa
		Ardozyga englypta
		Ardozyga englypta
		Ardozyga hemichlaena
		Ardozyga loemias
		Ardozyga macroplaca
		Ardozyga mesochra
		Ardozyga molyntis
		Ardozyga molyntis

Superfamily	Family	Species Name
		Ardozyga obeliscota
		Ardozyga telopis
		Ardozyga thermochroa
		Ardozyga xuthias
		Ardozyga spp. (4)
		Epibrontis hemichlaena
		Macrenches clerica
		Pycnobathra pityritis
		Tritadelpha microptila
	Hypertrophidae	
		Eupselia carpocapsella
		Eupselia melanostrepta
		Hypertropha chlaenota
		Peritropha oligodrachma
		Thudaca crypsidesma
		Thudaca haplonota
		Thudaca obliquella
	Lecithoceridae	
		Crocanthes glycina
		Crocanthes micradelpha
	Oecophoridae	
		Acanthodela erythrosema
		Acmotoma magniferella
		Acolasta scolia
		Aeolocosma iridozona
		Aeolothapsa malacella
		Ageletha elaeodes
		Ageletha hemiteles
		Agriophara cinderella
		Agriophara cinerosa
		Agriophara confertella
		Agriophara discobola
		Agriophara gravis
		Agriophara hyalinota
		Agriophara platyscia
		Agriophara spp. (6)
		Airogephyra sp.
		Antiopala sp.
		Antipterna euanthes
		Arachnographa micrastrella
		Archaerta dorsivittella
		Atelosticha phaedrella
		Atheropla crocea
		Atheropla decaspila
		Atheropla psammodes
		Atheropla sp.

Superfamily	Family	Species Name
		Atholosticta oxypeuces
		Barea atmophora
		Barea codrella
		Barea dryocoetes
		Barea epethistis
		Barea exarcha
		Barea hyperarcha
		Barea psologramma
		Barea pyrora
		Barea semocausta
		Barea turbatella
		Barea zygophora
		Barea spp. (2)
		Bida radiosella
		Catacometes phanozona
		Catadoceta xanthostephana
		Chrysonoma euchrysa
		Chrysonoma paracycla
		Coeranica isabella
		Compsotropha selenias
		Compsotropha strophiella
		Cosmaresta archedora
		Cosmaresta charaxias
		Crepidosceles glycydora
		Crossophora semiota
		Cryptophasa irrorata
		Cryptophasa rubescens
		Cryptophasa sp.
		Deigmoesta lithocosma
		Deigmoesta spp. (2)
		Diapatela sp.
		Endrosis sarcitrella
		Enoplidia simplex
		Eochrois dejunctella
		Eochrois epidesma
		Eochrois sarcoxantha
		Epicurica laetiferanus
		Epithymema incomposita
		Ericrypsina chorodoxa
		Euchaetis crypsichroa
		Euchaetis holocera
		Euchaetis inceptella
		Euchaetis metallota
		Euchaetis rhizobola
		Eulechria ceratina
		Eulechria convictella
		Eulechria electrodes
		Eulechria melesella
		Eulechria ophiodes
		Eulechria sigmophora
		Eulechria thermochroa
		Eulechria sp.
		(Eulechria) isopsepha
		(Eulechria) pelodora
		Eusemocosma pruinosa
		Garrha amata
		Garrha carnea
		Garrha leucerythra
		Garrha metrioipis
		Garrha miltopsara
		Garrha ocellifera
		Garrha pudica
		Garrha spp. (3)
		Haplodyta polybotrya
		Heliocausta oecophorella
		Hemibela callista
		Hemibela sp.
		Heteroteucha anthodora
		Heteroteucha dichroella
		Heteroteucha kershawi
		Heteroteucha occidua
		Heteroteucha ophthalmica
		Heteroteucha parvula
		Heteroteucha translatella
		Hoffmannophila pseudospretella
		Hoplomorpha camelaea
		Hoplostega ochroma
		Ioptera aristogona
		Ironopolia sobriella
		Leistarcha scitissimella
		Leistarcha tenuistria
		Lepidotarsa habrodelta
		Leptocroca sanguinolenta
		(Leptosaces) schistopa
		Lichenaula arisema
		Lichenaula calligrapha
		Lichenaula onychodes
		Lichenaula onychotypa
		Locheutis mesophragma
		Machaeritis aegrella
		(Machaeritis) grammophora

Superfamily	Family	Species Name
		Machetis aphrobola
		Maroga melanostigma
		Merocroca automima
		Microbela epicona
		Microbela monodyas
		Myrascia bracteatella
		Nephogenes graphica
		Ocystola crystallina
		Ocystola paulinella
		Odites sp.
		Oenochroa thermistis
		(Oecophora) eurrhoa
		Orthiastis hyperocha
		Oxythecta acceptella
		Oxythecta loxomochla
		Oxythecta lygrosema
		Oxythecta sp.
		Oxythecta zonoteles
		Palimeces poecilella
		Palimmeces percna
		Palimmeces poecilella
		Palimmeces sp.
		Pellopsis aerodes
		Phauloplana illuta
		Philobota arabella
		Philobota archepeda
		Philobota epipercna
		Philobota hypocausta
		Philobota impletella
		Philobota iphigenes
		Philobota moestella
		Philobota olympias
		Philobota orescoa
		Philobota pedetis
		Philobota productella
		Philobota scitula
		Philobota spp. (6)
		Philobota stella
		Philobota xiphopepla
		Phloeocetis sp.
		Phryganeutis cinerea
		Phylomictis maligna
		Phylomictis spp. (2)
		Phytotrypa anachorda
		Phytotrypa sp.
		Piloprepes anassa
		Poliorhabda auriceps
		Prionocris sp.
		Proteromicta sp.
		Psaroxantha basilica
		Psaroxantha sp.
		Scatochresis episema
		Scatochresis sp.
		Scieropepla polyxesta
		Sclerocris sp.
		Stathmopoda callichrysa
		Stathmopoda cephalaea
		Stathmopoda chrysochares
		Stathmopoda melanochra
		Stathmopoda pantarches
		Stathmopoda sp.
		Stictochila delosticta
		Stictochila metata
		Syringoseca mimica
		Syringoseca rhodoxantha
		Tachystola acroxantha
		Tachystola hemisema
		Tachystola sp.
		Tachystola stenoptera
		Tachystola thiasotis
		Tanyzancla argutella
		Telanepsia coprobora
		Telecrates laetiorella
		Telecrates melanochrysa
		Telocharacta metachroa
		Telocharacta sp.
		Temnogyropa sp.
		Thapsinotypa anthemodes
		Thema argoptera
		Thema chlorochyta
		Thema endesma
		Thema sp.
		Thema stasiastica
		Tortricopsis pyroptis
		Tortricopsis uncinella
		Tymbophora peltastis
		Wingia aurata
		Wingia hesperidella
		Wingia lambertella
		Wingia theophila
		Xylorycta leucophanes
		Xylorycta luteotactella

Superfamily	Family	Species Name
		Xylorycta sp.
		Xylorycta strigata
		Zonopetala quadripustulella
	Xyloryctidae	
		Scieropepla serina
		Tymbophora peltastis
	Geometridae	
		Acodia pauper
		Acodia sp.
		Adeixis inostentata
		Aeolochroma metarhodata
		Aeolochroma mniaria
		Amelora anepiscepta
		Amelora arotraea
		Amelora demistis
		Amelora goniota
		Amelora leucaniata
		Amelora mesocapna
		Amelora oncerodes
		Amelora synclera
		Amelora zophopasta
		Amelora spp. (3)
		Anachloris subochraria
		Anachloris subochraria
		Anachloris uncinata
		Androchela milvaria
		Androchela spp. (2)
		Apodasmia rufonigraria
		Aponotoreas dascia
		Aponotoreas epicrossa
		Aponotoreas petrodes
		Arhodia lasiocamparia
		Austrocidaria erasta
		Authaemon stenonipha
		Azelina biplaga
		Capusa cuculloides
		Capusa graodes
		Capusa senilis
		Casbia celidosema
		Casbia farinalis
		Casbia melanops
		Casbia oenias
		Casbia pallens
		Casbia tanaoctena
		Casbia tetramera
		Cassythaphaga macarta

Superfamily	Family	Species Name
		Chaetolopha leucophragma
		Chlenias banksiaria
		Chlenias belophora
		Chlenias ochrocrana
		Chlenias seminigra
		Chlenias stenosticha
		Chlenias sp.
		Chloroclystis approximata
		Chloroclystis catastreptes
		Chloroclystis filata
		Chloroclystis insigillata
		Chloroclystis metallospora
		Chloroclystis sp.
		Chlorocoma assimilis
		Chlorocoma cadmaria
		Chlorocoma carenaria
		Chlorocoma dichloraria
		Chlorocoma dichloraria
		Chlorocoma externa
		Chlorocoma melocrossa
		Chlorocoma stereota
		Chlorocoma tetraspila
		Chlorocoma spp. (5)
		Chlorodes boisduvalaria
		Chrysolarentia adornata
		Chrysolarentia bichromata
		Chrysolarentia cydalima
		Chrysolarentia epicteta
		Chrysolarentia euphileta
		Chrysolarentia heteroleuca
		Chrysolarentia imperviata
		Chrysolarentia lucidulata
		Chrysolarentia mecynata
		Chrysolarentia microcyma
		Chrysolarentia pantoea
		Chrysolarentia subrectaria
		Chrysolarentia symphona
		Chrysolarentia trygodes
		Chrysolarentia vicissata
		Chrysolarentia sp.
		(Chrysolarentia) arachnitis
		(Chrysolarentia) leucophanes
		(Chrysolarentia) plagiocausta
		(Chrysolarentia) plesia
		(Chrysolarentia) severata
		(Chrysolarentia) squamulata

Superfamily	Family	Species Name
		Ciampa arietaria
		Circopetes obtusata
		Cleora sp.
		Conosara castanea
		Conosara sp.
		Crypsiphona ocultaria
		Cyneoterpna wilsoni
		Dasybela achroa
		Dichromodes ainaria
		Dichromodes atrosignata
		Dichromodes confluaria
		Dichromodes estigmaria
		Dichromodes euscia
		Dichromodes indicataria
		Dichromodes longidens
		Dichromodes mesozona
		Dichromodes obtusata
		Dichromodes stilbiata
		Dichromodes spp. (3)
		Didymoctenia exsuperata
		Dinophalus serpentaria
		Dinophalus sp.
		Dissomorphia australiaria
		Dolabrossa amblopa
		Dysbatus singularis
		Dysbatus stenodesma
		Dysbatus sp.
		Eccymatoge callizona
		Eccymatoge morphna
		Ectropis bispinaria
		Ectropis calida
		Ectropis despicata
		Ectropis fractaria
		Ectropis sp.
		Epicompsa xanthocrossa
		Epicyme rubropunctaria
		Epidesmia hypenaria
		Epidesmia tryxaria
		Epyaxa sodaliata
		Epyaxa subidaria
		Eucyclodes buprestaria
		Eucymatoge scotodes
		Euloxia meandraria
		Euloxia sp.
		Fisera eribola
		Fisera hypoleuca

Superfamily	Family	Species Name
		Fisera perplexata
		Furcatrox australis
		Furcatrox furneauxi
		Furcatrox procera
		Gastrina cristaria
		Gastrinodes argoplaca
		Gastrinodes bitaeniaria
		Gastrophora henricaria
		Gynopteryx ada
		Heliomystis electrica
		Horisme mortuata
		Hypobapta diffundens
		Hypobapta tachyhalotaria
		Hypodoxa muscosaria
		Idaea costaria
		Idaea halmaea
		Idaea inversata
		Idaea nephelota
		Idaea philocosma
		Idaea probleta
		Idaea punctatissima
		Idaea spp. (2)
		Idiodes apicata
		Idiodes prionosema
		Idiodes siculoides
		Iulops argocrana
		Lackrana carbo
		Larentiinae sp.
		Liometopa rectilinea
		Maxates calaina
		Maxates centrophylla
		Maxates sp.
		Melanodes anthracitaria
		Melitulias graphicata
		Microdes diplodonta
		Microdes melanocausta
		Microdes squamulata
		Microdes villosata
		Microdes spp. (4)
		Mictodoca toxeuta
		Middletonia suavis
		Mnesampela comarcha
		Mnesampela heliochrysa
		Mnesampela lenaea
		Mnesampela privata
		Monoctenia falernaria

Superfamily	Family	Species Name
		Monoctenia sp.
		Nacophorini spp. (2)
		Nearcha nullata
		Nearcha ursaria
		Niceteria macrocosma
		Nisista galaeria
		Nisista notodontaria
		Nisista serrata
		Nisista spp. (3)
		Oenochroma barcodificata
		Oenochroma subustaria
		Oenochroma vetustaria
		Oenochroma vinaria
		Oenochroma sp.
		Palleopa innotata
		Paralaea ochrosoma
		Paralaea polysticha
		Paralaea porphyrinaria
		Paraterpna spp. (3)
		Parepisparis lutosaria
		Parosteodes fictiliaria
		Pasiphilodes testulata
		Phallaria ophiusaria
		Phelotis cognata
		Phrataria replicataria
		Phrataria transcissata
		Phrissogonus laticostata
		Picromorpha pyrrhopa
		Planolocha autoptis
		Plesanemma fucata
		Poecilasthena aedaea
		Poecilasthena aff. scoliota
		Poecilasthena anthodes
		Poecilasthena balioloma
		Poecilasthena fragilis
		Poecilasthena pulchraria
		Poecilasthena scoliota
		Poecilasthena thalassias
		Poecilasthena xylocyma
		Poecilasthena spp. (2)
		Prasinocyma semicrocea
		Prasinocyma sp.
		Psilosticha absorpta
		Psilosticha attacta
		Psilosticha pristis
		Rhinodia rostraria
		Rhynchopsota delogramma
		Scioglyptis canescaria
		Scioglyptis chionomera
		Scioglyptis loxographa
		Scioglyptis lyciaria
		Scioglyptis sp.
		Scopula optivata
		Scopula perlata
		Scopula rubraria
		Scopula sp.
		Selidosema leucoplecta
		Smyriodes aplectaria
		Smyriodes trigramma
		Stibaroma aphronesa
		Stibaroma melanotoxa
		Stibaroma sp.
		Syneora fractata
		Syneora mundifera
		Taxeotis exsectaria
		Taxeotis intermixtaria
		Taxeotis mimela
		Taxeotis mimela
		Taxeotis perlinearia
		Taxeotis spp. (2)
		Thalaina clara
		Thalaina selenaea
		Thallogama nigraria
		Visiana brujata
		Xanthorhoe anaspila
		Xanthorhoe percrassata
		Xanthorhoe strumosata
		Xanthorhoe vacuaria
		Zermizinga sinuata
		Zeuctophlebia squalidata
	Buccalatricidae	
		Tritymba spp. (2)
	Gracillariidae	
		Acrocercops spp. (2)
		Dialectica scalariella
	Roeslerstamiidae	
		Thereutis sp.
Hepialoidea		
	Hepialidae	
		Abantiades hyalinatus
		Abantiades labyrinthicus
		Abantiades latipennis

Superfamily	Family	Species Name
		Abantiades magnificus
		Aenetus ligniveren
		Cordyceps gunnii
		Elhamma australasiae
		Fraus bilineata
		Fraus fusca
		Fraus nanus
		Fraus polyspila
		Fraus pteromela
		Fraus simulans
		Fraus tedi
		Oncopera fasciculatus
		Oncopera intricoides
		Oncopera rufobrunnea
		Oxycanus antipoda
		Oxycanus australis
		Oxycanus sirpus
		Trictena atripalpis
Incurvarioidea		
	Adelidae	
		Nemophora chrysolamprella
		Ceromita leptostica
	Heliozelidae	
		Heliozela spp. (2)
	Incurvariidae	
		Perthida sp.
Nepticuloidea		
	Opostegidae	
		Pectinivalva sp.
Noctuoidea		
	Erebidae	
		Acontia clerana
		Acontia nivipicta
		Acyphas chionitis
		Acyphas semiochrea
		Alapadna pauropis
		Anestia ombrophanes
		Anestia semiochrea
		Asura cervicalis
		Asura lydia
		Calamidia hirta
		Castulo doubledayi
		Corgatha dipyra
		Crioa hades
		Damias procrena
		Dasypodia selenophora

Superfamily	Family	Species Name
		Diatenes aglossoides
		Diatenes gerula
		Egone sp.
		Epicyrtica lichenophora
		Eublemma nconspicua
		Euproctis limbalis
		Euproctis marginalis
		Euproctis melanosoma
		Euproctis sp.
		Halone pteridaula
		Halone sejuncta
		Halone servilis
		Iropoca rotundata
		Lithosiini sp.
		Nyctemera amicus
		Orgyia anartoides
		Palaeosia bicosta
		Palaeosia spp. (2)
		Pantydia canescens
		Pantydia diemeni
		Pantydia sparsa
		Phaeophlebosia furcifera
		Philenora elegans
		Philenora irregularis
		Philenora omophanes
		Praxis edwardsii
		Praxis pandesma
		Praxis porphyretica
		Praxis spp. (2)
		Prorocopis euxantha
		Rhapsa suscitatalis
		Rhodina falculalis
		Sandava scitisignata
		Sandava xylistis
		Schrankia sp.
		Scoliacma bicolora
		Scoliacma nana
		Scoliacma pactolias
		Spilosoma canescens
		Spilosoma curvata
		Spilosoma glatignyi
		Termessa laeta
		Termessa nivosa
		Thallarcha albicollis
		Thallarcha chrysochares
		Thallarcha partita

Superfamily	Family	Species Name
		Thallarcha phalarota
		Threnosia myochroa
		Threnosia sp.
		Tigrioides alterna
		(Trigonistis) asthenopa
		Utetheisa pulchelloides
	Noctuidae	
		(Dasygaster) epundoides
		(Leucania) obumbrata
		(Leucania) obusta
		(Leucania) sp.
		Aedia leucomelas
		Agrotis infusa
		Agrotis ipsilon
		Agrotis munda
		Agrotis porphyricollis
		Agrotis radians
		Athetis tenuis
		Australothis rubrescens
		Bathytricha truncata
		Buciara bipartita
		Chrysodeixis argentifera
		Chrysodeixis eriosoma
		Chrysodeixis subsidens
		Cosmodes elegans
		Dasygaster padockina
		Dasygaster sp.
		Diarsia intermixta
		Ectopatria aspera
		Ectopatria subrufescens
		Eutrichopidia latinus
		Hecatesia fenestrata
		Helicoverpa armigera
		Helicoverpa punctigera
		Hypoperigea tonsa
		Leucania (NASG) *diatrecta*
		Leucania (NASG) *uda*
		Mataeomera mesotaenia
		Mythimna convecta
		Neumichtis saliaris
		Neumichtis spp. (3)
		Neumichtis spumigera
		Persectania dyscrita
		Persectania ewingii
		Phalaenoides glycinae
		Phalaenoides tristifica

Superfamily	Family	Species Name
		Proteuxoa amaurodes
		Proteuxoa bistrigula
		Proteuxoa capularis
		Proteuxoa cinereicollis
		Proteuxoa florescens
		Proteuxoa hydraecioides
		Proteuxoa hypochalchis
		Proteuxoa marginalis
		Proteuxoa microspila
		Proteuxoa monochroa
		Proteuxoa oxygona
		Proteuxoa paratorna
		Proteuxoa restituta
		Proteuxoa rubripuncta
		Proteuxoa sanguinipuncta
		Proteuxoa spp. (6)
		Proteuxoa testaceicollis
		Proteuxoa tortisigna
		Thoracolopha verecunda
	Nolidae	
		Aquita plagiochyta
		Earias vittella
		Elesma sp.
		Elesma subglauca
		Nola aulacota
		Nola biguttalis
		Nola crucigera
		Nola cycota
		Nola delograpta
		Nola eucolpa
		Nola melanogramma
		Nola monozona
		Nola parallacta
		Nola paromoea
		Nola phaeogramma
		Nola pleurosema
		Nola pothina
		Nola semograpta
		Nola spp. (3)
		Nola tholera
		Nola vernalis
		Trigonistis asthenopa
		Uraba sp.
	Notodontidae	
		Destolmia lineata
		Epicoma melanospila

Superfamily	Family	Species Name
		Epicoma sp.
		Gallaba eugraphes
		Hylaeora eucalypti
		Psalidostetha banksiae
		Sorama bicolor
		Trichiocercus sparshalli
	Oenosandridae	
		Acontia clerana
		Discophlebia catocalina
		Discophlebia celaena
		Discophlebia lucasii
		Discophlebia sp.
		Oenosandra boisduvalii
Pterophoroidea		
	Pterophoridae	
		Platyptilia celidotus
		Sinpunctiptilia emissalis
		Stangeia xerodes
		Stenoptilia zophodactylus
		Wheeleria spilodactylus
Pyraloidea		
	Cambridae	
		Achyra affinitalis
		Anemosa exanthes
		Calamotropha delatalis
		Calamotropha dielota
		Calamotropha paludella
		Corynophora lativittalis
		Culladia cuneiferellus
		Eclipsiodes crypsixantha
		Eudonia aphrodes
		Eudonia protorthra
		Eudonia sp. *aff. aphrodes*
		Glaucocharis dilatella
		Hednota acontophora
		Hednota crypsichroa
		Hednota grammellus
		Hednota opulentellus
		Hednota pedionoma
		Hednota pleniferellus
		Hednota relatalis
		Hednota sp.
		Heliothela drosera
		Hellula hydralis
		Hygraula nitens
		Metasia capnochroa

Superfamily	Family	Species Name
		Metasia capnochroa
		Musotima nitidalis
		Musotima nitidalis
		Musotima ochropteralis
		Musotima ochropteralis
		Nacoleia rhoeoalis
		Nechilo macrogona
		Nomophila corticalis
		Notocrambus holomelas
		Parapoynx euryscia
		Sceliodes cordalis
		Scirpophaga imparellus
		Scoparia cleodoralis
		Scoparia emmetropis
		Scoparia favilliferella
		Scoparia hypoxantha
		Scoparia ithyntis
		Scoparia meyrickii
		Scoparia oxygona
		Scoparia philonephes
		Scoparia plagiotis
		Scoparia sp.
		Scoparia spelaea
		Scoparia syntaracta
		Scoparine sp.
		Sedenia cervalis
		Sedenia rupalis
		Tawhitia pentadactylus
		Tipanaea patulella
		Udea hyalistis
		Udea hyalistis
		Uresiphita ornithopteralis
	Pyralidae	
		Assara holophragma
		Assara subarcuella
		Astrapometis saburalis
		Callionyma sarcodes
		Catamola funerea
		Creobota grossipunctella
		Crocydopora cinigerella
		Cryptoblabes sp.
		Endotricha dispergens
		Endotricha ignealis
		Endotricha pyrosalis
		Etiella behrii
		Etiella chrysoporella

Superfamily	Family	Species Name
		Faveria tritalis
		Galleria mellonella
		Gauna aegusalis
		Heteromicta pachytera
		Meyriccia latro
		Meyrickella sp.
		Mimaglossa habitalis
		Mimaglossa nauplialis
		Ocrasa acerasta
		Orthaga sp.
		Orthaga thyrisalis
		Persicoptera aglaopa
		Phycitine spp. (4)
		Salma cholica
		Salma pyrastis
		Spectrotrota fimbrialis
		Stericta carbonalis
		Stericta marmorea
Sesioidea		
	Brachodidae	
		Miscera spp. (2)
	Choreutidae	
		Asterivora sp.
		Tebenna micalis
Sphingoidea		
	Sphingidae	
		Agrius convolvuli
		Hippotion scrofa
Thyridoidea		
	Thyrididae	
		Aglaopus pyrrhata
Tineoidea		
	Gracillariidae	
		Acrocercops sp.
	Psychidae	
		Hyalarcta nigrescens
		Lepidoscia adelopis
		Lepidoscia annosella
		Lepidoscia cataphracta
		Lepidoscia characota
		Lepidoscia protorna
		Lepidoscia scotinopis
		Lepidoscia spp. (2)
		Metura elongatus (case)
		Psychanisa baliodes
		Trigonocyttara clandestina

Superfamily	Family	Species Name
	Roeslerstammiidae	
		Harpedonistis gonometra
	Tineidae	
		Dryadaula anthrocorma
		Edosa fraudulens
		Edosa sp.
		Erechthias mystacinella
		Metapherna castella
		Mimoscopa ochetaula
		Moerarchis australasiella
		Moerarchis inconcisella
		Monopis crocicapitella
		Monopis ethelella
		Monopis icterogastra
		Monopis meliorella
		Nemetois arichalcis
		Opogona comptella
		Opogona protodoxa
		Opogona stereodyta
Tortricoidea		
	Tortricidae	
		Acropolitis excelsa
		Acropolitis rudisana
		Ancylis anguillana
		Ancylis phileris
		Ancylis pseustis
		Ancylis volutana
		Anisogona mediana
		Anisogona similana
		Arotrophora arcuatalis
		Arotrophora ericirra
		Arotrophora sp.
		Asthenoptycha epiglypta
		Asthenoptycha iriodes
		Asthenoptycha sphaltica
		Asthenoptycha spp. (3)
		Authomaema pentacosma
		Bactra sp.
		(Cacoecia) technitis
		Clarana hyperetana
		(Capua) eugrapta
		(Capua) euphona
		(Capua) leucobela
		(Capua) leucostacta
		(Capua) scaphosema
		Cnephasia redius

Superfamily	Family	Species Name
		Coeloptera epiloma
		Coeloptera sp.
		(Conchylis) subfurcatana
		(Conchylis) tasmaniana
		Constrictana constrictana
		Crocidosema plebejana
		Cryptoptila australana
		(Dichelia) clarana
		(Dichelia) cosmopis
		(Dichelia) thermaterimma
		Epiphyas ashworthana
		Epiphyas caryotis
		Epiphyas eucyrta
		Epiphyas fabricata
		Epiphyas lathraea
		Epiphyas postvittana
		Epiphyas xylodes
		Epitymbia alaudana
		Epitymbia cosmota
		Epitymbia eutypa
		Epitymbia isoscelana
		Epitymbia scotinopa
		Ericodesma indigestana
		Ericodesma liquidana
		Ericodesma sp.
		Euphona decolorana
		Euphona Group euphona
		Glyphidoptera insignana
		Glyphidoptera polymita
		Heliocosma incongruana
		Heliocosma sp.
		Hermenias rivulifera
		Herpystis avida
		Holocola deloschema
		Holocola lucifera
		Holocola pericyphana
		Holocola triangulana
		Holocola spp. (3)
		Isochorista acrodesma
		Meritastis lythrodana
		Meritastis polygraphana
		Meritastis pyrosemana
		Meritastis sp.
		Merophyas therina
		Palaeotoma sp.
		Peraglyphis hemerana

Superfamily	Family	Species Name
		Peraglyphis sp.
		Rupicolana mermera
		Rupicolana orthias
		Rupicolana stereodes
		(Sciaphila) debiliana
		Scolioplecta comptana
		Sobriana mnemosynana
		Sobriana ophiodesma
		Strepsicrates infensa
		Strepsicrates macropetana
		Syllomatia pertinax
		Tarachota cnaphalodes
		Technitis agrypna
		Technitis technitis
		Thrincophora dryinodes
		Thrincophora impletana
		Thrincophora lignigerana
		(Tortrix) polymicta
		Unplaced cosmopis
		Unplaced placoxantha
Yponomeutoidea		
	Glyphipterigidae	
		Glyphipterix amblycerella
		Glyphipterix chrysoplanetis
		Glyphipterix cometophora
		Glyphipterix gypsonota
		Glyphipterix perimetalla
	Plutellidae	
		Leuroperna sera
		Plutella xylostella
	Yponomeutidae	
		Zelleria spp. (3)
Zygaenoidea		
	Limacodidae	
		Doratifera oxleyi
		Pseudanapaea transvestita
	Zygaenidae	
		Hestiochora furcata
		Myrtartona coronias
		Neoprocris dolons
		Pollanisus lithopastus
		Pollanisus subdolosa
		Pollanisus viridipulverulenta

Native bee species recorded in the Otway region

The list is based on data from the Atlas of Living Australia (https://www.ala.org.au/). This data included records based on preserved specimens held in Museums Victoria and records based on human observations that came to ALA via websites such as iNaturalist (https://inaturalist.ala.org.au/), Bowerbird (http://www.bowerbird.org.au/) and PaDIL (http://www.padil.gov.au/). Note: no native bees were found during the Bioscan.

Family name	Species name	Common name
Aoidae		
	Amegilla (Notomegilla) chlorocyanea	Blue Banded Bee
	Exoneura (Exoneura) bicolor	Reed Bee
	Exoneura (Exoneura) robusta	Reed Bee
	Exoneura nigrescens	Reed Bee
Colletidae		
	Brachyhesma (Brachyhesma) sulphurella	Euryglossinae Bee
	Brachyhesma (Microhesma) healesvillensis	Euryglossinae Bee
	Callohesma calliopsiformis	Euryglossinae Bee
	Euhesma (Euhesma) halictina	Euryglossinae Bee
	Euhesma (Euhesma) inconspicua	Euryglossinae Bee
	Euhesma (Euhesma) latissima	Euryglossinae Bee
	Euhesma (Euhesma) walkeriana	Euryglossinae Bee
	Euryglossa aureopilosa	Euryglossinae Bee
	Euryglossina (Euryglossina) hypochroma	Euryglossinae Bee
	Euryglossina (Euryglossina) narifera	Euryglossinae Bee
	Euryglossina (Euryglossina) proctotrypoides	Euryglossinae Bee
	Hylaeus (Analastoroides) foveatus	Masked Bee
	Hylaeus (Edriohylaeus) ofarrelli	Masked Bee
	Hylaeus (Euprosopis) honestus	Masked Bee
	Hylaeus (Gnathoprosopoides) bituberculatus	Masked Bee
	Hylaeus (Heterapoides) extensus	Masked Bee
	Hylaeus (Prosopisteron) perhumilis	Masked Bee
	Hylaeus (Prosopisteron) quadratus	Masked Bee
	Leioproctus (Leioproctus) clarki	Leioproctus Bee
	Leioproctus (Leioproctus) versicolor	Leioproctus Bee
	Pachyprosopis (Pachyprosopis) haematostoma	Euryglossinae Bee
	Pachyprosopis (Pachyprosopula) kellyi	Euryglossinae Bee
Halictidae		
	Homalictus (Homalictus) brisbanensis	Homalictus Bee
	Homalictus (Homalictus) punctatus	Homalictus Bee
	Homalictus (Homalictus) sphecodoides	Homalictus Bee
	Lasioglossum (Australictus) plorator	Lasioglossum Bee
	Lasioglossum (Austrevylaeus) exoneuroides	Lasioglossum Bee
	Lasioglossum (Chilalictus) bicingulatum	Lasioglossum Bee
	Lasioglossum (Chilalictus) brazieri	Lasioglossum Bee

Family name	Species name	Common name
	Lasioglossum (Chilalictus) calophyllae	Lasioglossum Bee
	Lasioglossum (Chilalictus) clelandi	Lasioglossum Bee
	Lasioglossum (Chilalictus) disclusum	Lasioglossum Bee
	Lasioglossum (Chilalictus) erythrurum	Lasioglossum Bee
	Lasioglossum (Chilalictus) gilesi	Lasioglossum Bee
	Lasioglossum (Chilalictus) helichrysi	Lasioglossum Bee
	Lasioglossum (Chilalictus) hemichalceum	Lasioglossum Bee
	Lasioglossum (Chilalictus) imitans	Lasioglossum Bee
	Lasioglossum (Chilalictus) lanarium	Lasioglossum Bee
	Lasioglossum (Chilalictus) mundulum	Lasioglossum Bee
	Lasioglossum (Chilalictus) opacicolle	Lasioglossum Bee
	Lasioglossum (Chilalictus) orbatum	Lasioglossum Bee
	Lasioglossum (Chilalictus) repraesentans	Lasioglossum Bee
	Lasioglossum (Chilalictus) tamburinei	Lasioglossum Bee
	Lasioglossum (Parasphecodes) altichum	Lasioglossum Bee
	Lasioglossum (Parasphecodes) dissimulator	Lasioglossum Bee
	Lasioglossum (Parasphecodes) lacthium	Lasioglossum Bee
	Lasioglossum (Parasphecodes) melbournense	Lasioglossum Bee
	Lasioglossum (Parasphecodes) sulthicum	Lasioglossum Bee

Otway Bioscan
Great Otway National Park
July 2018–2019

Published by Museums Victoria 2019

Museums Victoria
GPO Box 666
Melbourne 3001
Victoria, Australia
Telephone: (+61 3) 8341 7777
Fax: (+61 3) 8341 7778

museumsvictoria.com.au

Design Megan Ellis
Typesetting Megan Ellis
Printed in Australia by Adams Print, Victoria
on Pacesetter Laser SPI
https://www.spicers.com.au/pacesetter-laser-spi

Cover: Adult stonefly *Dinotoperla uniformis* (Gripopterygidae), Aire River, October 2019. Photographer: Julian Finn | Source: Museums Victoria.