

2018 LINNEAN SOCIETY OF NSW NATURAL HISTORY FIELD SYMPOSIUM

**Volcanoes of Northwest New South Wales:  
Exploring Relationships Among Geology,  
Flora, Fauna and Fires**

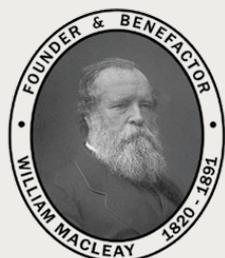
Coonabarabran 25th - 27th September 2018



**PROGRAM, ABSTRACTS  
AND  
FIELD GUIDE**

# Volcanoes of Northwest New South Wales: Exploring Relationships Among Geology, Flora, Fauna and Fires

Evidence of Miocene-age volcanic activity in NSW extends from Mt Warning through Mt Kaputar, the Warrumbungle Range and Coolah Tops, to Mt Canobolas near Orange. These resistant volcanic areas stand well above the surrounding regions and act as biotic islands to provide restricted, even unique, habitats for flora and fauna. The relationship between the underlying geology of the volcanic topography and the living biota is explored in the 2018 Natural History Field Symposium organised by the Linnean Society of NSW. Warrumbungle National Park, setting for the associated field excursion, was largely destroyed by fire in January 2013, with floods the following month adding to the devastation. Recovery of the landscape and biota from these events is also a major theme of the symposium. Recent research in this Park and the other volcanic centres, presented by the Geological Survey of NSW, the NSW Office of Environment and Heritage, universities and consultants, will highlight the significance of these regions to expanding our knowledge of the natural history and scientific heritage of NSW.



## THE LINNEAN SOCIETY OF NEW SOUTH WALES

Founded 1874  
Incorporated 1884

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The society exists to promote the cultivation and study of the science of natural history in all branches. The Society awards research grants each year in the fields of Life Sciences (the Joyce Vickery Scientific Research Fund) and Earth Sciences (the Betty Mayne Scientific Research Fund), as well as the William Macleay Scientific Research Fund for Microbiology. The Society offers annually a Linnean Macleay Fellowship for research, and publishes the *Proceedings*. It holds field excursions and scientific meetings including the biennial Sir William Macleay Memorial Lecture delivered by a person eminent in some branch of natural science.

Membership enquiries should be addressed in the first instance to the Secretary. Candidates for election to the Society must be recommended by two members. Membership fees and application form are available from our web site.

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This Program, Abstracts & Field Guide printed and sponsored by Imagination Graphics

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**Front cover:** Panorama of Warrumbungle Range, looking east from Bluff Mountain towards Beloungery Spire (centre) and Crater Bluff (right of centre). Photography by Hugh Percival.

**Back cover:** Crater Bluff (foreground) and Tonduron Spire in Warrumbungle National Park. Photography by Hugh Percival.

## PROGRAM OF PRESENTATIONS – WARRUMBUNGLES SYMPOSIUM 2018

### TUESDAY SEPTEMBER 25

09.00 – 09.30 **Registration** (also available at the Ice Breaker on Monday evening)

09.30 – 09.35 **Welcome** (**John Barkas**, President, Linnean Society of NSW)

09.35 – 09.50 **Chris Yeats** (GSNSW): Using geoscience to unlock the potential of western NSW

09.50 – 10.30 **Katharine Bull** (GSNSW) & Alexa Troedson: Permian pumice to Miocene magmas: volcanology of Warrumbungle National Park [Keynote]

10.30 – 11.00 MORNING TEA

11.00 – 11.20 **Alexa Troedson** (Consultant) & Katharine Bull: A new geology map of Warrumbungle National Park

11.20 – 11.40 **Astrid Carlton** (GSNSW) & Katharine Bull: Geophysical signatures of Warrumbungle National Park

11.40 – 12.00 **Felipe Oliveira** (GSNSW) & Astrid Carlton: Modelling the Warrumbungle National Park: creating a new 3D display model

12.00 – 12.20 **Keith Holmes** (UNE): The mid-Miocene Flora preserved in the diatomite beds of the Chalk Mountain Formation, Warrumbungle Volcano Complex

12.20 – 13.20 LUNCH

13.20 – 13.40 **Lin Sutherland** (Australian Museum): The rise and fall (creation and extinction) of Miocene central volcanoes in NW New South Wales: a link to an underlying lithospheric cavity?

13.40 – 14.00 **Peter Thompson** (Coonabarabran Landcare): Field observations of cobble and boulder stream deposits from the erosion of the Warrumbungle volcano.

14.00 – 14.20 **Mitch Tulau** (OEH), Sally McInness-Clarke & D. Morand: Mass movements in Warrumbungle National Park, NSW

14.20 – 14.40 **Simone Meakin** (GSNSW) & Angus M. Robinson: Geotales – Geotrails - collaborative geotourism initiatives and implications for the Warrumbungles region

14.40 – 15.00 **Richard Medd** & Colin Bowler: Biodiversity and endemism on Mount Canobolas

15.00 – 15.30 AFTERNOON TEA

15.30 – 15.50 **Michael Murphy** (NPWS), James Faris, Michael Mulholland & Jessica Murphy: Marooned on an extinct volcano: the conservation status of four narrow-range endemic gastropods at Mount Kaputar, northern inland New South Wales

15.50 – 16.10 **Tim Ralph** (Macquarie Univ.), Jamie Lobb & Yoshi Kobayashi: Fire history inferred from charcoal accumulation at Dunphy Lake, Warrumbungle Mountains

16.10 – 16.30 **Yoshi Kobayashi** (OEH), Tim Ralph & Peter Berney [to be presented by **Tim Ralph**]: Aquatic animal community at Dunphy Lake after the Wambelong fire indicates the importance of ephemeral pools and lake sediment for recovery process

## WEDNESDAY SEPTEMBER 26

09.30 – 09.50 **Liz Tasker** (OEH), Owen Price & Michael Storey: Fire and research in Warrumbungle National Park: an overview

09.50 – 10.10 **Andrew Denham** (OEH), Liz Tasker & Marianne Porteners: Fire impacts on vegetation in Warrumbungle National Park

10.10 – 10.30 **Daniel Lunney** (OEH), Indrie Sonawane, Martin Predavec, Robert Wheeler, Liz Tasker & Mike Fleming [to be presented by **Murray Ellis**]: Koalas and the 2013 fire in Warrumbungle National Park

10.30 – 10.50 **Clare McArthur** (Univ. of Sydney), Katherine Tuft & Mathew Crowther: Rock wallabies in the Warrumbungles pre 2013: impacts of predation risk, competitors and fire on diet, foraging and habitat quality

10.50 – 11.20 MORNING TEA

11.20 – 11.40 **Greg Chapman** (OEH), Xihua Yang, Sally McInnes-Clarke, Mitch Tulau & Tom Barrett: The Wambelong bushfire: Timely rapid assessment of soil erosion and flooding impacts

11.40 – 12.00 **Mitch Tulau** (OEH), R. McAlpine, S. Karunaratne, Sally McInnes-Clarke & Xihua Yang: Soil organic carbon and related impacts of the Warrumbungle wildfire

12.00 – 12.20 **Xihua Yang** (OEH), Qinggaozi Zhu, Mitch Tulau, & Sally McInnes-Clarke: Near real-time monitoring of post-fire erosion after storm events: a case study in Warrumbungle National Park, Australia

12.20 – 13.20 LUNCH

13.20 – 13.40 **Jennifer Taylor** (ACU) & Murray Ellis: Did the 2013 fire eliminate hollow trees from Warrumbungle National Park?

13.40 – 14.00 **Murray Ellis** (OEH) & Jennifer Taylor: Birds, bats, reptiles and burning in Warrumbungle National Park

14.00 – 14.20 **Boyd Wright** (UNE), Ian Simpson, Rod Fensham & John Hunter: Multiple ecological drivers behind recruitment variability of streaked wattle (*Acacia lineata* A.Cunn. ex. G.Don.) after fires of differing severity

14.20 – 14.40 **David McKay** (UNE) & Caroline Gross: Climate change places a fig-frugivore mutualism under threat in the Warrumbungles to Mt Kaputar region

14.40 – 15:00 **Jeremy Bruhl** (UNE), Ian Telford, Rose Andrew, Iain Moore, Margaret Stimpson et al.: Discovery of narrowly endemic plants of the volcanics of northern New South Wales and southern Queensland is critical to conservation and management

15:00 – 15.10 wrap-up, logistics for field trip

15.10 – 15.40 AFTERNOON TEA

## THURSDAY SEPTEMBER 27

Field trip (departs Coonabarabran Bowling Club 07.30 for 07.45, returns by 18.00)

# ABSTRACTS OF PRESENTATIONS

## Using geoscience to unlock the potential of western NSW

*Chris Yeats*

Executive Director, Geological Survey of New South Wales, Department of Planning & Environment

The Geological Survey of New South Wales (GSNSW) is the state's oldest continually operating government agency, with a history dating back to 1875. Although its core purpose as custodian of NSW geoscientific information has remained essentially unchanged throughout this long history, GSNSW owes its longevity primarily to its continued ability to leverage advances in technology and geoscientific knowledge, and to adapt and evolve to meet new challenges and changing community, government and industry expectations.

GSNSW's recent activities in the state's west include the Coonabarabran airborne geophysical survey. Flown in mid-2017, the survey collected new, high-quality magnetic and radiometric data that can be used to map soils, as well as subsurface geology, providing valuable information to the agricultural and mineral exploration industries. The area covered by the survey includes the iconic Warrumbungle National Park, and allowed GSNSW and the Office of Environment and Heritage (OEH) to collaborate in the production of a new geological map for the park. GSNSW has also produced a new 3D model of the national park, to be housed in the new Warrumbungle Visitor Centre, and is working with OEH and local councils to produce geotrails – self-guided geological tours designed to attract visitors to the region.

Commencing in the second half of 2018, the MinEx CRC is a 10-year, \$220 million collaboration between state and federal governments, the mineral exploration industry, CSIRO and Australian universities that aims to unlock the mineral potential of the three quarters of Australia where prospective rocks are buried under younger, barren rocks and sediment. GSNSW is a major participant in the CRC, and will focus its efforts on four underexplored areas of the state, including an area north of Dubbo. In addition to potentially stimulating mineral exploration activity in the region, the data collected will provide a valuable insight into the cover sequences, including information about soil and groundwater resources.

The social and economic sustainability of the western region of NSW has traditionally been heavily dependent on agriculture and mining. In the 21<sup>st</sup> Century, with new technologies and increasing automation changing the face of these industries, many regional communities are seeking to diversify into new areas, including tourism, to underpin future development. GSNSW, in collaboration with other organisations, will continue to work with the communities of western NSW to leverage the region's rich geological endowment to underpin the continued prosperity of regional NSW.

## **Permian pumice to Miocene magmas: volcanology of Warrumbungle National Park**

*Katharine F. Bull<sup>1</sup> and Alexa L. Troedson<sup>2</sup>*

<sup>1</sup> Geological Survey of New South Wales, Division of Resources and Geoscience, Department of Planning & Environment, 516 High Street, Maitland NSW 2320; email: kate.bull@planning.nsw.gov.au

<sup>2</sup> Troedson Geosciences Consulting; email: consulting@troedson.com.au

Warrumbungle National Park (WNP) encompasses the central parts of a hot-spot generated Miocene volcano that erupted through much older (late Palaeozoic to Mesozoic) sedimentary sequences of the Surat and underlying Gunnedah basins. Previous geological work has primarily focused on igneous petrology of the volcano, and has mostly been limited to areas outside WNP.

New mapping from this study shows Warrumbungle Volcano to be a complex shield volcano built from a series of mafic to felsic alkaline lavas, intrusions and volcanoclastic deposits, whose emplacement and magnetic anomalies coincide with regional-scale basement lineaments. The magmas were derived from a single differentiation trend that yielded highly fractionated and evolved felsic differentiates.

Volcanoclastic facies include autoclastic breccias associated with lava flow deposits and domes; pyroclastic (explosive) deposits such as mafic spatter-rich and felsic block-and-ash flow deposits; and volcanogenic sedimentary facies such as lahar deposits and polymictic vent-proximal volcanoclastic breccias.

A series of radial felsic dykes and elevated basement sandstones around the central vent of the volcano indicate inflation and dyke emplacement occurred late in the history of the volcano. Following erosion of most of the central area of the volcano, valley-fill volcanic deposits suggest catastrophic crater-rim collapse events, possibly in late Neogene–Pleistocene time. Continued erosion of the variably resistant flanks of the volcano has left us the spectacular landscape that is today's Warrumbungle National Park.

## **A new geology map of Warrumbungle National Park and environs**

*Alexa L. Troedson<sup>1</sup> and Katharine F. Bull<sup>2</sup>*

<sup>1</sup> Troedson Geosciences Consulting [consulting@troedson.com.au](mailto:consulting@troedson.com.au)

<sup>2</sup> Geological Survey of New South Wales, Division of Resources and Geoscience, 516 High Street, Maitland NSW 2320 [kate.bull@planning.nsw.gov.au](mailto:kate.bull@planning.nsw.gov.au)

We have created a new geology map of Warrumbungle National Park (WNP) and its environs. The map was commissioned by the NSW Office of Environment and Heritage (OEH) as part of the Warrumbungle Post-fire Research and Recovery Program. The Geological Survey of New South Wales (GSNSW) subsequently became an equal partner on the project. The new map was produced from a synthesis and interpretation of published and unpublished reference data, results of four weeks of fieldwork, petrographic analysis of field samples, and new remotely-sensed data including a high resolution LiDAR DEM acquired by OEH, and airborne geophysical data (radiometric and magnetic data, GSNSW 2017). Prior to this project, the available published geology maps were too broad scale to be useful for park management and scientific studies.

Key improvements from previous maps include the differentiation of Miocene Warrumbungle Volcanic Complex rocks into volcanic facies (Bull and Troedson, this volume), and revisions in and characterisation of the underlying Mesozoic to Paleozoic sedimentary basin sequences. The oldest rocks identified are small, isolated occurrences of Permian to Triassic Gunnedah Basin sequences which have been recognised at nine localities on the basis of fossil evidence, and distinctive lithologies including pumice- and shard-bearing quartz crystal tuffs and tuffaceous sandstones. Within WNP, the overlying Jurassic Surat Basin units consist of Pilliga Sandstone (cliff-forming, thick-bedded and cross-bedded, medium to coarse quartzose sandstone with common pebble bands), and the underlying Purlawaugh Formation, comprising intercalated thinly bedded siltstones and fine to medium grained sandstones characterised by poor outcrop. The Pilliga Sandstone is much more extensively exposed than had been mapped previously, particularly in the central area of the volcano where it forms a dissected plateau with cliffs and gorges, roughly 7-9 km in diameter. Probable Purlawaugh Formation is exposed in various localities in the central area, but outcrops are more limited than previously indicated. Complex contact geometry between basement sedimentary units and the volcanic facies suggest an irregular, eroded surface upon which volcanic rocks were deposited.

The new geology map has been integrated into the GSNSW's Statewide Seamless Geology database and the data will be freely available through GSNSW online systems. The new map and associated geological studies have been incorporated into geological educational materials in the new WNP Visitors Centre, and will inform geo-trails and other outreach projects in the future.

## Geophysical signatures of the Warrumbungle National Park

*Astrid Carlton and Kate Bull*

Geological Survey of New South Wales, Department of Planning & Environment

The NSW Government acquires airborne magnetic and radiometric data over NSW to support geological mapping, land use planning and regional industries, including agriculture and mineral exploration, and has surveyed approximately 88% of the state. In 2017, the Gilgandra to Coonabarabran region was surveyed, and the data used to support geological mapping of the Warrumbungle National Park. Radiometric data have been used to interpret surface geology, while magnetic data provide insight into the surface and subsurface geology.

Radiometric data are a measure of naturally occurring radioactive elements in the ground: potassium-40 (K), thorium-232 (Th) and uranium-238 (U). These radioelements emit gamma radiation that can be measured by crystals and photometric sensors mounted in an aircraft. Gamma radiation can only penetrate 20–50 cm of soil and rock and less than 10 cm of water, so radioelement data only provide information on rocks and soils at the surface.

To facilitate geological mapping, the radiometric data were presented in a ternary image where K, Th and U are represented by red, green and blue respectively. Areas high in all three elements appear white, whilst the absence of all three appears as black. Magenta represents high U and K, aqua represents high Th and U and yellow represents high K and Th.

Ground truthing confirmed the following main rock types in ternary radioelement imagery:

- Pilliga Sandstone appears as dark green to green or aqua, depending on water content and varying levels of U and Th; K < 1.5 %, Th 8.0–12.0 ppm and U < 2.5 ppm.
- Felsic to intermediate lava flows show as fuchsia to white; K 2.5–4.0 %, Th 5.0–12.0 ppm and U 1.5–3.5 ppm.
- Mafic lava flows appear fuchsia to dark red to red and fuchsia; K < 2.5 %, Th 4–5 ppm and U 0.5–2.0 ppm.
- Pyroclastic flows show as red, pink and white; K 1.0–4.5 %, Th 5.0–12.0 ppm and U 1.5–2.5 ppm.
- Mafic igneous intrusions appear red; K 1.0–2.5 %, Th 3.0–5.0 ppm and U 1.0–2.5 ppm.
- Felsic intrusions appear fuchsia to white to aqua; K 2.0–4.5 %, Th 7.0–50.0 ppm and U 2.0–10.0 ppm.
- Intermediate to felsic intrusions show as white; K 2.0–4.5 %, Th 7.0–10.0 ppm and U 2.0–3.5 ppm.

Magnetic imagery reveals buried and exposed lava flows, faults and numerous volcanic rocks that either solidified beneath the ground or erupted at the surface. The geology map produced will be of great use in mapping soils, flora and fauna.

## **Modelling the Warrumbungle National Park: creating a new 3D display model**

*Felipe Oliveira and Astrid Carlton*

Geological Survey of New South Wales, Department of Planning & Environment

In January 2013, almost 90% of the Warrumbungle National Park (WNP), including the Warrumbungle Visitor Centre, was destroyed by fire. As part of the reconstruction, a new 3D scale model was produced to replace the original 1970s diorama. The new display uses modern remote sensing data, and state-of-the-art 3D modelling and carving technology to create a model. The result is a topographically accurate, spatially correct and visually detailed model, which can be used for educational and scientific studies. This world-class museum-quality model provides a birds-eye view of the entire national park landscape, delivering an exceptional experience for scientists and visitors.

The terrain model is based on a Digital Elevation Model, generated using Light Detection and Ranging (LiDAR) data and Shuttle Radar Topography Mission data (SRTM). LiDAR data were acquired and supplied by NSW Spatial Services as 2 km by 2 km tiles, with a spatial resolution of 1 m. A total of 84 tiles covering the model area were clipped to the boundary of the WNP using PA Discover geophysical modelling software. Outside the WNP, SRTM data with a spatial resolution of 30 m were used. A 60 m-wide buffer of SRTM data was extended inside the WNP boundary to provide a seamless overlap between SRTM and LiDAR elevation data.

Data were subsequently imported into 3D modelling software Leapfrog, where tile alignment was tested, merged and rendered. A vertical exaggeration of 1.25 was applied to enhance the topography of the Warrumbungle Range. The digital model was exported in a routing-capable format and delivered to an external contractor for carving. Due to routing limitations, the data were sub-sampled to 16 m. Detailed features that required higher resolution, such as The Breadknife, were 3D printed separately and bonded to the routed model.

A surface photographic image generated from the airborne sensing (ADS80) was printed onto the routed 3D model surface. NSW Spatial Services provided the ADS80 at 50 cm resolution as Geotiffs. These tiles were merged and then clipped to the 3D model area using ERDAS IMAGINE software. The resolution of the image was limited by the printing technology to 2 m.

The 3D scale model will be displayed in the new Warrumbungle Visitor Centre. Visitors will be able to visualise the scale and grandeur of the volcanic event that helped create the rock formations in the Warrumbungle National Park we enjoy today. Scale models provide a realistic overview of the terrain for the untrained eye and will help visitors plan their trip to explore the park's features.

## **The mid-Miocene Flora preserved in the diatomite beds of the Chalk Mountain Formation, Warrumbungle Volcano Complex**

*W.B. Keith Holmes*

45 Kurrajong Street, Dorrigo, N.S.W. Australia 2453

Hon. Research Fellow, University of New England, Armidale.

The Chalk Mountain Formation occurs on a spur of the Warrumbungle Volcano Complex to the north-west of Coonabarabran, about 6km south of the village of Bugaldie. It is a deposit of diatomite, tuffs and a band of lignite underlain by basalt dated at 17.2 million years and overlain by basalt dated at 13.7 Ma. The bed of almost pure diatomite was quarried and mined from 1919 to 1968 with approximately 85,000 tonnes being transported by rail to Sydney. The Chalk Mountain Formation is well-known for its fossil fish, a fossil owl-nightjar and the presence of fossil insects and plant remains. Descriptions of fossil *Eucalyptus* fruit and leaves and a flower of *Ceratopetalum* have been published in *Proceedings of the Linnean Society of NSW*. A palynological study by Dr Helene Martin from diatomite layers and a lignite band revealed the presence of ferns, gymnosperms, especially *Araucaria*, *Podocarpus* and *Cupressus*, angiosperms dominated by *Casuarina*, Myrtaceae, grasses and lesser evidence of other still extant Australian genera. This fossil record reveals rainforest and woodland habitats in the Warrumbungle area and a warming and drying climate as the Australian Plate moved northwards during the Middle Miocene.

## **The rise and fall (creation and extinction) of Miocene central volcanoes in NW New South Wales: a link to an underlying lithospheric cavity?**

*F. Lin Sutherland*

Geoscience, Australian Museum, 1 William Street, Darlinghurst, Sydney, NSW 2010

Three impressive Miocene central volcanoes and allied lava fields form a curved chain through the NW NSW region. They are later-stage remnants of eastern Australian intraplate volcanism that dates back to 100 Ma and includes eruptions within the last 5000 years. These eruptions formed many basaltic lava fields and sporadic southward migrating central volcanoes with felsic cores that reflect northward movement of Australia over hotspots.

The north western NSW migratory chain extends south from a New England mantle plume-signature basalt field ( $23.9 - 21.3 \pm 0.3$  Ma) through the plume-generated Nandewar ( $18.9 - 18.5 \pm 0.02$  Ma), Warrumbungle ( $18.0 - 15.5 \pm 0.02$  Ma) and Canobolas ( $13.2 - 11.6 \pm 0.02$  Ma) central volcanoes. This trace potentially extends to minor alkaline activity ( $\sim 10$  Ma) at a southern tip near Oberon. This 'boomerang-like' curve of volcanism swells with increasing degrees of mantle melting to form the larger middle central volcanoes, Nandewar and Warrumbungle, then diminishes to form the smaller southern Canobolas volcano. The progressive 'boomerang' volcanic trace does not match the linear eastern Australian plate motion trend between 24 to 10 Ma, nor the trends shown by adjacent migratory volcanic chains in central western NSW, coastal NSW and the Tasman Sea submarine volcanoes. To explain this anomaly, detailed seismic tomographic studies that model lithospheric structure below the eastern continental margin were examined for any underlying structural causes. Seismic tomography reveals that cavities exist within the lithosphere-asthenosphere boundary (LAB). These holes allowed upwelling of hotter convective mantle melting and eruption of significant basalt lava fields. Noticeably, the north western NSW central volcanic 'boomerang' follows the western curved margin of such a cavity. This suggests a plume-like, lithospheric edge-driven mantle melting event formed this volcanic trace from  $\sim 29$  to  $34^\circ$  S over a 15 Ma duration, as plate motion carried the cavity across convective asthenosphere.

The ultimate genesis of the NW NSW volcanic trace extends back into SE Queensland, where the lithosphere had moved over thermal mantle upwells linked to the Tasman Sea and Coral Sea oceanic spreading floor rift margins. Such upwells produced the voluminous 26 – 23 Ma Main Range and Tweed central volcanoes which now form the border ranges and partly overlap into NSW. The thermal connection became dampened by passage of a thick lithospheric spine that exists under northern New England. Plume-related volcanism only flared up in northwest NSW when a lithospheric cavity arrived allowing thermal access.

## Field observations of cobble and boulder stream deposits from the erosion of the Warrumbungle Volcano

*Peter Thompson*<sup>1,2</sup>

<sup>1</sup> Coonabarabran Landcare Inc; <sup>2</sup> Western Heritage Group Inc

The Warrumbungle shield volcano has been eroding for 13 million years. Streams today are intermittent and carry a mostly fine sediment load, reflecting low stream energy with the current climate and good vegetation cover.

Beneath about a metre of fine sediments, most streams have a layer of cobbles, interpreted as dating from the last glacial maximum. The cold, arid climate of that time with sparse vegetation created intense run-off and high-energy flows that transported much coarser particles than today.

Other cobble layers are indurated and elevated several metres above current stream flood height (photo). The age of these deposits is estimated to cover the last million years or so, perhaps relating to earlier glacial periods with high-energy streams.



Wambelong Creek has an elevated deposit that shows an 'inverted landscape', where indurated cobbles and boulders have resisted erosion more than surrounding sandstone. Further west, a correlated cobble and boulder deposit is covered by 2 metres of finer alluvium. This appears to demonstrate a significantly greater longitudinal slope for the ancestral Wambelong Creek than the current Creek.

## Mass movements in Warrumbungle National Park, NSW

*M.J. Tulau<sup>1</sup>, S. McInnes-Clarke<sup>2</sup> and D. Morand<sup>3</sup>.*

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<sup>2</sup> NSW Office of Environment and Heritage, PO Box 1477, Gosford NSW 2250

<sup>3</sup> NSW Office of Environment and Heritage PO Box 856, Alstonville NSW 2477

Sediment delivery from forested headwaters is typically controlled by high magnitude and low frequency debris flow events triggered by post-fire runoff or mass-failure. The Warrumbungle National Park (WNP) wildfire of January 2013 burnt 56,290 ha, including 95% of the park, 72% of it at high-extreme severity. On 1 February a severe storm delivered between 60 and 90 mm of rain within 30 minutes. This event caused extraordinary flooding and soil erosion across WNP, including a number of large debris flows and other forms of mass movements, particularly in areas that experienced high rainfall erosivity.

We examined the distribution, types, stratigraphic contexts and causes of both historic and pre-historic mass movements using a 1 m LiDAR Digital Elevation Model and ADS40 digital imagery. We identified 485 separate movements >5 m wide, identifiable on the basis of a visible release head scarp. Ninety-seven per cent of these movements originated in volcanic-derived soils and within 500 m of the Pilliga Sandstone-Warrumbungles Volcanics stratigraphic boundary. Movements could be dated relatively on morphometric bases. One prehistoric movement was 1.1 km long, with an estimated volume of 2 million m<sup>3</sup>.

A risk assessment was undertaken on several mass movements and to understand the processes involved. In all cases mass failure was initiated in saturated colluvium and/or deeply weathered volcanic regolith. Several such areas were associated with known springs. LiDAR revealed much larger areas of instability immediately overlying the sandstone-volcanic boundary.

A model is proposed whereby mass movements along this boundary are the major landform evolution process shaping Warrumbungle National Park in the long-term.

## **Geotales and geotrails – collaborative geotourism initiatives and implications for the Warrumbungles region**

*N. Simone Meakin<sup>1</sup> and Angus M. Robinson<sup>2</sup>*

<sup>1</sup> Manager, Publications & Outreach, Geological Survey of New South Wales, Department of Planning & Environment

<sup>2</sup> Chair, Geotourism Standing Committee, Geological Society of Australia

Geotourism focuses on an area's geology and landscape as the basis for providing visitor engagement, learning and enjoyment. Geotrails present a way to experience a journey linked by an area's geological features. They are relatively easy to establish and represent a cost-effective means of enhancing regional development that has minimal impact on land management issues. Ideally linking sites and routes currently used by tourists, geotrails should form logical journeys between features that form part of a cohesive story. They should also incorporate biodiversity and cultural aspects (including mining and indigenous heritage) of a region, to ensure a rich visitor experience.

Collaboration between a wide range of organisations, who can provide expertise, equipment, funding and publicity, has been critical for several successful geotourism initiatives. The Geological Survey of NSW (GSNSW) has embraced outreach in recent years, benefiting greatly from relationships with the Geological Society of Australia, universities, councils, schools, museums, libraries, other government agencies, amateur geology clubs, indigenous groups, historical societies, tourism offices and local science hubs.

The most recent example of a successful collaborative project is the Port Macquarie Coastal Geotrail, which opened in May 2018. The GSNSW played an important role by developing signage, a free NSWGeoTours app and an educational brochure. The Newcastle Timewalk – a guided geological tour of the Newcastle seashore supported by a free brochure – has been a popular public event led by GSNSW during National Science Week in recent years. A supporting app for this geotrail is planned. The GSNSW also plans to develop several other geotrails in collaboration with other agencies, with an initial focus on the Warrumbungles region and the Tweed Valley. It is intended that the proposed Warrumbungle Volcanic Geotrail will link communities to the world-famous, volcanic landscapes of the Warrumbungle National Park, as well as similar natural heritage characteristics within the Mount Kaputar and Coolah Tops national parks, incorporating existing cultural heritage features.

## Biodiversity and endemism on Mount Canobolas

*Richard W. Medd<sup>1</sup> and Colin C. Bower<sup>2</sup>*

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Mount Canobolas in the Central West of NSW is a central or shield volcano, provincially known as The Mount Canobolas Volcanic Complex. It is considered to be the southernmost and youngest of the age-progressive volcanoes along the purported inland track which extends from Main Range in southeast Queensland south through the Nandewar and Warrumbungle provinces to Canobolas. Central volcanoes formed as the Australian continental plate moved northward across a hot-spot mantle plume. Mt Canobolas erupted over a period of about two million years in the mid to late Miocene epoch 13 to 11 million years ago and the province covers ~825 km<sup>2</sup> and radiates some 20 km from the summit of 1,397 m altitude. Trachyte kindred rocks predominate in the central complex, interlaced with a variety of volcanoclastics, with hawaiite on the outer edges. The central elevated area consists of cones, plugs, domes and dykes and throughout the eruptive duration subsidence juxtaposed many rocks of different ages. The mountain is a prominent 'landlocked island' protruding ~500 m above the surrounding now extensively cleared and highly modified agrarian plateau of the western Central Tablelands.

Mt Canobolas hosts a small remnant of subalpine vegetation. The Mt Canobolas State Conservation Area occupies most of the remnant and supports a high concentration of unique and threatened biodiversity. The known biota of the SCA exceeds 800 species and includes 12 threatened species together with at least nine endemic taxa comprising four plants, two of which are undescribed, three lichens, a velvet worm and an unnamed planarian. Further plant species occurring in the SCA are under investigation and considered likely to be new endemic species. One of three endangered ecological communities on the mountain, the Mt Canobolas *Xanthoparmelia* Lichen Community, is endemic to the Mt Canobolas Volcanic Complex. Listed threatened species comprise two plants, four mammals and six bird species. Because the SCA is of limited size and many of the endemic species have a restricted extent of occurrence they are highly vulnerable to anthropogenic environmental degradation.

Whilst there is some indication the endemic lithophytic lichens, the threatened Mt Canobolas Candlebark and the heath communities are substrate specific, there is less evidence of a geological association among other flora and fauna. We postulate that the presence of multiple endemic species in diverse groups of biota reflects the geographic isolation of Mt Canobolas as an inselberg of high altitude habitats that has provided an environment for species evolution by vicariance. Alternatively, Mt Canobolas has acted as a refugium for formerly widespread species that have become extinct elsewhere. The velvet worm and the planarian may fit into this category. In either event, the presence of these endemic species on the mountain is scientifically important and provides fascinating opportunities for research.

## Marooned on an extinct volcano: the conservation status of four narrow-range endemic gastropods at Mount Kaputar, northern inland New South Wales

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Volcanic activity in northern inland New South Wales 40-15 million years ago was followed by general continental-scale drying and coastward contraction of mesic ecosystems 15-2 million years ago. These processes in combination resulted in the creation of high-elevation climatic refuges such as Coolah Tops, Mount Kaputar and the Warrumbungle Range as western outposts of the mesic eastern highlands on the dry western slopes. These areas are important hotspots of land snail species diversity and endemism. A high-elevation and dry rainforest land snail community at Mount Kaputar, recognised as being of outstanding conservation significance, was listed as an endangered ecological community under NSW legislation in 2013. One species from this community, the Kaputar Pink Slug *Triboniophorus* sp. nov. “Kaputar”, is currently listed as endangered on the *IUCN Red List*. This paper provides an updated assessment of the conservation status of this species and assessment of another three endemic Mount Kaputar species (Bronze Rippled Pinwheel Snail *Cralopa kaputarensis*, Kaputar Carnivorous Snail *Vitellidelos kaputarensis* and Kaputar Keeled Snail *Thersites* sp. nov. “Kaputar”), concluding that all four species qualify for listing as endangered on the *IUCN Red List*.



Kaputar Pink Slug *Triboniophorus* sp. nov.



Kaputar Carnivorous Snail *Vitellidelos kaputarensis*

## **Fire history inferred from charcoal accumulation at Dunphy Lake, Warrumbungle Mountains**

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The long-term history of fire and environmental conditions in the Warrumbungle Mountains in eastern Australia are relatively unknown. Here we synthesise recent research that reconstructed fire history and catchment conditions using a macro-charcoal record from sediment cores in Dunphy Lake, Warrumbungle National Park (WNP). Dunphy Lake is a small, ephemeral wetland and the only lake basin in the highlands of WNP (~700 m.a.s.l.). We used sedimentology, geochemistry and macro-charcoal to characterise phases of sediment deposition and charcoal accumulation, as well as radiometric dating to constrain the age of depositional units. Presently, Dunphy Lake has infrequent wet phases related to local rainfall and runoff in its catchment. Pollen found in the upper 80 cm of the sediment profile indicated the presence of a Myrtaceae-dominated vegetation community (including Eucalypts) adapted to periodic wet and dry conditions for at least the last 450 years. The macro-charcoal record spanning the last ~2,200 years shows that the main periods of charcoal accumulation – interpreted as enhanced fire activity in the catchment – occurred between 450 and 200 years ago. High macro-charcoal concentrations tend to coincide with coarse sediment (sand) layers, suggesting that fires that generated large quantities of charcoal occurred at similar times to episodes of significant runoff and sediment flux from the catchment. This was certainly the case in 2013, when a rainstorm following the Wambelong fire caused significant flash flooding and severe erosion of waterways and hillslopes, with subsequent deposition of sediment and charcoal in the landscape. Our results suggest that over the long-term, periods of enhanced fire activity in WNP may coincide with an intensification of El Niño Southern Oscillation (ENSO). Further research is required to ascertain the nature of the relationships between past fire events, post-fire sediment aggradation and other environmental conditions, which are part of a complex biophysical response to environmental change, and possibly anthropogenic impacts, in the region.

## **Aquatic animal community at Dunphy Lake after the Wambelong fire indicates the importance of ephemeral pools and lake sediment for recovery process**

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Fires are a natural phenomenon in many terrestrial ecosystems. The ecological effects of fires can be complex, depending on the attributes of fires, landscapes, as well as local climate and weather. A large fire occurred in January 2013 within and adjacent to the Warrumbungle National Park, affecting a large area of the park including Dunphy Lake (the Wambelong fire). We assessed the aquatic animal community of Dunphy Lake in March and September 2014. The lake was largely dry and covered with grasses, with only small isolated pools of water in the lake. We found 53 invertebrate taxa including the larvae of the dragonfly *Austrogynacantha heterogena* and one vertebrate species (larvae of the frog *Litoria rubella*) in the pool-water samples. Artificial inundation of the lake sediment samples under laboratory conditions led to the emergence of 31 taxa, totalling 62 taxa in the lake overall. Our results indicate the importance of ephemeral pools and lake sediment as refugia against drought and fires for aquatic organisms. The conservation of these seemingly marginal habitats across the park would help the recovery process of aquatic organisms and thus maintain the aquatic species diversity and function after major environmental disturbance.

## Fire and research in Warrumbungle National Park: an overview

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In January 2013 the 'Wambelong' fire burnt 56,000 hectares, including almost 90% of Warrumbungle National Park, 36% of it at extreme severity (crown consumption), and a further 32% at high severity (understorey consumed and canopy scorched). The fire was unprecedented in the history of the park in its size and ferocity. Under extreme conditions it developed into a firestorm, burning more than  $\frac{3}{4}$  of the final area in a single day. The magnitude of the fire raised substantial concerns about the impact on the animals, plants and landscapes of the park, triggering funding of a three-year research program led by the NSW Office of Environment and Heritage. This program included components on fire severity mapping and analysis, soils and water, cultural heritage, fauna, vegetation, individual plant fire responses and citizen science, and has triggered several other related research projects. In this talk an overview of the Wambelong fire will be given, including where and how it burnt, and the fire regimes of the park and others in the region discussed. The three-year research program will be introduced and some of the key findings presented.

Post-fire vegetation recovery – White Gum Lookout Track



(left) July 2013 and (right) August 2014 (same location), both photos by Liz Tasker

## Fire impacts on vegetation in Warrumbungle National Park

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Fire is a disturbance that disrupts plant and animal communities and alters ecological processes. The impact of such disturbances depends on the frequency, extent and severity of fires. In the past sixty years, fires have been both infrequent and of low severity in the Warrumbungle Range until the Wambelong fire in January 2013. This fire caused significant change to vegetation in Warrumbungle National Park. The fire was of mixed severity, with the resulting impacts showing considerable spatial variability. Where fire was severe (more than one third of the reserve), all cypress pines (*Callitris endlicheri* and *C. glaucophylla*) were killed and entire eucalypt canopies were consumed. Most resprouting in eucalypts was basal (i.e., trees were topkilled), hence canopy cover and height was greatly reduced in these areas. Where fire severity was lower, many eucalypts resprouted epicormically and occasional cypress pines escaped scorching and hence mortality. Nevertheless, with cypress pines recruiting from small canopy seed banks (*C. endlicheri*) or from long distance dispersal (*C. glaucophylla*), we predict these structural changes will persist for the next 20-50 years. A second result of high severity fire was the stimulation of a substantial soil seed bank of acacias. Significant post-fire rainfall probably further enhanced germination and establishment of these acacias, leading to the creation of thickets in patches throughout the reserve. These thickets vary in species composition, but many remain dense and tall five years post-fire. However, density-dependent mortality and life history characteristics suggest that this is a short to medium term phenomenon, and that without additional disturbance, thickets will return to the more open woodland that typified these areas prior to the fire. The severity and extent of the fire also led to concern that some plant species would become locally extinct. We re-surveyed 57 floristic plots after the fire, established 13 new plots (to fill sampling gaps) and conducted *ad hoc* surveys for significant species. We conclude that although the fire modified the relative abundance of some species – promoting many species with soil seed banks at the expense of resprouters, very few species have reduced their area of occupancy. A second high severity fire within the next decade would likely cause population declines in at least some species, retard structural recovery and further reduce cypress pine abundance.

## Koalas and the 2013 fire in Warrumbungle National Park

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The extensive and intense bushfire of 2013 triggered concern about the fate of the koala (*Phascolarctos cinereus*) population in Warrumbungle National Park. Two weeks after the fire, one koala was seen along Wambelong Creek. Another was seen at a low-intensity burn-site at Mount Exmouth. Searches for Koalas in the Park by four local National Parks and Wildlife Service staff over six months following the fire did not result in any other sightings. Also, after the fire, about 500 park visitors were asked if they had seen a Koala, but none were seen. Two Koalas were rescued from just outside the boundary of the Park 10 days after the fire and were taken into care. While one died, the other was released into the Park following a long period of recovery (17 months). It was subsequently radio-tracked for 12 weeks, demonstrating that the post-fire stands of trees were sufficient for its survival.

To predict whether a Koala population will return to the Park, as well as assess the degree to which the fire may have caused the low numbers, we reviewed the historical record of koalas in the Park, as well as surveyed their current, regional distribution. Early in the history of the park, which was dedicated in 1953, Koalas were once thought to be locally extinct and, in the 1960s, the Park Trust decided to recolonize the park with Koalas from Victoria, even planting a stand of manna gum (*Eucalyptus viminalis*) as feed trees, which are not naturally found in the Park. However, the translocation did not take place because free-ranging Koalas were discovered in the Park in the late 1960s, and in 1969 the ranger dismantled a koala enclosure because there were large populations of koalas. Sue Brookhouse, one of the park visitor guides, began taking 'Koala walks' in the mid-1990s and regularly saw Koalas for some years. However, by the early 2000s and up until the fire, their numbers had declined markedly. Brookhouse (pers. comm.) estimated a decline of approximately 80%, and attributed this to drought – the millennium drought. Before the drought, she estimated approximately 49 out of 50 visitors saw a Koala: by the end of the drought only 1 in 50 had seen a Koala. Our research in the nearby Pilliga forests, as well as our regional surveys, indicates that these fluctuations were not confined to the Park: a major contemporaneous decline occurred regionally. The fire occurred when the koala population was already at a low point. Recovery of the Park's population is likely to be limited by the continued low regional populations. These findings show that the Koala population of the Park does not exist in isolation, and that a regional approach to Koala ecology and management planning is warranted.

## Rock wallabies in the Warrumbungles pre 2013: impacts of predation risk, competitors and fire on diet, foraging and habitat quality

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The brush-tailed rock wallaby, *Petrogale penicillata*, is a medium-sized mammalian herbivore that is specialised for living in rocky habitats. It is vulnerable to predation from terrestrial predators, particularly foxes, and from aerial predators such as the wedge-tailed eagle; and is in potential dietary competition with other herbivores including other native macropods. From 2006-2009, we studied the diet, foraging locations and habitat of rock wallabies in the Warrumbungles. Here, we summarise this research. Rock wallabies consumed a mixed diet of forbs, grasses and browse with small amounts of ferns, sedges and orchids/lilies. Importantly, this dietary mix was maintained by a combination of selection and avoidance of plant functional groups depending on their availability. Small scale burning of vegetation altered plant availability over time, and this effect was complicated by grazing from sympatric macropods. Biomass of forbs consumed by rock wallabies increased dramatically from 9 - 18 months post-fire, while biomass of grass was reduced but likely of higher quality during the same period. Browse biomass increased longer term, from 18 – 29 months post-fire. Grazing by sympatric macropods reduced availability of grasses and forbs for rock wallabies, particularly in burnt plots. In the absence of terrestrial predators, rock wallabies foraged up to 150 m from refuge and foraged in habitat with high food availability. But with predation risk, foraging was curtailed to areas within 50 m from refuge where food availability was low.

In summary, our results show that rock wallabies seek a diverse diet, diet availability can be enhanced by small scale burning patchy in space and time, but competition with sympatric macropods and, presumably, other herbivores can reduce this benefit. Our results also show that rock wallaby foraging is strongly constrained by predation risk, drastically restricting availability of suitable habitat. Without adequate predator control, the capacity for rock wallabies to maintain populations connected throughout landscapes lacking rocky refuge is likely to be low.

## **The Wambelong bushfire: Timely rapid assessment of soil erosion and flooding impacts**

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Several Australian state governments have set up multidisciplinary emergency natural resource response teams to visit fire grounds after large and intense wildfires. They rapidly assess and prioritise risks with costed ameliorative actions. Assessments include: soil erosion and flooding as well as associated impacts on water quality, flooding, public safety and protection of infrastructure, heritage, flora and fauna.

The NSW/ACT Burned Area Assessment Team (BAAT) deployed within days of the mid-January 2013 Wambelong fire which burned some 56,000 hectares near Coonabarabran, including over 95% of the Warrumbungles National Park, with 72% at high to extreme fire extremity. Modelled risk assessments of soil erosion, flooding, mass movement and water quality increased in relevance when a sudden and intense storm event on the afternoon on 1 February 2013 caused severe erosion and abrupt flooding.

A feature of the Wambelong BAAT deployment was the use of Multi-criteria Analysis Shell for Spatial Decision Support (MCAS-S) spatial modelling software, following guidelines in a pre-prepared manual. MCAS-S was used to map the impact of sheet erosion hazard, changes in runoff and flooding and increased potential for mass movement.

Erosion modelling used pre-prepared RUSLE inputs including: MODIS 2000-2012 ground cover time series; SRTM CSIRO DEM for slope and slope length; K factor soil erodibility based on soil type and surface rockiness from existing soil mapping; and SILO derived daily 1950-2010 rainfall erosivity.

Post fire ground cover was assessed using field observations and satellite burn severity mapping.

Flooding risk assessments were based on expected changes in run on and run-off, based on changes in interception from vegetation and leaf litter as well as expected changes in soil hydrophobicity.

Mass movement hazard was based on fire severity, existing soil mapping and field assessment.

Modelled output maps were dependent on, and limited to, the availability and quality of pre-prepared datasets and timely, field verification of classified satellite images. The modelled output maps were used by the BAAT to help prioritise a series of emergency ameliorative actions. Questions concerning the recovery of erosion resilience and the validity of the risk assessment impacts of the fire have given rise to further studies.

*Keywords:* Wildfire, bushfire, risk assessment, soil erosion, flood assessment, MCAS-S, RUSLE, Rapid Decision Support

## Soil organic carbon and related impacts of the Warrumbungles wildfire

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We examined the effects of the fire on soil organic carbon (SOC), nitrogen (N) and soil microbial activity, to better understand the likely long-term post-burn recovery trajectory.

We sampled soils at 64 sites (5 sub-sites for each, and 4 depths (0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm)) across the main geological/soil types (trachytes and sandstones) and four fire severity classes (0= unburnt, 1= slightly burnt, 2= moderately burnt, 3= extremely burnt). Soils were tested for LECO Total Organic Carbon (TOC), mid infrared SOC fraction estimations, and N, across the range of fire severities. Soil microbial activity was measured by MicroResp at a sub-set of 20 sites (0-5 cm). Site data was extrapolated by 1m Light Detection and Ranging Digital Elevation Model and the fire severity map.

It was found that almost half (48%) of the TOC in unburnt control sites in WNP is located in the top 5 cm, and almost three-quarters (74%) within the top 10 cm. There were significant differences in TOC, SOC fractions, N and soil microbial activity between the different rock/soil types and the fire severity classes for the 0-5 cm depth range. TOC declined with increasing fire severity – topsoil TOC in low severity sites was 14% lower than unburnt sites, and severely burnt sites were 54% lower. These results were also reflected in losses in N and reductions in microbial activity.

The highest TOC values were from unburnt volcanic topsoils (0-5 cm). Sandier and especially sandstone-derived soils had less SOC irrespective of the fire severity class, probably due to the sandier nature of those materials, lower water-holding capacity and capacity for the accumulation of SOC. The lowest TOC values were from severely burnt sandstone ridges, where most of the remaining SOC occurs as resistant OC (including charcoal).

The amount of SOC lost over the fire ground to 10 cm was 2.47 Mt (43 t/ha), with ~74,000 t of N lost from soil to the same depth.

The average TOC (0-5 cm) of sites not burnt in 2013 was 7.45% (trachytes 9.60%, sandstones 4.36%). A well-managed fire policy in the park has the potential to provide an equivalent sequestration into the future. These figures are much higher than averages in the central west of NSW, thus underlining the importance of forested ecosystems including national parks in carbon soil sequestration, and of WNP with its high proportion of trachytic and clay soils in particular.

## Near real-time monitoring of post-fire erosion after storm events: a case study in Warrumbungle National Park, Australia

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Wildfires in national parks can lead to severe damage to property and infrastructure, and adverse impacts on the environment. This is especially pronounced if wildfires are followed by intense storms, such as the fire in Warrumbungle National Park (WNP) in New South Wales, Australia, in early 2013. The aims of this study were to develop and validate a methodology to predict erosion risk at near real-time after storm events, and to provide timely information for monitoring of the extent, magnitude and impact of hillslope erosion to assist park management.

We integrated weather radar-based estimates of rainfall erosivity with the revised universal soil loss equation (RUSLE) and remote sensing to predict soil loss from individual storm events after the fire. Other RUSLE factors were estimated from high resolution digital elevation models (LS factor), satellite data (C factor) and recent digital soil maps (K factor). The accuracy was assessed against field measurements at twelve soil plots across the Park and regular field survey during the 5-year period after the fire (2013–17). Automated scripts in a geographical information system have been developed to process large quantity spatial data and produce time-series erosion risk maps which show spatial and temporal changes in hillslope erosion and groundcover across the Park at near real time.

The groundcover in WNP is generally increasing since the fire in early February 2013 and returned to near pre-burn level within 1 year with rapid increase in the first three months after the fire. The modelled average annual rate of hillslope erosion since May 2014 is 1.35 Mg ha<sup>-1</sup> year<sup>-1</sup>, and appears to be declining. On average, a storm event causes soil loss of 4.86 Mg ha<sup>-1</sup> year<sup>-1</sup> based on the model, but there is strong seasonal and spatial variation.

*Keywords:* geographic information system, rainfall erosivity, remote sensing, soil loss, weather radar.

## Did the 2013 fire eliminate hollow trees from Warrumbungle National Park?

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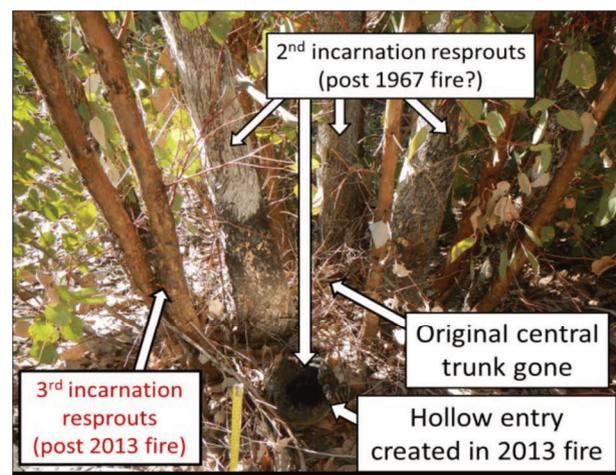
The severity of the 2013 bushfire that burnt >90% of Warrumbungle National Park, led to fear that most hollow-bearing trees had been destroyed, with severe impacts on hollow – dependent fauna. Close inspection is showing low abundance of hollow-bearing trees both before and after the fire. It seems the 2013 fires consumed dead timber and live trees, some hollow. However, this fire also generated new fallen and standing dead timber, and scars on trees which may accelerate hollow development. Overall there seems to be a slight net loss of hollows since the 2013 fire.

The current paucity of hollows cannot be solely due to the 2013 fire. On-ground investigations and historical records reveal a long history of human disturbance. Air photos show that the gentle slopes of the park were heavily cleared for grazing and cropping by the 1950s. Regeneration and tree planting since the dedication of the park have resulted in many young trees growing on these slopes, but few with hollows.

Through the park the oldest dead timber provides physical evidence of past events. Many trees show evidence of where past stems have died, probably in the 1967 fire, with subsequent basal resprouts killed by the 2013 fire, and a new generation of resprouts post 2013 (see figure). Even earlier, at least three periods of cutting and ringbarking in the park have affected current abundance of hollow-bearing trees: one using chainsaws to fell or ringbark trees; one using axes to ringbark at about waist high; and older, heavily weathered ringbarking marks often below knee height.

Additionally, there are remnants of sleeper cutting of ironbarks in the form of collections of fletches left over once sleepers were hewn from felled trees. In some cases the current live stems are the fourth incarnation of trees that have repeatedly had their above ground parts killed by people or fires. Conversely, some large trees seem untouched, but the reason why these were left is mostly unknown.

Tree hollows are not an abundant resource in Warrumbungle National Park, and this reflects a long history of diverse human disturbance coupled with periodic bushfires.



## **Birds, bats, reptiles and burning in Warrumbungle National Park**

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The volcanic landscape of Warrumbungle National Park supports a diverse fauna. At this location many Bassian species extend into western NSW (e.g., Eastern Horseshoe Bats), connection to the Great Dividing Range sees migrant birds visit from the north in summer (e.g., Olive-backed Orioles, Channel-bill Cuckoos), and an abrupt junction with the western plains means that there are many Eyrean species (e.g., Mallee Ringnecks, Little Pied Bats).

We assessed the status of bird, bat, and reptile fauna in the park following the 2013 bushfire. We surveyed areas of low (intact tree canopies), moderate (epicormic resprouting of eucalypts), and high (basal resprouting of eucalypts) fire severity.

Bird surveys in the 2014/15 and 2015/16 summers recorded 132 species. In 2014/15 surveys, detection rates were 25% and 50% lower in moderate and high severity areas respectively, compared to low severity areas. In the 2015/16 surveys, detection rates in all severity categories increased slightly with some differences among vegetation communities. Even in high severity areas threatened birds such as Diamond Firetails, Speckled Warblers and Turquoise Parrots were present, including parrots nesting in dead burnt eucalypt stems. Within 3 years of the fire, there was a high diversity of bird species in the park.

In 2015 ultrasonic recordings of bat activity identified 14 taxa, averaging 91 calls per night per site. Activity tended to decrease with increasing fire severity, but vegetation type had a strong influence. Activity was high in ironbark woodland, particularly in low severity areas. Trapping confirmed presence of nine bat species. Overall, bat activity was highest below 600m elevation, within 200m of creek lines and in lower fire severity areas.

The complex terrain of the park with numerous crevices and cracks is important habitat for bats. Three species identified in our surveys are obligate cave dwellers, while others opportunistically use rock shelters for roosting. The extensive woodlands adjacent to the rock features provide foraging and make the park ideal habitat for these bats.

In 2016/17 diurnal and nocturnal walking surveys recorded 28 reptile species in the park, and there were incidental observations of a further 8 species. Composition of the reptile fauna differed between vegetation communities, but 3-years after the 2013 fire we detected only slight variation with fire severity.

After the 2013 bushfire, Warrumbungle National Park supports a high diversity of bird, bat and reptile species across the park. This suggests that management of these species within the park can focus on general habitat restoration through vegetation restoration and microhabitat enhancement, rather than having to deal with critically low numbers of individual species facing extinction from the park.

## Multiple ecological drivers behind recruitment variability of streaked wattle (*Acacia lineata* A.Cunn. ex. G.Don.) after fires of differing severity

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A strong positive relationship between shrub recruitment rates and increasing fire severity often exists in Australian forest and shrubland communities. Nevertheless, despite this relationship being a key driver of woody regeneration trajectories and successional states after fire, the ecological mechanisms behind the effect are often poorly understood. We examined proximate drivers behind enhanced recruitment after high-compared to low-severity fire in streaked wattle (*Acacia lineata* A.Cunn. ex. G.Don.), an obligate-seeding shrub of the semi-arid Pilliga forest. Specifically, we aimed to test whether enhanced recruitment after high-severity burning relates to: (1) heat-stimulation of the soil-borne seedbank; (2) destruction of allelopathic compounds in soil that reduce germination rates and/or hinder seedling survival; and/or (3) incineration of dense litter beds that impede seedling emergence. We found strong support for hypothesis (1), as seeds had physical dormancy and germination of the shallowly buried seedbank was strongly enhanced by heat-stimulation. Hypothesis (2) is currently being assessed via a germination trial to examine whether seed germination and radicle growth rates are constrained by the application of aqueous *A. lineata* phyllode litter extract. Hypothesis (3) is also currently being tested, via a glasshouse trial to examine emergence rates of seedlings under contrasting litter density treatments. The applicability of these 3 hypotheses to *A. lineata* recruitment after fires of differing severity will be discussed at the 2018 Linnean Society of NSW Natural History Symposium.

## Climate change places a fig-frugivore mutualism under threat in the Warrumbungles to Mt Kaputar region

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*Ficus rubiginosa* is a keystone species for a large and diverse array of vertebrate frugivores in eastern Australia. Fig trees, in turn, require these frugivores for seed dispersal. The aims of this study were to investigate whether population fragmentation and/or climatic variation impacted avian-frugivore visitation to *Ficus rubiginosa* at the western, drier margin of the species' range.

Eighty-two bird species visited *F. rubiginosa* trees in this three-year study. Twenty-eight species were frugivores or frugivores and insectivores. Conditional inference tree analysis, using fourteen tested variables, identified the number of ripe syconia (fruit) in a tree as having the greatest influence on frugivore visitation ( $p < 0.05$ ). The number of ripe-and-ripening fruit in a tree had a significant positive influence on total time spent by frugivores in trees ( $\chi^2(1) = 178.79, p < 0.0001$ ). Up to seven percent of ripe fruit were comprised of unpollinated syconia that had developed and grown in concert with pollinated syconia to present larger crops of ripe fruit on trees. Crop size was influenced by rainfall, with the number of fruit set on a tree being a function of the average monthly rainfall during fruit development plus the rainfall in the month prior to syconia ripening ( $F = 15.64, p < 0.0001$ ). Fig population size influenced the assemblage of frugivore species recorded visiting trees but did not have an effect on the number of frugivores visiting trees or the rate of frugivore visitation. Predicted lower rainfall and increased incidence of drought could threaten the mutualism between *F. rubiginosa* and frugivores, and the viability of local populations of this keystone fig. Flow-on effects on fig-frugivore networks and associated communities throughout eastern Australia are likely to be negative. Results of limited investigations into the fire response of *F. rubiginosa* showed negative impacts of fire on aspects of female fitness. Understanding the potential compounding effects of fire on *F. rubiginosa* and its networks is an important area of further investigation.

## Discovery of narrowly endemic plants of the volcanics of northern New South Wales and southern Queensland is critical to conservation and management

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Currently there is an exciting focus on conservation of biodiversity in New South Wales, in particular through the Office of Environment and Heritage's Saving Our Species (SOS) program. The program is focused on State-listed Threatened species, but, predictably, some of the rarest and most threatened species are yet to be described and listed. We report on progress and plans for taxonomic studies on a diverse set of plant groups that include narrow endemics on the volcanics of northern New South Wales and southern Queensland. Such foundational taxonomic knowledge underpins management of biodiversity. For best value and outcomes, conservation efforts need to embrace thorough taxonomic study as an essential tool for assessment of conservation status and developing management strategies. More broadly, an important gap in knowledge is the lack of a regional assessment of the historical biogeography of northern New South Wales and southern Queensland (the MacPherson–Macleay Overlap) based on molecular phylogeny. Such a study would enhance our understanding of the species diversity of the region and allow generalisation of diversification processes (e.g., vicariance, ecological shift, hybridisation).



**Top row:** *Prostanthera lanceolata*, *Xerochrysum* sp. Mt Merino, *Banksia* sp. Mt Maroon, *Wahlenbergia telfordii*. **Bottom row:** *Schoenus rupicola*, *Melichrus* sp. Mt Maroon, *Bulbine* sp. Mt Kaputar, *Phebalium speciosum* (Images: J.J. Bruhl)



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