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Fungi collected at Waratah in May 2016. Drawing: Jo Lawrence.

SPECIAL ISSUE – DROUGHTS, FIRES AND 'STORMAGEDDONS' THE ECOLOGICAL IMPACTS OF EXTREME WEATHER

Bushfires in Tasmania – are the January-February 2016 highland fires a sign of things to come? *Nick Fitzgerald*

The past summer was an unusual one: it was the hottest summer on record in Tasmania and in the western half of the state rainfall was slightly below average following a record dry spring, driven in part by a strong El Niño event. Major lightning storms in January ignited scores of bushfires; some continued to burn for weeks. Also remarkable was the relatively few days of high fire danger. High fire danger days, like dry lightning, are predicted to become much more frequent in the coming decades.

There has been an increase in the number of lightning-ignited fires in Tasmania since 1980. Tens of thousands of hectares per year were burned by such fires in three of the past ten fire seasons. It seems that changed weather patterns are making 'dry lightning'—where lightning is not accompanied or followed by heavy rain—much more common in Tasmania.

Of the approximately 70 lightning fires which ignited in January 2016, around 20 continued to burn well into February in the west of the state, with insufficient rainfall to extinguish them. A bushfire which began in the Fisher River valley on the 13th January raced up the Devils Gullet, burning rainforest in the bottom of the gorge and sparse eucalypt forest on near-vertical rock faces, before reaching the flatter alpine country of the Central Plateau. This 'Lake Mackenzie Fire' burned around 26,000 hectares (around 2.5 times the size of Maria Island or Robbins Island). Another fire in the Mersey Valley, near Lake Bill, threatened the Walls of Jerusalem National Park, but fortunately the weather conditions did not propel this fire into the highland ecosystems.

While fire is a key part of the ecology of the Tasmanian Wilderness World Heritage Area (TWWHA) it can be very destructive in some

Burnt vegetation near Devils Gullet. Photo: Rod & Martha McQueen.

Burnt ridge near Devil's Gullet. Photo: Rod & Martha McQueen.

ecosystems. When fire-sensitive vegetation is replaced by more fire-tolerant and flammable vegetation the shift is usually permanent. After a month with less than 50 mm of rainfall, even rainforest can burn. Under such dry conditions, the normally stable boundaries between rainforest and other vegetation, such as scrub and moorland, will not stop the advance of a bushfire.

Tasmania is a global hotspot of conifer diversity. Eight out of our ten conifer species are ancient Gondwanan species, confined to cool moist habitats. They are typically very slow-growing, long-lived and have poor seed dispersal. They lack the various adaptations to fire found throughout the majority of Australia's flora. In addition to the conifers, Tasmania has an unsurpassed flora of ancient relictual (palaeo-endemic) plant species which require moist, fire-free habitats. The scientific and conservation significance of these species, and the communities they comprise, are important world heritage values of Tasmania's wilderness. Having remained largely unchanged since they first evolved on a humid Earth, these plants tend to be highly fire sensitive.

Some of the larger pencil pine (*Athrotaxis cupressoides*) trees killed by the recent fires would be close to 1000 years old. Long-term research sites at Mt Read and Mt Field investigating recovery after fires in alpine vegetation have shown virtually no recruitment of conifers or deciduous beech (*Nothofagus gunnii*), even where a local seed source remains. Cushion plants appear to be more resilient but are slow to recover. Apart from the local extinction of poorly-dispersed species with poor regeneration success (multi-decadal lack of pencil pine recruitment on the Central Plateau, for example, may be caused by marsupial browsing), the other major potential impact of highland fires is loss of organic soils by combustion and/or erosion.The age of these organic peat soils could date back to the beginning of the Holocene. Natural processes to reverse these almost instantaneous changes would require thousands of years.

Tasmania's Central Plateau is the stronghold of pencil pines and has seen frequent, localized, low severity fires since before the British occupied the country. Fires lit by graziers have burnt much of the Plateau (particularly in 1960-61 which was the driest spring-summer in the 80 years prior to 2015-16), resulting in the loss of around one-third of the extent and 10% of the population of pencil pine. King Billy pine (*Athrotaxis selaginoides*) forest on the West Coast Range and elsewhere was similarly impacted by anthropogenic fires from the 1880s into the early 1900s.

In the end, around 15,000 hectares—less than 2%—of the TWWHA was burnt in the 2016 summer and only a small proportion of this burnt area was fire sensitive vegetation. Probably less than 35 hectares of pencil pine was destroyed. The danger is that incremental losses like these will compound over the coming decades or, worse, conditions like the past summer coincide with severe fire weather with catastrophic outcomes. Active interventions, such as replanting or ex situ conservation, may need to be employed. DPIPWE is currently assessing the damage to the alpine ecosystems near Lake Mackenzie to determine management actions for this site.

The Lake Mackenzie fire burned the headwaters of part of the Mole Creek karst catchment. Where peat soils (organic soils) have burned, the land surface cannot act like a sponge as it once did. Previously, this sponge acted as a buffer to release water gradually. Now, the effects of rainfall events are seen quickly in the caves below the Western Tiers. These "flashier" hydrological phenomena could mean poor karst conservation outcomes: increasing effects of climate change, longer dry spells and more severe floods stress the karst ecosystems and the very substrates cave animals live upon.

Extensive fires in the Tarkine region burned mostly scrub and moorland with some wet eucalypt forest and rainforest. The 'Maxwell River Fire' in remote southwest Tasmania burned mostly buttongrass moorland and scrub. The Tasmanian Parks & Wildlife Service monitored this fire and the weather conditions in readiness to act if fire-sensitive vegetation became at risk, as happened in 2013 when a lightning fire burned 45,000 hectares near the Giblin River in southwest Tasmania, burning riparian Huon pine forest and reaching the edge of the alpine zone in the Western Arthur Range.

The Parks and Wildlife Service utilises a

Burnt trees and cushion plants near Lake MacKenzie. Photos: Rod & Martha McQueen.

Bushfire Risk Assessment Model and expert advice to monitor and predict threats to natural values, in line with their management goal: "No loss of fire-sensitive vegetation or other high conservation values in the TWWHA". However, there may be limitations to achieving the goal on the ground, due to severe conditions, remote locations and limited fire fighting resources.

It is difficult to ascribe climate change as a direct cause for any single event. It may seem strange to consider lightning fires as anthropogenic, but that is the logical conclusion from the facts of climate change. Large bushfires were very infrequent prior to European invasion and subsequently increased due to intentional and indiscriminate burning of the bush and changed land management. In the modern era, with restrictions on use of fire in the bush, improved understanding of bushfire science, better fire suppression capability and fire surveillance technology (including satellite images), we might expect to see less destruction caused by bushfires. However, these advances may not be enough to compensate for the increases wildfire frequency and severity we are beginning to see in this changing climate.

About the author

Nick Fitzgerald is a Geography and Spatial Sciences postgraduate student at the University of Tasmania in Hobart. His research interests include plant ecology, ecosystem restoration, vegetation dynamics and climate change impacts. His main study site is Macquarie Island, a 128 km² speck of land in the Southern Ocean.

Other articles by Nick can be found on his blog:

farsouthecology.wordpress.com

All articles in this issue are on the CNFN website.

Resprouting treefern near Lake MacKenzie. Photo: Rod & Martha McQueen.

Impact of the 2016 fires on the Mole Creek karst

Deb Hunter

Introduction

This article outlines the possible and probable impacts of the fires on the Central Plateau in 2016 on the Mole Creek karst's natural values and the karst resources used by the human community.

The Mole Creek karst is one of eastern Australia's largest and most densely cavernous karsts. It measures approximately 26 x 10 km and extends from the midslopes of the Great Western Tiers across the Mole Creek valley to the foot of the Gog Range. Its main catchment includes the higher slope of the Tiers and the northern margin of the Central Plateau which was burnt in the Lake Mackenzie/Mersey fire.

In 2013 the importance of the karst was recognised when the Tasmanian Wilderness World Heritage Area was extended from the edge of the Central Plateau to include much of the western escarpment of the Tiers and the Mole Creek karst and its catchment.

The Mole Creek valley is an important farming area, and the caves are important for tourism and speleology. The caves of the Mole Creek karst are recognised for their high degree of endemism in an obligate troglophile faunal assemblage. The karst fauna are vulnerable species and research is incomplete.

Streams in the Mole Creek landscape—tributaries of the Mersey River—flow underground for most of their courses for most of the year and surface water is scarce. The water-saturated (phreatic) zone of the karst is

Pseudokarst field formed in blocks of dolerite slumped from the scarp. The sub-alpine vegetation of this phenomenon ignited late on 19th January, likely by cinders carried on atmospheric rotors that mined the vegetation closer to the peat fire behind the camera's viewpoint. Patchy burns can also be seen on the scarp top right. Photo: Deb Hunter.

(Left) The dry epiphreatic chamber in Baldocks cave (Right) Rapid fluctuation in water levels (epiphreas) observed on 30th January following the 2016 escarpment fires. Photos: Deb Hunter.

important for water resources in a landscape with poor availability of surface water. The Mole Creek karst is a *fluviokarst*, where the water that flows through the karst systems arises not only from precipitation, but more importantly, it is filtered through rocks abutting the limestone at higher elevation.

Two important aquifers that release water to the karst drainage systems of Mole Creek have for a long time buffered inputs to the systems. The most substantial of these aquifers consists of a reservoir held in thick slope sediments eroded from higher elevations slopes on the Tiers. This perched aquifer overlies the forested karst contact (the geological boundary of the limestone with adjoining sedimentary rocks); it releases water gradually into the karst drainage systems. However, the majority of the obscured karst contact is now planted out to timber plantations of *Eucalyptus nitens*; plantations that are known for substantial interception of aquifer recharge in southeast Australia by virtue of high water demand in rapid growth phase. The second aquifer is comprised of streams that rise on the Central Plateau and upper escarpment of the Tiers that directly input the karst drainage systems. Most of these streams have been maintained as small but permanent streams, due to the sponge-like release of moisture throughout the year by the peat soils of the northern Central Plateau.

The loss of the peat based soils of the northern margin of the Central Plateau in the fires is likely to compromise their buffering effect on stream flows. Observations have already shown that broadacre plantations over the midslope perched aquifer have recently changed the karst hydrology. The aquifers enabled gradual release along the rivers over the seasons and release between potential meteoric phreas recharge events (a phreatic zone is where spaces in the rock are permanently water-filled). The likely effect most residents, water users and regular cavers will notice is higher magnitude oscillations in cave stream volumes. The epiphreas will also fluctuate more noticeably (the epiphreatic zone is the part of the cave system where the water level of the phreas seasonally fluctuates). The cave fauna will be vulnerable to longer dry spells and more frequent floods. While speleologists (cave explorers and researchers) will be alert for changes, others may encounter conditions they did not expect and face increased risk of flash flooding. Youth adventure groups with non-specialist leadership and unaccompanied general public dominate the use of easily accessible "wild" caves.

Documented Impacts

The author has observed unusual hydrological behaviour in one popular beginner group cave at Mole Creek, repeat trips encountering unexpected pools of water (see photos p. 7). Further, on one occasion since the fires, a one metre deep stream in the overflow surface channel outside this cave was found to be dry less than two hours later.

The peat burnt more thoroughly closer to the escarpment because it was fuelled by an increase in available oxygen. Sub-alpine impacts were patchy and limited by airflow characteristics. To the east-south-east of Mt Parmeener lies a depression formed by a slumped field of dolerite columns that can be regarded as a pseudokarst. This was partly explored by the author some years ago, and was found to contain dark cave-like spaces with troglophillic fauna including the cave spider *Hickmania troglodites*. The vegetation of the depression was burnt in the 2016 highland fires. (see p. 6)

The cave spider *Hickmania troglodytes* has been observed at the pseudokarst near Mt Parmeener. Photo: Deb Hunter.

Conclusion

It is imperative that sufficient resources be allocated to monitor the impact of the fires on the behaviour of the karst drainage systems, water quality and karst ecosystems dependent on karst hydrology. There may be a need to establish fauna sanctuaries and the impact on future water supplies must be assessed.

Severe floods with landslides in 2011 and 2016 have also profoundly affected the caves and changed the karst drainage. It will be important to integrate studies to achieve long-term views and strategies.

About the author

Deb Hunter is a speleologist and long term resident of Caveside with extensive knowledge of the Mole Creek karst. She is a founding member of the Mole Creek Caving Club, documenting and exploring caves at Mole Creek for nearly 40 years. She is involved in Australian exploratory and scientific remote area expeditions. Following a B.Env.Sc. with Honours in karst hydrochemogeology, she is undertaking a Masters analysing landscape evolution.

Damned fauna
Sarah Lloyd

Two stories dominated the media in Tasmania during the summer of 2016: the extensive bushfires and the 'energy crisis'. As a result of requests from members, the impacts of these events are described in this issue of TNN.

The fires received considerable media attention because they threatened lives and properties as they approached small towns and settlements in central north and northwest Tasmania. The destruction they wrought on the highland flora and karst system was only briefly discussed in the media.

The energy crisis and the low water levels in the lakes that supply electricity received almost daily media attention—at least until rain starting falling in mid-May. Issues outlined included the impact on the electricity infrastructure; the loss of production at two of the state's largest energy users: Bell Bay Aluminium and Norske Skog; the possibility of household power rationing; the expense involved in firing up the Bell Bay gas-fired power station and importation of numerous diesel generators; and the environmental impact of using diesel to power the generators. There was almost no mention of the impact of falling water levels on the fauna in the hydro impoundments, especially in yingina/Great Lake and Arthurs Lake, which both support rare and threatened species.

yingina/ Great Lake and Arthurs Lake

The 150 square kilometer yingina/Great Lake in Tasmania's central highlands is one of the largest natural bodies of freshwater in Australia. On December 4 1831 'protector' of Tasmanian Aborigines George Augustus Robinson described the lake and surrounding terrain as he and his party approach from the south:

'The Great Lake was not more than a quarter mile distant and in one part we could distinctly see the swans on the water ... Some of the natives from the south that had not before visited those parts, seemed struck with amaze on catching the first glimpse of this spacious water and called out, ironically, that it was the sea ... [it] had a fine appearance, and the strong northerly wind on the face of the water agitated the waters and the white foam gave it the appearance of the sea in miniature, together with the island and stony beaches and the surges of the waves breaking on the rocks.'

Between 1910 and 1915 yingina/ Great Lake changed irrevocably when the first dam was constructed on the Shannon River. Subsequent developments increased storage capacity and prevented the southward flow of water into the Derwent catchment, instead diverting it northward via the Great Western Tiers. The surface area increased from 11,330 to 17,612 hectares and drowned the series of separate lakes, shallow water and wetlands and their unique array of fauna. The Arthurs Lake impoundment was formed in 1963 following the construction of Arthurs Dam which inundated two natural water bodies—Sand Lake and Blue Lake—and Morass Marsh.

Lake habitats and threatened fauna

When full yingina/ Great Lake has a variety of habitats: extensive areas of emergent and submerged plants are associated with shallow and shelving shorelines; periodically inundated and exposed boulders and cobbles fringe the shores; and benthic (bottom) regions have fine grain sediment. These different habitats are favoured by different species, with some species using more than one habitat type depending on the stages of their life cycle.

Despite the considerable alterations to yingina/Great Lake it remains the centre of local endemism for several faunal groups including freshwater snails, galaxiid fishes, caddis flies and crustaceans with some species restricted to the lake and others also found in nearby water bodies. One species, the great lake caddisfly *Costora iena* that once inhabited weedy areas of the lake and its tributaries, is now listed as extinct. Other species listed as threatened or endangered include six freshwater crustaceans, (five isopods—yingina/Great Lake has the most diverse radiation of Phreatoicid isopods, a type of small shrimp, in the world—and one amphipod), two fishes (Shannon paragalaxias *Paragalaxias dissimilis* and Great Lake paragalaxias *P. eleotroides*), two snails (Great Lake snail *Glacidorbis pawpela* and Great Lake Hydrobiid snail *Beddomeia tumida*), several caddisfly species and a limpet. The Great Lake shrimp *Paranaspides lacustris*, although not listed on either the Commonwealth's Environment Protection and Biodiversity Conservation Act 1999 (EPBC) or Tasmania's Threatened Species Protection Act 1995 (TSPA), is included on the IUCN Red list of threatened species because of its high conservation significance.

Arthurs Lake provides habitat for the endemic Arthurs paragalaxias *P. mesotes* and saddled galaxias *G. tanycephalus*, both of which are threatened.

Threats to the fauna include predation, especially from brown and rainbow trout; and loss of suitable habitat mostly though changing water levels caused either by drought or, since the Bass Strait Cable connected Tasmania to the rest of the country, by drawing down water to sell electricity to users on the Australian mainland.

Chara beds

Among the significant habitats in yingara/Great Lake are the algal beds known as either 'shrimp' or 'Chara' beds. They are formed of *Chara* and *Nitella* 'stonewort' algae and were first detected during surveys in the 1970s but are known to have existed at least since the 1960s—and probably earlier. The beds are generally between 10 and 20 cm high with some reaching 30 cm. They are not only vulnerable to wave action, being only present on the sheltered shores protected from moderate to strong north-westerly and westerly winds,

yingina/Great Lake. Photo: J.J. Harrison Creative Commons Attribution Share Alike.

but also to declining water levels. There was a significant loss of 68% of Chara habitat between 1999 and 2001 though 'dewatering' and exposure on the shoreline.

A 2001 study, which confirmed the presence of the Chara beds identified in earlier studies, provided more information about their extent and importance to the fauna of the lake. They were found to have a significantly more diverse and abundant macroinvertebrate fauna than other benthic habitats on the lake slopes and are important habitat for the Shannon galaxias. The Great Lake shrimp and six of the seven yingina/ Great Lake phreatoicids show a preference for the Chara bed habitat. They are also of major importance for sustaining the lake's trout fishery. The beds have some ability to move when water level changes, but these fluctuations are probably too rapid for the beds to respond. Even if they do reestablish it is likely that the fauna will be negatively impacted through displacement, predation and a reduction in food.

Hydro priorities

In a paper '*Hydro power generation and the ecology of threatened fish species in Great Lake*' Hydro's priorities are outlined:

'the lakes are managed primarily for generating electricity; however, there are also recreation, irrigation, water supply and environmental health considerations.'

The paper describes the challenges posed by the prolonged below-average rainfall when water levels were reduced from 80% to 17% in the decade between 1997 and 2007. However, it was not until 2009 as a result of concerns about the impact of decreasing water levels on the threatened fishes that a three year study was initiated. The only other studies on the fauna of the lake (two in 1987 and one in 1988) concentrated on the trout fishery. A study in 1983 looked at the macrobenthic fauna in yingina/ Great Lake, Arthurs Lake and Lake Sorrell.

Galaxiid fishes

Fishes in the Galaxiidae family (e.g. *Paragalaxias* and *Galaxias* spp.) are scaleless small fish between 40–270 mm long with a dorsal fin placed well back on their bodies. Most are short-lived species with a lifespan of less than three years. They have a Gondwanan distribution with fifteen species occurring in Tasmania, of which eleven are endemic.

Tasmania's eleven threatened galaxiids (including ten endemics) that are listed on either (or both) the EPBC 1999 and TPSA 1995 are restricted to one or two water bodies or their associated streams and most have been affected to a greater or lesser extent by Hydro impoundments. For instance, the Lake Pedder Galaxias *G. pedderensis* was unable to persist in its natural habitat after Lake Pedder was dammed. Fear is held for the long term survival of a translocated population in Lake Oberon because of the low genetic diversity —only 34 fishes were moved.

The Central Plateau in Tasmania is regarded

Galaxias truttaceus. Some species of galaxias such as the spotted galaxias (above) are milky coloured and covered with small dots so these 'fishes of the Milky Way' were given the scientific name galaxias which is also used as their common name.
Although not one of the threatened fishes in yingina/Great Lake the spotted galaxias has an important role in the lake's ecology. Photo: John Simmons.

as a hotspot of fish endemism in Australia because of the presence of seven endemic non-migratory galaxiid species in the lakes and lagoons. Despite this there has only been one in-depth study of one of these fishes, the golden galaxias *G. auratus* that inhabits Lakes Crescent and Sorell. That study found that reduced water levels and unseasonal fluctuations could limit the breeding success because of loss of breeding habitat and loss of cues that initiate spawning such as rising water levels as a result of rain. Their short life cycle means that a failure to breed in one year could have a significant impact on their population and consecutive failures could be catastrophic.

The factors that threaten the golden galaxias are likely also to affect the other threatened galaxiids. Most are now restricted to artificially controlled waterbodies and fluctuations in water levels influence the availability and condition of different habitats. For instance, the littoral areas (i.e. around the shore) are used by many fishes at some stage of the life cycle either for spawning or during their juvenile phase, so falling water levels are likely to be a major threat to some species. Furthermore, because fish play an important ecological role within lakes, anything that threatens their existence also threatens the structure of the food webs and therefore many other species.

Fluctuations in the water levels also effect water quality. Wind on shallow water can cause suspension of sediments and increased turbidity. Increased sediment on benthic substrates can have a negative impact on the eggs of some species and it can also cause a reduction in the growth and abundance of macrophytes (i.e. water plants) because less light can penetrate the water. Some fish species can experience respiration problems because suspended particles clog their gill filaments.

Conclusion

At the beginning of June 2016 the water level in yingina/Great Lake was 16.97 m. below full having risen barely one meter after the heavy rain in mid-May; the 'flood catastrophe' in early June (aka 'stormageddon') raised the water a further metre and by the end of July the level was 15.21 metres below full. In contrast, many of the other hydro impoundments were well above the spill threshold by mid-May. This illustrates that the highland lakes are much more vulnerable to droughts than lowland lakes because they have relatively small catchments and get most of their water from precipitation. Therefore, frequent droughts associated with El Niño, along with increased use for water (e.g. for irrigation) and global climate change are likely to have an adverse impact on much of the fauna in the lakes.

The impact of falling water levels on the fishes finally made the news in early June after documents obtained through the Right to Information Act revealed that an internal Hydro memo from January blamed native fish egg and adult deaths during the spawning season on '*water level management*' or a '*combination of high draw-down rates and low lake levels*'. In the documents, Hydro scientists found retreating water levels left native fish and their eggs stranded on dry land and caused the deaths of underwater plant and invertebrate species. One document listed extinction as a worst-case scenario resulting from the dewatering of eggs.

It is clear that like threatened terrestrial fauna, the threatened species in the lakes are a low priority for this government.

Articles and photographs about aspects of natural history are invited. Please email **unformatted** word documents to the editor (sarahlloyd@iprimus.com.au). Photos should be reduced to approximately 600 KB and emailed separately, i.e. **NOT** embedded in the word document.

Deadlines for newsletters: November 30, March 30 and July 30.

SOIL BIOLOGY (Part 2)

Sue Gebicki

The environment is changing at an unprecedented rate and one of the best survival techniques for soil biota is adaptability, and to be adaptable they must be diverse. The most recent figures from a study of 2 million records for nearly 40,000 terrestrial species have found that across 65% of the land, biodiversity has decreased by over 10%.

The effects of disturbance to soil ecosystems may be positive or negative, depending on the amount. Generally, high disturbances are the main cause of species loss as only the species tolerant of stress can survive. In frequently disturbed soils well-adapted bacteria tend to predominate.

Causes of species loss include conversion of ecosystems, deep ploughing, irrigation, chemicals, vegetation removal, roads and building construction, over-grazing, the use of genetically modified organisms and unnatural fire regimes. These cause erosion, salination, pollution, compaction, and acidification.

Conversion of natural ecosystems to agriculture and changes in land use are the most common causes of extinction as they are imposed on large scales and do not allow species time to adapt. Research in disturbed forested ecosystems has shown that alteration of the soil can affect vegetational succession, in some cases resulting in sites that cannot be regenerated to particular vegetation communities. The conversion of forests and native grasslands to croplands and plantations reduces the soil's capacity to act as a carbon sink by as much as 20–40%.

Soil compaction is caused by heavy machinery, repeated tillage, running stock on wet soil and, in Australia, by introduced hard-hoofed animals. Compaction results in loss of soil aeration and water infiltration which favours anaerobic bacteria that are more likely to be pathogenic, leading to a decrease in plant growth and a loss of earth worms and microinvertebrates.

Additions to the soil include fertilisers, lime, chemicals, sludges and animal excreta. Fungicides reduce beneficial fungi and herbicides remove plants which reduces soil biota. Herbicides can be toxic to some organisms, particularly nitrifying bacteria, and their continued use significantly affect micro-organisms. Research has found long-term impacts on vegetation communities up to 16 years after a single herbicide application. The use

Collembolla such as *Odontella* sp. and *Dicyrtomina* sp. live in the top 5 cm of soil. Photos: Andy Murray.

of inorganic fertilisers has a range of effects: increased vegetation growth supports higher biota populations, but high applications of nitrogen fertiliser causes the microbial population to fall, probably by acidifying the soil. Nitrogen-rich fertilizers also favour bacterial growth over fungi. High inputs of fertilisers can reduce the symbiotic effectiveness of soil organisms. Pesticides alter the balance of soil biota by selectively removing some species.

Cultivation causes rapid decomposition and nutrient mineralisation through improved soil-stubble contact and increased respiration rate. This leads to less organic matter and fewer earthworms. It is particularly deleterious for fungi as it severs the hyphae.

The consequences of fire are determined by fire intensity, duration and frequency, soil moisture and vegetation type. High intensity fires remove or destroy litter and organic matter in the top few centimetres of soil, with a loss of nitrogen, carbon, phosphorus and other nutrients but an increase in nutrients such as calcium, phosphorus and potassium. Low intensity fires can increase the nitrogen availability in soil. Fire changes the water repellence of soil, making it more susceptible to erosion and ability to absorb heat. The re-establishment of soil biota after fire varies from a few days to several years. For example, Ratkowsky and Gates (2008) have found changes reflected in a fungal community more than 75 years after fire in a wet sclerophyll forest.

The removal or degradation of vegetation and deep tillage make the litter and topsoil more susceptible to erosion. This can set up a vicious cycle in which the eroded soils are less able to support vegetation and so are even more likely to erode. Australia is particularly prone to erosion due to its ancient and fragile soils. More than 90% of collembola are located in the top 5 cm of soil, so numbers decline rapidly if erosion occurs.

Salination that occurs near the soil surface can cause desiccation of some organisms. More salt-tolerant organisms may benefit by the increased availability of organic matter, although this will only be temporary if vegetation fails to grow. Salination can ultimately lead to desertification. Large swathes of soil in Australia have been lost to salinity through excessive extraction of groundwater. Vegetation removal and inappropriate irrigation causes the water table to rise, which brings dissolved salts into the top soil as the water evaporates.

When soils are covered by an impermeable layer, e.g. by urbanisation, the soil biota exhausts the existing moisture and organic matter and most eventually die. Roads have been shown to impact macroinvertebrate abundance and microbial activity for up to100 m from roadsides, and faunal diversity for 15 m. The pathogen *Phytophthora cinnamomi* is known to spread along roads, onto verges and into the watershed up to 600 metres from the road. The greatest incidence is near 4WD tracks – certainly worrying information for 'recreational' driving in World Heritage Areas.

Changes in soil pH can affect the metabolism of organisms by affecting the activity of enzymes and nutrient availability, and affecting the symbiotic relationships between vegetation and organisms. Most soil fauna have little capacity to cope with large changes in pH, and most macrofauna decrease in acidic soils.

Acidification is caused by pasture improvement and removal of crops, nitrogen fertilizers, nitrate leaching, build-up of organic matter and plantation forestry. While the build-up of organic matter is potentially acidifying, it can also buffer against acidification, depending on the nature of the organic matter and the soil history. Forestry involves the removal of biomass which contains large amounts of cations, resulting in the lowering of soil pH. This is further exacerbated when plantations of acidifying trees are established. The extent of acidity is increasing in the surface layers of cropping soils in all major grain growing areas of Australia.

Genetically modified plants have been found to principally affect the chemical processors, or decomposers, by altering the quantity and quality of growth substances, the structure of bacterial communities, bacterial genetic transfer and the efficiency of microbial-mediated processes. They favour the development of genetic resistance in target pest organisms, alter the mycorrhizal colonisation of roots and effect earthworm physiology.

Soil biota and climate change

The direct effects of climate change on the relative abundance and function of soil communities have been studied extensively. However, less focus has been placed on the indirect effects and the interactions between them, which may be as large, or larger than, the direct effects.

Analysis of the impacts of elevated CO^{2} on soil microorganisms concluded that levels of microbial biomass and fungal abundance increase, but conflicting results occur for bacterial diversity and abundance. Results demonstrate that increased CO^{2} causes changes in the structure of the soil.

Pauropod in forest litter. Photo: Andy Murray.

Results from warming showed positive and consistent results for increases of microbial, fungal and bacterial abundance, which almost certainly causes changes in the structure of the soil. However in long-term field studies these increases were found to be short-lived.

Drought was found to consistently increase fungal abundance relative to that of bacteria, but decrease the biomass and abundance of most microbial and soil fauna. It particularly impacts fauna that depend on a water film, such as protozoa and nematodes, and reduces the diversity of mites and collembola.

Fewer studies have been conducted on the effects of increased flooding and rainfall, although these are certain to alter the soil environment by increasing erosion, removing nutrients and litter, creating periods of anaerobic conditions and affecting the soil properties.

Analysis of the effects of climate change on soil fauna revealed that responses of different groups are highly variable. Nematodes increase in abundance with warming; collembola and enchytraeids increase with increased precipitation. Several studies found elevated CO^{2} levels caused a decrease in diversity of faunal groups and growth of earthworms and collembola.

Plants are migrating with temperature, but not much is known about the ability of microorganisms to shift their range. Climate change can provoke loss of species due to nutrient enrichment of native ecosystems which favour fast-growing species. Observations in Germany on a broad scale over the last 20 years have found the average yields of agricultural production increased by 10%. Mineral fertilization had been reduced and there were no large scale changes in agricultural practices, so the increase was possibly caused by climate change.

This article with references is on the disjunctnaturalist website.

WALKS PROGRAM OCTOBER – JANUARY 2017

BRING LUNCH, WATER AND CLOTHES FOR ALL WEATHER

Sun 2 October: Hawley Nature Reserve. Meet at 10 am towards the western (uphill) end of Arthur Street, Port Sorell. (Arthur St is off Alexander St. C708 just before the road turns right into Hawley Esplanade.) We will focus on ephemeral plants that occupy the rock plates. In particular we will keep our eyes out for the threatened pygmy clubmoss that was previously recorded but not seen in recent years. We will also inspect the *Spyridium obcordatum* caging experiment. A little off-track walking is required at a slow pace. (Leader: Phil Collier)

Sun 6th Nov: A ramble in the Meander Forests. Meet outside the general store in the main street of Meander at 10.00 am. We will then drive for about 20 minutes to the parking area near the bridge over the Meander River in the Meander Forest Reserve. From the parking area we will follow formed tracks through the forest. (Leader: Rod McQueen)

Sun 4th Dec: Return to the TLC's Panatana Reserve. Meet at the junction of the Frankford Highway and the road to Narawntapu NP at 10.00 am. This will be our second visit to Panatana for 2016 and will enable us to experience the Reserve in early summer. (Leader: Sarah Lloyd)

Sun 1 January: Dove Canyon Track from the Cradle Mountain Interpretation Centre. This 5 km-long loop track traverses several of the vegetation communities of the Cradle Valley area. Also see the very scenic junction of Pencil Pine Creek and Dove River, Dove Canyon and waterfalls. Part of the track is graded 4 "bushwalking experience recommended", but we will take it slowly. Bring a packed lunch. Meet at **9:30 am** at the Cradle Mountain Visitor Centre where cars can be pooled or transfer to the bus. A Park permit is required for the bus and cars that drive to the Interpretation Centre. (Leader: Phil Collier)

Fungimap in Tasmania

Financial and logistical support from NRM North, CCNRM, the Central North and Burnie Field Naturalists and the Australian Plant Society in northern Tasmania allowed Fungimap mycologists and supporters to present talks, workshops and forays in Launceston, Burnie and Waratah. These well-attended public events were followed by a scientific expedition to the fungi-rich rainforests of the Tarkine resulting in approximately 150 collections of fungi and two collections of myxomycetes being accessioned and databased with novel taxa to be described in due course.

Letter to the editor

In the past "The first Bonk of Spring" occurred regularly on 1st September. Then about 20 years ago, Banjo frogs, *Limnodynastes dumerilii* started calling on 31st August. The next year they started calling on 30th August. This one day earlier has continued most years until this year when Banjos at Bellingham on the north coast started calling on 17th August. Yet another illustration of the effects of climate change. Regards, Sue Woinarski

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