Forest serves as a source of water for livestock during dry season. Photo: W Karen.

and buffalos have always moved out of the forest to their traditional dispersal areas. Now they trample crops and sometimes people. Fearless troops of baboons infest settled areas in Marsabit town, raiding fields and endangering children. Other wild animals also regularly attack livestock and local people retaliate. The wildlife damage understandably undermines local public support for wider conservation efforts. The ecosystem faces obvious threats that go beyond the borders of the protected areas.

The mountain's ecology has been under pressure in the past. The Sokorte Guda dried up three times in the 1930s and 1940s, while the water level in the Sokorte Dika dropped substantially. The colonial administration, alarmed particularly by the livestock grazing pressure, increased the size of the protected forest and piped water from within to the periphery where both livestock and people could use it without intruding on the forest. Given today's dense settlements around the protected areas, better management of the 'buffer zones' is the best option. Their on-going conversion to farm plots and the clearing of vegetation directly reduces the total forested area, decreasing the ecosystem's capacity to naturally trap moisture from clouds and mist. This means not only that Marsabit is faced with critical water shortages, but that rain-fed agriculture, on which all the many settled people rely and its biodiversity, is severely threatened.

What next?

This article has touched on the most obvious causes and effects of human settlement and climate change on Marsabit Mountain. There is much that we still do not understand about the delicately interwoven forest ecosystem. However, it is certain that, as the mountain population soars, so does demand for the use of forest resources. Conservation policies and policing and management practices should incorporate the 'buffer zones' and the local communities' needs for resources for their survival. Future tree planting to increase vegetation cover should consider trees which host moisture-trapping mosses and lichens. Improving the wellbeing of the ecosystem-dependent communities and promoting the wise use and management of protected areas must underline any successful conservation policy. If the pressures on the ecosystem go unabated, the small forest is in a serious danger and its roles at risk. This will also be the case for the rich biodiversity and the people who depend on the health of the Mount Marsabit ecosystem.

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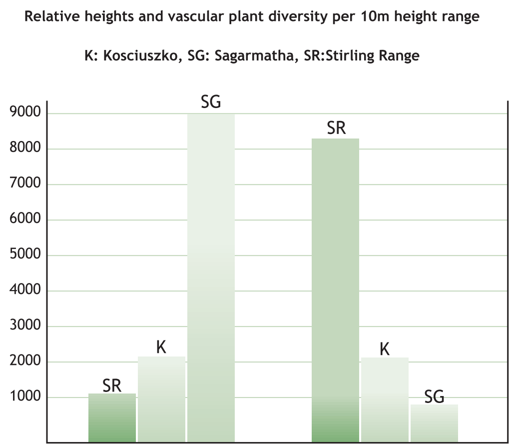
Responses to Threats and Impacts on the Outstanding Biodiversity Values of Low-Altitude Mountains in South Western Australia

Anne Cochrane, Sarah Barrett and John Watson

South western Australia is the most floristically rich region on the Australian continent and is one of the world's top biodiversity 'hotspots', with some 8,000 described vascular plants including numerous endemic and threatened species. The region contains a series of isolated mountain peaks in the Stirling Range National Park that are themselves biodiversity hotspots. Although small in absolute height (~1,095 metres maximum elevation), these small mountains are the highest points in the landscape for several thousand kilometres. However, they are truly 'Himalayan' in terms of their plant diversity with some 1,517 plant species and over 80 endemics, often with narrow distribution ranges on specific mountain peaks (Figure 1, Watson and Barrett 2004).

Figure 1
The Stirling Range - low in elevation but 'Himalayan' in plant diversity (Watson & Barrett, 2004)



Although located some 100 kilometres inland from the current day coastline, the Stirling Range peaks were once an isolated archipelago of islands in the Eocene marine incursion and they are now altitudinal islands of 'Gondwanan' habitat. Surveys have identified several Gondwanan relictual fauna species, particularly spiders and snails, which have close relationships with species found in other southern hemisphere areas including New Zealand and Madagascar.

The Stirling Range is surrounded by a highly modified agricultural landscape almost totally cleared of natural vegetation, and the peaks are therefore not only 'islands in the sky, but also islands of natural biodiversity in a surrounding terrestrial landscape (Figure 2). The biota of these peaks is also highly susceptible to a whole suite of threatening processes, including:

- plant pathogens, notably *Phytophthora cinnamomi;*
- inappropriate fire occurrence and its interaction with *Phytophthora cinnamomi;*
- climate change, in particular the impacts on fire behaviour, plant pathogens and plant regeneration from seed;
- recreation, in particular trampling, erosion and increased spread of plant pathogens on walkers' boots;
- feral animals, primarily European fox and European rabbit;
- isolation from other protected areas.

The range experiences a cool Mediterranean climate with cool to mild wet winters and warm to hot dry summers. Snow is rare and seldom lasts.

Current climate change scenarios indicate that south western Australia is developing longer drier spells of weather, a small regional temperature rise together with increased UV radiation and more frequent 'extreme' weather events. The predicted biotic response will be for species to 'migrate' further to the south west and to higher altitudes. Those species and communities around mountain summit areas have nowhere else to go, hence endemic montane plant species (some five of which are already Critically Endangered) and associated fauna habitat are likely to be heavily impacted by these changes.

Furthermore, these climatic changes have major ramifications for a number of the threatening processes listed above but in particular for unnatural fire regimes and plant disease (Watson, 2006). For example, any drying trend will dramatically increase the flammability of the vegetation and hence the wildfire threat, as well as generally compromising the effectiveness of wildfire suppression. Conversely, any increase in un-seasonal summer rainfall events, when soils are warm, inevitably causes a rapid flush in Phytophthora activity due to the resulting short term 'pseudo-tropical' soil conditions.

We briefly describe here some of the strategic planning, research and operational management responses being developed by the Department of Environment and Conservation (DEC) South Coast Region in the Stirling Range in an attempt to ameliorate threats to and improve the natural resilience of the natural biodiversity.

Strategic planning responses

A key strategy has been the development of a GIS model to identify those areas within the surrounding modified landscape that can maximise the retention and enhancement of vegetative connectivity at a regional scale. DEC has identified both local scale corridors of vegetation and 'stepping stone' or patchwork linkages to be established in the surrounding landscape that will improve connectivity to other un-cleared areas, including significant protected areas such as the Fitzgerald River National Park some 100 kilometres to the east. An early overview of this work is described in Watson and Wilkins (1999) with more detail in the subsequent macro-corridor report (Wilkins et al, 2006).

Figure 2. The Stirling Range - islands in the sky and in a surrounding agricultural landscape.
Photo: Anne Cochrane.

Research responses

A major new initiative has been developed to study temperature thresholds required for seed germination of native plant species including a number of threatened species (Cochrane and Daws, in preparation). Seed germination and early seedling growth are the most sensitive stages in a plant's life cycle and perhaps the most vulnerable to climate warming. South western Australia has experienced climate variation in the past and its native species may have a broad tolerance to extreme climate conditions but there is uncertainty regarding their ability to persist under currently projected climate warming. We believe that predicted increases in temperature associated with climate change may limit recruitment of obligate seeding species in vulnerable environments.

In this research, we are using a bi-directional temperature gradient system to create germination temperature profiles and to determine sensitivity of early radicle growth to temperature (Figure 3). Preliminary results for ten Stirling Range species indicate that some (e. g., *Kunzea montana*) have physiological tolerance to a wide range of temperatures for germination despite their narrow range and mountain habitat. We have demonstrated a negative relationship between percent germination and increasing mean temperatures for

Andersonia echinocephala, Calothamnus crassus and *Sphenotoma drummondii,* but only the latter displayed an extreme sensitivity to high temperatures that may threaten its survival and persistence under climate warming. Little difference in germination temperature profiles existed for those species assessed from both mountain and coastal habitats (e.g. *Banksia brownii*).

This seed-based approach for identifying extinction risk will assist in prioritising species for operational management responses and for directing limited resources towards further investigations, as well as a useful addition for bio-climatic modeling per se.

Operational management responses

Threats to the biodiversity of the Stirling Range and our current threat abatement strategies were previously reviewed with a special focus on the critically endangered Eastern Stirling Range Montane Heath and Thicket Community (Watson and Barrett 2004). This community overlays a highly popular tourist destination on the summit plateau of Bluff Knoll (at 1,095 metres, the highest peak in south western Australia) and it also covers a popular two-day wilderness ridge walk from Bluff Knoll to Ellen's Peak (1,012 metres). The threats, management operations and recovery strategies for this community may also have relevance for other mountain protected areas where extremely high-value conservation sites must co-exist with major visitor destinations.

DEC South Coast Region strategies aim primarily to improve community level resilience by increasing and refining existing management actions, including aerial phosphate spraying with the fungicide phosphate for Phytophthora control, feral animal baiting (notably the European rabbit), and hygiene/access management strategies for recreational use. DEC is continuing to refine fire management and fire suppression capability, including the introduction of spotter aircraft during the summer fire risk season and, since 2004, fast attack aerial water bombers.

At the species level, in addition to the seed germination research referred to above, DEC has an active seed conservation program that acts as an 'insurance' against species loss in the wild, providing a source of material for future species recovery. For several critically endangered montane plants conservation seed orchards have been successfully established outside the national park in the hope that re-introduction to Phytophthora-free areas can occur in the future. Efforts are being made to develop tissue culture techniques also with the aim of developing Phytophthora-resistant strains of susceptible species for re-introduction to the wild.

Figure 3. Seed germination temperature threshold studies.
Photo: Millennium Seed Bank Project.

Summary

Low altitude mountains occurring within global biodiversity hotspots can assume 'Himalayan' proportions in terms of their biodiversity. They may also play a significant role in addressing climate change scenarios due to their accessibility and the concentration of various threatening processes into relatively small areas. Research into seed germination thresholds may be particularly valuable in helping to prioritise the focus for further research and adaptive operational management targeting threatened species and montane plant communities.

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