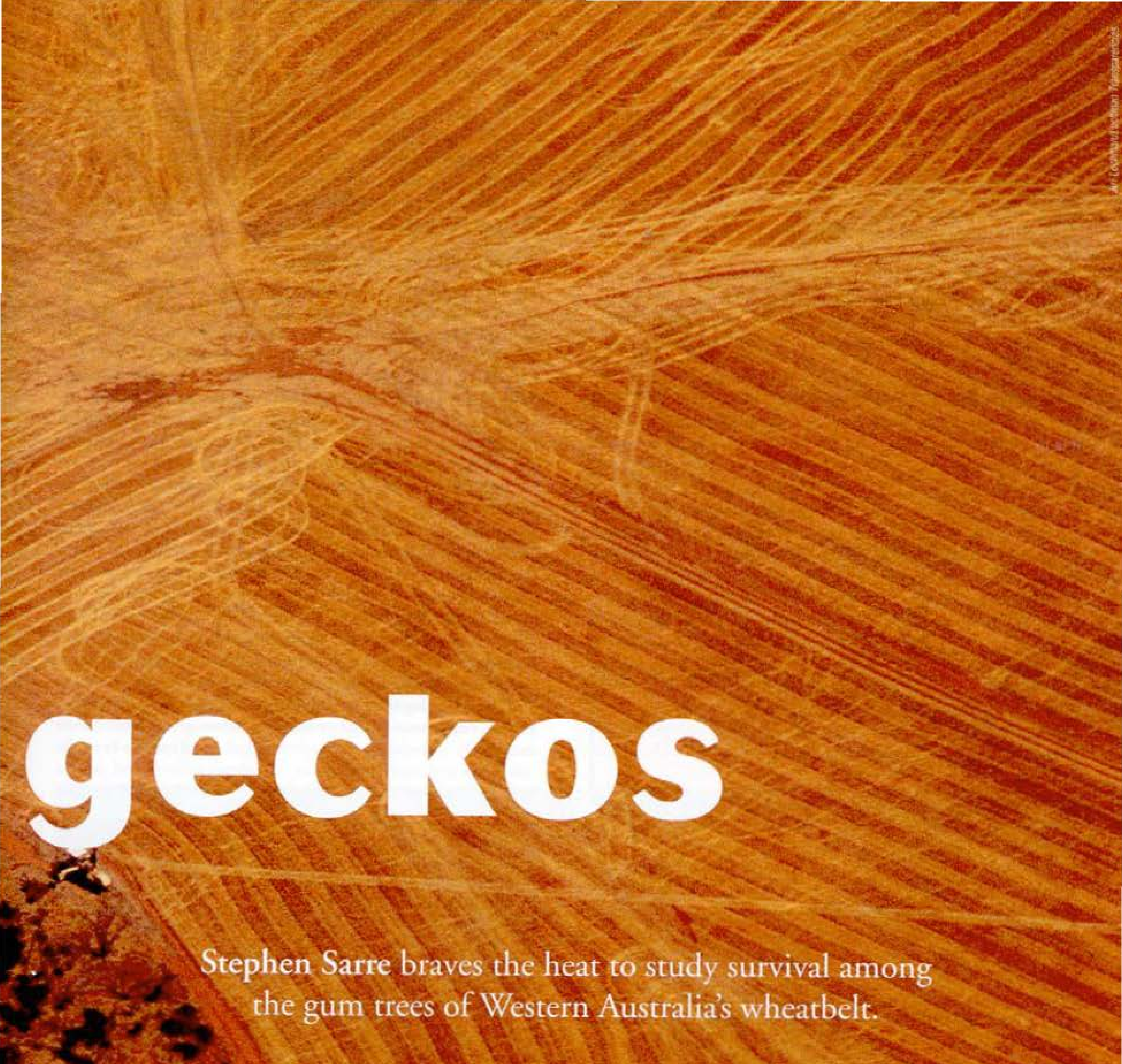
It is hard to believe that any native fauna could survive in barren-looking remnants such as this. Yet the reticulated velvet gecko (above left) and the tree dtella (above right) have done just that. With so much wildlife threatened by vegetation clearance and fragmentation, studying these species that have survived in the face of such radical habitat change might help to explain the demise of others.

A tale of two



geckos

Stephen Sarre braves the heat to study survival among the gum trees of Western Australia's wheatbelt.

Summer was showing us no mercy in the Western Australian wheatbelt: we had just recorded our 20th January day above 40°C. The galvanised iron and fibro house in which my volunteer assistant and I worked during the worst of the day was often hotter than outside and the air-cooler was pathetic in its ineffectiveness. The landscape beyond the house was dry and dusty, consisting largely of paddocks covered in wheat stubble and grazed by dour sheep.

We were sweltering in what appeared to be a biological desert. So why were we there? Put simply, we were learning about two species of gecko that have managed to survive among the district's remaining pockets of native vegetation.

This part of the wheatbelt, near the small rural town of Kellerberrin 200 kilometres east of Perth, was cleared early this century. What remains of the original vegetation exists mostly in tiny fragments which have become islands in a sea of wheat. Many of these remnant patches have been grazed regularly over the years by sheep and now contain only the original (often senescent) trees and some introduced grasses.

It is hard to believe that any of the native fauna could survive in these small and barren-looking remnants. Yet the reticulated velvet gecko, *Oedura reticulata*, and the tree dtella, *Gehyra variegata*, have done just that. With so much of our wildlife threatened by vegetation clearance and fragmentation, studying these species that have survived in the face of such radical habitat change might explain the demise of less-fortunate species, such as the five other species of gecko *(Crenodactylus ocellatus, Diplodactylus granariensis, D. maini, D. pulcher, D. spingerus)* that remain in large woodland reserves in the area, but no longer exist in small remnant patches.

Small numbers, big risk

The effects of widespread vegetation clearing on the biota is two-fold. First, there is the loss of habitat for plants and animals to occupy, and often, what remains is of lower quality. Second, there is the fragmentation of the habitat itself which results in large populations being split into many small, insular populations separated by a sea of wheat and pasture.

Theory as well as intuition tells us that making populations smaller will increase their chances of going extinct. One reason for this is that variation in the average survival and reproduction of individuals will be greater in smaller populations just through chance alone.

Remnant vegetation fragments in the Kellerberrin region, a landscape changed by clearing and the farming of wheat and sheep.

An extreme example would be a population in which only male offspring were produced in successive years, providing no females with which to produce subsequent generations. Such an event is very unlikely in a population of 1000 breeding individuals, but quite possible in a population of 10.

Another factor is environmental variation. For example, a bad drought may cause a large increase in mortality within populations. If the starting population is large, even a substantial decrease in numbers will leave enough individuals to re-populate the region once conditions improve. If the starting population is small, poor environmental conditions may eliminate enough individuals to cause the population to go extinct.

The characteristics of the species themselves will also have a bearing on their persistence. Those species with specific habitat requirements (specialists), such as those that dwell only in certain species of tree, are more likely to be affected by habitat clearance than those able to survive in a wide range of habitats (generalists), including the farmed landscape. Not only will more habitat be available to generalists, but they may also be able to move through the landscape, allowing migration and gene flows between disparate populations.

Good grounds for research

The area around Kellerberrin is typical of a landscape changed by vegetation clearance and the farming of wheat and sheep. For this reason, Dr Denis Saunders and his fellow researchers at the CSIRO Division of Wildlife and Ecology set up a research station near Kellerberrin in the mid 1980s to study the effects of such change on the native flora and fauna. The background information that they accumulated in the course of their research provided an excellent basis for examining questions of population persistence and extinction in a recently fragmented environment.

In 1900, before the Kellerberrin region was cleared, almost half of the land was covered with the smooth-barked *Eucalyptus* woodland used by the reticulated velvet gecko and tree dtella. Now, this type of woodland comprises only 2% of the land area of the region, mostly in small remnants of only a few hectares. There are few remnants (including nature reserves) that contain even modest stands of smooth-barked *Eucalyptus* woodland. Nevertheless, surveys of the wheatbelt conducted by the Western Australian Museum found that the reticulated velvet gecko and the tree dtella occurred in many nature reserves and remnant patches.

The intriguing thing is that the two species have quite different habitat requirements: the reticulated velvet gecko lives almost exclusively in hollows of smooth-barked eucalypts such as the distinctive and handsome gimlet (*Eucalyptus salubris*) and salmon (*E. salmonophloia*) gums, whereas the tree dtella has a broader

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Diplodactylus spinigerus.

Picking up the pieces

Stephen Sarre spent eight months over several years sweltering in the Western Australian wheatbelt as part of his PhD research with Dr Dave Shaw at the Australian National University. His main research interests are the processes of extinction and speciation in disjunct animal populations (particularly those caused by human activities) using a combination of ecological and genetic methods.

Sarre has worked on island lizards and tiger snakes and, in collaboration with Dr Chris Margules and Jacqui Meyers (both of CSIRO Wildlife and Ecology), is also examining the response of reptiles to an experimental habitat fragmentation in the south-east of New South Wales. At present he is taking a sabbatical from reptiles and is indulging his voyeuristic tendencies by using DNA fingerprinting to study the sex life of possums in New Zealand.

range of tastes, able to live in logs, under rocks and among rubbish, as well as in trees.

Although the two species share many remnants in the Kellerberrin region, they do not always occupy the same remnants. To determine how many remnants were occupied by the two species of gecko, I surveyed 32 gimlet and salmon gum remnants that had been isolated between 1900 and 1935. This work was done with Dr Graeme Smith and Jacqui Meyers, both of the Division of Wildlife and Ecology. The survey showed that the tree dtella (found in 30 remnants) had a higher level of remnant occupancy than the reticulated velvet gecko (23 remnants).

One reason for the difference might be that the tree dtella can maintain large populations (compared with the reticulated velvet gecko), making them resistant to extinction through chance happenings, or they might be able to move between remnants, preventing extinction. A further possibility was that populations of the reticulated velvet geckos were prone to larger fluctuations in size, rendering them more susceptible to extinction through bad luck.

My reason for sweltering in the wheatbelt in mid-summer was to explore the possible reasons for this difference by examining remnant populations of the two species in detail and comparing them with populations in nearby nature reserves.

Delving in darkness

Our field routine was simple. The geckos are nocturnal (a sensible characteristic given the extreme conditions in the Western Australian wheatbelt), so to catch them we also had to become nocturnal. Armed with head torches and an aluminium ladder, we would begin our patrol of a remnant as dusk descended, checking each tree and log for geckos.

Both species could be spotted by the reflection of torch light in their eyes, but the reticulated velvet gecko, sitting out on the tree trunks, was generally easier to see than the tree dtella. It was also easier to catch because it tended to stand still, hoping to avoid capture by not being spotted.

Catching the reticulated velvet gecko can be likened to picking apples, although, as with apples, there were always those that were out of reach. This was when the ladder came into operation. The tree dtella was more elusive, tending to sneak around at the base of logs and trees. If not pounced on immediately, it would disappear into inconspicuous crevices.

Upon capture, each animal was examined for marks (a unique series of clipped toes) from a previous capture. If we had caught it before, it was released where it was found; if not, it was placed in a numbered calico bag and retained for later measurement. This searching continued until no more animals could be seen, whereupon we would return to our residential furnace.

When pickings were slim, we might return after two hours with no or at best a handful of captures. On a good night, we might work until four in the morning. On our best night, we captured 109 reticulated velvet geckos from one remnant patch.

The following day, we would mark and measure the previous night's capture and take a sample of tissue from the tail (which is regenerative in geckos) for genetic analyses. The animals would be released at the site of capture during the next evening.

Pockets full of geckos

This work provided some unexpected results. For a start, the widespread and generalistic tree dtella was shown to persist in some tiny populations. In the 12 remnant populations that we examined,

Studying the geckos that have survived vegetation clearance might explain the demise of less fortunate species such as *Diplodactylus pulcher (below)* and *D. spinigerus* (left) which remain in large woodland reserves, but no longer exist in small remnant patches.

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population size ranged from a total of seven individuals to about 400, with seven remnants containing less than 50 individuals. Also, we found that population size is closely correlated with remnant area, indicating that the remnants contained close to their maximum carrying capacity of tree dtellas.

In contrast, the population sizes of the reticulated velvet gecko, while also small (ranging from twelve to about 430), showed no such relationship to remnant size or the amount of suitable habitat contained in the remnant. For example, one of the largest remnants contained one of the smallest populations. That particular remnant, while having a small population, had a high level of genetic variation when compared with most remnant populations. This indicated to me that this population had only recently become small because small populations tend to lose genetic variation quickly.

This finding is important because the survey of remnant occupancy done with Smith and Meyers showed that larger remnants were more likely to be occupied than smaller remnants. The implication is that while the reticulated velvet gecko has been able to maintain populations in large remnants so far, such populations may still be heading towards extinction.

The work also revealed that both species had quite mature populations, that is, they contained more adults than sub-adults. Both species are long-lived (up to 19 years for the reticulated velvet gecko and 15 years for the tree dtella).

This finding indicates that while the likelihood of an individual reaching adulthood may be low, once it is an adult it will probably live for a long time. This produces a stable population structure, with little variation in population size between years. It may also mean that many of the small populations have been saved from extinction to date by virtue of their citizens' longevity.

My genetic studies showed that female reticulated velvet geckos are unlikely to move between remnants. This means that small populations are unlikely to be 'topped up' by immigration and,

Efficient conservation relies on predicting extinction

Habitat fragmentation happens naturally on many scales in both time and space. It may occur because of local and regional variation in topography, climate or soils, or through major events such as sea level rises, or the formation of rivers or mountain ranges. All organisms have a disjunct distribution at some scale.

Habitat fragmentation also occurs when land is cleared by humans. Most obvious is the fragmentation that occurs through clearing for agriculture or forestry, but it can also be caused by urban encroachment, the building of roads, or the flooding of river valleys to make dams.

In many parts of the world, land clearance has occurred on a massive scale in a short period. For example, in the agricultural districts of southern Australia, more than 90% of the native vegetation in some regions has been cleared during the past 100 years!

The task facing wildlife managers is to identify the species most at risk to the impacts of land clearance and habitat fragmentation and to devise strategies to prevent their demise.

Clear consequences

Landscape modifications caused by land clearance present difficulties for the plant and animal species that remain. Less area is suitable for them to inhabit, and their distribution may become fragmented, posing special problems of survival in small, insular populations (see main article).

Land clearance also changes landscape processes that may affect species survival. The classic Australian example is rising water tables caused by tree clearance, which turn formerly arable land into salt pans by bringing salt to the soil surface. Other effects include changes to plant species composition, increased soil erosion and alteration of nutrient levels as well as wind and temperature regimes.

These environmental changes are likely to have important implications for resident animal species. Some species, such as magpies, may be favoured by the changes because they are well suited to open agricultural land. Others are not so fortunate and find it difficult to cope.

Which species should we study?

To understand the causes and dynamics of extinction in highly fragmented systems, population biologists must select appropriate species to study. Although the tendency is to work on endangered species that require urgent management attention, research on non-endangered species is also critical because it allows the manipulation and study of populations over time. Such flexibility is rarely possible when the overwhelming priority is the conservation of the species being studied. By taking a broad approach, management principles can be established which can then be applied to potentially-endangered, as well as currently-endangered species.

Factors that are considered in studying the effects of fragmentation on wildlife include:

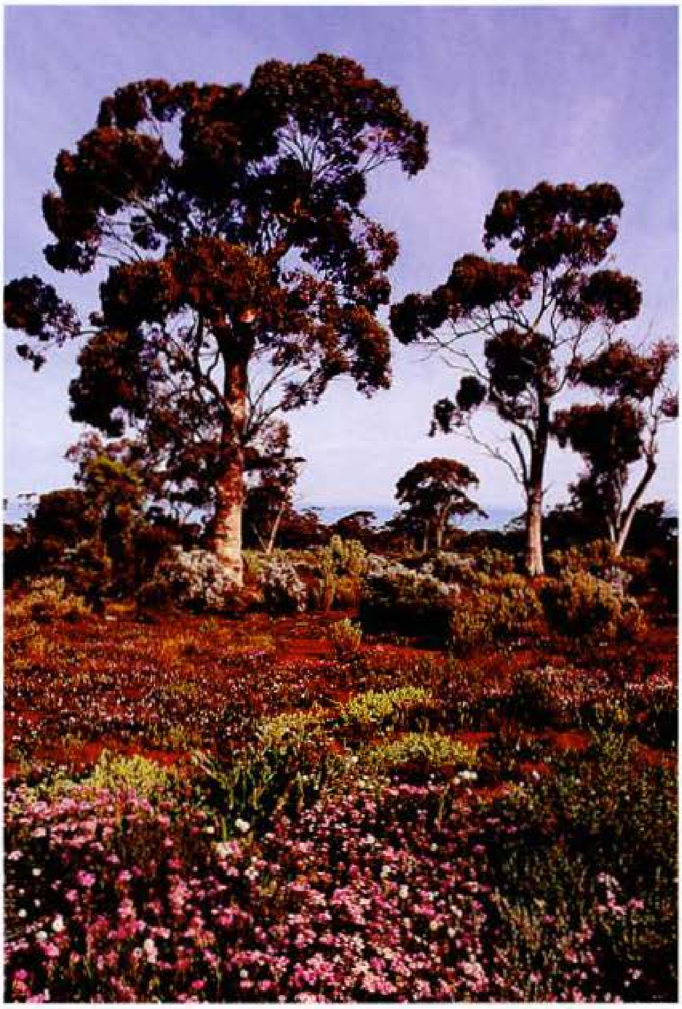
- the extent and quality of available habitat;
- the size of populations that can exist in that habitat;
- how populations of the species interact;
- what effect that interaction has on persistence;
- what impact the surrounding land use has on the species and its habitat; and
- how habitat fragmentation affects the impact of predators and competitors.

Predicting vulnerability

For a species to persist following habitat fragmentation, the resulting changes in its habitat must not fall outside its ecological, behavioural and physiological capabilities. If habitat changes within remnants are extreme or some critical component of the habitat (such as fruiting plants for frugivorous birds, or tree hollows for geckos) is lost, then many dependent species will be unable to persist.

In terms of the predictability of extinction from such causes, a species with broad habitat and resource requirements is less likely to find itself without essential resources than one which is more specialised. Thus, one way in which the vulnerability of a species to habitat fragmentation may be to an extent predictable, is in its degree of specialisation. If species can be categorised in this way, wildlife managers would be able to identify the most vulnerable species before they become critically at risk. This would reduce the massive expenditure of time and effort required to prevent extinctions. Only by studying a range of species can the applicability of this idea be determined.

Stephen Sarre



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Stephen Sarre

Which habitat would you prefer: a healthy salmon gum woodland, or a salt-affected paddock? The survival of the reticulated velvet gecko in remnant patches may depend on the efforts of wheatbelt farmers who are working to replace senescing vegetation remnants with larger, linked and well-managed on-farm reserves.

once a remnant has lost its population, there is little chance that another population will become established.

On the other hand, the very high level of occupancy enjoyed by the tree dtella in remnant habitat indicates that population extinction happens only rarely in that species.

In the light of current crude estimates of persistence times for small populations of other fauna, migration needs to be invoked to account for some of the observed high level of occupancy, although anecdotal evidence from this and other studies indicate that movement between remnants is low. This implies that very small populations of the tree dtella can persist for up to 80 years with only low levels of immigration.

Future quantification of the migration rate among tree dtella populations by genetic analysis could provide important estimates of the rates that are necessary for the persistence of very small populations.

This study has helped illuminate the advantages of a habitat generalist over that of a specialist in a modified landscape and the role of movement in reducing the chances of extinction.

Neither gecko is considered endangered as a species, but my study suggests that the reticulated velvet gecko is likely to experience a continued restriction of its range as it goes extinct in small patches. Its persistence so far in such remnants is a tribute to its long life span and to the quality of habitat provided by gimlet and salmon gums, but eventually large reserves will probably become the species' only strongholds.

The demise of the reticulated velvet gecko in remnant patches is likely because of the lack of regeneration of gimlet and salmon gums in most remnants. In recent years, wheatbelt farmers have been pursuing revegetation and regeneration programmes in an attempt to reverse some of the environmental problems brought about by excessive clearing in the past.

Perhaps these efforts have the best chance of ensuring the long-term survival of the reticulated velvet gecko and other species in the region by increasing the area of suitable habitat and by replacing the patches that are now senescing with larger, linked and well-managed on-farm reserves.

Meanwhile, before such programmes start to make substantial progress, let's hope that our native species are able to sweat it out in what remains of the native vegetation.

More about geckos and fragmentation

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