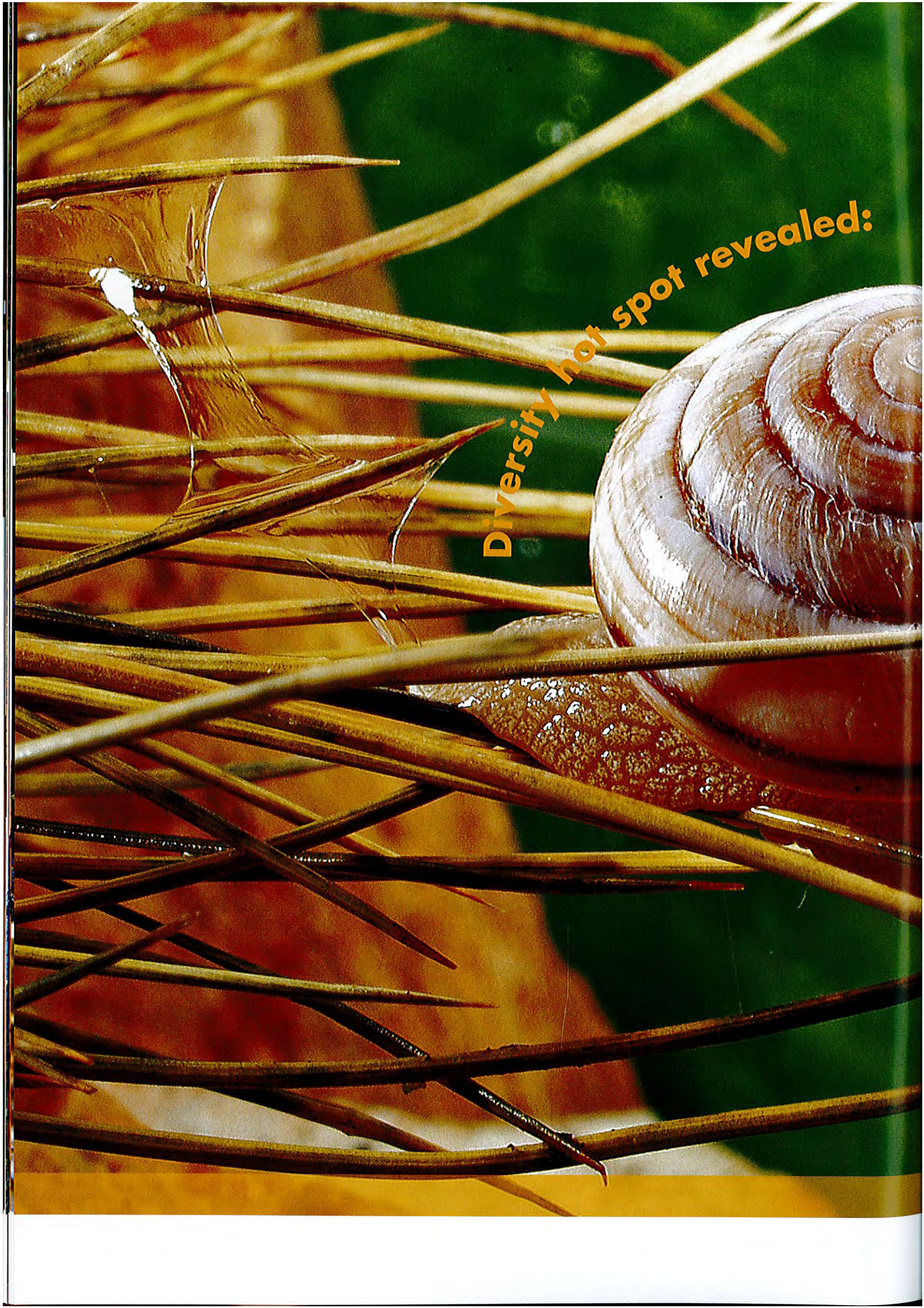
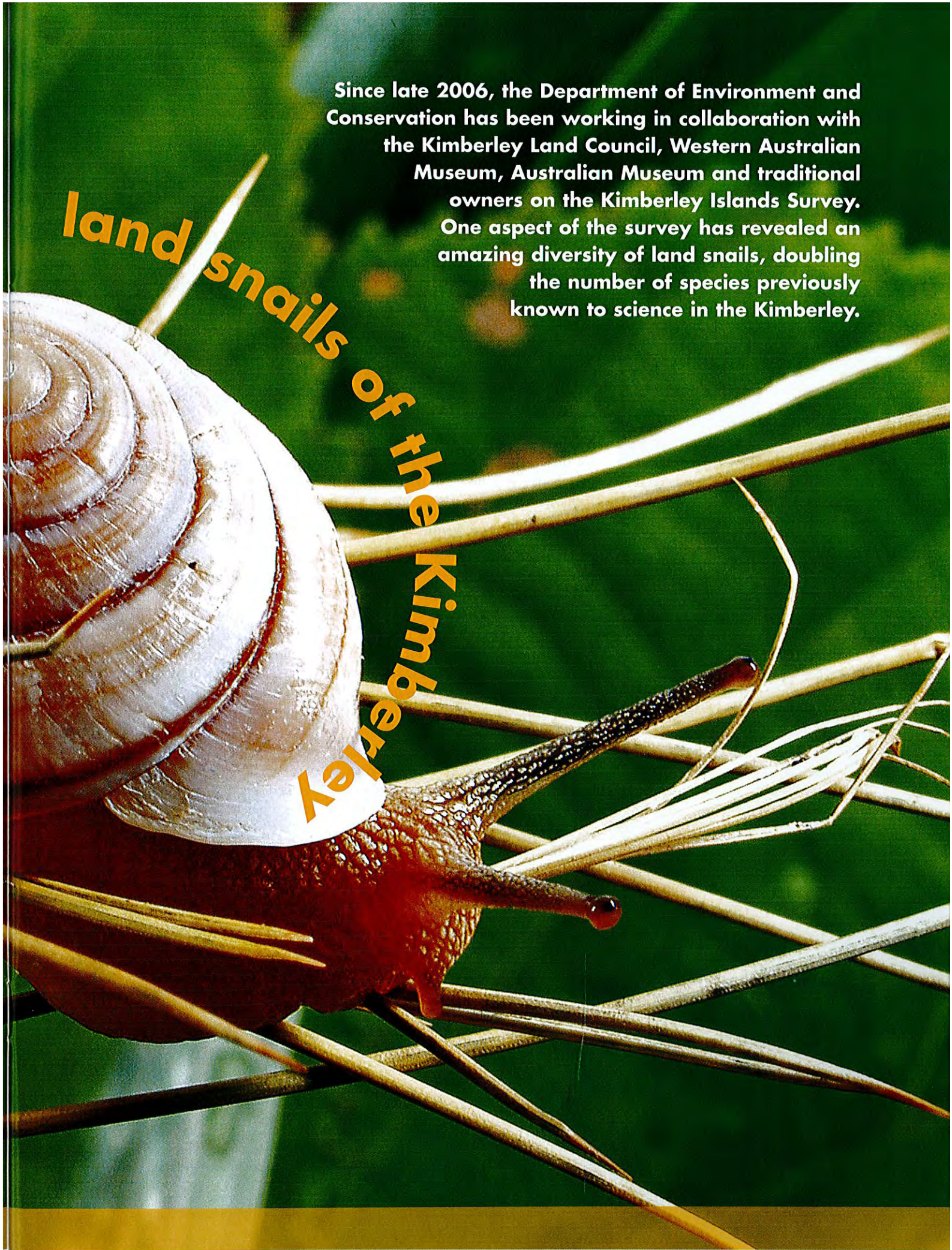


Diversity hot spot revealed:

land snails of the Kimberley

Since late 2006, the Department of Environment and Conservation has been working in collaboration with the Kimberley Land Council, Western Australian Museum, Australian Museum and traditional owners on the Kimberley Islands Survey. One aspect of the survey has revealed an amazing diversity of land snails, doubling the number of species previously known to science in the Kimberley.



by Lesley Gibson, Frank Köhler and Vince Kessner

The ancient spectacular landscapes of the Kimberley region of Western Australia are unique not only for their rugged beauty, but also for the incredible biodiversity they support. With so much of Australia's biodiversity exposed to various threatening processes, it is hard to believe that the north-west Kimberley has experienced no known plant or animal extinctions to date.

A component of this biodiversity which has received relatively little attention so far is the land snail fauna. Early work in the rainforests of the Kimberley uncovered a large diversity of land snail species, but up until recently, just how extraordinarily diverse this fauna is had not been fully recognised.

The land snail fauna of north-western Australia is dominated by the species of one family, the Camaenidae. Species of this family have developed adaptations that enable them to occupy a range of habitats from tropical rainforests to near deserts. Centres of high diversity appear to be the wetter coastal areas of the northern Kimberley where rainforest patches, including vine thickets, are most common.

Also within this area are extensive archipelagos and island groups which, created by the drowning of an ancient coastline, represent much of the adjacent mainland's geology and vegetation types. During a recent biological survey of a selected number of these islands it was realised that the Kimberley is a diversity hot spot for land snails.

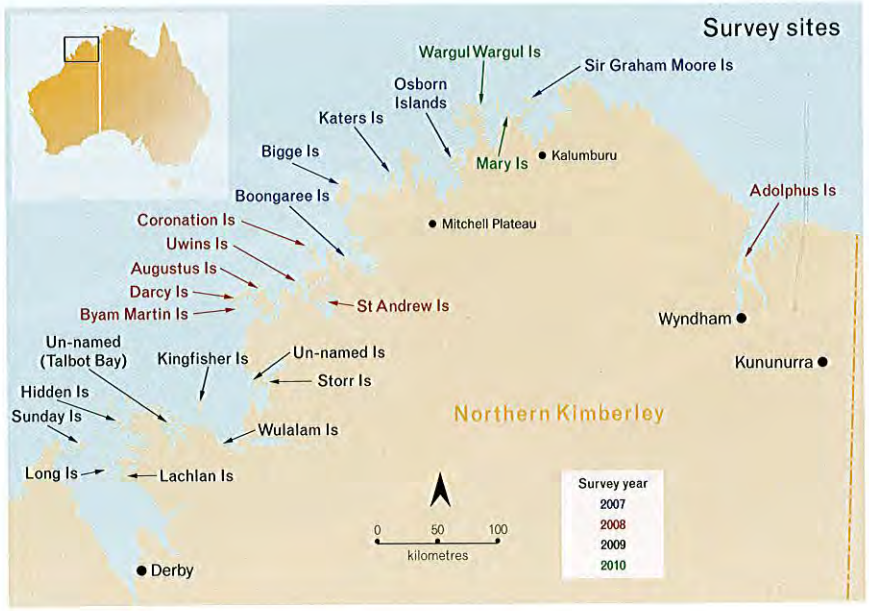
Snails: a target group

Being remote and inaccessible, the Kimberley islands have been largely sheltered from human-related disturbances. However, in recent years, there has been increasing interest in these islands, particularly for tourism, fishing, aquaculture, mining and oil and gas exploration. Information about the distribution of animals with limited mobility and restricted distributions, such as land snails, is crucial to gauge the possible impacts of these activities on a local to regional scale. For this reason, land snails were one of the groups targeted for the biological survey of the islands.

The survey also provided the opportunity to learn more about the diversity of land snails on the islands, as well as contributing to what is already known about the overall diversity of land snails in the Kimberley region in general. Additionally, as the islands are largely protected from mainland disturbances such as fire, pastoralism and introduced species, they have the potential to act as refuges for many species that are impacted by these threats, including the land snails.

The Kimberley Islands Survey has been ongoing since late 2006, and during this period the fauna and flora of 24 of the largest islands have been sampled. Field work for the survey is now complete, with analysis of the data collected well under way.

Selected sites on these islands have been visited twice, once for an extended period in the dry season and again for a shorter visit during the wet season. In collaboration with the Kimberley Land Council and Australian Museum, teams of scientists from the Department of Environment and Conservation and the Western Australian Museum have been conducting the surveys, in conjunction with traditional owners from the Balanggarra, Uunguu, Dambimangari, Mayala and Bardi-Jawi peoples.



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Main A newly discovered species of *Rhagada* collected from Byam Martin Island.

Above A newly discovered species of *Kimboraga*.
Photos – Vince Kessner/DEC

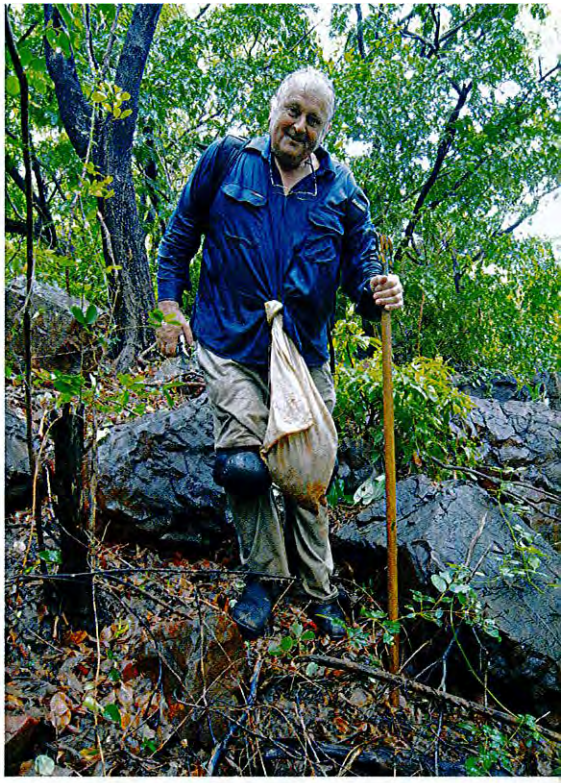
Sampling land snails

Once dropped off by helicopter, the snail collector in the survey team had six days at each site to search for land snails. Densely vegetated areas such as vine thickets are suitable habitat for land snails and so these were usually targeted.

Collecting land snails is an arduous task, particularly in the dry season when the snails are aestivating. This is a form of hibernation carried out during the driest time of the year and snails do this to conserve moisture, burying themselves in the soil or sheltering deep in rock crevices or under rock piles. Many species use calcified mucus to seal their shell to the surface of a rock, log or even to another snail shell. Other species are 'free sealers', meaning that once retreated to their hideaway, they secrete a sheet of mucus across their shell opening. Finding the snails involves raking leaf litter, lifting rocks, digging, searching under logs and examining tree crevices. Litter samples are also collected and later sorted in the laboratory. Some of the smaller species of snails are found this way.

It is usually easier to search for snails in the wet season, although climatic conditions during this period make it less than pleasant. If there has been sufficient rainfall, the snails emerge from their retreats and can be found on trees, moving among the leaf litter, or along rock surfaces. Land snails are active for only a short period of time during the wet season, when feeding, reproduction and growth take place.

Land snails are hermaphrodites, having both male and female reproductive organs. Individuals exchange sperm and their eggs are fertilised internally. Typically, young snails mature as functioning males by their third wet season, with female organs maturing late in the same season. By the fourth wet season the snails function as both males and females. They may live as long as eight years.



Right DEC senior technical officer Vince Kessner collecting land snails in the wet season.
Photo – Mike Lyons/DEC

Below right Kimberley Islands.
Photo – Jiri Lochman

The Kimberley Islands Survey

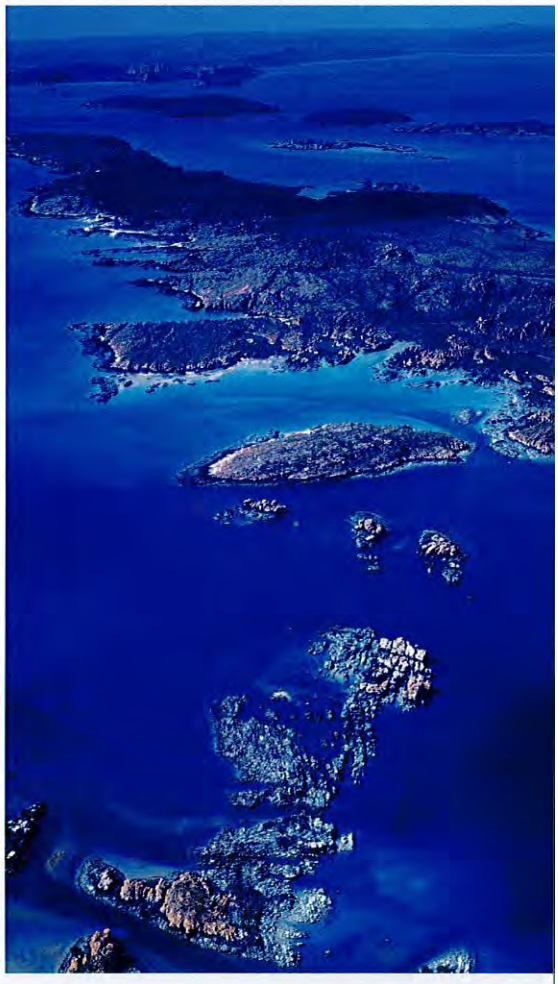
In December 2006, the Department of Environment and Conservation, in collaboration with the Kimberley Land Council, Western Australian Museum and Australian Museum, started preparations for a biological survey of the remarkable islands of the Kimberley (see 'Treasures of a sunken coastline', *LANDSCOPE*, Winter 2008).

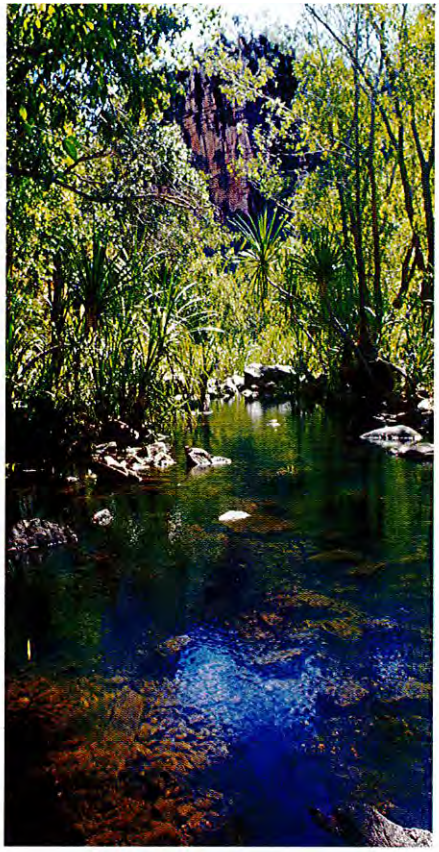
While there was information on plant and animals for some islands, most previous studies had been opportunistic or focused on particular types of species. The survey aimed to expand knowledge of six ecologically and biogeographically different components of biodiversity across the variety of islands present. The survey focuses on mammals, reptiles, frogs, birds, plants and land snails, groups considered highly susceptible to threatening processes affecting the mainland.

The project was jointly funded by the Western Australian and Australian governments, with three dry season (winter) and wet season (summer) surveys planned over three years.

There are hundreds of islands along the Kimberley coast, with 155 of them bigger than 100 hectares, 22 of more than 1,000 hectares and nine exceeding 2,500 hectares (two of which are nearly 20,000 hectares). While most of the islands are big enough to support a diversity of plants and animals, only a small subset could be sampled within the project's time frame. As such, 19 of the biggest islands were initially chosen, especially those with a variety of geological surfaces and those at varying distances from the coast (and therefore variable distances from land-based threats). An additional five islands were added to the selection during the survey.

To date, the survey has revealed the presence of additional island populations of many vertebrates, and has more than doubled the species lists from most of the islands visited. Being among the most diverse but least known groups, land snails were expected to add most to the species inventory.





Above Stuck together—a smaller species of land snail sealed to a much larger species.
Photo – Vince Kessner/DEC

Above right Kimberley wetland.
Photo – Marie Lochman

What species is that?

There are various ways to identify land snail species. Some species can be identified by the shape of their shell alone. However, as the shell morphology often reflects ecological adaptations rather than relationships, just using shells may not always be a reliable way to determine species.

A more reliable source of information is the internal anatomy of the animals. Where there are only subtle shell differences between species, they can usually be differentiated by diagnostic features of their reproductive organs. Identifying species in this way is a very time-consuming task as each specimen needs to be dissected, and then organs carefully measured and compared. Sometimes the radula (a ribbon that supports the snail's teeth and is used to scrape food off surfaces) can be used in the identification process.

Species differences can also be detected using modern genetic techniques, sometimes called DNA barcoding. This is usually a very efficient method of separating species that look very similar. However, as this approach can also be subject to errors, it is best complemented by anatomical descriptions.

Interestingly, species found at the same locality (sympatric species) tend to show more obvious differences in their shell shape than species occupying geographically separated habitats (allopatric species). Sympatric species often belong to different genera, with each genus showing unique adaptations with respect to aestivation behaviour, life style, body size or shell shape, indicating that they use distinct ecological niches. In fact, the shape of the shell can give some clues as to the type of substrate snails use. For example, species with flattened shells use mainly horizontal surfaces, while species with tall spired shells tend to use vertical surfaces, and species with globe-shaped shells tend to burrow in soft soil. Shell size can also give some clues about the habitat land snail species use. Larger snails are often found in moister habitats.

Revealing results

Prior to the Kimberley Islands Survey, 185 camaenid land snail species in 23 genera were known from the Kimberley region and immediately adjacent areas. This is the largest known regional diversity of camaenids in Australia. Even more astounding is the fact that all of these species and almost all of the genera are endemic to the region; that is they are found nowhere else.

Generally, the species have very restricted geographic ranges with an average range size on the mainland of well below 20 square kilometres. Some species are even found on only a single rock outcrop, with a range diameter of mere metres.

While the Kimberley Islands Survey is still in progress, 175 species have been identified as a result of the survey, including some that were collected during earlier surveys on the Kimberley mainland. With 142 of these being newly discovered species, the number of known species in the Kimberley has almost doubled as a result of this project.

On the islands, about 90 camaenid species have been identified (72 new species and five new genera) with almost all of them being endemic to their respective island. Up to 12 sympatric species have been recorded on a single island which is exceptional for Australian camaenids and only equalled by some regions in tropical Queensland.

The survey also provided information about non-camaenid snails. So far, the survey has revealed 21 species of non-camaenid snails from both terrestrial (16 species) and freshwater (five species) habitats. Most terrestrial species are widespread and found on a multitude of islands, and all

species found in the current survey were already known from the Kimberley. Fewer species of freshwater snails are likely to be found on the islands due to the scarcity of permanent or semi-permanent freshwater bodies on the surveyed islands. In general, the diversity of non-camaenids is comparatively low, with only 50 species known from the Kimberley. Unlike the camaenid land snails, the geographic distributions of the non-camaenid species are not restricted to the Kimberley, but extend widely to other regions. The tiny size of non-camaenid snails (one to 10 millimetres) probably enables their dispersal by wind, water and birds.

Why so many?

Historical changes in climate are the likely explanation for the amazing diversity of land snails now found in the Kimberley. About five to 10 million years ago, the global climate went through a phase of cooling and drying. As sea levels fell and rainfall decreased, the lush rainforests that covered much of northern Australia at that time contracted into wetter coastal areas, leaving isolated rainforest patches. Favoured by land snails, these habitat patches became refuges for the ancestral populations of today's land snails. Unable to travel the distances between patches, over time new land snail species evolved within each rainforest patch. With the same evolutionary processes occurring within each of these patches, the end result is a suite of species assemblages that are unique to each patch.

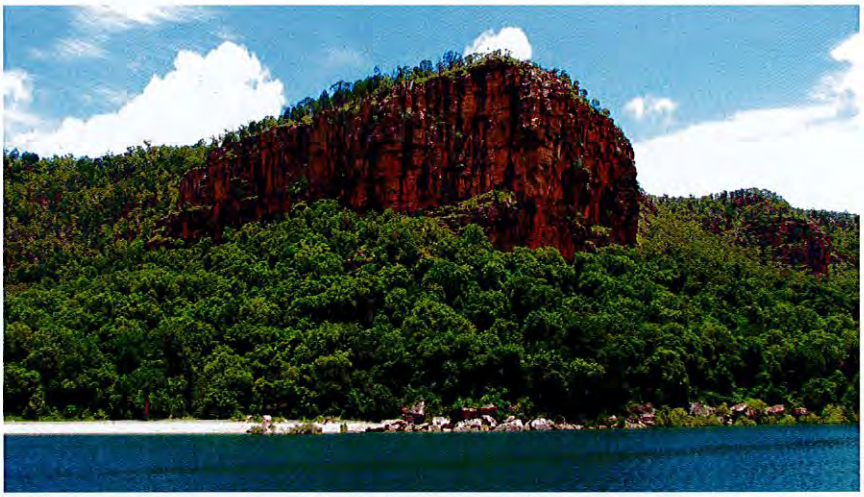
Diversity hot spot

Through the survey of just a small number of islands and selected areas on the mainland, there has been a substantial increase in knowledge about the diversity of land snails in the Kimberley. This suggests that the number of undiscovered species in the Kimberley is likely to be considerable. There are still a significant number of unsurveyed islands and other equally inaccessible areas on the Kimberley mainland. Current evidence suggests that at least 600 endemic camaenid land snail species may exist in the region, making the Kimberley a hot spot of diversity and endemism for this group—certainly in Australia and perhaps even on a global scale.

Right A newly discovered species of *Amplirhagada*.
Photo – Vince Kessner/DEC

Below Vine thickets at the base of a cliff wall.
Photo – Lesley Gibson/DEC

Bottom A newly discovered species of *Torresitrachia* collected from Boongaree Island.
Photo – Vince Kessner/DEC



Lesley Gibson is a senior research scientist at the Department of Environment and Conservation (DEC) and is the Kimberley Islands Survey project coordinator. Lesley is based at DEC's Wildlife Research Centre in Woodvale. She can be contacted on (08) 9405 5152 or by email (lesley.gibson@dec.wa.gov.au).

Frank Köhler is a malacologist (a zoologist specialising in the study of molluscs) and a DEC senior research scientist based at the Australian Museum in Sydney, where he is also a research associate. He can be contacted on (02) 9320 6382 or by email (frank.koehler@austmus.gov.au).

Vince Kessner is a DEC senior technical officer based at Adelaide River in the Northern Territory. He can be contacted on (08) 8976 7237 or by email (vincekess@bigpond.com).

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