

Habitat characteristics of jewelled gecko (*Naultinus gemmeus*) sites in dry parts of Otago

Tony Jewell and Shirley McQueen

DOC RESEARCH & DEVELOPMENT SERIES 286

Published by
Science & Technical Publishing
Department of Conservation
PO Box 10420, The Terrace
Wellington 6143, New Zealand

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.

Individual contributions to the series are first released on the departmental website in pdf form.

Hardcopy is printed, bound, and distributed at regular intervals. Titles are also listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Science & technical*.

© Copyright November 2007, New Zealand Department of Conservation

ISSN 1176-8886 (hardcopy)

ISSN 1177-9306 (web PDF)

ISBN 978-0-478-14334-8 (hardcopy)

ISBN 978-0-478-14335-5 (web PDF)

This is a client report commissioned by Otago Conservancy and funded from the Science Advice Fund. It was prepared for publication by Science & Technical Publishing; editing and layout by Amanda Todd. Publication was approved by the Chief Scientist (Research, Development & Improvement Division), Department of Conservation, Wellington, New Zealand.

In the interest of forest conservation, we support paperless electronic publishing. When printing, recycled paper is used wherever possible.

CONTENTS

Abstract	5
1. Introduction	6
2. Methods	7
3. Results	9
4. Discussion	10
5. Conclusions and recommendations	14
6. Acknowledgements	15
7. References	16
Appendix 1	
Search effort, site visit details and characteristics of the nine sites visited	18

Habitat characteristics of jewelled gecko (*Naultinus gemmeus*) sites in dry parts of Otago

Tony Jewell¹ and Shirley McQueen²

¹ Glenvale Orchard, 216 Ripponvale Road, RD 2, Cromwell 9384, New Zealand

² Department of Conservation, PO Box 5244, Dunedin 9058, New Zealand
Email: smcqueen@doc.govt.nz

ABSTRACT

The jewelled gecko (*Naultinus gemmeus*) may be close to extinction in Central Otago due to habitat removal and modification by post-settlement fire and pastoralism. This study aimed to characterise the habitat of sites in dry parts of Central Otago where jewelled geckos still exist and assess how habitat has changed at sites where the species is no longer present. This species is likely to have once been widespread across Central Otago, when native woody vegetation was present at most mid- to low-altitude sites. However, only two widely separated populations are now known, both at the edges of the Central Otago area. In this study, sites in dry parts of Central Otago where jewelled geckos have previously been reported were surveyed and habitat features were recorded during summer 2006–07. It was found that the distribution of jewelled geckos in Central Otago appears to be determined by the presence of refugia from historic fires and extreme low temperatures in rocks or vegetation; persistence of diverse, woody, native vegetation; and site aspect and altitude. No jewelled geckos were observed during this study. Although this was probably largely due to the cryptic nature of this species and the short survey duration, some sites were extremely degraded and suitable habitat has been removed or severely modified over most of the area. Determining where jewelled geckos have persisted in dry parts of Otago, and the characterisation of the habitat both at these sites and at sites where the species is no longer found will help to guide drylands restoration, the prioritisation of sites for protection and the reintroduction of native species.

Keywords: jewelled gecko, *Naultinus gemmeus*, Otago drylands, woody vegetation

© November 2007, New Zealand Department of Conservation. This paper may be cited as: Jewell, T.; McQueen, S. 2007: Habitat characteristics of jewelled gecko (*Naultinus gemmeus*) sites in dry parts of Otago. *DOC Research & Development Series 286*. Department of Conservation, Wellington. 19p.

1. Introduction

The jewelled gecko (*Naultinus gemmeus*) (McCann, 1955) is a diurnal, arboreal gecko that is found only in the southeast of the South Island, New Zealand. It has been given a threat status of 'gradual decline' by the Department of Conservation (DOC) (Hitchmough et al. 2007), and is considered vulnerable because its range has become fragmented through loss of forest and shrubland habitat. It has strongholds at Banks Peninsula, inland Canterbury and Otago Peninsula (Whitaker et al. 2002), and additional populations at isolated sites at Hakataramea (South Canterbury), Waianakarua (North Otago) and Te Anau (Southland). Further sightings of individual animals have been reported from widely separated locations, including Nugget Point, Oturehua, Lammerlaw Stream, Hunter Valley, Paradise and Lake Wakatipu (records obtained from the DOC herpetofauna database). However, many of these reports, including those at dry inland sites in Otago, are now decades old and have not been reconfirmed since then. Population density assessments have only been conducted at some coastal sites (Shaw 1994; Schneyer 2001), and little is known about recruitment at any site. There is a need to ensure that populations are secure over the full geographic range (DOC & MfE 2000).

Jewelled geckos are a component of the relict drylands ecosystem fauna in Otago (see Rogers et al. (2005) for definition of drylands). Forest and woodland was once widespread in the drier parts of Otago. However, indigenous ecosystems in the dry zones east of the Southern Alps have been considerably modified by periodic fires since the arrival of humans c. 750 yBP, and agricultural practices following the arrival of Europeans (Rogers et al. 2005), so that all that now remains of indigenous woody vegetation in this region is isolated areas of shrubland (Walker et al. 2003; 2004a, b), very little of which is legally protected (Walker et al. 2006; Rogers et al. 2005).

The fossil record for birds suggests that the avian fauna of pre-settlement drylands was very diverse, but has been reduced catastrophically, with local and national extinctions of many functionally significant species (Worthy & Holdaway 2002). Distribution data for grand (*Oligosoma grande*) and Otago (*O. otagense*) skinks indicates that these once widespread species have suffered over 90% reduction in range (Whitaker & Loh 1995; Whitaker et al. 2002; Berry & Gleeson 2005). Equivalent information is limited for jewelled geckos, but distribution records, together with evidence that most of Otago was once covered in forest or woodland (Walker et al. 2003), suggest that in pre-settlement times jewelled geckos would have been widely dispersed across Central Otago, and the species may have suffered similar declines to grand and Otago skinks. Lizards would have been important functional components of pre-settlement dryland ecosystems, as fruit- and nectar-eating lizards can be significant pollinators and dispersers of seed for many trees and shrubs (Whitaker 1987; Lord & Marshall 2001).

Some dryland sites have the potential to succeed back to a state where tall, native, woody plants dominate, provided that burning is prevented,

browsing and grazing are discontinued, ambient seed sources are present, and dominance of exotic grass swards is disrupted through shading by the woody plant community (Wells 1972; Walker et al. 2004b; 2005). However, the time frames required may be long and plant diversity may be restricted to those species that have local seed sources and are able to successfully establish under the prevailing conditions at a particular site. Where depleted soils and lack of native seed sources preclude spontaneous succession, intervention will be required, and this is the focus of ongoing research (Walker et al. 2005). It is increasingly recognised that modified areas, previously regarded as having little value for conservation, are important for maintaining and restoring biodiversity (Rogers et al. 2005), especially where habitat is fragmented and scarce. A wider range of dryland biodiversity may be protected by focusing on the conservation requirements of the more vulnerable components. Some areas that now offer suitable habitat may have had populations of jewelled geckos in the past but lost these during fires. If suitable fire refugia for the geckos are absent and the site is geographically isolated from other populations, this loss may be permanent.

The purpose of this research was to establish where jewelled geckos have persisted in dry parts of Otago, characterise the habitat at these sites, and assess how habitat has changed at sites where the species is no longer present. This information will be useful in guiding drylands restoration, the prioritisation of sites for protection and the reintroduction of species. This could also assist in the conservation of other threatened species, such as grand and Otago skinks.

2. Methods

The DOC herpetofauna database was searched for sites at which *N. gemmeus* had previously been reported in Otago. Five sites that were located in and bordering dry areas of Otago and an additional four sites that were not listed in the database, but appeared to have suitable habitat, were visited during November 2006–February 2007 (Table 1; Fig. 1). Some sites listed in the database were not surveyed, mainly because of their highly modified state and/or difficulties with access. At each site, vegetation was surveyed by scanning from a distance with binoculars, followed by close inspection. A qualitative assessment of habitat (vegetation, altitude, rock formations) was also carried out. Details of site visits are provided in Appendix 1. The results of short surveys such as these should not be regarded as a reliable indication of whether jewelled geckos are present or absent at a site, as *Naultinus* spp. are highly cryptic and their emergence is highly dependent on current and recent weather (R. Hitchmough, DOC, pers. comm.).

TABLE 1. SITES VISITED DURING THIS STUDY.

LOCATION	DATE OF REPORT	STATUS OF SITE
Timber Gully, Lammerlaw Stream catchment	2005*	Lammerlaw Stream Covenant
Fiddlers Creek, 25 m upstream from Devils Creek	Apr 2005*	Te Papanui Conservation Park
Little Kyeburn, Mt Buster, Ida Range	28 Dec 2005*	Pastoral Lease
Rough Ridge, south of Oturehua	1985	Private land
Beaumont, Central Otago	1 Mar 1997	Private land
Clutha River/Mata-Au—Island Block, Beaumont	NA	Conservation Stewardship Area
Falls Dam	NA	Private land and road reserve
Shepherds Creek	NA	Pastoral Lease
Locharburn Scenic Reserve	NA	Conservation area

* Reliable record.

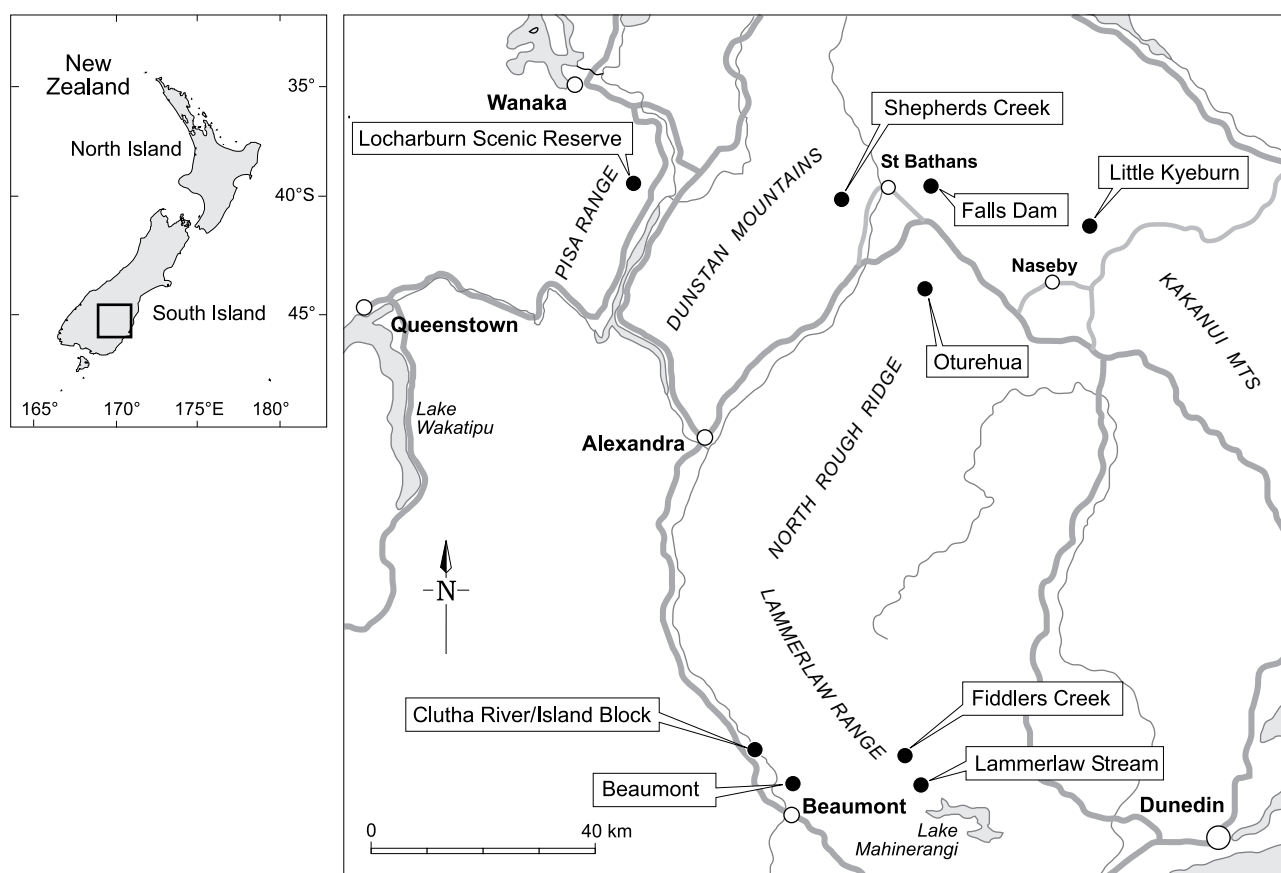


Figure 1. Location of sites visited during this study.

3. Results

At all sites visited there was evidence of extensive burning of vegetation in the past, and some sites may have lost all woody vegetation at times. The two Beaumont sites and Falls Dam have degraded habitat with only seral (i.e. successional and adjusting to disturbance) woody vegetation, in which jewelled geckos are unlikely to be present. Although it is possible that the Rough Ridge site near Oturehua could support a small population of jewelled geckos, the present vegetation has regenerated in an area where suitable habitat was historically decimated by fire over a wide area; therefore, it is unlikely that this species has persisted at this site. The only report of a jewelled gecko at Rough Ridge is from this site, and it was from the driest part of the area covered by this study; furthermore, this report is not particularly reliable, as the observer was not experienced in surveying for this species and there are no photographs of the lizard.

Jewelled geckos may be present at the other sites surveyed, where there is evidence of vegetation having survived fires (mature beech (*Nothofagus* spp.) or Hall's totara (*Podocarpus hallii*)) in boulder fields or on bluffs, which would also have provided refugia from fire for lizards such as jewelled geckos. Little Kyeburn and Lammerlaw Stream catchments are highly likely to support populations of jewelled geckos, especially since individuals of this species have been reliably reported from there in recent years. At Little Kyeburn, the extent of habitat and the diversity of fauna and flora (Appendix 1) suggest that the population could be large. Jewelled geckos have not been reported from Shepherds Creek (Dunstan Mountains) or Locharburn Scenic Reserve (Pisa Range), but both have good habitat that might support a population, fire refugia for plants and lizards in rock outcrops and boulder fields, and fire-sensitive plants such as Hall's totara. At Locharburn, a lizard was detected (by the characteristic rustling of vegetation as it fled) in the canopy foliage of a kanuka (*Kunzea ericoides*) shrub, about 1 m above the ground. However, although this is consistent with jewelled gecko behaviour, it is also typical of several species of skink, including *O. maccanni*, which is known to be present at the site.

At Little Kyeburn and Lammerlaw stream catchments, where jewelled geckos are known to be present, the aspect is south facing in the general area but east facing in the more immediate area of habitat, with sunny basking sites available. The Oturehua site has a westerly aspect and plentiful good basking sites. The site where a jewelled gecko had been reported from at Beaumont was on the south-facing bank of the Clutha River/Mata-Au; however, this is very open to sun. All sites visited were within stream or river catchments.

At all sites where jewelled geckos are known to be present or have been reported from, basement rock is Haast schist of higher (at Oturehua and Lammerlaw Stream) or lower (at Beaumont and Little Kyeburn) grade (Bishop & Turnbull 1996; Turnbull 2000; Forsyth 2001), outcropping as bluffs and blocky boulderfields. These rock formations often provide plentiful crevices suitable for lizard retreats.

The highest site visited was Fiddlers Creek (Lammerlaw Range), at an altitude of 840 m.a.s.l. The highest site visited where jewelled geckos are known to persist is Little Kyeburn stream catchment (800 m.a.s.l.).

No jewelled geckos were found during surveys of the nine sites, and nor were there any other indications of their presence (e.g. sloughed skins). This can be partly explained by the relatively short duration of survey at each site and the time of survey (afternoon rather than morning). However, weather conditions were suitable (dry and warm) on most days (Duggan 1991), and the Shepherds Creek site was searched immediately after mist had dispersed at midday, which should have been ideal for detecting basking lizards. The lack of common species of skink at Shepherds Creek is difficult to explain, especially as a population of green skinks (*O. chloronoton*) is known from a location c. 1 km upstream and unidentified geckos belonging to the nocturnal *Hoplodactylus maculatus* complex were found at this site (Appendix 1).

4. Discussion

Historical fire refugia may have been important determinants of the present-day distribution of *N. gemmeus*. In Central Otago, dry climatic conditions promote hotter burning and more extensive and destructive fires, and reduce the rate of regeneration of woody vegetation. Populations of jewelled geckos would not be expected to have persisted at sites where all woody vegetation was destroyed by historic fire, due to a lack of food resources, shelter from climatic extremes, and cover in which to hide from predators during the time between extreme fire events and regeneration of significant shrublands. The two sites where jewelled geckos are known to have persisted that are in, or close to, dry parts of Otago (Little Kyeburn and Lammerlaw Stream) are notable for the presence of rock bluffs, boulderfields and deeply incised gullies, which have provided refugia for fire-sensitive vegetation such as Hall's totara. Remnant Hall's totara on the Pisa Range, Central Otago, may be centuries old (Wells 1972). Where this species has survived historic fires, it is likely that there has always been some woody vegetation present, as well as rock crevices, which would provide necessary shelter, cover and probably food resources for lizards. Populations of jewelled geckos are known to be present in the Hunter Valley, northwest Otago, and at Glencoe Station, North Otago. The Hunter Valley site has not been subjected to extensive fires for centuries (Wardle 2001a, b), and the Glencoe Station area is adjacent to North Waianakarua River covenant, a remnant of mature podocarp forest that is unlikely to have been burnt for perhaps hundreds of years, which may have provided a refuge for many plant and animal species from fires in the surrounding area.

The diversity of native flora may also be important in determining the distribution of jewelled gecko populations. The understoreys of forests and diverse shrublands are likely to provide fruits, pollen and nectar, and support a high diversity of invertebrates (Derraik et al. 2001), all of which

are important food sources for lizards. Where the understorey is being systematically removed by grazing, there will be little or no regeneration of woody vegetation. There is a high diversity of indigenous plants and animals at both Little Kyeburn and Lammerlaw Stream, with many shrubs that produce fruits palatable to geckos (and birds), and lianes (*Muehlenbeckia* spp. and *Rubus* spp.) that can provide cover for many invertebrates (Appendix 1). The jewelled gecko populations at Hunter Valley, in northwest Otago, and Glencoe Station, in north coastal Otago, have access to diverse indigenous vegetation. At the Hunter Valley site where jewelled geckos have been seen, the vegetation is mainly forest of co-dominant silver (*N. menziesii*) and mountain (*N. solandri*) beech (Wardle 2001a) with a complex sub-canopy and edge of native plants (J. Fleming, Wanaka Area Office, DOC, pers. comm.). At Glencoe Station, steep slopes above the Waianakarua River (north branch) are dissected by gullies with bluffs, in which small forest remnants remain. Dominant plants here are kowhai (*Sophora microphylla*), broadleaf (*Griselinia littoralis*) and cabbage tree (*Cordyline australis*), but also common are lancewood (*Pseudopanax crassifolius*), marbleleaf (*Carpodetus serratus*), wineberry (*Aristotelia serrata*) and *Fuchsia excorticata*. Extensive kanuka-dominated woodland covers the slopes between gullies. Fruiting shrubs on bluffs and boulder fields include *Pentachondra pumila*, *Leucopogon fraseri* and *Gaultheria crassa*.

Refugia from extreme low temperatures may be important for jewelled geckos to survive winters in Central Otago and inland Canterbury. Inland sites regularly experience more extreme temperatures and much drier conditions than the coast. Although remnant mature forest trees (beech and Hall's totara) may be associated with the persistence of jewelled geckos because they provided historic fire refugia, they may also provide refugia from the cold, as the canopy traps relatively warm air. Shrubland alone is unlikely to provide this unless it is unusually dense. Additional refugia may be provided by rock crevices in bluffs and screes. Reports of jewelled geckos in the Aoraki/Mt Cook area, Canterbury, come from sites near remnant beech forest and creviced rock. At all sites in Central Otago where jewelled geckos are present or have been reported from, the rock type is Haast schist, with outcrops and boulderfields that could provide refugia from fire and cold, as well as predators.

Aspect and altitude may also contribute to jewelled gecko distribution. All lizards need suitably warm basking sites to arouse from torpor and become active (Heatwole 1976; Stebbins 2003). A cold, shady site in a deep gully is not likely to provide this requirement. At both Little Kyeburn and Lammerlaw Stream sites, although the wider area is south facing, locally sunny aspects are readily available because slopes are variable at smaller scales. Jewelled geckos may have persisted at these sites because vegetation on cooler, wetter, south-facing hill slopes and damp vegetation in shady gullies is generally less susceptible to damage from hot-burning fires. This may also explain the proximity of jewelled gecko sites to stream catchments.

Altitude may limit jewelled gecko distribution, as they are unlikely to live permanently above the natural limit for tall woody vegetation. Walker et al. (2003) described pre-settlement vegetation between 1000 m and 1340 m a.s.l.

as being characterised by bog pine (*Halocarpus bidwillii*), mountain toatoa (*Phyllocladus alpinus*) and snow totara (*Podocarpus nivalis*), which once grew to at least 1300 m.a.s.l. in Central Otago. Although it is not known whether jewelled geckos lived in this vegetation, the record of a jewelled gecko from Fiddlers Creek at 840 m.a.s.l. is evidence that they do visit sites above 800 m.a.s.l., although the vegetation there now (predominantly tussock grassland) is unlikely to support a population. Lammerlaw Stream catchment (780 m.a.s.l.) and Little Kyeburn (800 m.a.s.l.) are the highest sites that appear to currently support populations of jewelled geckos.

The impacts of introduced predatory mammals and birds on jewelled geckos are difficult to assess, and are probably site specific and related to the availability of cover provided by vegetation and rock outcrops. Jewelled gecko populations have persisted at Banks and Otago Peninsulas, where they have been exposed over a long period of time to a range of introduced avian and mammalian predators (including rodents (*Mus musculus* and *Rattus* spp.), mustelids (*Mustela* spp.), brushtail possums (*Trichosurus vulpecula*) and cats (*Felis catus*)) (King 1990). Divaricating shrubs and dense lianes are likely to provide protective cover for arboreal species, making them less vulnerable to predation than lizard species that spend more time on the ground. However, if their habitat is fragmented, jewelled geckos may have to travel at ground level between patches, and the composition and structure of vegetation between patches could influence vulnerability to predation. At both Little Kyeburn and Lammerlaw Stream, tussock grasses, ferns and low shrubs provide complete ground cover between patches of taller vegetation, which may reduce predation risk to lizards on the ground, although this will not be as effective where the cover is patchy or sparse. A complicating factor is that ground cover such as rank exotic grass, when seeding abundantly, may enhance rodent populations, leading to increased cat and mustelid densities (Ratz 2000). Although predator guild dynamics in forest may be different from those in seral vegetation, impacts of predators on jewelled geckos in forest will remain unknown until better detection methods for geckos are developed.

The known distribution and reported observations of jewelled geckos from the last 40 years, together with evidence of historic dominance of woody vegetation in most mid- to low-altitude parts of Central Otago (Walker et al. 2003), suggest that this species was once widespread across Otago. Most reports of jewelled geckos are from chance observations. The small number of records from Central Otago is probably partly due to a lack of focused survey effort, and partly due to the loss of suitable habitat from much of the area as a result of historic fires. Past surveys, such as those carried out by the New Zealand Wildlife Service between 1984 and 1989, focused on large skinks (grand, Otago and scree (*O. waimatense*)) and noted common lizards, but did not specifically conduct searches for jewelled geckos. Since the latter tend to use different habitats from these saxicolous (rock-dwelling) skinks, their detection was unlikely during these surveys; in fact, the only report of a jewelled gecko (near Oturehua) in the publications from these surveys was not made by a member of the survey team (Whitaker 1986). Although no jewelled geckos were observed during this study, there is uncertainty when interpreting negative search results, as not

only can this species be very difficult to detect (Duggan 1991), particularly in tall and dense vegetation, but jewelled geckos are also likely to vary dramatically in abundance levels between sites, as has been found in lowland *Coprosma* shrublands on Otago Peninsula (Shaw 1994). There are areas in coastal Otago where extensive, apparently suitable habitat remains, but where jewelled geckos have not been found. For example, it is difficult to explain why jewelled geckos persist at Lammerlaw Stream but have not been reported from Waipori Gorge Scenic Reserve, c. 30 km to the southeast, which is a legally protected, warmer site at lower altitude, with far more extensive shrublands and mixed beech/podocarp forest. It is possible that geckos live in forest canopy at this site and have not been detected due to a lack of appropriate survey techniques and effort.

The potential for reinvasion by *N. gemmeus* into patches of seral woody vegetation would depend on a population surviving at adjoining sites and the woody plant community becoming diverse enough to support jewelled geckos. In Central Otago, the presence of refugia from cold may also be necessary. Coastal forests and shrublands on Otago and Banks Peninsulas have been burnt, grazed and browsed over a long period of time, yet populations of jewelled geckos persist here (Johnson 1982), indicating that patches of suitable habitat must have always been present. Jewelled geckos have reinvaded sites over time, as shrublands regenerated. In the Beaumont area, for example, jewelled geckos may still be present in Bowlers Creek and Beaumont River gorge; the absence of jewelled gecko reports may simply be due to lack of survey effort. Regeneration of woody vegetation in the wider Beaumont area would enable any jewelled geckos present to expand their range. Where there are large distances between patches, translocation of animals may be necessary in the long term, to preserve the allelic diversity of populations (Berry et al. 2005).

5. Conclusions and recommendations

Site characteristics that are considered to have contributed to the persistence of jewelled geckos in Central Otago include refugia from historic fires (boulder fields and bluffs); persistence over time of diverse, woody vegetation, providing food resources; dense and/or tall vegetation and rocks, providing protection from predators; and warm basking sites and refugia from extreme cold during winter. Further investigation is required into the use of winter refugia by inland jewelled gecko populations in order to survive extreme cold. The main threats to their habitat are grazing, browsing, burning and herbicidal spraying of vegetation; the exclusion of grazing animals is critical to ensure the survival of forest remnants (Johnson 1982).

Since jewelled geckos have low detectability, improved detection methods are required to better understand their survival and distribution. Examples may include recording ultrasound vocalisation, and using artificial cover objects or tracking tunnels located in vegetation rather than on the ground.

The morphological variation of jewelled geckos should be investigated over their entire range. Despite the close genetic similarity of the three populations sampled so far, each differs in a number of features, including mouth colour, foot pad colour and the presence or absence of sexual colour dimorphism. These differences may indicate evolutionarily significant units that should be managed separately from each other (R. Hitchmough, DOC, pers. comm.).

Research into the impacts of low temperature on the survival of neonates, and the annual reproductive cycle of inland populations of jewelled geckos could enhance our understanding of their ecological requirements. Wilson & Cree (2003) found that female jewelled geckos on Otago Peninsula gave birth to young in late autumn, which may be unique in lizards from the cool-temperate zone. How birth in this season affects neonate survival during winter requires further investigation. They also found that female *H. maculatus* in a cool climate gave birth biennially, whereas females from populations in warmer parts of New Zealand had an annual reproductive cycle. Similarly, jewelled gecko populations in colder parts of Canterbury and Otago may have a different reproductive cycle from those in milder areas such as Banks and Otago Peninsulas.

The conservation status of the jewelled gecko in Otago is in urgent need of revision. Previous assessments may have been unduly optimistic and not based on sound data, giving a false impression of distribution and the availability of suitable habitat. Whitaker et al. (2002) considered that the species was 'widely distributed', 'able to occupy seral habitats such as regenerating manuka and kanuka', 'present at a number of protected sites', had 'relatively high population densities at some sites in Otago Peninsula' and that 'large areas of habitat remain'. In Central Otago, jewelled geckos are 'widely distributed' in the sense that there are great distances between few populations, the area of suitable habitat is not large, and jewelled geckos may

not be able to survive in seral vegetation in climatic extremes. Habitats vary dramatically in history, climate, ecology, exotic species diversity/abundance and land management. We do not know which combination of features the jewelled gecko requires. There are many examples of seral shrubland habitat that is adjacent to permanent refugia in which jewelled geckos have never been detected; thus it may be that they can only occupy a limited variety of shrubland types.

In all populations, the recruitment of neonates should be monitored. It is likely that the jewelled gecko is a long-lived species, with low reproductive rates (Cree 1994). Some members of the New Zealand nocturnal gecko genus *Hoplodactylus*, which are the closest relatives of *Naultinus* geckos, have extreme longevity, e.g. up to 42 years in *H. maculatus* aff. *maculatus* 'Canterbury' (Lettinck & Whitaker 2006). Without adequate levels of recruitment, populations may appear to be stable, but rapidly become extinct when aged adults die.

The jewelled gecko may be close to total extinction in Central Otago. Very few populations are known to persist, and none are known to be present at any protected sites. Extinction over the majority of the species' natural range in Central Otago, where suitable habitat has been severely modified or completely removed, has probably already occurred. Furthermore, population trends, natural history and primary threats are uncertain. Suitable habitat at Otago Peninsula is patchy and does not cover a large area, and the population there has undergone serious decline over the last decade (Schneyer 2001). While large areas of apparently suitable habitat remain in coastal Otago (e.g. Catlins forest and Waipori Gorge), there are no records of jewelled geckos being found there. Therefore, extensive survey should be carried out to confirm presence rather than assume this.

6. Acknowledgements

We thank Carol and Nic McKenzie, Graham Thomas, and Peter and Sarah Shaw for permission and assistance with access to their properties; Alison Cree, Rod Hitchmough, John Barkla, Trudy Anderson, Marieke Lettinck and Mandy Tocher for reviewing the manuscript; and all the many other people who assisted with this project.

7. References

- Berry, O.; Gleeson, D.M. 2005: Distinguishing historical fragmentation from a recent population decline: shrinking or pre-shrunk skink from New Zealand? *Biological Conservation* 123: 197-210.
- Berry, O.; Tocher, M.D.; Gleeson, D.M.; Sarre, S.D. 2005: Effect of vegetation matrix on animal dispersal: genetic evidence from a study of endangered skinks. *Conservation Biology* 19(3): 855-863.
- Bishop, D.G.; Turnbull, I.M. 1996: Geology of the Dunedin area. Institute of Geological and Nuclear Sciences 1:250000 geological map 21. Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand.
- Cree, A. 1994: Low annual reproductive output in female reptiles in New Zealand. *New Zealand Journal of Zoology* 21: 351-372.
- Derraik, J.G.B.; Barratt, B.I.P.; Sirvid, P.; Macfarlane, R.P.; Patrick, B.H.; Early, J.; Eyles, A.C.; Johns, P.M.; Fraser, P.M.; Barker, G.M.; Henderson, R.; Dale, P.J.; Harvey, M.S.; Fenwick, G.; McLelland, I.D.; Dickinson, K.M.J.; Closs, G.P. 2001: Invertebrate survey of a modified native shrubland, Brookdale Covenant, Rock and Pillar Range, Otago, New Zealand. *New Zealand Journal of Zoology* 28: 273-290.
- DOC (Department of Conservation); MfE (Ministry for the Environment) 2000: The New Zealand Biodiversity Strategy: our chance to turn the tide. Wellington, New Zealand. 146 p.
- Duggan, L. 1991: Emergence behaviour of *Naultinus gemmeus*, the jewelled gecko, on Otago Peninsula. *University of Otago Wildlife Management Report No. 14*. 41 p.
- Forsyth, P.J. 2001: Geology of the Waitaki Area. Institute of Geological and Nuclear Sciences 1:250000 geological map 19. Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand.
- Heatwole, H. 1976: Reptile ecology. University of Queensland Press, Queensland, Australia. 178 p.
- Hitchmough, R.; Bull, L.; Cromarty, P. 2007: New Zealand threat classification system lists—2005. Department of Conservation, Wellington, New Zealand. 194 p.
- Johnson, P.N. 1982: Forest and scrub vegetation on Otago Peninsula. Botany Division, Department of Scientific and Industrial Research, Dunedin, New Zealand (unpublished). 50 p.
- King, C.M. 1990: The handbook of New Zealand mammals. Oxford University Press, Auckland, New Zealand. 600 p.
- Leathwick, J.; Wilson, G.; Rutledge, D.; Wardle, P.; Morgan, F.; Johnston, K.; McLeod, M.; Kirkpatrick, R. 2003: Land environments of New Zealand—Nga Taiao o Aotearoa. David Bateman, Auckland, New Zealand. 160 p.
- Lettinck, M.; Whitaker, T. 2006: *Hoplodactylus maculatus* (common gecko). Longevity. *Herpetological Review* 37: 223-224.
- Lord, J.M.; Marshall, J. 2001: Correlations between growth form, habitat and fruit colour in the New Zealand flora, with reference to frugivory by lizards. *New Zealand Journal of Botany* 39: 567-576.
- Ratz, H. 2000: Movements by stoats (*Mustela erminia*) and ferrets (*M. furo*) through rank grass of yellow eyed penguin (*Megadyptes antipodes*) breeding areas. *New Zealand Journal of Zoology* 27: 57-69.
- Rogers, G.; Walker, S.; Lee, W. 2005: The role of disturbance in dryland New Zealand: past and present. *Science for Conservation* 258. Department of Conservation, Wellington, New Zealand. 122 p.

- Schneyer, N. 2001: Effects of avian predation and habitat degradation on the population dynamics of the jewelled gecko (*Nautilinus gemmeus*) from Every Scientific Reserve, Otago Peninsula, New Zealand. Unpublished MSc thesis, University of Otago, Dunedin, New Zealand. 168 p.
- Shaw, T. 1994: Population size, distribution, home range and translocation of the jewelled gecko, *Nautilinus gemmeus*, at the Every Scientific Reserve, Otago Peninsula. *University of Otago Wildlife Management Report No. 56.6*. 75 p.
- Stebbins, R.C. 2003: A field guide to western reptiles and amphibians. Houghton Mifflin Field Guides, Boston, MA, USA. 544 p.
- Turnbull, I.M. 2000: Geology of the Wakatipu Area. Institute of Geological and Nuclear Sciences 1:250000 geological map 18. Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand.
- Walker, S.; Lee, W.G.; Rogers, G.M. 2003: The woody vegetation of Central Otago, New Zealand: its present and past distribution and future restoration needs. *Science for Conservation 226*. Department of Conservation, Wellington, New Zealand. 99 p.
- Walker, S.; Lee, W.G.; Rogers, G.M. 2004a: Pre-settlement woody vegetation of Central Otago, New Zealand. *New Zealand Journal of Botany 42*: 613-646.
- Walker, S.; Lee, W.G.; Rogers, G.M. 2004b: The woody vegetation of Central Otago, New Zealand. *New Zealand Journal of Botany 42*: 589-612.
- Walker, S.; Price, R.; Rutledge, D.; Stephens, R.T.; Lee, W.G. 2006: Recent loss of indigenous cover in New Zealand. *New Zealand Journal of Ecology 30*: 169-177.
- Walker, S.; Rogers, G.; Norbury, G.; Stephens, T.; Lee, W. 2005: Research needs for the conservation of dryland biodiversity—a scoping report. Landcare Research contract report LC0405/150. Department of Conservation, Wellington, New Zealand (unpublished). 56 p.
- Wardle, P. 2001a: Distribution of native forest in the upper Clutha district, Otago, New Zealand. *New Zealand Journal of Botany 39*: 435-446.
- Wardle, P. 2001b: Holocene forest fires in the upper Clutha district, Otago, New Zealand. *New Zealand Journal of Botany 39*: 523-541.
- Wells, J.A. 1972: Ecology of *Podocarpus ballii* in Central Otago, New Zealand. *New Zealand Journal of Botany 10*: 399-426.
- Whitaker, A.H. 1986: A survey of the lizards of the Alexandra area, Otago 2-11 December 1985. Otago 'giant' skink survey #3. New Zealand Wildlife Service, Wellington, New Zealand (unpublished). 24 p.
- Whitaker, A.H. 1987: The roles of lizards in New Zealand plant reproductive strategies. *New Zealand Journal of Botany 25*: 315-328.
- Whitaker, A.H.; Loh, G. 1995: Otago skink and grand skink recovery plan (*Leiopisma otagense* and *L. grande*). *Threatened Species Recovery Plan 14*. Department of Conservation, Wellington, New Zealand. 40 p.
- Whitaker, A.H.; Tocher, M.D.; Blair, T.A. 2002: Conservation of lizards in Otago Conservancy 2002-2007. Department of Conservation, Wellington, New Zealand. 92 p.
- Wilson, J.L.; Cree, A. 2003: Extended gestation with late-autumn births in a cool-climate viviparous gecko from southern New Zealand (Reptilia: *Nautilinus gemmeus*). *Austral Ecology 28*: 339-348.
- Worthy, T.H.; Holdaway, R.N. 2002: The lost world of the moa: prehistoric life of New Zealand. Canterbury Press, Christchurch, New Zealand. 718 p.

Appendix 1

SEARCH EFFORT, SITE VISIT DETAILS AND CHARACTERISTICS OF THE NINE SITES VISITED

LOCATION	DOMINANT VEGETATION	LANDFORM, ASPECT, ROCK TYPE	WOODY BIOME* / LENZ†	SEARCH EFFORT, WEATHER, ANIMAL SPECIES AND COMMENTS
Lammerlaw Stream catchment, Lammerlaw Range	Actively regenerating beech (some mature trees) surrounded by diverse shrublands (manuka, small leaved <i>Coprosma</i> spp., <i>Gaultheria antipoda</i> , <i>Leucopogon colensoi</i> , <i>Muehlenbeckia complexa</i> and <i>Rubus</i> spp.), herbfields and tussock grassland. The site is notable for a very dense ground cover of ferns, herbs and large tussocks. Remnant Hall's totara.	Long, narrow, east-facing gully; tributary of Lammerlaw Stream, which flows south from Lammerlaw Plateau. High-grade Haast schist outcrops as small bluffs and tors along stream banks. Altitude of 780 m.a.s.l.	XII (beech, mountain toatoa, kowhai, manuka) / Q4	Searched for 2–3 h on a hot, still, sunny afternoon. Fire refugia present in beech forest. New Zealand falcon (<i>Falco novaeseelandiae</i>) present. Diverse area within an extremely modified landscape.
Fiddlers Creek, Lammerlaw Range	Extensive tussock grassland, sparse shrubland (<i>Dracophyllum</i> spp. and prostrate <i>Coprosma</i> spp.).	Large schist rock tor beside a stream. Few crevices on the rock tor. Altitude of 840 m.a.s.l.	IX (bog pine, snow totara, mountain toatoa, shrubland) / Q3	Searched < 1 h in the late morning; warm, windy and overcast. Location unlikely to support a population of <i>N. gemmeus</i> .
Little Kyeburn upper catchment, Ida Range	Bluffs and boulderfields. Dense growths of prostrate snow totara (<i>Podocarpus nivalis</i>) and snow totara/Hall's totara hybrids, and <i>Coprosma</i> spp., dense growths of the vines <i>M. complexa</i> and <i>Rubus</i> spp. Shrubs include <i>Gaultheria crassa</i> , <i>Dracophyllum</i> spp., <i>Myrsine nummularia</i> , <i>Olearia odorata</i> , <i>Hebe rakaiensis</i> and <i>Olearia cymbifolia</i> . Extensive shrublands downstream predominantly <i>Discaria toumatou</i> and small leaved coprosma (<i>C. propinqua</i> , <i>C. rugosa</i> , <i>C. species 't'</i>); also include <i>O. bullata</i> , <i>O. odorata</i> , <i>Aristotelia fruticosa</i> , <i>Carmichaelia petriei</i> , <i>Corokia cotoneaster</i> , <i>Rubus schmidelioides</i> , <i>Leucopogon fraseri</i> and <i>Lycopodium fastigiatum</i> .	Extensive boulder fields and scree below bluffs. Rocks are low-grade Haast schist. Easterly aspect. Altitude of 800 m.a.s.l.	VII (beech, Hall's totara, snow totara) / Q2	Searched for 2–3 h on a warm, still, overcast afternoon in January, and on a hot, still sunny afternoon in February. Fire refugia (boulder fields/scree). Diverse fauna: mountain tree weta (<i>Hemideina maori</i>), several large species of unidentified snails, stick insects (<i>Niveaphasma</i> sp.), New Zealand falcon and cryptic skinks (<i>Oligosoma inconspicuum</i> ; rare in this part of Otago). It is also the highest altitude population of <i>N. gemmeus</i> presently known from Otago. Scree skinks (<i>O. waimatense</i>) present in screes 5–6 km to west.

Continued on next page

LOCATION	DOMINANT VEGETATION	LANDFORM, ASPECT, ROCK TYPE	WOODY BIOME* / LENZ†	SEARCH EFFORT, WEATHER, ANIMAL SPECIES AND COMMENTS
Oturehua, Rough Ridge	Small leaved <i>Coprosma</i> spp., <i>Discaria toumatou</i> , <i>Muehlenbeckia complexa</i> and <i>Rubus schmidelioides</i> .	Small gully with tors at base of north Rough Ridge. Rocks are high-grade Haast schist. West-facing aspect. Altitude of 580 m.a.s.l.	III (kowhai woodland) / N4	Searched for 2–3 h in afternoon; weather still, hot and sunny. <i>Oligosoma maccani</i> present.
Beaumont (east of Clutha River/ Mata-Au, across from Curries Flat)	Previously extensive (but patchy and grazed), kanuka/ <i>Coprosma</i> /kowhai shrubland with some rock bluffs. Recent herbicide application has caused widespread death of all vegetation in vicinity of reported <i>N. gemmeus</i> , apart from a patch of (mainly) kowhai.	Rock outcrops and small bluffs on ridges. Rocks are low-grade Haast schist. Altitude of 100 m.a.s.l.	XI (beech, kowhai, cabbage tree) / Q4	Searched for 2–3 h on a warm, still, partly cloudy afternoon. New Zealand falcon present. Bluff faces above river support extensive areas of native shrublands, which provide potential habitat. Isolated beech trees downstream. Original report is dubious, but jewelled geckos present 25 km east in similar habitat (Lammerlaw Stream). It is possible that the wider area could support a population of <i>N. gemmeus</i> .
Clutha River/ Mata-Au—Island Block, Beaumont (DOC-administered land)	Extensive mature kanuka shrubland of low diversity.	Slope above west side of Clutha River/Mata-Au, a few rock outcrops, poorly creviced tors. Rocks are low-grade Haast schist. Altitude of 100 m.a.s.l.	XI (beech, kowhai, cabbage tree) / Q3	Searched for 1–2 h in afternoon; warm, still, overcast weather. Lack of fire refugia. Whole area probably devoid of suitable habitat at some stage in the past due to burning.
Falls Dam	Patchy shrublands in gorge and around screes: small leaved <i>Coprosma</i> spp., <i>Discaria toumatou</i> , <i>Rubus schmidelioides</i> , <i>Muehlenbeckia complexa</i> .	Rocky gorge and blocky screes of greywacke interbedded with mudstone (Forsyth 2001). Altitude of 600 m.a.s.l.	IV (kanuka, kowhai, Hall's totara) / N4	Searched 2–3 h in late afternoon; weather still, hot and sunny. <i>O. waimatense</i> and <i>O. chloronoton</i> present in screes.
Shepherds Creek gorge, Dunstan Mountains	Steep arid (mostly exotic) grasslands and extensive shrubland (mainly <i>Coprosma</i> spp. and <i>Discaria toumatou</i>). Many Hall's and snow totara, including mature trees in fire refugia (scree, bluffs).	Open valley below gorge in Shepherds Creek (drains eastern side of Dunstan Mountains). Vertical ribs of rock, and extensive, blocky, deep boulder field on south-facing slope. Rocks are low-grade Haast schist. Altitude of 700 m.a.s.l.	IV (kanuka, kowhai, Hall's totara) / N3	Searched for 3–4 h around midday; mist cleared, then warm, sunny, still weather. Fire refugia in scree and bluff. Notable for lack of other lizard species, but unidentified geckos belonging to the nocturnal <i>H. maculatus</i> complex found here. <i>O. chloronoton</i> present upstream.
Locharburn Scenic Reserve, Pisa Range	Extensive low forest of predominantly kanuka and Hall's totara.	East-facing slope with outcrops of high-grade Haast schist. Altitude of 600 m.a.s.l.	VII (beech, Hall's totara, snow totara) / Q2	Searched 2–3 h in late afternoon; weather hot, still and sunny. Rock outcrops have provided fire refugia for woody vegetation, and potentially for lizards.

* See Walker et al. 2004b.

† See Leathwick et al. 2002.

DOC Research & Development Series

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.

Individual contributions to the series are first released on the departmental website in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are also listed in the DOC Science Publishing catalogue on the website, refer www.doc.govt.nz under Publications, then Science & technical.