The New Caledonian Leopard Skink *Lacertoides pardalis* (Reptilia: Scincidae); a review of the species' morphology, distribution, behavior and conservation

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ABSTRACT

Lacertoides pardalis is a large species of skink with uniquely small body scales, probably the smallest of any skink species in relation to its size. It was described in 1997 from two specimens from a single site in the far south of New Caledonia. Since the original description more than a decade ago a number of additional specimens (ranging from juveniles to large adults) have been collected in the region and these specimens in combination with field observations have provided new information on the species' biology, most notable of which are a live-bearing mode of reproduction, and insights into its trophic ecology. Stomach analysis indicates an omnivorous diet with saurivory of other skink species, predation of various invertebrates, and an unexpectedly high prevalence of frugivory, indicating this species may play an important role in seed dispersal. This is the first record of this ecological trait in the New Caledonian scincid lizard fauna. The new records also represent significant extensions in the range of the species, and confirm a preference for habitat in areas of outcropping peridotite rock set in low maquis shrubland. The area from which *Lacertoides pardalis* was initially described has changed dramatically during the period since its discovery, primarily from activities associated with the establishment of facilities and infrastructure throughout southern New Caledonia, particularly those to support the recently established and extensive nickel mining operation on the Goro Plateau. Because the species is still only known from a limited number of locations, one of which is in close proximity to mining operations, the species has been listed as 'Vulnerable' under IUCN criteria. Further work on the detailed ecology and biology of the species are required to better manage the populations of this species in the wild.

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RÉSUMÉ

Le scinque léopard de Nouvelle-Calédonie *Lacertoides pardalis* (Reptile : Scincidae), une revue de la morphologie, de la distribution, du comportement et de la conservation de l'espèce.

Lacertoides pardalis est un scinque endémique de grande taille, caractérisé par de petites écailles sur tout le corps. Cette espèce a été décrite pour la première fois en 1997, à partir de 2 spécimens en provenance d'un unique site de récolte, dans l'extrême sud de la Grande Terre. Depuis la description originale, il y a une dizaine d'année, plusieurs individus ont été capturés dans la même région (des juvéniles mais également des spécimens adultes de grande taille). Ces captures permettent de fournir des informations sur la biologie et l'écologie de l'espèce, en particulier, une reproduction vivipare et un régime alimentaire généraliste, reposant sur de la prédation d'invertébrés mais également sur d'autres espèces de reptiles et de façon plus inattendue avec une frugivorie importante. *L. pardalis* pourrait jouer un rôle important pour la dissémination de certaines espèces du maquis, voire de lisières forestières. Ces nouvelles captures ont permis d'élargir significativement l'aire de répartition connue de l'espèce, qui est considéré vulnérable (VU) selon les critères de la liste rouge de l'IUCN. Cependant, la région d'où est connue *L. pardalis* a subi de profondes transformation au cours de la dernière décennie, en raison du développement de projet minier sur le plateau de Goro. Des études complémentaires restent à mener pour conserver cette espèce originale et unique des habitats de maquis rocheux du sud de la Nouvelle-Calédonie.

INTRODUCTION

New Caledonia has an extremely rich lizard fauna composed entirely of skinks (Scincidae, 50 species), gekkonid geckos (Gekkonidae, 6 species) and Southwest Pacific geckos (Diplodactylidae, 35 species). On a species per area basis this richness greatly exceeds that of larger Pacific islands including New Zealand. Equally as remarkable is the exceptionally high level of regional and localized endemism. All genera and species of Southwest Pacific geckos and all but three species of skinks are in genera endemic to the region, and the level of species richness will only increase as further new species and genera await description in both groups. By contrast there are few Pan-Pacific lizard taxa present in New Caledonia, and all but one of the gekkonid geckos found there are species with widespread distributions throughout the Pacific region (Bauer & Henle 1994), and most may be the result of human introduction (Grant-Mackay *et al.* 2004; Kennedy 2001).

Our recent studies have revealed an exceptional degree of endemism concentrated on the territory's ultramafic surfaces, areas which extend as a near-continuous block over much of the southern third of the island and as a series of near-coastal massifs scattered along its west side. The southern and western ultramafic areas have each been identified as a distinct biogeographic region for lizards (Bauer & Sadlier 2000; Bauer *et al.* 2006a; Sadlier *et al.* 2009), each with a number of endemic lizard species (Bauer *et al.* 2006a, 2006b, 2012; Sadlier *et al.* 2004, 2006, 2009, 2013, 2014a, 2014b). Today the vegetation over much of these ultramafic ranges is dominated by maquis, a low heath-like shrubland that extends from low to high elevation. In contrast humid forest on the ultramafics is now usually present as remnant patches of varying size surrounded by maquis habitat, although large areas of forest occur in the high rainfall areas of the southeast ranges. Prior to the arrival of humans humid forest is thought to been more extensive and that much of the existing maquis formations seen today are secondary and largely the result of extensive and repeated firing (McCoy *et al.* 1999; Perry & Enright 2002), both pre- and post- European settlement. Humid forest is characterized by a high level of lizard species richness, reflecting the diversity of niches within this habitat, and probably also its carrying capacity in terms of the biomass and diversity of invertebrates available as food (Jourdan & Sadlier pers. comm.) By contrast the lizard fauna of maquis shrubland tends to be less species-rich, and in the southern region is considered to be depauperate (Bauer & Sadlier 2000). The only truly maquis-dependant species of skinks are the sister taxa *Lioscincus tillieri* (Sadlier & Bauer, 1999) and *Lioscincus maruia* (Sadlier *et al.* 1998) which occupy the ultramafic surfaces of the southern and central ranges respectively, and *Lacertoides pardalis* a species known only from ranges in the far south of the island (Sadlier *et al.* 1997). In the central-west/northwest region ranges a number of species in the recently described diplodactylid gecko genus *Dierogekko* also appear to show a high level of reliance on maquis habitat (Bauer *et al.* 2006a), as does the recently described skink *Lioscincus vivae* (Whitaker *et al.* 2004), but it is not known yet, whether these taxa are strictly confined to this habitat.

The southern ultramafic region species *Lacertoides pardalis* was described from specimens collected on Kwa Néie in the far south of the Grande Terre in 1995, at a road cutting through maquis shrubland with extensive outcroppings of low

rock on lateritic soil (Sadlier *et al.* 1997). At the time it was assumed to show a degree of reliance on this particular type of habitat, which on the Goro Plateau was noted as being restricted to the vicinity of the Kwa Néie range and adjoining Monts Nengoné. In the 15 years since its discovery the Kwa Néie site has been visited several times during the course of general field surveys in the area (Sadlier & Shea 2004, 2006; Sadlier 2009) and additional samples of *Lacertoides pardalis* have been obtained from this site. Further, survey work in other areas of southern New Caledonia has resulted in the discovery of several other populations (Sadlier & Jourdan 2010; Whitaker Consultants, unpublished survey results), increasing significantly the potential area of occupancy for the species and confirming the original assumptions regarding the species preference for maquis habitat associated with areas of outcropping peridotite. Over this time we have opportunistically collected further samples that have provided additional data on aspects of the morphology and biology of the species that we report here. Also, tissue samples from this material have allowed a preliminary assessment of the degree of inter-population genetic variation across the species' range. Our additional field research in the area has also allowed us to more accurately assess the species' potential distribution in the region, and the threats posed by current and proposed mining and development activities in the region (Pascal *et al.* 2008).

MATERIALS AND METHODS

Systematics

Institutional prefixes for the specimen referenced are as follows: AMS - Australian Museum, Sydney; CAS - California Academy of Sciences, San Francisco; MNHN - Muséum national d'Histoire naturelle, Paris.

The characters used in the re-description of *Lacertoides pardalis* were derived as follows: Measurements: snout to vent length - measured from tip of snout to caudal edge of anal scales; axilla to groin distance - measured from middle of base of the forelimb to middle of base of hindlimb; forelimb to snout length - measured from tip of snout to middle of base of forelimb; hindlimb length - measured from middle of base of hindlimb to tip of fourth toe including nail; tail length - measured from caudal edge of anal scales to tip of tail, on complete original tails only. Body measurements are expressed as percentages of snout to vent length (SVL) in the taxon accounts. Scalation: Head scalation follows Sadlier (2010). For characters used in the re-description abbreviation is given in parentheses: midbody scale rows (MBR) - number of longitudinal scale rows around body counted midway between axilla and groin; dorsal scale rows (DSR) - number of scales in a row from first scale posterior to parietal scale to last scale at the level of vent opening; fourth finger (FFS) and toe (FTS) scales - number of dorsal scales on fourth digit of hand and foot, distal scale contains claw and basal scale broadly contacts adjacent basal scale of third finger or toe; fourth finger (FFL) and toe (FTL) lamellae - number of ventral scales on fourth digit of hand and foot, distal scale contains claw and basal scale is last largely undivided scale at a point level with intersection of third and fourth digits. Bilaterally scoreable scalation characters were counted on both sides and the mean value used; in the holotype description these values are presented as left/right values.

The number of presacral and postsacral vertebrae (complete original tails only) were determined from radiographs prepared using a Eresco AS2 X-ray machine at exposures of 30 sec at 30 kV.

Polarities for morphological characters(*) follow Sadlier (2010).

Genetic data

We obtained sequence data from a 514 bp fragment of the mitochondrial NADH dehydrogenase 2 (ND2) gene from nine samples from three of the four known locations for *Lacertoides pardalis* and the outgroups used are those from broader phylogenetic studies on New Caledonian skinks (Smith *et al.* 2007) and sequences for these were obtained from Genbank (Appendix 1). Protocols and analyses follow those outlined in Sadlier *et al.* (2012a, 2012b).

DIETARY ANALYSIS

Faecal material and gut contents were stored in 70% alcohol and analyzed under a dissecting microscope. Due to the digested nature of the material examined, invertebrates could only be identified to order or family level. Reptilian remains were identified to species by comparison of scales present in samples with a reference collection. Plant materials were also identified to family or genera using comparison with herbarium specimens from the IRD Herbarium.

SYSTEMATIC PART

Lacertoides pardalis Sadlier, Shea & Bauer, 1997

Figure 1

Lacertoides pardalis Sadlier, Shea & Bauer, 1997: 381.

TYPE MATERIAL — AMS R.148050 (holotype) and MNHN 1996.2662 (paratype) both originally cited as from Kwa Néie, collected by R. Sadlier & G. Shea 28 September 1995.

The species was described from two individuals collected on Kwa Néie in 1995. Since its description a further 10 specimens of *Lacertoides pardalis* have been obtained from sites across southern New Caledonia. These specimens have provided considerably more information on morphological and genetic variation within the species. Character states marked with an asterisk are those that in combination diagnose *Lacertoides* from all other genera in the *Eugongylus* group of skinks.

MATERIAL EXAMINED — The species is redescribed from 3 sub-adult males (95, 76 & 75 mm SVL), 4 adult females (102-131 mm SVL) and 2 subadult females (81 mm SVL), and 3 juveniles (64-67 mm SVL).

DESCRIPTION — Tests for sexual dimorphism in scalation found no significance differences for the scalation characters surveyed.

Measurements (adults and subadults only). Distance from axilla to groin 50.8-65.4% SVL (mean = 56.4, n = 12); distance from forelimb to snout 34.8-41.8% SVL (mean = 38.7, n = 12); hindlimb length 44.7-53.1% SVL (mean = 49.5, n = 12); *tail length 197.0-217.3% SVL (mean = 209.7, n = 7).

Scalation (all specimens). Naris situated within a single nasal scale and with a prominent postnasal suture, rarely fused to form a crease; frontonasal broader than long, *divided anteriorly and laterally such that such that two additional elongate scales are present either side, and prevent contact with the adjacent nasal and rostral scale, one pair being positioned laterally and contacting the anterior loreal + nasal and the other pair being positioned anteriorly and contacting the nasal + rostral, with the two elements of the latter pair meeting medially above the rostral to exclude contact between with the frontonasal and rostral scales, on some individuals the elements of the anterior and lateral pairs of these scales fuse to the adjacent scales (Figure 2); prefrontals moderately large and in moderate contact medially; frontal longer than broad; supraoculars four; *frontoparietals fused; interparietal distinct; parietals large, distinct, and in narrow to point contact behind interparietal; nuchals usually *divided into two or more large scales; upper secondary temporal scale single; temporal scales on side of head fragmented, the homologies are difficult to discern in some cases but present as follows where the scales can be discerned with some confidence: primary temporal single or divided into two scales, secondary temporal usually divided to form two, occasionally three scales, rarely single, tertiary temporals two or three; postlabials two, occasionally three; nasals moderately to widely separated; supraciliaries usually 8 (58%), occasionally 7, rarely 9; upper labials usually *8 (75%) with the sixth subocular, occasionally 7 or 9; lower labials *7 or 8 (80%), rarely 6 or 9; upper labials separated from contacting the lower eyelid by a *complete subocular row of 9-12 scales; loreals two, each contacting the labials broadly; postmental contacting first and second lower labial; transversely enlarged chinshields three, first pair in broad contact,

FIGURE 1

Coloration of *Lacertoides pardalis*: (**A**) typical boldly marked adult from Montagne des Sources; (**B**) older more obscurely marked adult from Kwa Néie.

second pair separated by two scales, *third pair divided such that five scales separate those scales bordering the labials either side; body scales smooth, and *extremely small; lower eyelid with an obvious, centrally-located, semi-transparent disc; midbody scale rows 67-77 (mean = 71.25, sd = 2.90); dorsal scale rows 139-158 (mean = 149.7, sd = 5.63); scales on top of fourth finger 14-17 (mean = 16.2, sd = 0.66); lamellae beneath fourth finger 19-23 (mean =20.92 sd = 1.22); scales on top of fourth toe 21-26 (mean = 23.4 sd = 1.41); lamellae beneath fourth toe 30-37 (mean = 34.1, sd = 2.12).

Osteology. Presacral vertebrae 29; postsacral vertebrae 61 and 63 on the two juvenile specimens (CAS 205843 and AMS R.152644 respectively) both of which have complete tails, and 61 for the holotype (AMS R148050); premaxillary teeth *9.

Coloration. The species epithet (Sadlier *et al.* 1997) was assigned to emphasize the unique ocellated pattern on the body. It was based at the time on two specimens, one an adult female (holotype) the other a subadult male. Since then additional large specimens of both sexes have been obtained, as well as juveniles. No obvious sexual dimorphism in color or pattern was reported in the original description and there is none evident between the larger specimens of either sex collected since. What has been observed with the additional specimens collected is that the distinctiveness of the pattern of dark ocelli is reduced in the largest individuals (all females). Also, the single individual (an adult female) from high elevation habitat (840 m) on the plateau area of Montagne des Sources is darker in coloration overall, a trait often typical of high elevation populations of some skinks (pers. obs.), but observations of additional individuals are needed to determine whether this trend is consistent throughout the population.

COMMENTS — The 'supranasal' scale character originally described for *L. pardalis* requires amendment. The presence of supranasal scales in skinks was one of the primary characters used in assigning species to groups early in the history of skink systematics, but differences in the terminology and interpretation of head scalation characters have made its use in the diagnoses and descriptions by early workers difficult to follow, and subject to misinterpretation (Sadlier 2010). Greer (1974) in his assessment of the polarity of character states in skink systematics regarded the presence of supranasal scales as indicative of the 'primitiveness' of a taxon, and its loss as apomorphic. Within the *Eugongylus* group of skinks, of which *Lacertoides pardalis* is a member, this character has been re-examined across a range of taxa (Sadlier 2010) and found it to be highly variable in structure. This calls into question the utility of a simplistic presence *vs* absence in assigning polarity, and hence past perceptions of the presence of this character state as a common platform within the *Eugongylus* group from which shared derivations by fusion of the elements of the supposed supranasal were interpreted as evidence of relationship. In the light of the assessments made, large, well defined, and putatively homologous supranasal scales in the *Eugongylus* group occur only in *Eugongylus* (some taxa), *Emoia*, *Tachygyia* and in the New Caledonian genus *Phoboscincus* (Sadlier 2010). The paired head scales in *Lacertoides pardalis* referred to as 'supranasal' scales by Sadlier *et al.* (1997) in the original

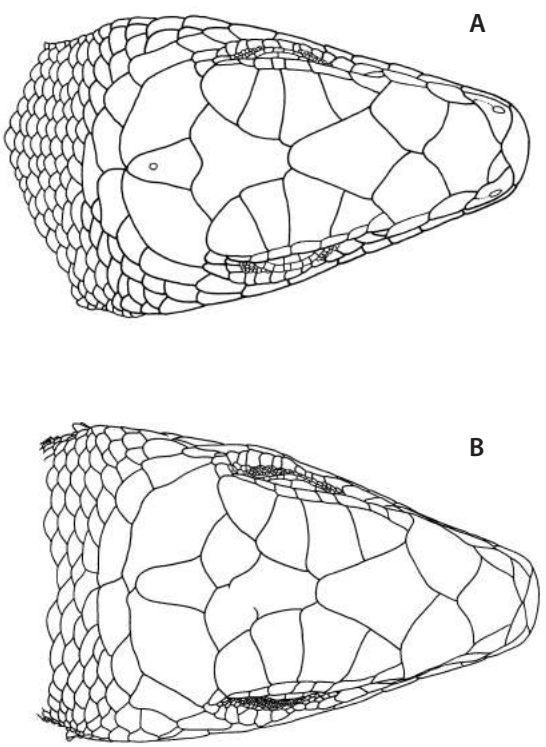

FIGURE 2

Dorsal head scalation of *Lacertoides pardalis*: (**A**) showing the condition in the holotype (AMS R.148050) and paratype (MNHN 1996.2662) in which the lateral pair of scales were absent and only the anterior pair (referred to as 'supranasal' scales in the original description) are present (fused to the nasal on the left side in the holotype); (**B**) the condition typical of most individuals in which fragmentation in the region of the frontonasal and nasal scales (AMS R.164376 - upper) has produced two additional scales either side.

description of the species are considered an independent derivation resulting from fragmentation in the region of the frontonasal and possibly nasal scales (Figure 2), and not homologous with the supranasal scales of *Phoboscincus* or *Eugongylus*.

POPULATION DIFFERENTIATION — Despite extensive survey work in southern New Caledonia in the past 10-15 years *Lacertoides pardalis* still remains known from only a few locations scattered across the region. In particular, extensive survey work on the Plaine des Lacs at a number of sites located between the Ka Yé Wagwé and Kwa Néie and across a range of habitat types, including extensive areas of maquis on the broken and outcropping lateritic cuirasse cap that characterizes much of the plateau, has failed to record the species. This would suggest the species is absent from intervening areas and has a fragmented distribution. However the genetic data available (Table 1) does not show a level of differentiation between populations consistent with long-term isolation of these populations from each other, rather the levels of within population differentiation are not markedly different from those between populations. We can only assume that despite its strong preferences for a particular habitat profile that is neither widespread nor continuous across the landscape, the species is capable of sufficient migration through intervening maquis shrubland to maintain gene exchange.

TABLE 1

Uncorrected pairwise distances based on a 514 bp fragment of the mitochondrial geneND2.

	1	2	3	4	5	6	7	8	9	10
1 *Lioscincus nigrofasciolatum* AMS R.144361 Mt Dore										
2 *Lacertoides pardalis* CAS 205843 Kwa Néie	0.204									
3 *Lacertoides pardalis* AMS R148050 Kwa Néie	0.187	0.024								
4 *Lacertoides pardalis* AMS R.148051 Kwa Néie	0.187	0.024	0.003							
5 *Lacertoides pardalis* AMS R.164350 Kwa Néie	0.188	0.025	0.007	0.007						
6 *Lacertoides pardalis* AMS R.164376 Kwa Néie	0.186	0.025	0.001	0.001	0.005					
7 *Lacertoides pardalis* AMS R180299.001 Kwa Néie (Mine A1)	0.191	0.030	0.009	0.009	0.013	0.008				
8 *Lacertoides pardalis* AMS R.180300.001 Ka Yé Wagwé	0.187	0.024	0.003	0.003	0.004	0.001	0.009			
9 *Lacertoides pardalis* AMS R.167429 Ka Yé Wagwé	0.197	0.037	0.017	0.017	0.018	0.016	0.022	0.014		
10 *Lacertoides pardalis* AMS R.167430 Ka Yé Wagwé	0.195	0.033	0.012	0.012	0.013	0.010	0.018	0.009	0.021	
11 *Lacertoides pardalis* AMS R.174594 Montagne des Sources	0.184	0.039	0.021	0.021	0.022	0.020	0.027	0.018	0.030	0.027

DISCUSSION

The additional specimen records and observations acquired since the species' description in 1997 have not only extended its distribution more widely across the south of the island, but also provide important additional information on its biology, both of which have contributed significantly in a recent assessment of the species' conservation status (Whitaker & Sadlier 2011). Here we present a summary of that additional information.

DISTRIBUTION AND BEHAVIOR

The species has now been recorded four locations in southern New Caledonia (Figure 3):

– the plateau area at Montagne des Sources on the watershed between the Rivière Dumbéa and Rivière Blanche.

– Rivère Blanche in the Réserve naturelle terrestre de la Haute Yaté.

– Ka Yé Wagwé a large isolated range on the Plaine des Lacs in the vicinity of the Chutes de la Madeleine.

– the Kwa Néie in the far south of the region near the Baie de Prony.

Lacertoides pardalis has so far been recorded primarily from maquis habitat with outcropping rock (peridotite), predominately maquis shrubland, and one occasion from adjacent canopied maquis at the Rivière Blanche site. Comparative and more extensive searches of maquis shrubland on lateritic soils or cuirasse in the region have failed to record the species in that habitat, neither has it been recorded from areas of peridotite within humid forest.

At Montagne des Sources the species was recorded at around 800 m elevation in the area of the Plateau des *Calliotropsis* (Figure 4A). A single individual was detected active in the middle of the day in the vicinity of a small isolated rock outcropping surrounded by low maquis shrubland; more extensive areas of outcropping rock were also scattered across the plateau. This site lies at the apex of the range that forms the watershed of the Dumbéa River on one side and the watershed of the Rivère Blanche on the other side.

At Rivière Blanche a single individual was recorded from outcropping rock at around 400 m elevation near the crest of the ridge in the vicinity of the 'Houp Géant', and another from adjacent canopied maquis paraforestier (Joël Delafenetre DENV – pers. comm.). The vegetation in this area comprises humid forest in the gullies but dense maquis elsewhere and on the crest of the ridge – a typical pattern for the lower ridges in this river valley.

Ka Yé Wagwé is a large, isolated east-west ridge on the north side of the Plaine des Lacs approximately 5km in length and reaching a height of 200-330 m above the surrounding laterite plateau. There are some small patches of humid forest at its base but the range is covered by moderately-low dense maquis shrubland on the lower slopes and a low open maquis on the mid- to upper slopes. The range is unremarkable when viewed from the south, rising steeply but progressively to the crest at 500-630 m. However, it falls away abruptly on the northern side where the underlying peridotite forms a broken escarpment about 2km long and with bluffs and cliffs 2-20 m in height (Figure 4B). Several adult individuals were observed in crevices within the more extensive areas of cliff and other individuals were detected among crevices on outcrops, and

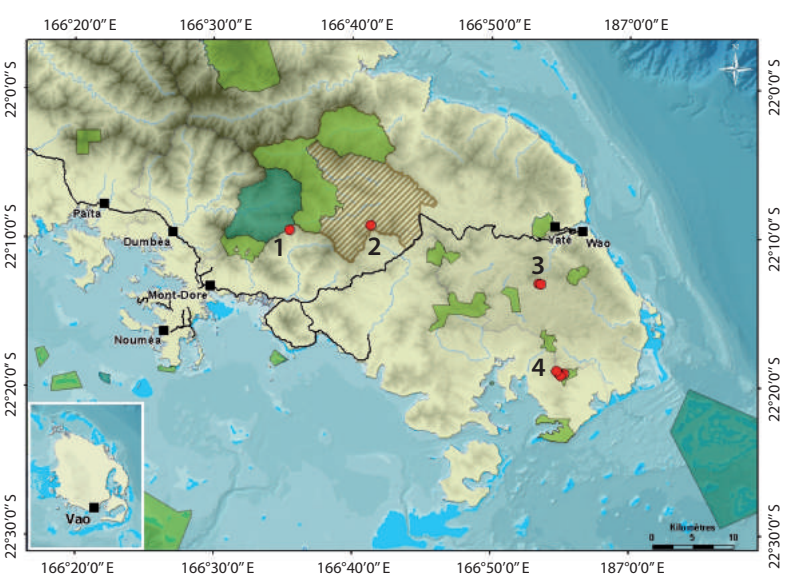

FIGURE 3

Locations from which *Lacertoides pardalis* has been recorded in southern New Caledonia – solid circles are specimen records, hollow circles observations: 1) Montagne des Sources (AMS R.174594 22°08'17"S 166°35'55"E); 2) Rivière Blanche (obs. 22°09'03.1"S 166°41'40.2"E, obs. 22°09'04.9"S 166°41'38.4"E); 3) Ka Yé Wagwé (AMS R.167429 22°12'50.7"S 166°53'40.9"E; AMS R.167430 22°12'56.0"S 166°53'47.8"E); 4) Kwa Néie (AMS R.148050 22°18'48.3" S 166°54'58.7"E; MNHN 1996.2662, AMS R.152643–44, CAS 205843 22°18'51.9"S 166°55'06.7"E; AMS R.164350 & AMS R.164380 22°19'05"S 166°55'18"E; AMS R.164376 22°19'01"S 166°54'52"E; AMS R.166137 22°18'48.9"S.

a single subadult was also observed in a small area of outcropping rock on the top of the ridgeline away from the escarpment.

Kwa Néie is part of a series of connected ranges to the south of the Plaine des Lacs and separated from Ka Yé Wagwé by the extensive basin and accompanying wetlands of the lakes Lac en Huit and Grand Lac. The species has been recorded from a number of sites on Kwa Néie over the last 10 years. Most records are from searches made along the road to the transmitter tower that runs from a low saddle at ~280 m elevation to the summit of the range at ~490 m, primarily through the Réserve Naturelle Terrestre de la Forêt Nord. The track meanders up the north face of the range, passing initially through low (~1 m high), dense maquis shrubland near the crest of a low ridge (280-340 m) on which the underlying peridotite frequently surfaces, often as large exposed boulders (Figure 4C), but also on road embankments. It then passes through dense humid forest between 340-420 m, an area with extensive exposed peridotite at the surface, emerging into moderately low (~1-2 m tall) dense maquis shrubland on a steep slope near the summit (420-480 m), again with underlying peridotite frequently exposed as large outcrops. Six individuals have been recorded from exposed peridotite in cuttings where it passes through dense maquis between 280-340 m, and two from dense maquis shrubland in the area of the summit. A single adult individual has also been recorded from a crevice in rocks on the face of the track cutting where it passes through humid forest. This site was close to the interface between the

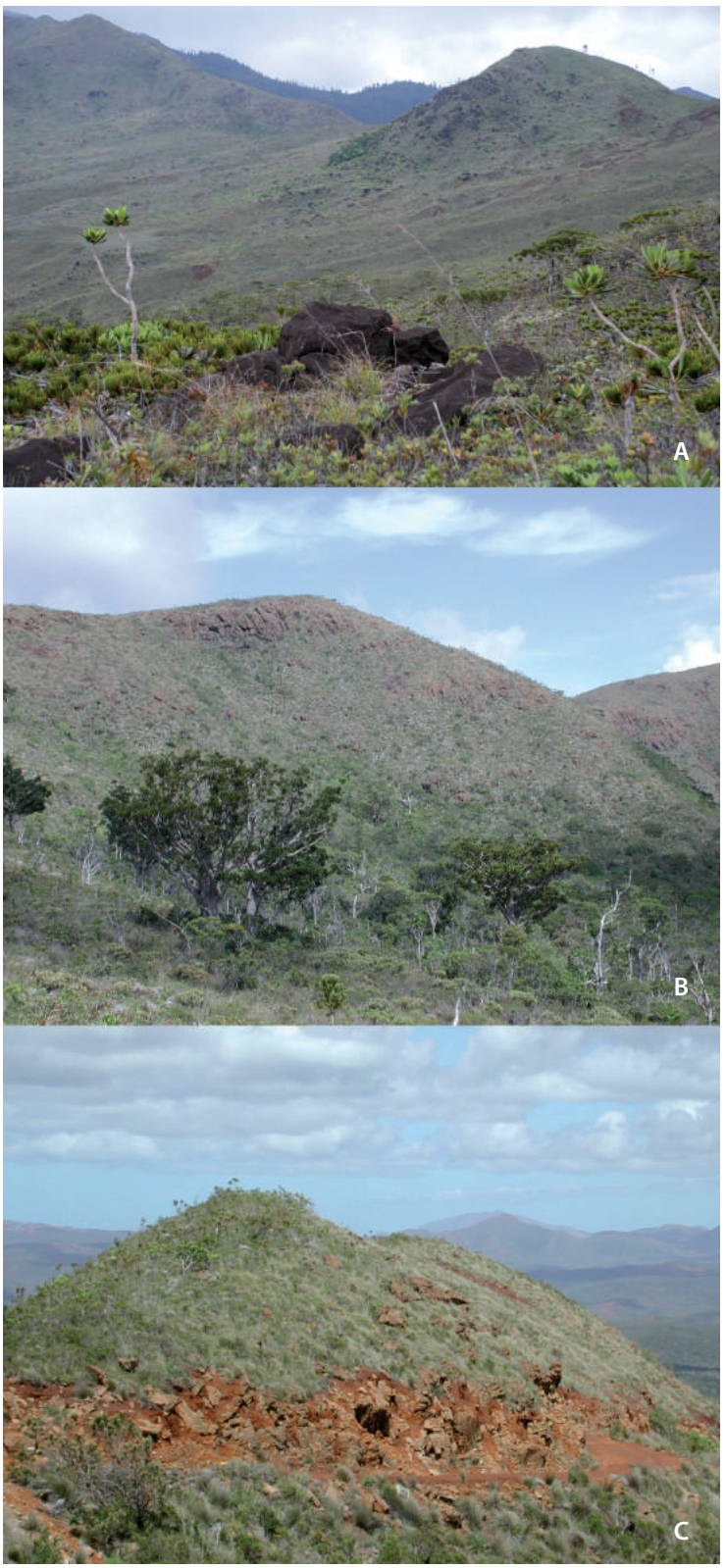

FIGURE 4

Habitat of *Lacertoides pardalis*: (**A**) isolated rock outcrop surrounded by low maquis shrubland at around 800m elevation on Montagne des Sources; (**B**) broken peridotite escarpment with bluffs and cliffs 2-20m in height near the summit of Ka Yé Wagwé; (**C**) dense maquis shrubland between 280-340m near the crest of the ridge on Kwa Néie near where the holotype was collected, note underlying peridotite present as large outcropping boulders.

humid forest and maquis shrubland at ~ 420 m, and the species' presence there is likely to be an artifact of the openness and continuity of rocky habitat offered by the track rather than an extension of its habitat preferences into humid forest, particularly given the close proximity of the adjacent maquis shrubland. A single large individual of *Lacertoides pardalis* has also been recorded from the southeast face of Kwa Néie in an area of mine concession comprising low maquis shrubland with extensive large peridotite boulders, where it was detected amongst crevices in an outcrop.

Lacertoides pardalis appears to be one of the most wary of the New Caledonian skinks. It has been disturbed or observed while active only on four occasions, and always at, or in close proximity to, a retreat site in or under rock. The majority of the remaining records are from individuals detected by strategically placed glue traps at the entrance to likely looking crevices in rocks. Several juveniles were detected along the transmitter tower track on Kwa Néie by turning exposed rocks embedded in soil in the road cutting, and the holotype from a shallow burrow in soil immediately beneath a large rock in the road cutting. Retreat sites included natural or partially excavated burrows in soil below rocks, and narrow crevices within outcropping rock or formed by rock on rock. While there is a clear preference for habitats that include rocky sites these can take the form of either, outcropping rock with a matrix of rock on rock, outcrops and rock faces with crevices, or in artificial situations such as road cuttings with large rocks embedded in a soil matrix – but only on exposed peridotite, not cuirasse, and predominately in maquis shrubland vegetation. These types of rock-dominated habitats tend to be situated mostly (but not always) near the crest of a ridgeline.

Maturity and reproduction

Lacertoides pardalis is one of the largest skinks in New Caledonia exceeded in size only by the two species of *Phoboscincus*. Despite living in tropical latitudes the species appears to have a typically temperate zone mode of reproduction that is strongly seasonal. The four largest individuals recorded (SVL 102-131 mm) are all females. The initiation of reproductive activity in adult females appears to be in the spring/early summer months (*i.e.* middle of the tropical dry season) with parturition in the mid-summer (*i.e.* late dry season/early wet season). Of the two large females collected in spring the largest (AMS R.174954 SVL 131 mm) collected in October was vitellogenic and carried 4 (1 left/3 right) very large yolked ovarian follicles, whereas the other (AMS R.148050 SVL 102 mm) collected in late September was mature but not reproductive. A large female (AMS R.164380 SVL 131 mm) collected in late December carried five (2 left/3 right) large oviductal yolk masses. No foetus was obvious but there was a vascular network over each of the large yolk masses indicating viviparity. Reproductive inactivity and quiescence in females likely occurs in the late summer/winter (*i.e.* wet/early dry season), as a mature female (AMS R.167429 SVL 134 mm) collected in February (early wet season) was non-reproductive, having only slightly (1/3) enlarged ovarian follicles. A small female (AMS R.167430 SVL 81 mm) collected February was immature and lacked enlarged or convoluted oviducts that would indicate reproductive activity in previous seasons.

The four largest males (75-95 mm) all have small testes with barely differentiated seminiferous tubules indicating they are reproductively immature. Three (AMS R.166137 SVL 76 mm, AMS R.164376 SVL 81 mm & R.164350 SVL 95 mm) were all collected mid-summer in late December (*i.e.* end of dry season). The single male (MNHN 1996.2662 SVL 75 mm) collected in the early spring/summer season (late September 1995) also had small testes, and if mature would have been expected to have enlarged testes at this time of year, suggesting immaturity at this size.

The three smallest individuals (AMS R.152643-44 & CAS 205843 SVL 64-67 mm) were all collected after summer in May (*i.e.* end of the wet season). Their size and the relative size of the developing clutch mass in the single gravid female carrying early term embryos would indicate that these juveniles were most likely the young from the previous year *i.e.* approximately 14-16 months old.

Dietary habits

Dietary analyses were conducted on stomach contents from 7 adults and subadults, also one faecal sample was collected from a specimen that defaecated during handling. The frequency of various food items sorted from gut contents is given in Table 2.

Our study showed that *Lacertoides pardalis* are an omnivorous, generalist species, consuming a wide array of food types. At least 15 invertebrate groups were recorded, including earthworms, snails, spiders and insects (ants, bees, wasps, caterpillars, weevils - Table 2). The number of invertebrate prey items per stomach varied between 1-5. Some prey items (such as nitidulid beetles) may be secondary prey inadvertently ingested when fruit were being eaten. Amongst the invertebrates we also identified *Solenopsis geminata* (tropical red fire ant), an invasive ant that thrives in maquis areas, indicating a capability to adapt to new prey.

Stomach analysis also recorded body parts and scales of both young and adult *Caledoniscincus austrocaledonicus* on two occasions (Table 2), the first record saurivory for this species. *Lacertoides pardalis* is a large skink and as such could prey on a range of other lizards, particularly skinks. Saurivory in New Caledonian skinks has also been recorded for several other large species including *Caledoniscincus festivus*, *Lioscincus nigrofasciolatum*, and *Phoboscincus garnieri* (Jourdan et al., work in progress) and the gecko *Rhacodactylus auriculatus*, all of which have included *Caledoniscincus* spp. in their diet, indicating the common and widespread members of that genus could form an important opportunistic part of the diet of the lizard fauna.

The most significant find in the dietary analysis was a high prevalence of frugivory, with numerous seeds and fruit parts recorded (Table 2). The consumption of fruits was totally unexpected for a ground-dwelling skink in maquis shrubland (Bauer & DeVaney 1987, Shea *et al.* 2009). Seeds and fruits belonging to at least four shrub species in the Myrtaceae and Sapotaceae were found in five (70%) of the specimens examined. The high number of seeds ingested suggests *Lacertoides pardalis* may play a role in the dispersal of some plants in the maquis (such as *Uromyrtus* or *Leptostylis*), and possibly also for some typically forest species that are found on forest margins (such as *Planchonella*). This fruit consumption pattern may be seasonal (detailed phenology of the plants consumed should be investigated), but it may have a significance for maquis shrubland renewal and functioning. Fruit as a component of the diet has been recorded for the gecko *Rhacodactylus leachianus*, particularly on the offshore islands off the Isle of Pines (Aaron – references), but this is the first record of such dietary pattern in New Caledonian skink lizard fauna. Frugivory is commonplace in NZ skinks, including in similar sorts of habitats. In particular, *Oligosoma otagense* (which is remarkably similar to *Lacertoides* in morphology, size, habitat and behavior) and *Oligosoma grande* which are both crevice inhabitants of rock outcrops in tussock/shrubland habitats, both consume very large quantities of fruits. Furthermore, they selectively feed on fruit at certain times of year, even though fruits of the same species are available at other times and invertebrates are uniformly available from spring to autumn. This preferential consumption of fruit is thought to indicate a special dietary need, probably in relation to the reproductive cycle.

During the dietary analysis we recorded a high parasite load (Nematoda) for most specimens (from 1 to 79 nematodes per stomach or pellet), with only 2 stomachs clear of nematodes. This high parasite load may be a consequence of predatory behavior on other skink species.

Conservation status

Lacertoides pardalis is present at only four locations, its extent of occurrence is approximately 24 km² and its area of occupancy is estimated to be <2 km². There are no quantitative data on population size and trends for the species but observations at the two sites, Kwa Néie, and Ka Yé Wagwé, indicate it occurs at low population density at both locations. *Lacertoides pardalis* was recently assessed as Vulnerable D2 using IUCN criteria (Whitaker & Sadlier 2011).

Our observations indicate *Lacertoides pardalis* is restricted to areas of outcropping peridotite rock set in low maquis shrubland. The distribution of such habitat in the Grande Sud is very restricted, and is most extensive on the crests of ranges where the underlying rock becomes exposed. As such, the potential habitat is likely to have a dendritic distribution that is fragmented, has a high edge to area ratio, and neither the extent of occurrence nor area of occupancy are likely to increase substantially, even with further records. The more extensive areas of the species preferred habitat occur on the crests of the ranges, and populations on the ridge tops are at risk from disturbance in the construction of access tracks, and from wildfires, which tend to increase in intensity as they move upslope. Further, these ridge tops are also the preferred

sites for wind powered electricity generators, the installation of which has expanded in the region in recent years, and results in extensive disturbance to the top of the ridges.

The species has now been recorded from three reserves in the Grand Sud and is considered to be well represented within the New Caledonian protected areas network. However, the Réserve Naturelle Terrestre de la Forêt Nord which includes part of the Kwa Néie population lies in close proximity to the industrial area and activities associated with the mining operations on the Goro Plateau. Within the context of the species' known distribution the population on Kwa Néie is one of the two largest and, although partly within a reserve, the close proximity to mining activities place this population in a vulnerable position. As such, the long-term conservation of *Lacertoides pardalis* would be greatly enhanced by the addition of Ka Yé Wagwé as a protected area within the provincial reserve system. The population on Ka Yé Wagwé is likely to be large by virtue of the extent of preferred habitat for the species along the crest of the range. Further, this area of habitat, which is dominated by exposed rock, is perhaps less likely to be affected by wildfires than other sites within the species' range. Further work on the detailed ecology and biology of the species are required to better manage the populations of this species in the wild.

TABLE 2

Dietary items. *one specimen of *Solenopsis geminata* and two specimens of *Pheidole* sp.

IDENTITY OF ITEMS			N° OF ITEMS	N° OF INDIVIDUALS
PLANTS				
Myrtaceae	Seeds	*Uromyrtus ngoyensis*	187	5
	Seeds	*Myrtastrum rufo-punctatum*	3	1
	Fruit parts	*(Uromyrtus* sp.)	2	2
Sapotaceae	Fruits	*Leptostylis (Pycnandra)* sp.	3	1
	Fruits	*Planchonella* sp.	1	1
Total plant items			196	
Plant items undet.	not fruit/seed			5
INVERTEBRATES				
Oligocheta			1	1
Gasteropoda			1	1
Arachnida	Acari Oribata		1	1
	Aranea	Undet.	1	1
Insecta	Coleoptera	Nitidulidae	1	1
		Curculionidae	1	1
		Cerambycidae	1	1
		Tenebrionidae	1	1
		Undet. larvae	1	1
	Lepidoptera	Undet. Caterpillar	1	1
	Hymenoptera	Chrysididae	1	1
		Megachilidae	1	1
		Sphecidae	3	2
		Formicidae*	4	2
	Psocoptera		1	1
Total invert. items			20	
Parasite load	Nematoda		119	5
VERTEBRATE				
	Scincidae	*C. austrocaledonicum*	2	2
	Skin shed			1

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REFERENCES

BAUER A.M. & DEVANEY K.D. 1987 — Comparative aspects of diet and habitat in some New Caledonian lizards. *Amphibia-Reptilia* 8: 349-364.

BAUER A.M. & HENLE K. 1994. Das Tierreich 109 — Gekkonidae. Part 1, Australia and Oceania. Walter de Gruyter, Berlin. Xiii + 306 p.

BAUER A.M. & SADLIER R.A. 2000 — 'The Herpetofauna of New Caledonia'. (Society for the Study of Amphibians and Reptiles: Ithaca NY). 310 p, 24 pls.

BAUER A.M., JACKMAN T., SADLIER R.A. & WHITAKER A.H. 2006a — A revision of the *Bavayia validiclavis* group (Squamata: Gekkota), a clade of New Caledonian geckos exhibiting microendemism. *Proceedings of the California Academy of Sciences* 57(18): 503-547.

BAUER A.M., JACKMAN T., SADLIER R.A. & WHITAKER A.H. 2006b — A new genus and species of diplodactylid gecko (Reptilia: Squamata: Diplodactylidae) from northwestern New Caledonia. *Pacific Science* 60 (1): 125-135.

BAUER A. M, SADLIER R.A., JACKMAN T.R. & SHEA G.S. 2012 — A new member of the *Bavayia cyclura* species group (Reptilia: Squamata: Diplodactylidae) from the southeast ranges of New Caledonia. *Pacific Science* 66: 239-247.

GRANT MACKIE J. A., BAUER A. M. & TYLER M.J. 2004 — Stratigraphy and herpetofauna of Mé Auré cave (site WMD007), Moindou, New Caledonia. *Cahiers Archéologiques* 15: 295-306.

GREER A.E. 1974 — The generic relationships of the scincid lizard genus *Leiolopisma* and its relatives. *Australian Journal of Zoology*, *Supplementary Series* 31:1-67.

JAFFRÉ T. 2005 — Conservation programmes in New Caledonia, western Pacific: in place for the dry forest, but urgently needed for ultramafic vegetation. *BGjounal* 2(1): 13.

JOURDAN H., SADLIER R., BAUER A., 2001 — Little fire ant invasion (*Wasmannia auropunctata*) as a threat to New Caledonian Lizard: Evidences from a sclerophyll forest (Hymenoptera: Formicidae). *Sociobiology* 38(3): 283-301.

KENNEDY A. 2011 — The fossil herpetofauna of the Pindaï Caves, New Caledonia: with implications for the effect of human habitation on island faunas. M.Sc. Thesis, Villanova University, Pennsylvania, USA. 222 p.

McCOY S., JAFFRÉ T., RIGAULT F. & ASH J.E. 1999 — Fire and succession in the ultramafic maquis of New Caledonia. *Journal of Biogeography* 26: 579-594.

PASCAL M., RICHER DE FORGES B., LEGUYADER H. & SIMBERLOFF D. 2008 — Mining and other threats to the New Caledonia biodiversity hotspot. *Conservation Biology* 22(2): 498-499.

PERRY G.W. & ENRIGHT N.J. 2002 — Humans, fire and landscape pattern: understanding a maquis-forest complex, Mont Do, New Caledonia, using a spatial 'state-and-transition' model. *Journal of Biogeography* 29: 1143-1158.

SADLIER R.A. 2009 — Targeted survey for the rare regional endemic lizard *Lacertoides pardalis* at Forêt Nord, Prony. Unpublished report by Cygnet Surveys & Consultancy to Vale Inco Nouvelle-Calédonie. 14p.

SADLIER R.A. 2010 — Systematic studies of the scincid lizards of New Caledonia. PhD. Thesis, Griffith University, Queensland. 199 p.

SADLIER R.A. & BAUER A.M. 1999 — The scincid lizard *Lioscincus tillieri* (Reptilia: Scincidae) from New Caledonia in the southwest Pacific: new information on the species, biology, distribution, and morphology. *Records of the Australian Museum* 51(1): 93-98.

SADLIER R.A., BAUER A.M., WHITAKER A.H. & SMITH S.A. 2004 — Two new species of scincid lizards (Squamata) from the Massif de Kopéto, New Caledonia. *Proceedings of the California Academy of Sciences* 55(11): 208-221.

SADLIER R.A., BAUER A.M. & SMITH S.A. 2006 — A new species of Nannoscincus Günther (Squamata: Scincidae) from high elevation forest in southern New Caledonia. *Records of the Australian Museum* 58: 29-36.

SADLIER R.A., BAUER A.M., WOOD, P.L. JR., SMITH S.A. & JACKMAN T. 2013 — A new species of lizard in the genus *Caledoniscincus* (Reptilia: Scincidae) from southern New Caledonia and a review of *Caledoniscincus atropunctatus* (Roux). *Zootaxa* 3694 (6): 501-524.

SADLIER R.A., BAUER A.M., WOOD P.L., SMITH S.A., WHITAKER A.H., JOURDAN H. & JACKMAN T. 2014a — Localized endemism in the southern ultramafic bio-region of New Caledonia as evidenced by the scincid lizards in the genus Sigaloseps (Reptilia: Scincidae), with a description of four new species, *in* GUILBERT É., ROBILLARD T., JOURDAN H. & GRANDCOLAS P. (eds), Zoologia Neocaledonica 8. Biodiversity studies in New Caledonia. *Mémoires du Muséum national d'Histoire naturelle*, 206: 81-116.

SADLIER R.A., BAUER A. M., SMITH S.A., SHEA G.M. & WHITAKER A.H. 2014b — High elevation endemism on New Caledonia's' ultramafic peaks - a new genus and two new species of scincid lizard, *in* GUILBERT É., ROBILLARD T., JOURDAN H. & GRANDCOLAS P. (eds), Zoologia Neocaledonica 8. Biodiversity studies in New Caledonia. *Mémoires du Muséum national d'Histoire naturelle*, 206: 117-128.

SADLIER R.A. & JOURDAN H. 2010 — Inventaire herperlogique des aires protegees de la province sud. Rapport de Convention DENV Province Sud, Convention n° 313.07 - Avenants ½. Nouméa. 27 p.

SADLIER R.A., SHEA G.M., & BAUER A.M. 1997 — A new genus and species of lizard (Squamata, Scincidae) from New Caledonia, Southwest Pacific, *in* NAJT J. & MATILE L. (eds), Zoologia Neocaledonica 4. *Mémoires du Muséum national d'Histoire naturelle*, 171: 379-385.

SADLIER R. & SHEA G. 2004 — Étude faunistique spécifique herpétofaune sur le site minier Goro Nickel proposé. Unpublished report to Goro Nickel S.A., Australian Museum Business Service, Sydney. 31 p.

SADLIER R.A. & SHEA G.M. 2006 — Étude de l'herpétofaune de quatre réserves spéciales du grand sud de la Nouvelle Calédonie et propositions d'orientations de mesures de conservation - Réserve spéciale botanique Forêt Nord, Réserve spéciale botanique Cap N'Doua, Réserve spéciale botanique Pic du Pin, and Réserve spéciale botanique Pic du Grand Kaori. Unpublished report by AMBS to Direction des Resources Naturelles, Province Sud, Noumea. 70 p.

SADLIER R.A., SMITH S. A., BAUER A.M. & WHITAKER A.H. 2009 — Three new species of skink in the genus Marmorosphax SADLIER (Squamata: Scincidae) from New Caledonia, *in* GRANDCOLAS P. (ed.), Zoologia Neocaledonica 7. Biodiversity studies in New Caledonia. *Mémoires du Muséum national d'Histoire naturelle*, 198: 373-390.

SADLIER R.A., WHITAKER A.H. & BAUER A.M. 1998 — Lioscincus maruia, a New Species of Lizard (Reptilia: Scincidae) from New Caledonia, Southwest Pacific. Pacific Science 52(4): 334-341.

SHEA G., JOURDAN H., SADLIER R.A., BAUER A. 2009 — Natural history of the New Caledonian whiptailed skink Tropidoscincus variabilis (Bavay, 1869) (Squamata: Scincidae). *Amphibia-Reptilia* 30: 207-220

SMITH S.A., SADLIER R.A. & BAUER A.M., AUSTIN C.C. & JACKMAN T. 2007 — Molecular phylogeny of the scincid lizards of New Caledonia and adjacent areas: Evidence for a Single Origin of the endemic skinks of Tasmantis. *Molecular Phylogenetics and Evolution* 43: 1151-1166.

WHITAKER A.H. & SADLIER R.A. 2011 — Lacertoides pardalis, *in* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 28 November 2011.

WHITAKER A.H., SADLIER R.A., BAUER A.M. & WHITAKER V.A. 2004 — Biodiversity and Conservation Status of Lizards in Threatened and Restricted Habitats of North-Western New Caledonia. Report by Whitaker Consultants Limited to Direction du Développement Économique et de l'Environnement, Province Nord, Koné, New Caledonia. vi + 105 p.

Sadlier R.A., Shea G.M., Jourdan Hervé, Whitaker A.H., Bauer A.M.

The New Caledonian leopard skin Lacertoides pardalis (Reptilia: Scincidae) : a review of the species' morphology, distribution, behavior and conservation.

In : Guilbert E. (ed.), Robillard T. (ed.), Jourdan Hervé (ed.), Grandcolas P. (ed.). Zoologia neocaledonica : 8. Biodiversity studies in New Caledonia.

Paris : MNHN, 2014, p. 31-44.

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