A Review of the Morphology, Biology, Distribution and Conservation Status of the New Caledonian Scincid Lizard *Simiscincus aurantiacus* (Reptilia: Scincidae)

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Abstract. *Simiscincus aurantiacus* was described in 1997 from a single specimen collected in humid forest habitat on Mt Koghis in southern New Caledonia. The recent acquisition of a number of additional specimens from surveys conducted in the south of the island has provided new information on the species' morphology, biology and distribution. The results of field studies indicate it has a scattered distribution across the region that includes both humid forest and tall, canopied maquis forest habitats, and that it can persist in even extremely small remnants of these forest types and appears to have a primarily subterranean mode of existence. The additional material collected has also allowed an assessment of variation in the species' morphology, including an unusually long tail the basal half of which is uniformly rounded. Morphological studies suggest a close relationship between *Simiscincus aurantiacus* and the regionally sympatric fossorial species *Graciliscincus shonae*, and genetic studies undertaken since its description place these taxa within a larger group that also includes the surface active species of the genera *Caledoniscincus* and *Phaeoscincus*, the latter only recently established. The information on the species' distribution and biology presented here supports its recent IUCN Red List assessment as Vulnerable.

Keywords. Scincidae; *Simiscincus*; New Caledonia; morphology; forest; fragmentation; vulnerable.

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The southern ultramafic region of New Caledonia has a rich and diverse lizard fauna that includes a number of regionally endemic species and genera (Bauer & Sadlier, 2000; Sadlier, 2010). The landscape of the region is dominated by steep, high ranges dissected by deep river valleys, but with an extensive low-mid elevation ultramafic plateau in the far south in the area known as the Grand Sud.

This region is home to 17 endemic species of skink including taxa in four primarily endemic genera, and six endemic species of gecko (Table 1), the majority of which have only been recognized in the past 20 years, while new species are still being described. Included are six species of skink restricted to high elevation habitats (Sadlier & Bauer, 2000; Sadlier *et al*., 2006, 2014a,b), primarily in forest habitat. The uniqueness and diversity of the region's lizard fauna support its recognition as a distinct and significant bioregion (Sadlier, 2010). Unfortunately, the landscape has undergone extensive human-mediated habitat modification (McCoy *et al*., 1999; Perry & Enright, 2002) both pre- and post European settlement, a scenario complicated by past, current and future potential exploitation of parts of the region for nickel mining (Pascal *et al*., 2008).

Field research conducted over the past 10 years on the ultramafic surfaces of the Grand Sud, including the Plaine des Lacs, Goro Plateau and adjacent ranges, has greatly enhanced our understanding of the distribution and habitat preferences of many lizard species. As a consequence our perceptions as to their perceived "rareness", particularly with respect to those species thought to be primarily reliant on forest habitats which are now highly fragmented, has changed. The pattern emerging indicates that some of the species of skink regarded as forest dependent are influenced as much by certain attributes of microhabitat, such as moisture, as they are by the structural characteristics of habitat type. As a consequence, the distribution of a number of species can extend across a range of forest habitats (both humid forest and tall maquis forest), and even into adjacent areas of maquis scrub when the preferred microhabitat attributes are present. By contrast, the majority of truly "narrow range" species in southern New Caledonia appear to be those restricted to high elevation habitats, usually forest, with both deep and relatively recent historical contraction of forest, probably spanning from the Miocene through to Pleistocene, as the likely factor driving isolation and speciation, as exemplified by the radiation of three species in the genus *Sigaloseps* endemic to the high elevation ranges associated with the Kouakoué and Humboldt massifs (Sadlier *et al*., 2014a).

Simiscincus aurantiacus was described in 1997 from a single specimen collected in mid-elevation humid forest habitat on Mt Koghis in the ranges of the southern ultramafic region adjacent to the Grande Sud. It is an elongate skink with a particularly broad snout (Fig. 1), and has a number of unusual, and in some cases unique, morphological traits, features which contributed to the erection of a monotypic genus to accommodate it. At the time of discovery the specimen was detected under a rock and retreated into the complex of crevices and holes in the forest floor. This behavior in combination with certain morphological traits suggested that it likely led a primarily subterranean existence (Sadlier & Bauer, 1997). Since then a further 16 individual records have been made from a number of locations scattered across the region, and from a range of forest types that includes both humid forest and tall canopied maquis scrub. Most records are from captures made on strategically placed glue traps, and despite extensive diurnal survey time within forest habitat the species has not been trapped during daylight hours, nor has it been observed active during the course of field studies.

Table 1. Skinks and geckos endemic to the southern ultramafic bioregion—species in genera primarily endemic to the region are highlighted with asterisk.

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Diplodactylidae		*Bavayia geitiana*	Wright, Bauer & Sadlier, 2000
Diplodactylidae		*Bavayia goroensis*	Bauer, Jackman, Sadlier, Shea & Whitaker, 2008
Diplodactylidae		*Bavayia nubila*	Bauer, Jackman, Sadlier & Shea, 2008
Diplodactylidae		*Bavayia septuiclavis*	Sadlier,1989
Diplodactylidae		*Eurydactylodes symmetricus*	(Andersson, 1908)
Diplodactylidae		*Correlophus sarasinorum*	Roux, 1913
Scincidae		*Caledoniscincus notialis*	Sadlier, Bauer, Wood, Smith & Jackman, 2013
Scincidae	*	*Graciliscincus shonae*	Sadlier, 1986
Scincidae	*	*Lacertoides pardalis*	Sadlier, Shea & Bauer, 1997
Scincidae		*Marmorosphax montana*	Sadlier & Bauer, 2000
Scincidae		*Nannoscincus fuscus*	Günther, 1872
Scincidae		*Nannoscincus garrulus*	Sadlier, Bauer & Smith, 2006
Scincidae		*Nannoscincus mariei*	(Bavay, 1869)
Scincidae		*Phaeoscincus ouinensis*	Sadlier, Shea & Bauer, 2014
Scincidae		*Phasmasaurus tillieri*	(Ineich & Sadlier, 1991)
Scincidae	*	*Sigaloseps deplanchei*	(Bavay, 1869)
Scincidae	*	*Sigaloseps ruficauda*	Sadlier & Bauer, 1999
Scincidae	*	*Sigaloseps balios*	Sadlier, Bauer & Wood, 2014
Scincidae	*	*Sigaloseps ferrugicauda*	Sadlier, Smith, Shea & Bauer, 2014
Scincidae	*	*Sigaloseps pissinus*	Sadlier, Shea, Whitaker, Bauer & Wood, 2014
Scincidae	*	*Sigaloseps conditus*	Sadlier, Bauer & Wood, 2014
Scincidae	*	*Simiscincus aurantiacus*	Sadlier & Bauer, 1997
Scincidae		*Tropidoscincus variabilis*	(Bavay, 1869)
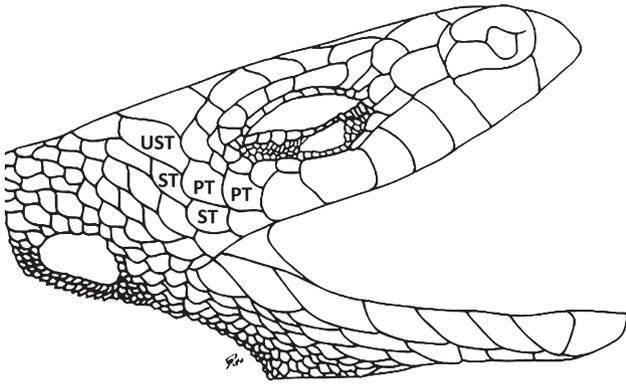
Figure 1. Lateral head scalation of *Simiscincus aurantiacus* (holotype AM R.148050) showing the position of the two large scales bordering the posterior edge of the eye between the last supraciliary and pentultimate upper labial, re-interpreted as two primary temporal scales (PT), bordered along the posterior edge by two secondary temporal scales (ST) and a single upper secondary temporal scale (UST) uppermost.

Morphological similarities between *Simiscincus aurantiacus* and *Graciliscincus shonae* have previously been documented (Sadlier & Bauer, 1997), the traits shared by both species likely being associated with a particular mode of subsurface biology. The suite of morphological apomorphies shared by *Simiscincus aurantiacus* and *Graciliscincus shonae* would indicate that they are sister taxa (Sadlier, 2010), but there is little support for this relationship from genetic studies (Smith *et al*., 2007), other than that both reside within the broader group that also includes *Caledoniscincus* and the recently described *Phaeoscincus* (Sadlier *et al*., 2014b).

It is the purpose of this paper to provide an account of the morphological variation in *Simiscincus aurantiacus* based on the additional material obtained since the species description 20 years ago, to document the expanded distribution and range of habitats from which the species has now been recorded, and to provide a reassessment of its conservation status.

Systematics

The original description of *Simiscincus aurantiacus* was limited to the holotype, the only known specimen at that time. With an abundance of distinctive character states to diagnose the species there was no hesitation in recognising it as a highly distinctive evolutionary entity. However, the lack of comparative material did not allow for an understanding of variation within the species, not just for the standard meristic and mensual characters typically used to describe the species, but also for an assessment of the extent of variation in some of the more unusual character states associated with body form and osteology, or of sexual dimorphism in body form and colouration. The additional material collected in the intervening 20 years since its discovery offers the opportunity to present here a description of variation in the species, and is based on five adult males (one of which is the holotype) and nine adult females. Measurements are presented as a percentage of body length as expressed by the distance from the tip of the snout to the vent (SVL) and terminology for scalation follows that used by Sadlier & Bauer (1997) in the original description, unless where specifically noted.

A revised account of the morphology of *Simiscincus aurantiacus*: A particularly unexpected aspect of body form apparent in the specimen collections made has been the length and morphology of the tail. The tail of the holotype of *Simiscincus aurantiacus* had been lost, and the specimen had only a healed-over basal part of the tail when captured. The tail length of individuals with nearly complete tails collected subsequently are long, almost twice the body length, and even more surprising more or less evenly cylindrical over the anterior half of the length of the tail.

The body size of adult males (n = 5) ranges from 68–85 mm SVL and adult females (n = 9) 74–87 mm SVL; distance from axilla to groin 54.2–60.0% SVL (mean = 57.9, n = 14); distance from forelimb to snout 34.8–41.7% SVL (mean = 37.2, n = 14); hind-limb length 29.1–36.1% SVL (mean = 30.9, n = 14); tail length of the individual with the longest most complete tail (as determined by x-rays) 181.3% of SVL (last c. 10 mm regenerated).

The description of the holotype of *Simiscincus aurantiacus* identified a number of unusual apomorphies in the configuration of the head scales that included: a frontonasal scale more than twice as broad as long; widely separated prefrontal scales; a single well developed loreal scale with a small semilunar scale positioned anterodorsally on the right loreal largely separating contact between that scale and the nasal scale; an oblique division of last upper labial; fragmentation of the temporal scales; and two (rather than three) pairs of enlarged chinshields.

Examination of the holotype and the additional 13 specimens confirms the presence of widely (80%) to very widely separated prefrontal scales and the presence of a small semilunar scale positioned on the anterodorsal margin of the large loreal scale in all individuals that is best interpreted as the anterior loreal which has undergone significant reduction in size, a trait seen in several other New Caledonian skink genera *(Marmorosphax, Graciliscincus* and some *Nannoscincus)*. The extent of fragmentation of scales at the rear of the jaw makes the homology of the posterior upper labial and adjacent temporal scales difficult to determine. The original description interpreted the anterior-most of two large scales bordering the posterior edge of the eye between the last supraciliary and penultimate upper labial as being a division of the last upper labial scale, with the posterior-most of these two large scales as the (single) primary temporal scale. Examination of the additional material indicates the homology of these particular scales may best be interpreted as two primary temporal scales (Fig. 1), a condition which occurs in 61% of cases but with fusion of these scales in the remainder, and with the last upper labial reduced in size such that it is smaller (rather than larger—the typical condition in skinks) than the preceding penultimate upper labial scale. Frequent fusion of these two large scales bordering the posterior edge of the eye (40%) is taken as evidence of a reversal to the pleisiomorphic condition of a single primary temporal. Further, no case of fusion between the anterior-most of these large scales with the adjoining last upper labial (to give a larger and taller scale), and which could be interpreted as a reversal to the pleisiomorphic condition, has been observed. Following this interpretation the homology of the remaining temporal scales would be that the posterior edges of the primary temporal scales are bordered by the last upper labial scales, two lower secondary temporal scales, and the upper secondary temporal scale,

Figure 2. Colouration of a typically boldly marked adult (sex unknown) *Simiscincus aurantiacus* from the Kwé River west.

with the secondary temporals in turn bordered posteriorly by three (occasionally four) tertiary temporal scales. The configuration of the chinshields also shows variation, with two pairs of enlarged scales posterior to the postmental scale as the modal condition, but with the shield posterior to these varying considerably, typically where the third pair of enlarged shields would be positioned. In some individuals the scales could be interpreted as representing a (third) pair of enlarged chinshields divided medially (as seen in *Marmorosphax* and *Kanakysaurus*), or were compressed and resembled the genial shields bordering the posterior lower labial scales. The number of upper labials scales was consistently seven. Variation was observed in the number of lower labials which were modally six (85%), rarely five or seven, and in the number of supraciliary scales which was modally seven (89.3%), occasionally six.

There was no discernable sexual dimorphism in scalation for the body and limbs, and minimal variation in these characters for all specimens examined as follows: midbody scale rows 36–40 (mean = 37.0, sd = 1.30, n = 14); dorsal scale rows 91–102 (mean = 98.0, sd = 2.93, n = 14); scales on top of the fourth finger 8–10 (mean = 9.25, sd = 0.47, n = 14); lamellae under the fourth finger 12–18 (mean = 15.4, sd = 1.47, n = 14); scales on top of the fourth toe 12–16 (mean = 14.1, sd = 0.84, n = 14); lamellae under the fourth toe 25–29 (mean = 27.25, sd = 1.41, n = 14).

The holotype, and a number of specimens of *Simiscincus aurantiacus* collected subsequently, were x-rayed (n = 8) and consistently had 29 presacral vertebrae, the number regarded as the plesiomorphic state for the endemic New Caledonian skink radiation. The individual with the most complete tail had 52 postsacral vertebrae. The extent of tail missing in this individual was small, and even a modest increase in the number of vertebrae by three to a possible total of 55 would only place it at the very upper limits of the plesiomorphic

state (50±5), and an increase by five to a possible total of 57 just within the range for the apomorphic state (>55) for the endemic New Caledonian skink radiation (Sadlier, 2010). One of the most unusual morphological traits of the holotype of *Simiscincus aurantiacus* was its highly elevated number of premaxilliary teeth, 19. Examination of a further seven individuals on which this trait could be assessed showed this to be the modal state, with one individual having a reduced number of 17 and one at 18.

The 14 specimens examined are remarkably uniform in coloration and pattern, and show little differentiation from the original description of the holotype, all having the black upper lateral color to the side of the head and body, and bright orange color to the lower lateral surface of the body and the venter (Figs 2, 3). The only obvious variation observed was in the extent of dark markings on the scales on the throat back to the level of the forelimbs. In most (n = 7) adult females each scale of the throat was heavily marked with dark coloration (Fig. 3), but in two individuals (R.172096 and R.171364) the dark markings were only moderately (or less) present. By comparison the dark markings to the throat of adult males were not as uniformly distributed, and where present these markings were boldest anteriorly around the margins of the chin, and more diffuse posteriorly, except for the smallest male (68 mm SVL) which had the boldly marked throat color typical of the adult females, indicating that the intensity of dark coloration may be progressively lost with maturity in males (as seen in the skink genera *Marmorosphax* and *Kanakysaurus*). The tail (which was not present on the holotype at the time of description) differs in coloration to the body. The top and sides of the tail are dark in color overall compared to the body, predominately a mix of dark grey with brown and black markings, and lighter grey below, but with dorsal, lateral and ventral colors of the body extending onto the basal part of the tail.

Figure 3. Ventral coloration of adult female *Simiscincus aurantiacus* (AM R.179770) showing bright orange color to the underside of the body typical of both sexes and bold dark coloration to the throat typical of females.

Specimens examined (all Australian Museum specimens): R.144356 Mt Koghis (22°10'43"S 166°30'20"E), Aug. 1994 (holotype); R.164368 Forêt Nord (22°19'28"S 166°54'51"E), 19 Dec. 2004; R.168159 Pic du Pin (22°14'50"S 166°52'58"E), 26 Oct. 2007; R.171364 Goro Plateau, Kwé Nord (22°17'43"S 166°58'38"E), 5 Nov. 2008; R.172096 Goro Plateau, Kwé Nord (22°16'47"S 166°56'46"E), 14 May 2009; R.172910 Goro Plateau, Kwé Nord (22°16'38"S 166°58'39"E), Nov. 2009; R.174503 Rivière Bleue, Parc Provincial de la Rivière Bleue, Lieu dit des Bucherons (22°6'32"S 166°41'25"E), 5 June 2010; R.174506 Goro Plateau, Kwé Nord Range (22°16'33"S 166°57'26"E), 21 June 2010; R.174507 Goro Plateau, Plaine des Lacs (22°15'35"S 166°56'52"E), 1 Sep. 2010; R.175547 Goro Plateau, Plaine des Lacs (22°13'8"S 166°57'12"E) May 2011; R.179762 Touango River near Plaine des Champ de Bataille (22°16'14"S 166°45'7"E), 11 Oct. 2013; R.179770 Riviere des Pirogues—upper reaches near Col des Deux Tétons (22°12'0"S 166°42'2"E), 23 June 2014; R.179779 Kwé River west, KO4 basin (22°17'19"S 166°55'55"E), 29 July 2014; R.179780 Kwé River west, KO4 basin (22°17'45"S 166°56'4"E), 29 July 2014; Kwé River west, KO4 basin (22°17'56"S 166°54'57"E) 6–10 Jan. 2015 (observation—Sadlier *et al.*, 2015); Lake Yaté near the confluence of the Rivière des Lacs (22°9'22"S 166°50'2"E), 1 Dec. 2012 (observation—Sadlier *et al.*, 2014c).

Intergeneric relationships: The placement of *Simiscincus aurantiacus* in a monotypic genus at the time of its description was not problematic given it could not be accommodated in any existing genus (within or outside the *Eugongylus* group of skinks) without compromising the diagnosis of existing genera as monophyletic groups. At the time of its description similarities in morphology and biology between *Simiscincus aurantiacus* and *Graciliscincus shonae* were identified, and by inference a sister relationship was assumed.

The first substantial inference of relationships between *Simiscincus aurantiacus* and other *Eugongylus* group taxa comes from the genetic phylogeny of Smith *et al.* (2007). This study produced the first broad-scale phylogeny for the New Caledonian skink fauna based on combined DNA sequence data for the mitochondrial ND2 gene and nuclear c-mos and Rag-1 genes, identifying a number of discrete genetic groupings of genera, each of which represented an independent lineage within a largely monophyletic New Caledonian radiation. Notably it identified a subgroup of genera that included *Caledoniscincus* + *Simiscincus* + *Graciliscincus* + "*New Genus* Mt Taom" (now = *Phaeoscincus taomensis*). However, while monophyly of this subgroup of genera received high support from Bayesian posterior probability values (BPP 1.00) it received only low support from maximum parsimony (MP) bootstrap values (<50%), and relationships between the included genera were typically low (BPP around 50% and MP <50%). Regardless, a relationship of *Caledoniscincus* to either *Simiscincus* or *Graciliscincus,* as inferred by their inclusion in the same genetic group (the "*Caledoniscincus* subgroup"—Sadlier, 2010) was unexpected and had not previously been considered. A similar grouping of *Caledoniscincus* + *Simiscincus* + *Graciliscincus* was retrieved in a subsequent re-analysis of the mitochondrial ND2 nuclear Rag-1 sequence data combined (Ineich *et al.*, 2014), with similarly high support from Bayesian posterior probability values (BPP 1.00) but low support from maximum parsimony (MP) bootstrap values (<50%). This analysis now included the giant skink *Phoboscincus bocourti* (missing in the earlier analysis) but omitted the taxon now recognized as *Phaeoscincus taomensis* (included in the earlier analysis). It identified *Simiscincus* and *Graciliscincus* as sister taxa (high support BPP of 1.00 but low MP of <50%), but in the absence of *Phaeoscincus taomensis* from the analysis

the robustness of this relationship is open to question. Note the genus *Phaeoscincus* includes two taxa, *Phaeoscincus taomensis* the type species which was included in the genetic study of Smith *et al.* (2007), and *Phaeoscincus ouinensis* known only from a single specimen nominally placed in the genus on morphological criteria, and for which genetic data are not available.

The monophyly of the "*Caledoniscincus* subgroup" identified in the genetic studies receives support from a suite of diagnostic morphological apomorphies that include reduction in the size of the prefrontal scales and a degree of fusion of elements of the first cervical vertebra, the atlas (the state for this character is unknown for *Phaeoscincus*). Among the endemic New Caledonian skink radiation reduction in size of the prefrontal scales is only otherwise seen in the *Nannoscincus* group. However, in *Nannoscincus* the degree of diminution is extreme and the scale can be variably lost in some species, and as such the modes of reduction of the prefrontal scales seen in the "*Caledoniscincus* subgroup" and in the *Nannoscincus* group are considered to be most likely independently derived. Fusion of the elements of the atlantal vertebra also occurs in *Nannoscincus*, *Sigaloseps* and *Celatiscincus* (the latter two members of the *Lioscincus* group as defined by Sadlier, 2010) and its presence in each group is at this point best interpreted as an independent derivation.

Although the internal relationships between the genera within "*Caledoniscincus* subgroup" were not well resolved in the genetic studies, a putative sister relationship for *Simiscincus* and *Graciliscincus* does receive support from a suite of morphological apomorphies. Both have undergone an elongation of the body and reduction in the size of the limbs, character states typical of subterranean skinks. Interestingly, both species also share apomorphies that typify their particular mode of fossorial existence, including: a relatively stout tail over much of the basal half of its length; an extremely broad snout as typified by a frontonasal scale being nearly or more than twice as broad as long, and in having an elevated number of premaxillary teeth (13 in *Graciliscincus* and a mode of 19 in *Simiscincus*); and a shortening of the snout as expressed via an extreme reduction in the anterior loreal such that it is a semilunar scale positioned on the anterodorsal margin of the nasal. These are physical traits that would be expected to have evolved in a species that exploits the use of existing passageways beneath the forest floor, rather than pushing through and displacing substrate at the subsurface level, such as the species of *Nannoscincus*. By contrast the species of *Caledoniscincus* are all day active heliothermic species that are usually conspicuous and abundant, and have the body form more typical of a surface-active species of skink.

Graciliscincus and *Simiscincus* each also have an independent suite of unique apomorphies that identify the two genera as each being on independent evolutionary trajectories. *Graciliscincus* has undergone a significant elongation of the body as evidenced by the relationship of axilla-groin length to total snout-vent length (62–66%) and in having a significantly elevated number of presacral vertebrae (34+ vs mode 29 for most endemic New Caledonian skink genera). It has also undergone: a reduction in the number of upper labial scales to six by what appears to be fusion of the anterior labial scales to produce an extended and elongate anterior-most scale; extreme diminution of the prefrontal scales; and further fusion in the elements of the first cervical

vertebrae (atlas) such that the atlantal arches are fused to the intercentrum dorsally and to each other to form a complete ring. The extent of development in these character states in *Graciliscincus* would appear to be associated with evolution towards a progressively more extreme sub-surface existence mode than that inferred for *Simiscincus*. By contrast, *Simiscincus* has a number of more pleisiomorphic traits (character state polarities from Sadlier, 2010) that include: a less elongate body with an axilla-groin length relative to total snout-vent length of 58%; larger prefrontal scales than *Graciliscincus shonae*; seven supraciliaries; the anterior upper labial scales even-sized; only 29 presacral vertebrae; and the atlantal arches of first cervical vertebrae fused to the intercentrum but not fused dorsally to each other as they are in *Graciliscincus*. However, *Simiscincus* does have several apomorphies not found in *Graciliscincus* that includes a division of the primary and lower secondary temporals, and an exceptionally high number of premaxillary teeth, the latter a highly derived osteological trait unique within the *Eugongylus* group of skinks.

Distribution, biology and conservation

Distribution: Extensive survey work across the Grand Sud of southern New Caledonia over the past eight years has greatly enhanced our knowledge of the extent and distribution of many lizard species in the region, and of the range of habitats they occupy. *Simiscincus aurantiacus* has now been recorded from a number of sites scattered across the Grand Sud (Fig. 4), including areas of humid forest within the reserves Forêt Nord, Pic du Grand Kaori, Pic du Pin and Parc de la Rivière Bleue, and smaller areas of humid forest often in close proximity to these reserves (Fig. 5). The majority of these sites are on the extensive low elevation ultramafic plateau (100–200 m) that comprises much of the far south of the island. The plateau is transected by chains of mid elevation ranges (c. 450 m) in its interior, and dissected by steep valleys in the east associated with river systems. The best known natural features of the region are the large natural freshwater lakes from which the place name of Plaine des Lacs is derived, and the Chutes des Madeleine, a broad waterfall in the river draining the elevated plateau on which the Plaine des Lacs is located.

It has also been recorded from a number of sites within tall, sometimes canopied, maquis forest habitat (paraforest and preforest) a forest-like vegetation association (Fig. 6), but usually only where these habitats occur on a broken ferralitic iron cap (cuirasse) or on areas of outcropping and broken peridotite. In the Grande Sud both humid forest and tall maquis forest habitats occur singularly as isolated patches of varying size, or in combination as a continuous grade, but ultimately surrounded by extensive areas of dense-open maquis scrub. As a consequence the distribution of *Simiscincus aurantiacus* in the region is highly fragmented. The combination of paraforest and preforest habitat on a broken cuirasse surface is most prevalent in the southeast in the region on the Goro Plateau and the Plaine des Lacs. Here the species' occurrence in tall canopied maquis forest habitats appears to be highly correlated with the presence of the extensive matrix of subsurface sheltering and foraging sites provides by the underlying, broken, cuirasse cap.

The north and west area of the Grand Sud, an area largely

Figure 4. Locations from which *Simiscincus aurantiacus* has been recorded in southern New Caledonia (green dots), with key locations mentioned in the text against sites.

encompassed by the ranges and drainage of the Rivière des Pirogues, is dominated by maquis shrubland, with humid forest usually present as isolated patches in gullies at the base of the ranges and canopied maquis habitat as small isolated patches in gullies or as narrow transitional zones around the perimeter of forest patches. In this area these forest types are usually on a lateritic soil surface. The distribution of *Simiscincus aurantiacus* here is represented by only a few scattered records: one from humid forest at the Touango River near the Plaine des Champ de Baitille, one from a small area of humid forest in a gully at Col des Deux Tétons, and one from a very small area of paraforest in a gully near the confluence of Rivière des Lac and Lac Yate. The record from humid forest at the Touango River was not surprising given the forest was located in a gully with extensive outcropping peridotite rock present in its interior, ideal habitat for the species. Conversely, its presence in the patch of humid forest at Col des Deux Tétons was not expected, given the forest here was on a lateritic soil surface that lacked outcropping rock or a broken cuirasse cap, and had few fallen logs on the forest floor—in effect providing very few suitable sheltering sites. The most surprising record was the species' presence in a small patch of paraforest habitat (Fig. 7) near the confluence of Rivière des Lac and Lac Yaté, a site surrounded by extensive areas of maquis shrubland and distant from larger areas at forest habitat (7 km from Forêt Cachée and 10 km

from Pic du Pin). However, the interior of the gully had an area of broken outcropping peridotite, apparently sufficient in itself to provide the necessary microhabitat for the species to persist in this isolated forest remnant.

The area adjacent to, and to the north of the Grand Sud, is dominated by steep-sided, high elevation ranges (c. 1000 m asl) which lie at the southern end of the Chaine Centrale, the elevated ranges that dominate the landscape of much of New Caledonia. The ranges adjacent to the Grand Sud have not been subject to the systematic survey work undertaken in that region. The occurrence of *Simiscincus aurantiacus* in the ranges is limited to the record of the holotype from mid-elevation humid forest on Mt Koghis and a single individual recorded from low-elevation humid forest in the Parc Provincial de la Rivière Bleue. The lower-mid slopes of the ranges are dominated maquis shrubland, with humid forest persisting mostly as isolated patches, but with more extensive areas of forest habitat at the base of the ranges adjacent to rivers, and at higher elevations. The distribution and extent of canopied maquis forest habitat (paraforest and preforest) in these ranges is difficult to comment on, but is also likely to be present as small isolated patches or as narrow transitional zones around the perimeter of humid forest. The fossorial species *Graciliscincus shonae* is similar in ecology and distribution to *Simiscincus aurantiacus* and has been recorded in these ranges as far north as Mt Dzumac

Figure 5. Typical humid forest remnant in the Grand Sud *(A)* surrounded by lingo-herbaceous maquis shrubland, and interior of forest *(B)*; note large logs on forest floor that provide sheltering sites for *Simiscincus aurantiacus*.

Figure 6. Typical patch of tall maquis paraforest on cuirasse *(A)* in the Grand Sud, and interior of paraforest *(B)*; note extensive broken cuirasse cap that provide sheltering sites for *Simiscincus aurantiacus*.

Figure 7. Isolated area of maquis paraforest in gully on low range near Lac Yaté *(A)*, and the interior of the paraforest showing extensive outcropping peridotite *(B)* from which *Simiscincus aurantiacus* was recorded.

in humid forest at 900 m elevation. Given the similarities shared by these two species in terms of their evolutionary history, biology and morphology, and that they occur in sympatry over most of their known range, it is conceivable that the distribution of *Simiscincus aurantiacus* could likewise extend further north into these ranges, and into forest habitat at higher elevations than previously recorded.

Population differentiation. The genetic relationships of the various populations of *Simiscincus aurantiacus* were investigated as part of a study initiated by Valé Nouvelle-Calédonie (see Sadlier & Bauer, 2014) to provide information reflecting the evolutionary histories of the lizard faunas across the Grand Sud, which in turn would provide a framework for the identification of specific management units within the species investigated, and for which management actions could then be developed i.e. the Evolutionary Significant Units (ESU's) of Moritz (1994).

To assess the relatedness between populations of *Simiscincus aurantiacus* sequence data were generated for the mitochondrial ND2 gene to retrieve fine scale patterns, and from the more conservative nuclear RAG1 gene to retrieve broader and historically deeper patterns of relatedness within the species. The sampling for *Simiscincus aurantiacus* included all known populations in the Grand Sud for which genetic samples were available. Sampling for the mitochondrial ND2 gene comprised eight individuals representing seven different sites, and sampling for the nuclear RAG1 gene included 8 individuals with multiple sampling (n = 3) from Kwé Nord. Genetic differentiation between samples for the mitochondrial ND2 gene (Table 2) was minimal, typically less than 1%, and there was no regional sub-structuring. The population from Forêt Nord was exceptional in being approximately 2% different from all other populations sampled. Somewhat paradoxically, the nuclear RAG1 gene showed greater genetic diversity than observed for the mitochondrial DNA, but still with no geographic structure to this diversity, a pattern of genetic variation consistent with a single widespread population with continuity of gene flow between populations historically, but with a recent reduction in variation of the mitochondrial DNA in association with strong selection for a particular mutation that also affects linked sites (a selective sweep; Maricic *et al*., 2013).

The distribution of humid forest in the southern ultramafic region is highly fragmented, with extensive areas of low, open maquis shrubland between the areas of forest, and the distribution of canopied maquis forest habitat is similarly fragmented. The extent to which the mosaic of forest and shrubland seen today is human induced or natural has been a point of conjecture. Maquis vegetation is diverse and highly specialized in its adaption to "toxic" nickel bearing soils (Lowry, 1998; Lowry *et al*., 2004), traits which could be interpreted as reflecting a long evolutionary history for this vegetation type. The inference of a long-term persistence of maquis habitat in the region has implications with regard to the extent of historical connectivity of forest habitat, which in turn would also have implications with regard to the extent of historical connectivity in distribution of forest dependent species.

The results of genetic studies showed the various populations in the region maintained sufficient connectivity to enable gene flow, and by inference forest habitat suitable for *Simiscincus aurantiacus* was historically

Table 2. Uncorrected pairwise distances between individuals of *Simiscincus aurantiacus* for the mitochondrial ND2 gene, with the New Caledonian skink *Phoboscincus garnieri* included for outgroup comparison (AM specimen numbers with R prefix).

				1	2	3	4	5	6	7	8	9
1	*S. aurantiacus*	R.164368	Forêt Nord	—								
2	*S. aurantiacus*	R.171364	Kwé Nord	0.0193	—							
3	*S. aurantiacus*	R.172096	Kwé Nord Range	0.0210	0.0018	—						
4	*S. aurantiacus*	R.172910	Kwé Nord	0.0193	0.0000	0.0018	—					
5	*S. aurantiacus*	R.174503	Rivière Bleue	0.0263	0.0070	0.0088	0.0070	—				
6	*S. aurantiacus*	R.174507	Plaine des Lacs	0.0245	0.0053	0.0070	0.0053	0.0018	—			
7	*S. aurantiacus*	R.175547	Plaine des Lacs	0.0210	0.0018	0.0035	0.0018	0.0088	0.0070	—		
8	*S. aurantiacus*	R.180396	Rivière des Lacs	0.0228	0.0035	0.0053	0.0035	0.0105	0.0088	0.0053	—	
9	*P. garnieri*	R.151965	Mt Koghis	0.2294	0.2189	0.2172	0.2189	0.2172	0.2189	0.2207	0.2224	—

widespread across the Grand Sud. This is very different from the landscape seen today which is one dominated by expanses of maquis shrubland with forest habitat present as isolated patches, a scenario clearly attributed to the presence of humans on Grande Terre. Whether the extent of past connectivity between populations of *Simiscincus aurantiacus* was achieved through a historically continuous unit of forest or as a shifting mosaic of forest and maquis progressing through successional stages from shrubland to forest is not known. Fluctuations in the presence of forest vegetation in the region in recent times (over a period of approximately the past 130,000 years) have been reported from studies of the distribution of pollen in core samples from perched still-water lakes on the Goro Plateau (Hope & Pask, 1998; Stevenson & Hope, 2004), with its periodic absence attributed primarily to fire (McCoy *et al*, 1999). While the time frame of these results is too recent to be directly referable to the phylogenic structure retrieved in the genetic study, it does provide evidence for cycles of presence/loss/reappearance of forest habitat in the region, and by inference support for the scenario of a shifting mosaic of forest and maquis vegetation through time.

Biology: *Simiscincus aurantiacus* has not been observed active and only two have been found by searching under sheltering sites, both in the interior of humid forest habitat. One (the holotype) was located beneath a rock in an area of outcropping peridotite in forest on Mt Koghis, and immediately sought shelter in the underlying matrix of crevices in the rock and soil below. The other was located beneath a small log on soil on the forest floor at the base of Forêt Nord. The remaining records for the species are from individuals captured on glue traps set on forest floor or among rocks and logs in forest habitat, or, in or next to openings in the exposed and broken cuirasse cap in canopied maquis forest habitat. Only on two occasions have individuals been caught on traps on the open forest floor away from obvious sheltering sites. While these data support earlier inferences of a primarily subterranean mode of existence derived from morphology and (limited) field observations (Sadlier & Bauer, 1997), it appears the species is also active on the surface of humid forest habitat. Further, both were recorded in early morning checks of traps, indicating they were most likely active either late in the previous day and/or at night. Such on-surface activity late in the day and/or at night may account for the presence of scales of *Simiscincus aurantiacus* in rodent stomach contents studies (Jourdan *et al*., 2015; Thibault *et al*., 2016).

Maturity and reproduction: Three adult males collected in the austral mid-late winter months of June (R.174503—SVL 72.5 mm), July (R.179779—SVL 71.5 mm) and August (R.144356—SVL 85 mm) had enlarged testes (turgid with seminiferous tubules obvious), whereas two adult males collected in the austral mid-summer months of November (R.172910—SVL 74 mm) and December (R.164346—SVL 68 mm) had the testes reduced in size by comparison. It is equivocal as to whether the reduced testis size in the smallest individual which was collected in December indicates it is a subadult or a reproductively inactive mature individual. Adult females collected in the austral mid-late winter month of July and the spring months of September/October had enlarged yolked ovarian follicles in the ovaries. The individuals collected in July had two (R.179780—SVL 74 mm—1 left /1 right) and four (R.179770—SVL 82 mm—2 left /2 right), enlarged follicles, and the individuals collected in September (R.174507—SVL 85 mm—1 left /2 right) and October (R.168159—SVL 82 mm) each had three enlarged follicles. The number of enlarged follicles recorded during these months appears to closely reflect the potential clutch size when compared to the observed number of shelled eggs present in gravid individuals. Three large shelled eggs were recorded in an individual collected October (R.172096—SVL 80 mm) and four from an individual collected in early December (specimen from 1 Dec. 2012 listed in Specimens Examined). Two adult females collected in the austral winter months of May (R.172096—SVL 82 mm) and June (R.174506—SVL 75 mm) had enlarged oviducts but no indication of obvious enlargement of the ovarian follicles, indicating that these females had passed eggs and were now reproductively quiescent in the post summer period.

Conservation: The genetic data indicates the various (now) isolated populations of *Simiscincus aurantiacus* are part of a single discrete evolutionary unit, and that the preferred habitat for the species was likely once more widespread across the Grand Sud, although it is possible these populations could have undergone periods of natural disjunction associated with fluctuations in extent of forest habitat historically. However, since human occupation of the island the species distribution has become highly fragmented and undergone a significant reduction in area of occupancy and total population size as a consequence of the widespread loss of closed forest and canopied maquis forest habitat from recurrent wildfires. Some areas of habitat have also been lost to mining and logging, or degraded through disturbance associated with these activities. All post-human occupation

impacts are ongoing. *Simiscincus aurantiacus* is currently ranked as Vulnerable (B1ab (i, ii, iii, iv)) on IUCN Red List criteria (Whitaker & Sadlier, 2011), having an extent of occurrence (B1) estimated to be less than 100 km², being severely fragmented in distribution, with a continuing decline (observed, inferred or projected) in its extent of occurrence, area of occupancy, area, extent and/or quality of habitat, and number of locations or subpopulations. The data presented here support that ranking. There are no quantitative data on population size and trends for this species.

The species biology indicates it relies on forest habitats, and as such would clearly benefit from the preservation of areas of forest habitat. However, it is unlikely to be able to migrate between the now isolated forest patches. The designation of areas of forest and/or maquis habitats as potential corridors has recently been proposed as a conservation strategy for avifauna in the Grand Sud (Desmoulins & Barré, 2004), to enable animals to migrate across the landscape and thereby alleviate the possibility of genetic bottlenecks between populations of forest dependent species occupying isolated patches of habitat. For *Simiscincus aurantiacus* the relatively low level of genetic differentiation between populations would suggest that maintenance of genetic diversity through corridors (or translocation) is not at this time a high conservation priority for the species relative to other issues. Further, from a point of practicality, the effectiveness of corridors in facilitating migration between the scattered populations of *Simiscincus aurantiacus* would be entirely dependent upon these corridors reaching a level of development sufficient to maintain the desired microhabitat and resources required for this species.

The most immediate and serious conservation priorities for the long-term persistence of *Simiscincus aurantiacus* are in the prevention of further loss and fragmentation of the species' preferred habitat through the clearing of humid forest and canopied maquis forest habitat, and in the prevention of further degradation of the remaining areas of these forest habitats. The loss of forest habitats from activities associated with mining are in the main obvious, but tend to be localized, while the impacts of habitat degradation from wildfire and exotic species are widespread across the landscape of the Grand Sud. Throughout the region forest habitats are under threat from wildfires in maquis shrublands which threaten forest margins, a situation exacerbated in periods of drought (Ibanez *et al.*, 2012). More insidious and pervasive is the disturbance and loss of microhabitat from the activities of introduced species. Ungulates (deer and pigs) damage the litter layer and disturb ground sheltering sites (such as rocks and logs), and through browsing open the forest understory and lower humidity. The introduced ant *Wasmannia auropunctata* has invaded areas of humid forest habitat in the Grand Sud, and is expected to have a negative impact indirectly through a reduction in abundance or diversity of the invertebrate prey for lizards in forest habitats. Introduced mammals are also potential predators, and predation on lizards by feral cats and rats has been identified as a threatening process (Jourdan *et al.*, 2015) for the New Caledonian lizard fauna. The scales of *Simiscincus aurantiacus* have been recorded from the stomach contents of rats (Jourdan *et al.*, 2015; Thibault *et al.*, 2016), and although not reported from cat scat analysis studies (Jourdan *et al.*, 2015), predation by cats on individuals active on the forest floor at night could also be expected to occur.

The species occurs in several reserves in the Grand Sud, including the Réserve Naturelle de la Forêt Nord, Pic du Grand Kaori, Pic du Pin and Parc Provincial de la Rivière Bleue. The primary management actions for *Simiscincus aurantiacus* would be in identifying key populations for conservation management within the existing reserve system and in developing management strategies to moderate threats to these key populations.

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