

New distribution records: four species of giant geckos (Gekkota: Diplodactylidae) occur in syntopy on Île des Pins, New Caledonia

Lennart Hudel^{1,*}, Leonard Georg¹, and Linus Henkel¹

New Caledonia is considered a global biodiversity hotspot (Myers et al. 2000), and it is particularly known for its high degree of microendemism (Bauer and Jackman, 2006; Caesar et al., 2017). In terrestrial vertebrates, squamates are among the most species-rich groups, and they are mainly represented by two clades: lygosomine skinks (Scindidae: Lygosominae) and diplodactylid geckos (Gekkota: Diplodactylidae) (Bauer and Sadlier, 2000; Bernstein et al., 2015). Many range-restricted species from these two groups have been described recently (e.g., Bauer et al., 2006; Sadlier et al., 2014; Skipwith et al., 2014), and at least 25 species of New Caledonian skinks and geckos are known only from single localities (Meiri et al., 2018). While many areas remain poorly studied and discoveries of additional range-restricted taxa will likely continue with increased sampling effort, even comparatively well-studied areas remain not only a source for new taxa (e.g., Wright et al., 2000; Sadlier et al., 2019), but consistently yield new distribution records for species that had not been detected at those sites before. For example, *Rhacodactylus auriculatus* (Bavay, 1869) was considered to be restricted to the ultramafic areas of southern New Caledonia (Bauer and Sadlier, 2000) until it was discovered to be widespread in maquis habitats in the northwestern part of the island (Whitaker et al., 2004). *Correlophus ciliatus* Guichenot, 1866 and *Rhacodactylus leachianus* (Cuvier, 1829) were assumed to not occur in northwestern New Caledonia until they were recently (Sanchez et al., 2015) discovered at a relatively small and already well-studied site that

had been regularly visited by herpetoculturists and herpetologists for almost 20 years (Seipp and Henkel, 2000; Whitaker et al., 2004). This indicates that the detection probabilities for such cryptic species are low, that their distribution record is likely incomplete, and that further systematic sampling effort is necessary in New Caledonia not only to investigate undescribed diversity, but to understand distribution patterns and ecology of already described taxa.

Here, we report new distribution records for *Mniarogekko chahoua* (Bavay, 1869) and *Rhacodactylus trachycephalus* (Boulenger, 1878) from Île des Pins, a moderately large island approximately 50 km south of the New Caledonian mainland (Fig. 1), where the occurrence of both species was previously in doubt (Bauer et al., 2012; Geneva et al., 2013). We furthermore report distribution records for *Rhacodactylus leachianus* and *Correlophus ciliatus*, both of which occur syntopically with the former two species on the Île des Pins.

Material and Methods

From 14–18 March 2019, we conducted nocturnal searches for geckos in closed humid forest and along forest edges in the western parts of the Île des Pins, as well as on the satellite island Brosse (Fig. 1). Survey tracks were chosen opportunistically, avoiding private property and degraded forests, and included the Pic N'Ga hiking track and public roads. Tracks were walked in one direction and not repeated in the same night to avoid duplicate observations. Searches were conducted between 1800 and 2100 h. Flashlights were used to illuminate stems, branches, and the canopy of shrubs and trees on both sides of tracks. Abrupt movements and the reflecting retina (Fig. 2C) facilitated detection of animals even when they were moving high in the canopy. Observed geckos were checked with binoculars and, if possible, photographed and identified using Bauer and Sadlier (2000) and Bauer et al. (2012). GPS

¹ Faculty for Biology and Psychology, Georg-August-Universität, Wilhelm-Weber-Straße 2, 37073 Göttingen, Germany.

* Corresponding author. E-mail: lennart.hudel@stud.uni-goettingen.de

tracks were recorded using a Garmin eTrex 20x. In total, we surveyed 8.8 km of forest tracks at an effort of 6:10 h on Île des Pins and 3.4 km of forest tracks at an effort of 2:35 h on Îlot Brosse, with 2–6 surveyors per track. As a rough measure of abundance, we calculated encounter rates per hour of search effort, and corrected for the respective number of surveyors (Nekaris *et al.*, 2008).

Results and Discussion

On Île des Pins, we encountered seven native species of geckos: *Bavayia* aff. *robusta* (Wright *et al.*, 2000; Geneva *et al.*, 2013), *B. sauvagii* (Boulenger, 1883), *Nactus pelagicus* (Girard, 1858; $n = 2$), *Correlophus ciliatus* ($n = 15$), *Mniarogekko chahoua* ($n = 4$), *Rhacodactylus trachycephalus* ($n = 3$), and *R. leachianus* ($n = 9$). On Îlot Brosse, we encountered only *R. leachianus* ($n = 7$) and *B. sauvagii* ($n = 3$). Due to their cryptic colouration and small size, it was often impossible to determine

the identity of geckos in the genus *Bavayia* ($n = 34$) to species level when they were observed high on tree trunks or branches, and we therefore did not calculate encounter rates for *B. aff. robusta* and *B. sauvagii*. Of the four species of giant geckos, *Correlophus ciliatus* was most commonly encountered, at a mean encounter rate of 0.57 (0.00–1.96) individuals / effort hour. *Mniarogekko chahoua* and *R. trachycephalus* were less common, at encounter rates of 0.24 (0.00–0.64) and 0.13 (0.00–0.67) individuals / effort hour, respectively. The mean encounter rate of *R. leachianus* on Île des Pins (0.35 individuals / effort hour, 0.00–1.00) was considerably lower than on Îlot Brosse (0.90 individuals / effort hour).

The spectacular *Correlophus ciliatus* was rediscovered on Île des Pins in 1994 (Seipp and Klemmer, 1994), but precise locality data is not available for any voucher specimens from the island. The only precise locality

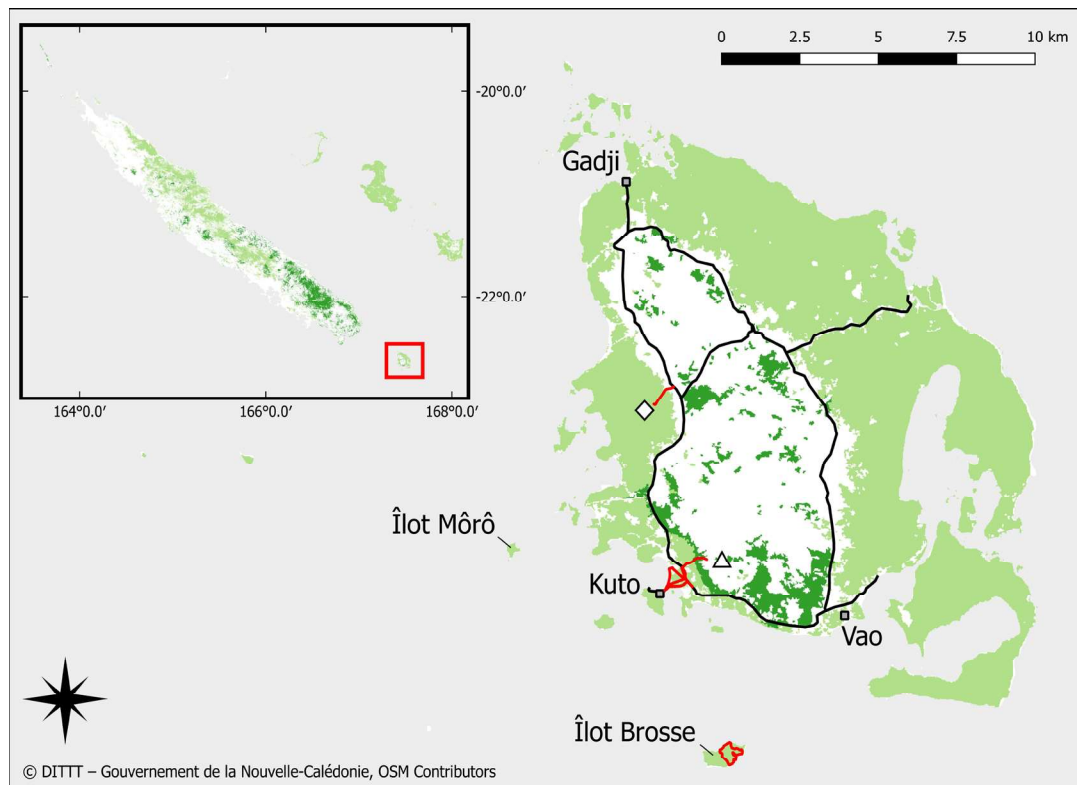


Figure 1. Map of the study area with tracks surveyed (red; 12.2 km total) in the western portion of Île des Pins and on Îlot Brosse. The inlay shows the position of the Île des Pins ca. 50 km southeast of mainland New Caledonia. The previously known documented range of *R. trachycephalus*, Îlot Môrô, is indicated. Forest cover on calcareous and ultramafic soil is shown in light and dark green, respectively, and the Grotte de la Troisième (◇) as well as the summit of Pic N'Ga (△) are marked.

given for this species from Île des Pins is Kucaariüü (22.5863°S, 167.5206°E) in the northeast part of the island (A.H. Whitaker sight record, cited in Bauer et al., 2012). Furthermore, the abundance and conservation status of this species remain poorly known. We encountered this species at all sites surveyed, but at varying densities: only single individuals (0.13–0.64 individuals / effort hour) could be observed in the humid forest at the entrance of the Pic N'Ga hiking track (22.6533°S, 167.4539°E) and at Baie de Kanumera (22.6616°S, 167.4446°E; Fig. 2A), but the species was reasonably common (0.67 individuals / effort hour) at forest edges north of Kuto (22.6569°S, 167.4452°E) and very abundant (1.96 individuals / effort hour) in the humid forest around Grotte de la Troisième (22.6104°S, 167.4387°E). Individual perching height varied from 0.5 m to ca. 8 m. We encountered freshly hatched, juvenile as well as adult individuals of both sexes.

The presence of *Mniarogekko chahoua* on Île des Pins has been mentioned by several herpetoculturists (de Vosjoli, 1995; Seipp and Henkel, 2000), but

voucher specimens for phylogenetic analyses or specific locality data have been lacking (Bauer et al., 2012; Geneva et al., 2013). We observed this species at three different localities in the western portion of the island: two individuals were observed climbing at heights of approximately 8–10 m in trees at the roadside between Kuto and Wero (22.6560°S, 167.4475°E), one individual was observed climbing a vine at approximately 10 m aboveground close to Grotte de la Troisième (22.6104°S, 167.4387°E), and one individual was observed on a large tree trunk approximately 4 m aboveground, close to Baie de Kanumera (22.6616°S, 167.4446°E; Fig. 2B).

Similarly, even though Île des Pins is given as the type locality of *Rhacodactylus trachycephalus* (Bauer et al., 2012) and voucher specimens supposedly from this island have been used in phylogenetic analyses (Vences et al., 2001), no precise localities are known, and the presence of this recently recognized species on the island has been debated: Bauer and Sadlier (1994) and de Vosjoli (1995) were unable to detect it, and its current

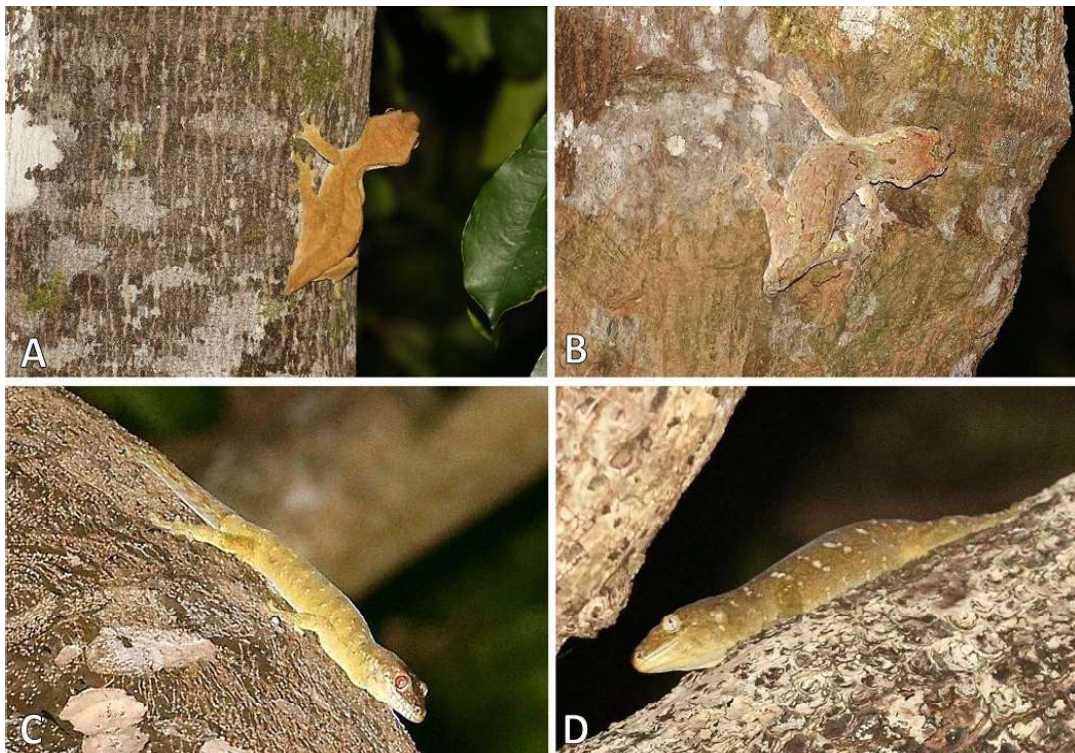


Figure 2. Giant gecko species encountered in syntopy close to Baie de Kanumera, western Île des Pins. (A) *Correlophus ciliates*. (B) *Mniarogekko chahoua*. (C) *Rhacodactylus trachycephalus*. (D) *Rhacodactylus leachianus*.

IUCN Red List assessment as ‘critically endangered’ (Bauer *et al.*, 2012; Geneva *et al.*, 2013) stems from the assumption that it is restricted to the small western satellite island Môrô (Fig. 1). We observed three individuals of this species close to Baie de Kanumera (22.6616°S, 167.4446°E), climbing at heights of 3–8 m aboveground in the same tree. One individual was observed climbing a phone line and retreated to the tree when disturbed (Fig. 2C). The observations were made on subsequent nights, and individuals could only be distinguished via photographs based on different stages of tail regeneration. These observations are in concordance with Cunkelman (2005), who reported a high degree of site fidelity in this species, and that diurnal retreats on Môrô were always occupied by at least two or more individuals.

Whereas the species has been recorded from numerous satellite islands (Geneva *et al.*, 2013), precise locality data for *Rhacodactylus leachianus* from Île des Pins proper is known only from Gîte Kodjeue in the west (22.5986°S, 167.4194°E) and Kucaarüü in the east (22.5863°S, 167.5206°E; Bauer *et al.*, 2012). We observed the species close to Baie de Kanumera (22.6616°S, 167.4446°E, Fig. 2D), at forest edges north of Kuto (22.6569°S, 167.4452°E), and within the humid forest surrounding Grotte de la Troisième (22.6104°S, 167.4387°E).

All four species of giant diplodactylid geckos present on Île des Pins occur syntopically in the western portion of the island: we encountered all species in close vicinity to each other near Baie de Kanumera and encountered all but the rare *R. trachycephalus* in the humid forest surrounding Grotte de la Troisième. This raises questions about population densities, niche partitioning, and displacement between the different species. Additionally, the presence of all four species in relatively modified habitat around Baie de Kuto and Baie de Kanumera is unexpected, as they are commonly assumed to be restricted to mature and undisturbed humid forest (Bauer and Sadlier, 2000). As it is of direct consequence for conservation efforts, the extent to which these species are resilient to habitat disturbance should be investigated. Furthermore, the occurrence of these species in close vicinity to the regions most impacted by tourism on Île des Pins might put these populations at even larger risk for poaching than those on satellite islands. As all four species are sought-after by reptile hobbyists (Seipp and Henkel, 2000), and in the light of a recent increase in the poaching of New Caledonian geckos and skinks, a strategy for the protection of these

species on the Île des Pins is urgently needed.

Whereas some of the coralline satellite islands surrounding Île des Pins have been the focus of a recent review of reptile diversity and distribution (Geneva *et al.*, 2013), an equally large number of satellite islands and large portions of Île des Pins itself have yet to be investigated. Our findings indicate that *Mniarogekko chahoua* and *Rhacodactylus trachycephalus* are likely to occur elsewhere on Île des Pins, and we believe that an increased survey effort is necessary for several reasons. Firstly, it is apparent that the current distribution data for these species must be considered preliminary. Secondly, only limited data exist on the ecology of New Caledonian diplodactylids (Cunkelman, 2005), and Île des Pins could represent a favourable system to study these species in sympatry, and to investigate how they partition habitats. Thirdly, given the high degree of genetic differentiation between micro-endemic New Caledonian taxa, and in the light of the recent description of a northern sister taxon to *M. chahoua* (Bauer *et al.*, 2012), *Mniarogekko* from Île des Pins could potentially represent a distinct species. It is therefore advisable to collect tissue samples from these populations for phylogenetic analyses. Lastly, by confirming that *R. trachycephalus* is not restricted to Môrô, our results necessitate the re-evaluation of this species’ current threat assessment (Bauer *et al.*, 2012) as ‘critically endangered’: the criterion B1 (extent of occurrence < 100km²) is no longer applicable, and the number and degree to which populations are fragmented (criterion B1b) is unknown. Additionally, a continuing decline in habitat extent and characteristics (criteria B2b i–iii), or of populations and individuals (criteria B2b iv–v) are equally speculative and in urgent need of investigation.

For further studies aimed at closing these knowledge gaps, we suggest an approach that combines the randomized selection of transects and a systematic distance sampling (Thomas *et al.*, 2010) that accounts for low detection probabilities. Complementary to this, species distribution models (Guisan and Thuiller, 2005) should be applied to predict the occurrence of species to preselect sampling sites.

Acknowledgements. We thank Rémi Auteret (Parc Forestier et Zoologique Noumea) for his hospitality and support in New Caledonia, as well as Kea Schmoll (Universität Göttingen), Svenja Breil (Universität Hannover), and Annika Georg (Gießen) for their patience between and kind support during surveys. We thank Aaron M. Bauer (Villanova University) for his helpful comments on this manuscript.

References

- Bauer, A.M., Sadlier, R.A. (1994): The terrestrial herpetofauna of the Île des Pins, New Caledonia. *Pacific Science* **48**: 353–366.
- Bauer, A.M., Sadlier, R.A. (2000): The Herpetofauna of New Caledonia. Society for the Study of Amphibians and Reptiles, Ithaca, New York, USA.
- Bauer, A.M., Jackman, T. (2006): Phylogeny and microendemism of the New Caledonian lizard fauna. *Proceedings of the 13th Congress of the Societas Europaea Herpetologica*. Vol. 9, 13.
- Bauer, A.M., Jackman, T., Sadlier, R.A., Whitaker, A.H. (2006): A new genus and species of diplodactylid gecko (Reptilia: Squamata: Diplodactylidae) from northwestern New Caledonia. *Pacific Science* **60**: 125–136.
- Bauer, A.M., Jackman, T.R., Sadlier, R.A., Whitaker, A.H. (2012): Revision of the giant geckos of New Caledonia (Reptilia: Diplodactylidae: Rhacodactylus). *Zootaxa* **3404**: 1–52.
- Bernstein, J., Bauer, A.M., Jackman, T., Wang, Y.Y. (2015): Phylogenetic analysis, species identification and delimitation of New Caledonian geckos and skinks using DNA barcoding. *Genome* **58**: 195–195.
- Caesar, M., Grandcolas, P., Pellens, R. (2017): Outstanding microendemism in New Caledonia: more than one out of ten animal species have a very restricted distribution range. *PLoS One* **12**(7): e0181437.
- Cunkelman, A.A. (2005): Ecology of *Rhacodactylus leachianus* and *R. trachyrhynchus* in an area of sympatry. Unpublished M.S. thesis, Villanova University, Villanova, Pennsylvania, USA.
- de Vosjoli, P. (1995): Notes from a herpetological field trip to New Caledonia, Part One: Account from the daily journals of Philippe de Vosjoli and Frank Fast. *The Vivarium* **6**(5): 4–7, 12, 14–17, 36–38, 40–43.
- Geneva, A.J., Bauer, A.M., Sadlier, R.A., Jackman, T.R. (2013): Terrestrial herpetofauna of Île des Pins, New Caledonia, with an emphasis on its surrounding islands. *Pacific Science* **67**: 571–590.
- Guisan, A., Thuiller, W. (2005): Predicting species distribution: offering more than simple habitat models. *Ecology Letters* **8**: 993–1009.
- Meiri, S., Bauer, A.M., Allison, A., Castro-Herrera, F., Chirio, L., Colli, G., Das, I., Doan, T.M., Glaw, F., Grismer, L.L., Hoogmoed, M. (2018): Extinct, obscure or imaginary: the lizard species with the smallest ranges. *Diversity and Distributions* **24**: 262–273.
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A., Kent, J. (2000): Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–858.
- Nekaris, K.A.I., Blackham, G.V., Nijman, V. (2008): Conservation implications of low encounter rates of five nocturnal primate species (*Nycticebus* spp.) in Asia. *Biodiversity and Conservation* **17**: 733–747.
- Sadlier, R.A., Bauer, A.M., Wood, P.L., Jr., Smith, S.A., Whitaker, A.H., Jourdan, H., Jackman, T. (2014): Localized endemism in the southern ultramafic bio-region of New Caledonia as evidenced by the lizards in the genus *Sigaloseps* (Reptilia: Scincidae), with descriptions of four new species. *Zoologica Neocaledonica* **8**: 79–113.
- Sadlier, R.A., Deuss, M., Bauer, A.M., Jourdan, H. (2019): *Kumiesaurus albiauris*, a new genus and species of scincid lizard from the Île des Pins, New Caledonia, with comments on the diversity and affinities of the region's lizard fauna. *Pacific Science* **73**: 123–142.
- Sanchez, M., Cassan, J.R., Duval, T. (2015): A new locality for *Correlophus ciliatus* and *Rhacodactylus leachianus* (Sauria: Diplodactylidae) from Nêhoué River, northern New Caledonia. *Herpetology Notes* **8**: 553–555.
- Seipp, R., Klemmer, K. (1994): Wiederentdeckung von *Rhacodactylus ciliatus* Guichenot 1866 im Süden Neukaledoniens (Reptilia: Sauria: Gekkonidae). *Senckenbergiana Biologica* **24**: 199–204.
- Seipp, R., Henkel, F.W. (2000): *Rhacodactylus*: Biology, Natural History & Husbandry. Edition Chimaira, Frankfurt, Germany.
- Skipwith, P., Jackman, T., Whitaker, A.H., Bauer, A.M., Sadlier, R.A. (2014): New data on *Dierogecko* (Squamata: Gekkota: Diplodactylidae), with the description of a new species from Île Baaba, Province Nord, New Caledonia. *Mémoires du Muséum National d'Histoire Naturelle* **206**: 13–30.
- Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A., Burnham, K.P. (2010): Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* **47**: 5–14.
- Vences, M., Henkel, F.-W., Seipp, R. (2001): Molekulare Untersuchungen zur Phylogenie und Taxonomie der neukaledonischen Geckos der Gattung *Rhacodactylus* (Reptilia: Gekkonidae). *Salamandra* **37**: 73–82.
- 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. Unpublished report by Whitaker Consultants Limited to Direction du Développement Economique et de l'Environnement, Province Nord, Koné, New Caledonia.
- Wright, J.L., Bauer, A.M., Sadlier, R.A. (2000): Two new gecko species allied to *Bavayia sauvagii* and *Bavayia cyclura* (Reptilia: Diplodactylidae) from New Caledonia. *Pacific Science* **54**: 39–55.