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Assessment of Glue Traps in Subtropical Maquis Shrubland: Applications for the Study of the New Caledonian Leopard Skink (*Lacertoides pardalis*)

Matthias Deuss[1] and Hervé Jourdan

Aix Marseille Université, France's National Centre for Research (CNRS), French National Research Institute for Sustainable Development (IRD), Avignon Université, Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale (IMBE), Centre IRD de Nouméa, BPA5, 98848 Nouméa cedex, Nouvelle-Calédonie
[1]Corresponding author; e-mail: matthias.deuss@ird.fr

Abstract.—**Among the endemic skinks of New Caledonia, the Leopard Skink is one of the species best adapted to Maquis shrublands on ultramafic surfaces. These habitats, particularly those exposed to mining activities and bushfires, are regularly surveyed for herpetofauna; however, capture techniques available for such surveys are limited. Glue traps (GTs) are the most commonly used method, but are criticized for the risk they pose to wildlife. We propose here an evaluation through a review of research conducted on the Leopard Skink. We evaluate, for the first time, the efficiency of baiting GTs with canned fruits. We also test two alternative techniques: artificial refuges and funnel traps. Their very low capture rates lead us to favour the use of GTs. The use of fruit baiting allows on average to double the daily catches of Leopard Skinks. Mortality may be reduced by installing traps under cover and frequent checks. Glue traps are currently the most effective technique for surveying the herpetofauna of New Caledonian maquis shrublands. However, recaptures are very rare, which limits the prospects for population monitoring using mark-recapture methods. This issue remains a challenge for future conservation measures in these specific habitats facing high levels of threats.**

Key Words.—artificial refuges; baiting; funnel traps; mortality; population estimate; skinks; trapping

***Résumé*.— Parmi les scinques endémiques de Nouvelle-Calédonie, le Scinque-léopard est l'espèce la plus adaptée aux maquis miniers. Ces habitats, particulièrements exposés aux activités minières et aux feux de brousse, sont régulièrement l'objet d'études herpétologiques réglementaires. Pourtant, les techniques de capture disponibles pour ces études sont limitées. Les pièges collants sont les plus utilisés, mais sont critiqués pour le risque qu'ils font courir à la faune. Nous en proposons ici une évaluation à travers la synthèse des études dédiées au Scinque-léopard. Nous avons évalué pour la première fois l'efficacité de l'appâtage des pièges collants avec des fruits au sirop. Nous avons également testé deux techniques alternatives: les abris artificiels et les nasses. Leurs taux de capture très faibles sont rédibitoires, ce qui nous a conduit à privilégier l'utilisation des pièges collants. L'utilisation d'appâts permet en moyenne de doubler les captures journalières de scinque-léopard. L'adoption de bonnes pratiques (installation des pièges sous abri, relèves fréquentes) permet de limiter les taux de mortalité. Les pièges collants restent donc à l'heure actuelle la technique la plus efficace pour inventorier l'herpétofaune des maquis miniers de Nouvelle-Calédonie; toutefois, les recaptures sont très rares, ce qui limite les perspectives pour un indice d'abondance robuste dans une optique de suivi des populations en maquis minier.**

Mots-clés.—appâtage; estimation de population; mortalité; nasses; piègeage; refuges artificiels; scinques

Introduction

The herpetofauna of New Caledonia includes 107 described species of lizards (Bernstein et al. 2021), and more than 40 species awaiting description (Bauer et al. 2012; Skipwith et al. 2016; Bernstein et al. 2021). As a result of an exceptionally high rate of endemism, about 1.4% of the described lizard fauna of the world is found only in New Caledonia, including 23% of all diplodactylid geckos and 14% of eugongyline skinks (http://www.reptile-database.org). Despite a large amount of taxonomic work published in the last 25 y, studies dealing with ecology or demography are relatively scarce. Apart from a few notable exceptions (Duval et al. 2019), there are no abundance estimates for any population of the 69 threatened species (International Union for Conservation of Nature [IUCN] 2021). Instead, most ecological surveys have dealt with index counts (e.g., See Unpublished Reports: Sadlier and Swan 2010; Astrongatt 2017b) or encounter rates

(See Unpublished Reports: Whitaker and Whitaker 2007).

Most lizard species in New Caledonia are found either in closed forest or Maquis shrublands. In particular, Maquis shrublands on ultramafic surfaces (soils poor in minerals and rich in heavy metals) are the most commonly sampled natural habitats during mitigation surveys for environmental assessment requirements in the context of the regulation of mining activities. Indeed, New Caledonia contains one third of the nickel reserves of the world (L'Huillier and Jaffré 2010). It is estimated that 45% of the threatened reptiles in New Caledonia are impacted by mining activities (IUCN 2021).

Shrubland habitats are diverse but can be characterized by rugged terrain, large surfaces of hard, bare soil and rocky outcrops, and embedded within low, dense vegetation (Isnard et al. 2016; Jaffré 2022). Their surface area is currently expanding as human-induced bushfires increases in frequency (Gomez et al. 2015; Mangeas et al. 2019). Animal densities are generally low in Maquis shrublands, and there is a lack of appropriate sampling techniques for herpetofaunal surveys, but some methodological research is documented (See Unpublished Reports: Sadlier 2009). Because of the low and dense vegetation, visual encounter surveys are less efficient than in closed forest habitat, and the use of pitfall traps is made almost impossible by the steep and harsh terrain. As a consequence, glue traps (GTs) have become by far the most widely used technique for inventory and monitoring of a variety of skink species in Maquis habitats and in most surveys of closed-forest areas.

The New Caledonian Leopard Skink (*Lacertoides pardalis*) is a diurnal, heliothermic, live-bearing lizard endemic to the southern ultramafic region of New Caledonia, and the only skink in this country known to feed mostly on fruits (Sadlier et al. 1997, 2014, 2018). This skink is strictly dependant on ultramafic Maquis shrubland with outcropping peridotite and screes (see Fig. 1). Deep cracks in peridotite outcrops are used as shelters and several species of native fruit shrubs grow between those. These habitat conditions are mostly represented near the crest of ridgelines, on eroded slopes, and along rocky riverbanks. This unique habitat preference among New Caledonian lizards makes it particularly sensitive to mining activities and wildfires throughout much of its range (unpubl. data). For this reason and its low number of known locations, it is ranked as Vulnerable (VU) on the Red List of the IUCN (Sadlier et al. 2021).

The extreme wariness of the Leopard Skink makes it very difficult to detect visually, which partly explains why it was only discovered in 1995 (Sadlier et al. 1997). Sadlier et al. (2014) estimated that this species had only been observed while active on four occasions. Glue traps (GT) have been the preferred detection technique since the first dedicated surveys for this species in 2008 (Sadlier 2009), although other techniques have been briefly attempted, such as visual surveys (Laigret 2005) and small mammal cage traps (Sadlier 2009).

Glue traps have a number of obvious advantages for herpetological surveys: they are lightweight, inexpensive, and easy to use. A single operator can easily deploy a large number of traps in remote areas (Fitzgerald 2012). On the other hand, this technique involves risks for both target and non-target animals, including stress and death by dehydration or predation (Vargas et al. 2000). Those risks have resulted in restrictions on the use of GTs in some countries, such as England and New Zealand (Chapple 2016; Baker et al. 2020; Fay 2022). Only a few studies have evaluated the efficiency of GTs (Bauer and Sadlier 1992; Rodda et al. 1993; Whiting 1998; Glor et al. 2000) and not all of them included data on mortality. Vargas et al. (2000) reported the death of 10 Green Anoles (*Anolis carolinensis*) out of a set of 21 glue-trapped specimens, but those deaths occurred during the one-week-long captivity following capture, suggesting the release technique, rather than the very short time spent on the traps (15 min), was the cause. Similarly, all 54 Littoral Whiptail-skinks (*Emoia atrocostata*) captured by Rodda et al. (1993) died post-release within 6 h. Ribeiro-Júnior et al. (2006) reported a 15.57% mortality rate of 244 lizard captures during an extensive survey of forested habitats in Brazil. In New Caledonia, Duval et al. (2019) reported a 62% mortality rate of 60 lizard captured in humid forest, with one daily check of the traps.

Regarding surveys dedicated to the Leopard Skink, capture rates appear overall quite low, and mortality has never been estimated. There is still a need for

Figure 1. Typical habitat of Leopard Skinks (*Lacertoides pardalis*) on the Goro Plateau in southern New Caledonia. Heavily eroded slopes covered with fire-induced Maquis vegetation can be seen in the background. (Photographed by Matthias Deuss).

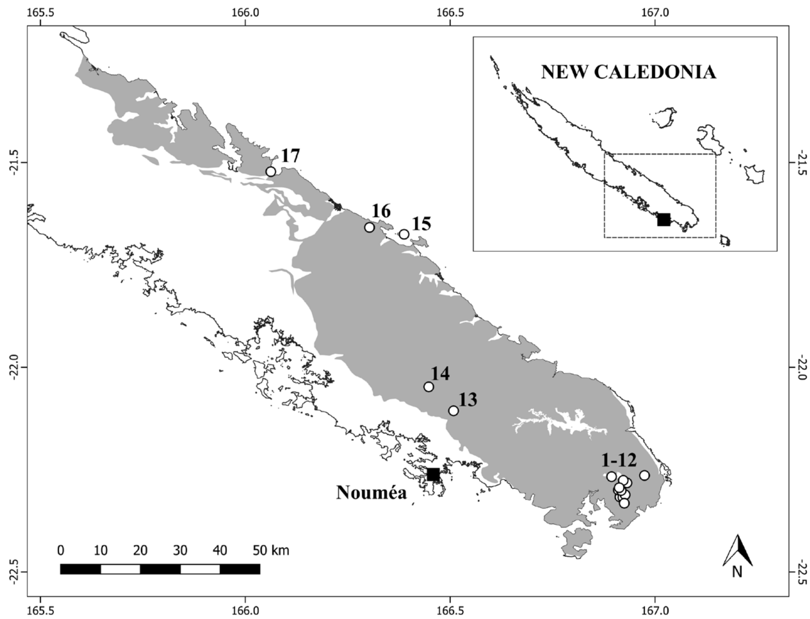

Figure 2. Locations where glue traps have been used sucessfully to capture Leopard Skinks (*Lacertoides pardalis*) since the mid-2000s (n = 17). Numbers refer to sites mentioned in the text. Grey areas represent the southern ultramafic region of Grande Terre, New Caledonia, currently considered as the maximum potential extent of Leopard Skink distribution. (Data from the Government of New Caledonia; https://georep.nc/).

improvement of alternative capture and observation techniques for this species and other endemic squamates found in Maquis shrublands of New Caledonia. Funnel traps (FTs) and artificial refuges (ARs) are widely used in some countries (e.g., France, Australia, New Zealand). Both techniques induce little or no mortality risk and do not require any digging (Chapple 2016), although predation by rodents inside FTs has been documented and should be taken into account (Woolley et al. 2022).

During the initial phase of our research project dedicated to the feasibility of mitigation translocation for the Leopard Skink, we tested and compared several capture techniques, including GTs, FTs and ARs. Our main goal was to develop an efficient methodology to detect and monitor the Leopard Skink to improve conservation measures for this rare and shy species. In particular, we focused on the use of GTs to improve their efficiency and safety in the context of field surveys in conservation mitigation projects.

Materials and Methods

Origin of data.—We used two separate datasets in our study. We obtained the first set from the compilation of all recorded captures of Leopard Skink specimens by general herpetofaunal inventories and dedicated surveys from 2008 to 2021 (See Unpublished Reports). These surveys were carried out in the context of mitigation measures for mining companies. They include a dedicated survey carried out at the type locality; a few more dedicated surveys for the detection of the species on localities falling within the range of industrial; a series of monitoring surveys carried out at the type locality and an adjacent site; and a translocation operation and the following monitoring surveys of the recipient site. We produced the second dataset during the course of our research program, which was aimed at testing and comparing various capture techniques as well as detecting new populations to highlight the range of occupied habitats. As a consequence, we carried out our capture sessions at a variety of locations, many of which were not visited during previous surveys.

Site selection.—We included 17 sites searched for Leopard Skinks using GTs in our study (Fig. 2). In the southeast, areas surrounding the nickel mines and a factory of the Goro Plateau have been the most intensely surveyed (sites 1–12). The Leopard Skink was originally discovered on the Kwa Néi site (site 1). At this location, the population was concentrated on the upper slopes of a ridge covered by low, dense Maquis vegetation, with many extensive peridotite outcrops and close to a transition zone between open Maquis, closed Maquis, and closed forest. Many sites covering the whole range of natural vegetation types have been surveyed for herpetofauna around the Grand Sud region (e.g., Sadlier and Shea 2006; Sadlier and Swan 2010) and although most surveys involved glue traps, Leopard Skinks were only found in similar habitats (Fig. 1). During the course of our research, we discovered and surveyed a

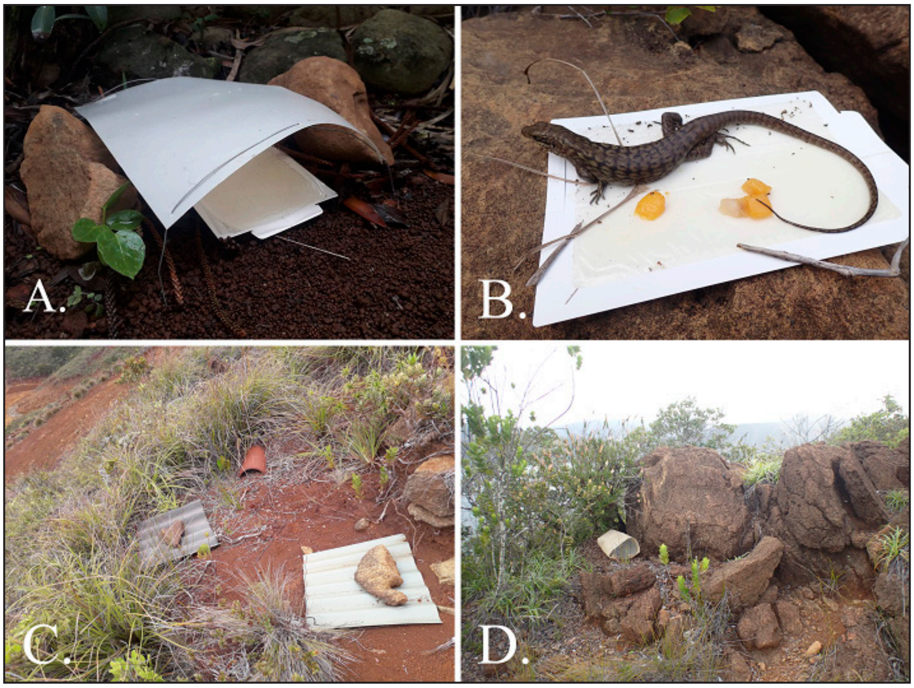

Figure 3. (A) Glue trap displayed under a home-made plastic cover. Rocks on each side prevent the trap from being dragged out by lizards. (B) Adult Leopard Skink (*Lacertoides pardalis*) caught on a glue trap baited with canned fruit. (C) Artificial refuges *in situ*. (D) G-minnow FT strategically placed alongside an isolated peridotite outcrop on Némou Island, New Caledonia, covered with shade cloth and baited. The only two captures of Leopard Skinks occurred here. (Photographed by Matthias Deuss).

number of new localities, some of them representing original habitats for the Leopard Skink. At the Dumbéa site (site 13), the skinks are found around the peridotite bedrock and screes bordering the Dumbéa river, and the nearest vegetation is generally a semi-open, tall Maquis shrubland. Némou (site 15) is a small elevated island located on the southeast coast, < 2 km away from the mainland. The Leopard Skinks found there constitute the only known insular population of this species and occupy a range of open to tall closed Maquis habitat. Additionally, a skink was found at 40 m elevation at Presqu'île de Bogota (17; Astrongatt 2019) and another at 900 m elevation in montane Maquis shrubland around Mts Dzumac (site 14), thereby extending the elevational range of this species. All sites have in common the ultramafic substrate and the presence of peridotite outcrops, used as refuges by Leopard Skinks, but tall, forest-like Maquis is now added to the total spectrum of vegetation types occupied by this species.

Trap designs.—All GTs that we used in New Caledonia are Trapper Max glue traps (Bell Laboratories Inc., Windsor, Wisconsin, USA), a 17 × 11 cm cardboard covered by non-toxic glue. Initially made for catching rodents, the traps are baited with a mild banana-flavored scent. In the first set of data, we did not bait GTs further, but for the second dataset, we systematically added pieces of canned fruit (a mixture of pears, peaches, and pineapples) as has been done in most surveys targetting frugivorous skinks in New Zealand (Lettink and Monks 2016). We placed baits in the middle of the cardboard and replaced them every day in the morning. We also designed covers made from 20 × 30 cm plastic sheets, tied upon two wire hoops (Fig. 3). When we could not place GTs under natural covers such as rocks, we set them under those covers, providing trapped lizards with shade and protection from avian predators. The covering allowed us to use a significantly lower the number of traps we needed to use, as the adhesive can be quickly degraded and made less effective by rain or morning dew. We set traps on flat ground and bordered them with rocks to prevent them from slipping or being dragged by the lizards from under the covers. When searching for new populations, we usually set GTs in lines of 10 m intervals, either next to a potential retreat (i.e., a rocky outcrop with cracks) or to a fruiting shrub. We baited trap lines in the morning and checked them 2–3 times everyday, depending on the weather.

We used Gee's Minnow Funnel Traps (FT) with a 3.175 mm mesh size and 22.2 mm entrance (model MT28; Pentair Aquatic Ecosystems, Cary, North Carolina, USA) in a similar way alternating with GTs on the same transect line or grid. We baited FTs with pieces of fruits placed under both entrances, hidden under vegetation as well as possible and covered with 90% shade cloth to reduce heat (Fig. 3). We filled their bottom with dead leaves as well to provide cover and humidity to the lizards, as high temperatures can be of concern inside FTs (Thompson and Thompson 2009).

We tested three AR designs, inspired from Lettink and Cree (2007): terracotta tiles, onduline, and corrugated iron sheets. Both onduline and iron sheets were single-layered 50 × 50 cm squares. We deployed ARs at three sites in regular grids of stations spaced 10 m apart (Fig. 3). Each station consisted of the three types of ARs, no more than 1 m apart from each other. We monitored ARs every 3 mo for over a year, early in the morning or under poor weather conditions preventing lizards from coming out, such as rainy and windy days.

Density estimation.—Density estimation of Leopard Skinks is challenging and has never been achieved so far. Capture-Mark-Recapture (CMR) is widely recognized as the most robust way to estimate the abundance of animal populations but relies entirely on reasonable recapture probabilities (Rodda 2012). Depletion sampling, or Capture-Rate-Decline Analysis, is an alternative absolute density estimator that has rarely been attempted for squamate populations (Rodda 2012). In this technique, population size is inferred from the accumulation rate of new captures. Assumptions for this technique include population closure, which can be assumed on a short period of time, and the ability to mark or recognize individuals. In our case, we systematically used photo-identification, as we found that the examination of head scale abnormalities, such as unusually divided or fused scales, is very frequent and reliable in this species (unpubl. data). The low recapture rates achieved during the course of our study oriented us towards depletion sampling instead of CMR. We attempted to estimate population size using this technique on Némou Island in May 2021. We deployed GTs on a standardized grid of three parallel lines of 30 traps along the ridge line known to host a reasonably abundant population of Leopard Skinks.

Sex and age class determination.—Capture data gathered over the years confirm the prediction of Sadlier et al. (2014) that the Leopard Skink mostly conforms to a seasonal mode of reproduction. As a result of the synchronicity of births, which probably occur around January, individuals in the early stages of their lives show a similar growth rate and cohorts can be defined based on snout-to-vent length (SVL) and date of capture. There is no sexual dimorphism in color pattern. Males tend to be more slender, with slightly larger heads, but these features alone are not reliable. Therefore, sex determination of adult individuals relies entirely on the eversion of hemipenes. We defined four age classes of lizards we captured: (1) Juveniles are individuals born < 1 y prior to their capture, supposedly between January and February. Juveniles reach 50 mm SVL in February, 60–75 mm SVL by the end of the wet season (April to June), and 75–90 mm SVL in the last quarter of the year (dry season). Sex can not be determined by eversion of hemipenes at this stage; (2) Subadults are individuals born the previous year and captured before the mating period in August-September. Reproductive maturity is reached during this transitional phase and hemipenes can be everted when males reach about 95 mm SVL. SVL ranges between 90 and 110 mm by the end of the wet season; (3) Adults are at least 18 mo old by the time of their first mating season. The minimal SVL is about 110 mm. Sex determination is unequivocal; (4) Mature adults are arbitrarily defined as those individuals ≥ 130 mm SVL. Information on adult growth rate is scarce but data from captive individuals suggest that adults grow slowly after the first 2 y of their lives and probably reach this length by the age of four or five.

Statistical analyses.—We used mean daily capture rates to compare the success of baited vs. unbaited GT sessions, primarily using a non-parametric Wilcoxon test. We did not compare mean capture rates directly between sessions as trap numbers varied from one day to another. We assumed that captures rates were independent between consecutive days of the same session. Due to the heterogeneity of the dataset, many parameters varied between GT sessions. We used Generalized Linear Models (GLMs) to estimate the effect of the following factors and variables on daily capture rates: (1) site; (2) baiting; (3) trap placement, either in grids, lines or patches; (4) number of traps; (5) season, approximated as quarter of the year; (6) quantitative weather parameters obtained from the closest weather stations: minimum and maximum daily temperature and mean daily relative humidity; and (7) qualitative estimates of weather parameters expressed as four-level parameters: rain, wind, and cloud cover. Unfortunately, the dispersion of data was too low to allow for any kind of Analysis of Variance (Fig. 4). Consequently, none of the explanatory variables had a significant effect, and our results are not commented further. We used R version 4.1.1 (R Core Team 2020) for all analyses. For all tests, $\alpha = 0.05$.

Results

During the course of our study, we deployed 90 permanent AR stations at three sites known to support Leopard Skink populations. They did not yield a single specimen of any lizard species. The absence of results deterred us from expanding this technique to further locations. We completed 1,180 trap-days for FTs at five locations. We caught only one adult female and one juvenile. Both were found two days apart in the same

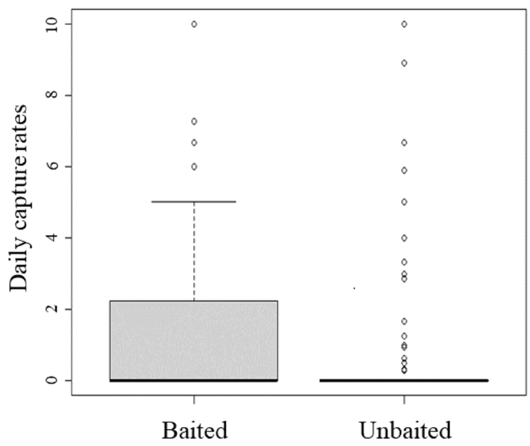

Figure 4. Boxplot showing median and dispersion of daily capture rates of lizards for baited and unbaited glue trap sessions.

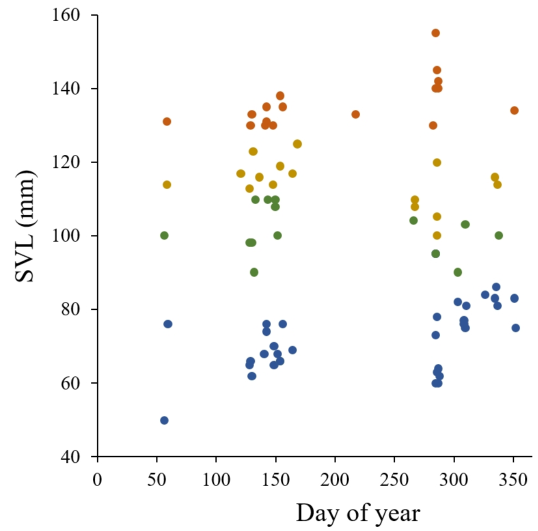

Figure 5. Age class of 82 Leopard Skinks (*Lacertoides pardalis*) caught on glue traps, ranked by snout-to-vent-length (SVL) and day of capture. Classes are large adults (reddish brown), adults (golden brown), subadults (green), and juveniles (blue).

trap on Némou Island. This very low capture rate, added to the costs and bulkiness of FTs, made us discontinue with this technique as well.

The only significant results were achieved using GTs. We listed and analyzed 25 trapping sessions from other studies specifically targetting Leopard Skinks, along with the 15 sessions we carried out (see Appendix Table for details and mean capture rates of all trapping sessions). Of those 40 sessions, 19 were carried out using fruit baits and 21 without (Table 1). The mean daily capture rate for all GT sessions is 0.96 skinks per 100 trap-days ± 1.90 (standard deviaition). We found a significantly higher mean daily capture rate for baited GT than for unbaited traps (W = 6,394, P < 0.001). Baited GTs caught more than twice as many Leopard Skinks as unbaited GTs. Glue traps captured Leopard Skinks of all ages. Trapping sessions revealed a somewhat balanced demographic structure of the sampled populations, with typically more juveniles than specimens from older age classes (Fig. 5).

We caught most squamate species occurring in Maquis shrublands on GTs (Table 2). Although Common Litter Skinks (*Caledoniscincus austrocaledonicus*) were the most captured lizard species overall, we caught most (106 of 129 captures) on Némou (site 15). The Leopard Skink was the second-most abundant lizard we caught and was the most frequently captured species on most sessions. Despite having caught 25 individuals in 19 d of depletion trapping, the capture rate remained steady and failed to decline over time, except in poor weather conditions when lizard activity was low (Fig. 6). The data did not allow for a Capture-Rate-Decline Analysis.

Table 1. Total captures sessions (TCS) with number of sites in parentheses, total trap days (TTD), number of captures, and mean daily capture rate (MDC; captures per 100 trap days) ± standard deviation obtained from the 40 glue trap (GT) sessions.

Treatment	TCS	TTD	Captures	MDC
Unbaited GTs	21 (10)	9,602	41	0.61% ± 1.80
Baited GTs	19 (10)	4,949	65	1.32% ± 1.94

Discussion

Artificial refuges and funnel traps.—The inefficiency of ARs can be explained by two reasons. First, ARs are mostly used in temperate countries where they provide shelter and thermoregulation opportunities for squamates (Hoare et al. 2009). The subtropical climate of southern New Caledonia offers warm conditions most of the year, so that skinks probably do not spend much time sheltering during the day, except in

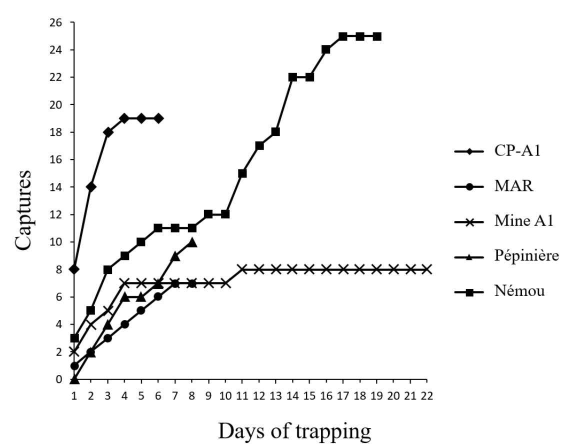

Figure 6. Capture accumulation curves during consecutive days of trapping of lizards for five of the most intensive glue trapping sessions.

Table 2. Capture numbers of Common Litter Skinks (*Caledoniscincus austrocaledonicus*), Leopard Skink (*Lacertoides pardalis*), Tillier's Maquis Skink (*Phasmasaurus tillieri*), Southern Whiptailed Skink (*Tropidoscincus variabilis*), Marble-throated Skink (*Marmorosphax tricolor*), *Bavayia* aff. *sauvagii*, Southern Litter Skink (*Caledoniscincus notialis*), Green-bellied Tree Skink (*Epibator nigrofasciolatus*), Knob-headed Giant Gecko (*Rhacodactylus auriculatus*), Giant Litter Skink (*Caledoniscincus festivus*), Deplanche's Shiny Skink (*Sigaloseps deplanchei*), and Pelagic Gecko (*Nactus pelagicus*) recorded and associated mortality rates from a subset of 4,109 trap-days. Data were unavailable for most of the unbaited sessions. *Bavayia* aff. *sauvagii* has no common name available.

Species	No. captures	Captures / 100 trap-days	No. deaths	Mortality rate / 100 captures	Mortality rate / 100 trap-days
Caledoniscincus austrocaledonicus	129	3.14	8	6.2	0.19
Lacertoides pardalis	52	1.27	4	7.7	0.10
Phasmasaurus tillieri	25	0.61	2	8	0.05
Tropidoscincus variabilis	13	0.32	0	0	0
Marmorosphax tricolor	12	0.29	1	8.3	0.02
Bavayia aff. *sauvagii*	9	0.22	1	11.1	0.02
Caledoniscincus notialis	4	0.10	0	0	0
Epibator nigrofasciolatus	3	0.07	0	0	0
Rhacodactylus auriculatus	3	0.07	0	0	0
Caledoniscincus festivus	2	0.05	0	0	0
Sigaloseps deplanchei	2	0.05	0	0	0
Nactus pelagicus	1	0.02	1	100	0.02

very specific conditions such as heavy rains. Secondly, the chosen design for our ARs may be unattractive to the Leopard Skink. Over the course of this study, we established that this species is very selective regarding shelter sites (unpubl. data). It prefers rocky outcrops standing high over the vegetation, with deep and narrow cracks providing safe shelters and easy access to their sun-basking spots. ARs are typically laid flat on the ground below the level of the surrounding vegetation.

The low capture rate of FTs is not easily explained but the wariness of the Leopard Skink may be the cause as has been shown previously with other lizards (Carter et al 2012; Kundey and Phillips 2021). We conducted a short experiment in captivity with five specimens placed in an enclosure with a baited funnel trap and no other source of food. Only two of them entered the traps after a few hours. The odd result of catching the only two specimens in the same trap in the field also suggests that trap placement is paramount and optimal configuration is difficult to predict (Lettink and Seddon 2007). Lettink and Monks (2016) highlighted the fact that capture probabilities of funnel trapping and all forms of live trapping vary greatly between species and microhabitats, even at the individual level, and that some species are more likely to be caught by ARs than FTs or vice versa.

Glue traps.—Baited GTs caught about two times more Leopard Skinks than unbaited traps on average. Although this difference could be explained by a combination of factors, a number of elements tend to show the attractiveness of fruit baits to Leopard Skinks. In baited GT sessions for which the total herpetological community was recorded, Leopard Skinks were frequently the most captured species (Table 2), immediately followed by Tillier's Maquis Skink (*Phasmasaurus tillieri*), a nectar-feeding skink probably equally attracted by the syrup of the bait. Opportunistic observations on baited camera traps and in captivity also showed that Leopard Skinks will readily feed on canned fruit (unpubl. data). Whether the predominance of these two species in baited GT sessions reflects a specific effect of the baits or the relative density and/or activity of all lizard species in Maquis habitats is unclear. This could not be tested due to irregular records of other lizard species in past surveys dedicated to the Leopard Skink, and differences in herpetofaunal communities between sites.

Besides baiting, several site characteristics are likely to affect capture rates, the most obvious being the density of the target species, which in our case is not known, but also densities of competitor and predator species. Among these, predation has only been demonstrated by House Cats (*Felis domesticus*), through the presence of body scales typical of the Leopard Skink in scats collected during our survey at the Dumbéa site, along the river. Previous analyses of cat and rat (*Rattus* sp.) feces have not detected this species (Palmas et al. 2017), although rats could prey upon juveniles (Thibault et al. 2017). The exotic predators and native lizard community only differs in Némou, where feral cats are absent and Ship Rats (*R. rattus*) are predominant over Pacific Rats (*R. exulans*).

The large Southern Whiptailed Skink (*Tropidoscincus variabilis*) is also absent from Némou, but common on all other sites. Although not in competition for fruit resources (Shea et al. 2009), its absence seems to favor Leopard Skinks and allow them to dwell in closed habitats, from which they are absent on the mainland. We suspect that the smaller size and darker coloration of Southern Whiptailed Skinks give them an advantage over Leoprad Skinks for thermoregulation in closed and humid habitats. Indeed, Southern Whiptailed Skinks are often seen in moderate densities in sunny patches of the forest floor, and their presence may prevent Leopard Skinks from settling in this habitat.

Other site characteristics of possible significance are vegetation cover and availability of fruit resources. Session-specific factors that could influence captures are weather conditions and trap placement. Unpublished radiotelemetry data confirmed that Leopard Skink activity decreases in winter, with fewer movements between refuges and feeding places. Their activity during the wettest days of the rainy season is also expected to be low, and it is the least practical time to operate GTs. Best results are achieved during the 2nd and 4th quarters of the year, which are warm enough, but with less frequent rain episodes. Trap placement is highly dependent on the configuration of the terrain and the desired goal. Radiotelemetric surveys suggest that adult Leopard Skinks are able to travel up to 100 m in one day to reach their feeding places and return to their refuge, but overall they only cross a small portion of their total home range everyday (unpubl. data). This behavior is generally noted in squamates (Rodda 2012). As a consequence, a given trap may stay in place for several days before it is visited by a single skink. For any animal species, when the aim is to detect a population at a new locality, traps should be deployed in lines to maximize the number of territories overlapped (Read et al. 1988; Jones et al. 1996; Tasker and Dickman 2001). On the other hand, if the aim is to estimate the density of animals, traps should be deployed in a grid to maximize recaptures and permit estimation of trap-revealed home ranges.

***Density estimation and population monitoring*.**—Our results confirmed that recaptures of lizards on GTs were too few to estimate density using CMR. So far we recorded only four recapture events. An adult female was recaptured after 3 y, < 70 m from its initial location (See Unpublished Reports: Astrongatt 2018), and a subadult male caught by us in November 2019 was recaptured 6 mo later. The remaining two recaptures, both juveniles, were the only individuals recaptured within the same trapping session, respectively four and 10 d apart. Thus, the total number of immediate recaptures amounted to two of 94 captures for which photo-identification was available, or 2.13%, which makes CMR not estimable.

Our depletion sampling attempt in Némou (site 15) also did not succeed. Having followed 10 of the individuals caught on that session by radiotelemetry, we conclude that the trap grid only crossed a small portion of home ranges of lizards. This could explain why our capture rate never seemed to decrease, and the probability to catch a given individual must have been low. Promising results were obtained from other major trapping sessions. Capture accumulation curves did reach a plateau for two of the five most successful sessions. On mine A1 (sites 3,4), several parallel lines of traps were set, efficiently covering a restricted area of suitable habitat. The steep decline of the curve suggests that we captured all resident adult individuals (n = 4) in this area. On CP-A1 (site 5), GTs were set in stations of 10, targetting peridotite outcrops, with 15 stations placed at intervals of about 50 m. The resulting set-up consisted of patches of traps regularly crossing the ridge line, where Leopard Skinks are expected to concentrate because of the availability of rocky outcrops. This method of trap placement may be optimal because captures reached a plateau after 4 d, considering that each trap station was removed after three consecutive days without capture. This placement did not provide a reference area for density estimation, however, and several skinks may have escaped detection in the intervals. Future attempts should focus on areas of homogeneous habitat, large enough to encompass home ranges of several lizards, which likely would be a total surface of several hectares, and would require a significant labor force. Beyond density estimation, GTs, if repeated in the same conditions and on the same period, could reveal demographic trends such as fluctuations in recruitment, survival of the young, or carrying capacity of the habitat for adults. The relative number of mature adults at a particular location could inform on the quality and stability of the habitat.

***Mortality rates associated with glue traps*.**—Although efforts can be made to reduce risks associated with GTs such as using plastic covers and making frequent checks, mortality can not be reduced to zero. In the course of the studies synthesized here, five Leopard Skinks were found dead on GTs (4.7% of all captures). Of these, three died from heat stress, one was eaten by a rat and the last one by endemic ants *Polyrhachis guerini*. When using GTs, extreme care should be given to proper relocation of traps, with plastic tags and GPS coordinates. Overall mortality per 100 captures was kept under 10% for most species, better than previously reported and supports making three daily checks of traps. Deaths caused by heat stress likely occurred within 2–3 h, and happened either because the trap cover was momentarily in direct sunlight, or because the skink managed to drag the trap from under its cover. Although these were rare events that can be somewhat avoided, we consider three checks per day mandatory. When mortality is considered against the total trapping effort, rates remained under 0.2–0.1% for Leopard Skinks.

Nonetheless, it is a serious issue and should always be documented. When operating on locations known to be home to severely restricted or endangered species, GTs should not be used. This study illustrated the risks involved by heat in Maquis shrublands. In rainforest habitats, mortality is mostly the result of predation by flatworms, ants, and rodents (Duval et al. 2019).

Applications of glue traps and alternative techniques.—Despite the ecological and behavioral similarities between the Leopard Skink and some of the large *Oligosoma* skinks from southern New Zealand (Tocher 2003; Germano 2007; Lettink and Monks 2019), the FT and AR capture methods traditionally used in that country proved to be inefficient in our situation. Our study demonstrated that GTs are the only effective method for capturing Leopard Skinks. Nonetheless, we provide information on two alternative techniques suitable when detection of the species is the only objective, along with our recommendations on the use of GTs, including array design, manpower requirements, and cost according to the different study objectives (Table 3). Although this can now be easily achieved, future research should focus on detection by camera traps baited with fruit to keep disturbance to a minimum and avoid mortality of target and non-target species. Estimating long-term recapture probability on GTs will be decisive to determine if absolute density estimators can be obtained with this technique, and if so, can they achieve robust monitoring of threatened populations.

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Table 3. Review of available techniques for the survey of Leopard Skinks (*Lacertoides pardalis*) depending on the desired goals and recommendations for best practices. Costs are given in U.S. dollars.

Method	Goals / survey design	Cost and labor force	Advantages / disadvantages
Glue traps	**Detection:** requires a minimum of 50 to 100 traps set in lines at 10 m intervals for 3 d of decent weather conditions. **Capture:** as above. In healthy populations an average of one capture a day can be expected for 50 glue traps. **Density estimation:** has not been achieved to date but may be possible through depletion sampling. Requires regular grids of traps set at a maximum of 10 m intervals. More than 1 ha (121 traps) should be covered to include several adults home ranges. Probability of recapture on the long term are unknown.	Unit cost : approx. $30 a box of 72 traps. Lifespan in the field up to 3–4 d under covers but depends on rainfall and rodent densities. Two experienced operators can set up, cover and bait up to 100 traps in half a day and check them three times a day in typical Leopard Skink habitats.	+ No observer bias + Relatively inexpensive + Moderately remote areas can be surveyed + Very effective for terrestrial skinks - Significant mortality rates - Unchecked traps are a serious threat to lizards, adverse weather conditions must be anticipated - Recapture rates are low on the short term and unknown on the long term - Should be avoided when females are gravid from November to January
Camera traps	**Detection:** opportunistic observations suggest that a few camera stations baited with fruits daily can record the presence of Leopard Skinks but no quantification has been attempted. Individual identification is highly uncertain.	Unit cost : from $120 to $600, about $300 on average for a camera with good detection performances.	+ No observer bias + Easy to set up + Moderately remote areas can be surveyed - Expensive - Detection rate is unknown
Visual searching	**Detection:** can be attempted by checking peridotite outcrops with large cracks with binoculars during cold season on sunny or overcast days. Suitable cracks can be checked again at night with a torch.	No cost apart from standard fieldwork equipment. One experienced observer can cover a large area in a few hours.	+ Low cost + Access to remote areas - Strong observer bias - Unefficient during warm season

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Matthias Deuss specializes in herpetology in France. He is particularly interested in the life history of reptiles, as well as their phylogeny, biogeography, conservation, and the development of observation techniques in the field. Settled in New Caledonia since 2015, he devotes his time to the exploration of natural environments to improve the knowledge on the endemic skinks and geckos of this country. Matthias seeks to improve the awareness of the general public to biodiversity through his photographs and volunteer work for local associations. Between 2019 and 2022, he dedicated his Ph.D. at the French National Research Institute for Sustainable Development (IRD) to the conservation of the New Caledonian Leopard Skink. This project, from which this publication is derived, covers several fields, including the experimentation of capture methods, genetic structure of populations, ecological niche modeling, and the study of life traits by radiotelemetry. (Photographed by Emilie Ducouret).

Hervé Jourdan works as a Researcher for the French National Research Institute for Sustainable Development (IRD) within the Institut Méditerranéen de Biologie et d'Ecologie (IMBE). Since the mid-1990s, he has worked in New Caledonia and the Pacific region. Hervé has been developing research on the sustainable conservation of island terrestrial ecosystems, with a particular interest in biotic interactions between exotic species and native species. He completed his Ph.D. in 1999 at the Toulouse University, Toulouse, France, on the impacts of the invasive ant *Wasmannia auropunctata* on the various components of terrestrial biodiversity, including lizards. His research targets indicator elements of the trajectory of natural, degraded, or restored ecosystems, with invasive animal and threatened endemic species models (such as lizards and various insects taxa). Hervé favors experimental work in the field. (Photographed by Matthias Deuss).

Appendix Table. Details of glue trapping sessions including date of start, trapping effort, and number of lizards captured, with mean capture rates in parentheses calculated over the full length of each session at sites in New Caledonia. Location numbers refer to the map in Fig. 1. Number of captures is per 100 trap-days.

Location	Date	No. of traps	Total trap-days	No. of captures
Unbaited Traps				
Kwa Néi - summit (1)	26 February 2013	12	36	0
Kwa Néi - ridge (2)	26 February 2013	45	135	0
Mine A1 - A (3)	26 February 2013	13	39	0
Mine A1 - BC (4)	26 February 2013	10	30	1 (3.33)
CP-A1 (5)	8 October 2014	60	120	3 (2.50)
MAR (6)	6 January 2015	30	120	3 (2.50)
KO2P2 (7)	5 August 2015	44	88	0
KO4 (8)	17 August 2015	10	50	0
KO2P3 (9)	26 October 2015	44	44	0
CP-A1 (5)	11 October 2015	50–150	560	19 (3.39)
Mine A1 - A (3)	6 October 2015	70	350	0
Mine A1 - BC (4)	6 October 2015	60	300	1 (0.33)
Mine A1 - A (3)	18 January 2016	60–120	840	0
Mine A1 - BC (4)	18 January 2016	100–300	1360	3 (0.22)
Mine A1 - A (3)	4 October 2016	40–120	680	0
Mine A1 - BC (4)	4 October 2016	80–230	1470	3 (0.20)
Kwa Néi - summit (1)	25 November 2017	17	85	0
Kwa Néi - ridge (2)	25 November 2017	103	515	1 (0.19)
Mine A1 - A (3)	23 October 2018	100–110	520	0
Mine A1 - BC (4)	23 October 2018	60–360	2220	6 (0.27)
Presqu’île Bogota (17)	13 November 2019	20	40	1 (2.50)
Baited Traps				
Kwa Néi - summit (1)	15 December 2008	12	24	0
Kwa Néi - ridge (2)	15 December 2008	43	86	2 (2.33)
Mine A1 - A (3)	16 December 2008	10	10	1 (10.00)
Mine A1 - BC (4)	16 December 2008	10	10	0
MAR (6)	30 April 2019	30–50	380	7 (1.84)
Mine A1 - BC (4)	20 November 2019	30	90	1 (1.11)
Dumbéa (13)	26 November 2019	40	120	2 (1.67)
Kwa Néi - ridge (2)	10 December 2019	40	120	0
Némou Is. (15)	25 February 2020	30	90	3 (3.33)
Kwa Néi - ridge (2)	12 May 2020	40	320	0
Mine A1 - BC (4)	27 May 2020	30–50	930	8 (0.86)
Mine Yolande (16)	21 September 2020	60–66	186	3 (1.61)
Dumbéa (13)	30 September 2020	40	120	0
Mts Dzumac (14)	20 October 2020	60	180	1 (0.56)
Crête Lac en Huit (10)	27 October 2020	30	90	1 (1.11)
Cascade Camille (12)	27 October 2020	20	60	1 (1.67)
Pépinière Est (11)	24 November 2020	60–86	563	9 (1.60)
Mts Dzumac (14)	26 January 2021	60–90	240	0
Némou Island (15)	7 May 2021	50–90	1330	25 (1.88)