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Ecological Factors Associated with Burrow System Occupancy by Great Desert Skinks (*Liopholis kintorei*)

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Abstract: The great desert skink (*Liopholis kintorei*, locally known as tjakuṟa) occupies burrow systems in arid regions of central Australia. Most burrow systems remain occupied for an average of 4, and up to 10, years by the same related individuals. The circumstances associated with changes in occupancy are under active investigation. Factors linked to tjakuṟa abandoning burrow systems include intense fires and predation by feral cats (*Felis catus*). We examined ecological factors associated with whether burrow systems that were occupied in the previous year were currently occupied by tjakuṟa. We determined occupancy of previously occupied tjakuṟa burrow systems by the presence of fresh scats in their latrines. We also assessed the size, vegetation cover, and proximity of termite calics to burrow systems. Neither overall vegetation cover nor spinifex cover was related to burrow system occupancy, but larger burrow systems were more likely to remain occupied. Burrow systems within 10 m of termite structures were more—and those within 2.5 m of *Grevillea* were less—likely to remain occupied by tjakuṟa. The role of woody vegetation (*Grevillea*) and termite presence on risk of predation, the behavior of tjakuṟa, and burrow system occupancy merits further investigation on a longer timescale.

Keywords: conservation; habitat; lizard; termites; tjakuṟa

Academic Editor: Michael Wink

Received: 7 January 2025
Revised: 11 February 2025
Accepted: 13 February 2025
Published: 15 February 2025

Citation: Eifler, M.A.; Eifler, D.A. Ecological Factors Associated with Burrow System Occupancy by Great Desert Skinks (*Liopholis kintorei*). *Diversity* **2025**, *17*, 134. https://doi.org/10.3390/d17020134

1. Introduction

Burrowing is a strategy used by vertebrates for coping with environmental, as well as social and physiological, challenges [1]. Burrows can create a microhabitat with cool, moist conditions and stable temperatures that provide protection from predators [1–4] and from fire [5] as well as access to food [6]. Burrow systems also figure prominently in the social systems of some mammals such as prairie dogs [7], naked mole rats [8], and degus [9] as well as some lizards [10]. However, variation in environmental factors such as temperature, moisture, and fire regimes arising from climate change can influence burrow quality [11,12]. Conservation efforts can use short-term responses of animals to environmental changes (i.e., food availability, vegetation cover) as a proxy for estimating long-term consequences for survival and reproduction [12]. For example, the loss of vegetation following burns might make prey species that occupy burrows more obvious to predators and change food availability for burrowing animals [2,13]. Burrow systems increase habitat complexity and provide shelter for many species [1,14,15] but for burrowing species, the relationship between vegetation cover, food availability, and predation can be complex [3,14,16].

The great desert skink (*Liopholis kintorei*), known locally as the tjakuṟa, is a large skink from the arid interior of Australia that is at high risk of extinction (i.e., listed as vulnerable by the IUCN) [17]. Having once occupied much of central Australia, their distribution has been reduced to a handful of small areas that are mostly protected [18]. Tjakuṟa construct interconnected tunnels in burrow systems that can span up to 13 m, have as many as 20 entrances, and be occupied for as long as 10 years [19]. Burrow systems are occupied by groups of related lizards, including adults and offspring from multiple years ($\overline{X}$ = 4 years) [19]. Tjakuṟa are omnivorous [10,20], consuming a variety of plant material and invertebrates [21]. When foraging, they alternate between ambush and active foraging strategies depending on time of day [20]. Termites (Termitidae) are an important diet item for many arid zone lizards [22] and have been considered a primary invertebrate food source for tjakuṟa (particularly *Drepanotermes perniger*) [19,20].

An increasingly large proportion of burrow systems are abandoned by tjakuṟa, and various factors have been associated with burrow systems becoming unoccupied [18]. Two factors—introduced predators and fire regimes—acting either singly or interactively, commonly have been implicated in tjakuṟa burrow system occupancy [2,5,13,23–25]. Altered fire regimes can affect tjakuṟa burrow system inhabitants directly or through the effect of fire on the plant community [2,5,25]. Food availability is likely to change with fire regimes [26] but has not been directly measured. Introduced predators, especially feral cats (*Felis catus*), can dramatically influence faunal communities in general [13] and tjakuṟa populations in particular [24]. The reduction in vegetative cover that results from fire can enhance predator presence at tjakuṟa burrows [5,23] and reduce burrow system occupancy [25] but the effects of fire on predation varies with fire intensity [2].

We undertook a study to examine the relative importance of ecological factors associated with burrow system occupancy, proposing possible mechanisms for their influence. We examined the current occupancy status of tjakuṟa burrow systems recorded as active ca. 11 months prior, measuring vegetation characteristics and evaluating the proximity of termites. We hypothesized that continued burrow system occupancy would be associated with proximity to termite calics. In addition, we hypothesized that vegetation would affect burrow system occupancy.

2. Methods

We collected data from 23 December 2014–11 January 2015 in Uluṟu-Kata Tjuṯa National Park (UKTNP), Northern Territory, Australia (25.36° S 131.02° E). The habitat consisted of hummock grassland dominated by spinifex (Poaceae: *Triodia basedowii*), as well as numerous grasses and shrubs, interspersed with open sand. To assess habitat characteristics associated with tjakuṟa burrow systems, we first visited 81 sites identified as active during the February 2014 census undertaken by UKTNP and classified by them as being currently occupied or unoccupied by tjakuṟa. During the February 2014 baseline surveys, the number of entrance holes was counted, and latrine contents were examined to determine the presence of resident juveniles, subadults, and adults based on scat size (juvenile < 15 mm, subadult 20–30 mm, adult > 35 mm) [18]. Following UKTNP protocols during our December–January surveys, we identified a burrow system as currently occupied if its latrine contained fresh scat. Regardless of occupancy status, we assessed each burrow system by counting the number of burrow openings (=burrow size), counting the number of termite calics within 2.5 m and 10 m radiuses and conducting a vegetation analysis. We used the latrine as the center point for the vegetation transects and for the termite surveys. If more than one latrine was present, we used a point that was in the center of the latrines. If no latrine was located, we used the center of the burrow openings as the origin point for transects.

To conduct the vegetation analysis at each burrow system site, we ran four transects 2.5 m long from the center point to the north, south, east, and west. Using the line intercept method, we determined total percent cover along each transect as well as the percent cover occupied by different species of plant along each transect. We also counted the number of woody plants > 1 m high within 2.5 m of the latrine. We identified individual plants to species.

Statistical analyses were performed using Minitab 21.4 (College Park, PA, USA), with a significance level of 0.05. Values are presented as mean ± SE. We looked for factors associated with whether each burrow that was active in February 2014 was occupied or unoccupied the following Dec–Jan using binary logistic regression. A stepwise selection procedure, with $p < 0.15$ for addition and removal, was used to identify a final model. Initial variables included in the analysis were total vegetation cover, *Grevillea* cover, spinifex cover, number of termite calics within 2.5 m, number of termite calics within 10 m, number of age classes present during the 2014 survey, and number of burrow holes as well as presence or absence of (1) woody plants > 1 m high within 2.5 m of the latrine, (2) *Grevillea* > 1 m high within 2.5 m of the latrine, and (3) termite calics within 10 m of the latrine.

3. Results

3.1. Demographics

In <1 year, 36% of known active burrow systems were no longer occupied (29 of 81 burrows active in February 2014). Our final model indicated that continued burrow occupancy was related to aspects of vegetation, termite proximity, and burrow system size (overall model: binary logistic regression: $\chi^2 = 16.17$, $df = 3$, $p = 0.001$, $R^2 = 29\%$). Burrow systems with more entrance holes were more likely to be occupied (binary logistic regression: $\chi^2 = 4.87$, $df = 1$, $p = 0.027$; Figure 1). The number of age classes present in a burrow system in 2014 was not related to occupancy status.

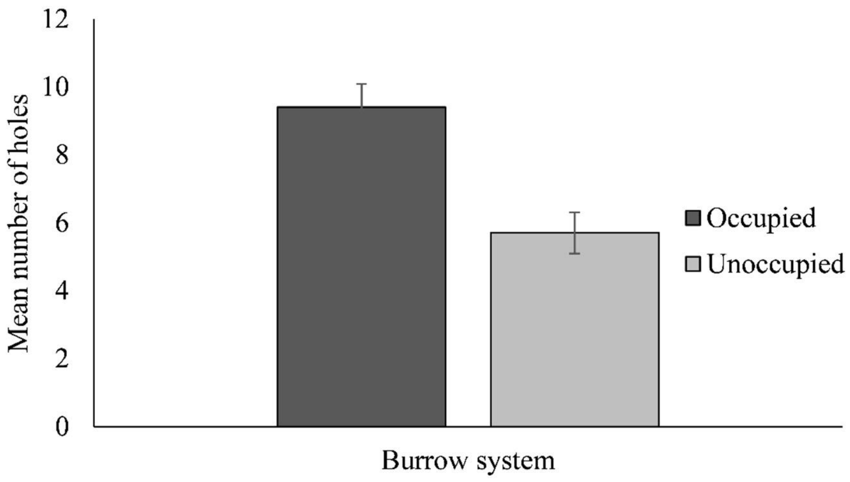

Figure 1. Abundance of burrow entrance holes (mean ± SE) for occupied and unoccupied *Liopholis kintorei* burrow systems.

3.2. Habitat

Vegetation cover was largely composed of spinifex, with the next most pervasive species contributing relatively little to overall cover. Although 21 plant species were encountered over the course of sampling, only 3 accounted for most of the plant cover in the burrow systems (94% total: spinifex (Poaceae, *Triodia basedowii*; 71.4% of plant cover), Grevillea (Proteaceae, *Grevillea* sp., 10.8%), and fireweed (Malvaceae, *Rulingia loxophylla*; 11.8%)), but the levels of total cover, spinifex cover, and *Grevillea* cover were not included in the final model. The presence or absence of *Grevillea* was important, as burrow systems close to *Grevillea* >1 m high were more likely to be unoccupied (binary logistic regression: $\chi^2 = 7.03$, $df = 1$, $p = 0.008$; Figure 2).

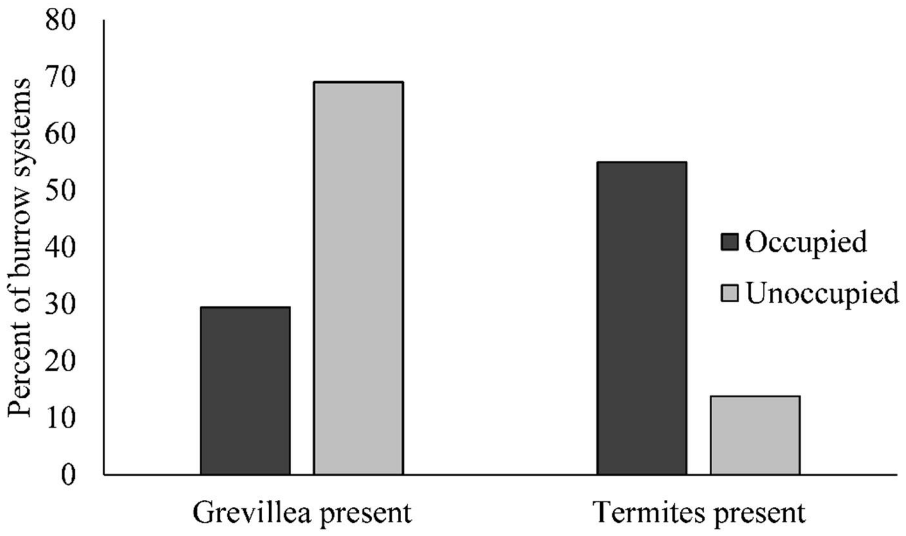

Figure 2. Prevalence of termite calics within 10 m and *Grevillea* plants >1 m high within 2.5 m of occupied and unoccupied *Liopholis kintorei* burrow systems.

Termite presence was significantly related to burrow occupancy status. Unoccupied sites rarely were close to termite structures; termite calic structures were present within 2.5 m for only three burrow systems (all active). When looking at a larger scale, the presence of termite calic structures within 10 m of the center of a burrow system was significantly related to occupancy status (binary logistic regression: $\chi^2 = 7.27$, $df = 1$, $p < 0.007$; Figure 2).

4. Discussion

In less than 1 year, 36% of tjakuṟa occupied burrows systems became unoccupied, indicating that > 1/3 of the study population either relocated or died within 1 year. Given the large effort required to construct burrow systems, tjakuṟa are unlikely to abandon an existing system without good cause. The factors contributing to the risk of extinction for tjakuṟa are complex and our short-term study provides only a snapshot of ecological factors associated with changes in burrow system occupancy. Our work should provide a springboard for future, more extensive studies that can explore the importance of social factors [12,27,28] as well as the interplay between fire regimes and vegetation, food availability, and predator pressure affecting burrow system persistence [24].

Burrow placement and occupancy can be tied to distinct structural or habitat preferences as well as to distinct fitness benefits or costs [1,12,25,26,29]. Tjakuṟa burrow system occupancy was most strongly associated with aspects of vegetation structure and proximity to termites. Vegetation can play an important role in defining habitat quality by potentially influencing burrowing efforts, food distribution, or predator detection [1,4], which in turn can influence fitness costs and benefits. Proximity to *Grevillea* was associated with a shift from a burrow system being recently occupied to becoming unoccupied, while termite presence increased the likelihood of continued occupancy.

Animals could select habitat based on a variety of factors that vary spatiotemporally [30]. Although the amount of spinifex cover can influence population levels for some species in our study area [31] and has been identified as a crucial habitat feature for tjakuṟa [5,25,26], in our study the type of cover (spinifex vs. woody vegetation (i.e., *Grevillea*)) had more of an effect on burrow system occupancy status than the amount of cover. Woody vegetation, particularly *Grevillea*, was associated with tjakuṟa burrow systems becoming unoccupied. The amount of cover near burrow entrances affects tjakuṟa activity [26], which in turn could influence foraging and predation risk [24]. The presence or absence of *Grevillea* could arise from fire regime practices, as fire reduces vegetation cover and can affect whether tjakuṟa burrow systems remain occupied [2,5,18,23].

Tall woody vegetation such as *Grevillea* could benefit tjakuṟa by stabilizing the soil, which can enhance the strength of burrow tunnels [25], providing shade, or enhancing invertebrate prey populations. The cost of tall woody vegetation lies in their potential attractiveness to predators [32]. Feral cats and other predators could prefer or be attracted to woody patches either as landmarks or shade patches, which can in turn increase the frequency of encounters between predators and tjakuṟa. Areas with less or no woody vegetation could be less recognizable to predators as hunting sites or represent areas more difficult for effective hunting.

Food distribution and availability, as indicated by the presence of termite structures, was positively related to continued burrow occupancy—burrow systems that remained occupied were more likely to be near termites (<10 m from the center of a burrow system). Tjakuṟa burrows could be constructed preferentially close to mounds, with group size and burrow longevity relating to proximity and longevity of termite colonies [19,20]. Being near active termite colonies that serve as an important food source might be necessary to sustain multigenerational burrows of tjakuṟa. In addition, the risk of predation could be reduced by proximity to abundant termite food that reduces the need to forage widely [20,33]. Tjakuṟas can stray as much as 150 m from their burrows during a night of foraging [19]. Although predation issues can be difficult to tease out during a short-term study, a greater understanding of the challenges facing tjakuṟa might be reached through future work on understanding the ecological distribution of termites and other diet components [21].

In addition to their role as a food source, termite colonies can affect habitat structure by altering soil conditions and associated vegetation [34]. Lizards in other systems are known to live in close association with termitaria, sometimes even within them [35–38]. Habitat structure can influence predation risk and predation risk can, in turn, influence habitat selection [39]. In UKTNP, woody vegetation and termites both contributed to whether burrow systems remained occupied, highlighting the interaction between habitat and predation-related factors. Burrow systems might be more likely to remain occupied when tjakaṟa can forage successfully near their burrows in habitats that do not attract predators.

Feral cats can significantly impact local fauna [13,23,24,40,41], with nocturnal, terrestrial, small-bodied animals living in open habitats and in groups—such as tjakuṟa—being particularly susceptible to cat predation [41]. Because tjakuṟa burrow systems are more likely to become unoccupied when *Grevillea* trees are present, we recommend the maintenance of areas with relatively little woody vegetation when managing tjakuṟa habitat, particularly the elimination of *Grevillea*. Future research also could focus on understanding the distribution and abundance of termites relative to vegetation.

Author Contributions: Conceptualization, M.A.E. and D.A.E.; methodology, M.A.E. and D.A.E.; formal analysis, D.A.E.; investigation, M.A.E. and D.A.E.; data curation, M.A.E. and D.A.E.; writing—original draft, M.A.E. and D.A.E.; writing—review and editing, M.A.E.; visualization, M.A.E. and D.A.E.; funding acquisition, D.A.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Erell Institute.

Data Availability Statement: The data presented in this study are openly available in [Dryad] [https://datadryad.org/stash], accessed on 12 February 2025.

Acknowledgments: We acknowledge the support provided by the Director of National Parks, the traditional owners and park staff of Uluṟu-Kata Tjuṯa National Park, and Parks Australia. The views expressed in our paper do not necessarily represent the views of the Australian Government. We are grateful to the indigenous people (Aṉangu) for granting us permission to conduct research in the park, and to UKTNP officials, particularly Kerrie Bennison, for facilitating our work. Drew Dittmer helped us with all aspects of the project and interfaced on our behalf with local community members and park officials. Under the direction of park rangers Alan Harbour and Linda Fejo, the Mutitjulu Community Rangers Adam Hill, Steve Dingley, Michael Wilson, Liam, and Lee provided excellent assistance in the field and good company. We thank Ben Thornton for plant identifications. Belanna Pho provided feedback on the manuscript. Funding was provided by the Erell Institute. UKTNP provided us with housing and access to a vehicle, equipment, and logistical support.

Conflicts of Interest: The authors declare no conflict of interest.

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