Feeling the pressure at home: predator activity at the burrow entrance of an endangered arid-zone skink.

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Abstract

Habitat modification and invasive species are among the most important contemporary drivers of biodiversity loss. These two threatening processes are often studied independently and few studies have focused on how they interact to influence species declines. Here we assess the predation pressure placed on the threatened great desert skink (Liopholis kintorei) and how this interacts with fire-induced habitat modifications. We collected daily track data of potential predators for one month at 30 great desert skink burrow-systems where vegetation cover varied significantly after experimental burns. We used these data to evaluate potential predation pressure at the burrow-system and assess whether fire influenced predator pressure. We supplemented this analysis by documenting predation via the inspection of large mammalian predator scats collected from great desert skink habitat. The level of feral cat activity at a burrow-system entrance was significantly higher than that of any other potential predator, however fire had no effect on the visitation rates of feral cats, dingoes or large snakes to great desert skink burrow-systems. The remains of great desert skink were found significantly more frequently in feral cat scats, compared to fox and dingo scats. We provide the first direct evidence that feral cats are a significant predator for great desert skink, thus supporting the hypothesis that feral cat predation is a key threatening process. Feral cat activity was not influenced by small-scale experimental burns, however, this does not preclude an effect of larger scale fires and we recommend further research exploring this possible interaction.

Key words: Liopholis kintorei, feral cats, habitat modification, fire, threatened species.

Introduction

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Habitat modification and invasive species are the most important contemporary drivers of biodiversity loss (Purvis et al. 2000; Didham et al. 2007; Fisher and Lindenmayer 2007; Brook et al. 2008; Doherty et al. 2015). However, these two threatening processes are often studied independently rather than as drivers that interact synergistically; few studies have focused on their possible interactions, and indirect effects on species declines that may occur as a result of these interactions (Hobbs 2001; Didham et al. 2005; Didham et al. 2007; Brook et al. 2008; Chalfoun et al. 2009; Conner et al. 2011; McGregor et al. 2014; Hradsky et al. 2017).

Predator-prey relationships are likely to be strongly influenced by the interaction between habitat modification and invasive species. Variability in vegetation structure influences the outcome of predator-prey interactions because predation risk and hunting success can be affected by attributes of the habitat occupied by both predator and prey (Janssen et al. 2007; Chalfoun et al. 2009; Conner et al. 2011; McDonald et al. 2016; Hradsky et al. 2017). For example, an experiment investigating the short-term effects of a prescribed fire on the red fox (Vulpes vulpes) and feral cat (Felis catus) and their native mammalian prey in southeastern Australia found that under pre-fire conditions invasive predators were more likely to occur at sites with an open understory, whereas most small- and medium-sized native mammals were positively associated with understory cover. Fire reduced understory cover by more than 80%, and resulted in a 5-fold increase in the occurrence of invasive predators and the relative consumption of medium-sized native mammals by foxes doubled (Hradsky et al. 2017). Many invasive species take opportunistic advantage of habitat modification and therefore increase their overall impact within these habitats (Didham et al. 2005; Janssen et al. 2007; McDonald et al. 2016; McGregor et al. 2014; Hradsky et al. 2017). In many cases structurally complex habitats have been shown to decrease predation risk by providing refuges or shelter for prey, reducing encounter rates between predator and prey, hindering foraging activity of predators and reducing predator kill rate success (Fischer and Lindenmayer 2007; Janssen et al. 2007; Robinson et al. 2013; McGregor et al. 2014; Hradsky et al. 2017). A study conducted in northern Australia by McGregor et al. (2014) on the interactive effects between habitat modification and potential predator pressure found that modifications of habitat produced by grazing, and particular fire types, have strong effects on feral cat movement behaviour. Specifically, they showed that feral cats (Felis catus) selected areas with low grass cover and that intense fires and grazing created habitat conditions that are favoured by feral cats, increasing predator pressure on prey species.

In recent history, Australia has suffered the greatest loss of native vertebrate species of any continent (Johnson 2006). Diagnosing possible threatening processes associated with native species population declines, and understanding the underlying mechanisms and interactive effects driving these declines, is critical to the delivery of appropriate and effective conservation management (Hobbs 2001; Norris 2004; Didham et al. 2007; Brook 2008). In Australia, predation by introduced mammalian predators and habitat loss and/or modification are widely considered to be the key threats contributing to this significant national loss of species (Gibbons et al. 2000; Johnson 2006; Woinarski et al. 2007; Wilson 2012; Frank et al. 2014; Woinarski et al. 2014).

In the Australian context, it will often be necessary to consider key threatening processes in the context of changed fire regimes. Since as early as the Tertiary, fire has been recognised as a major influence shaping Australian environments (Kershaw et al. 2002; Mooney et al. 2012) and it continues to be one of the largest drivers of habitat modification. For thousands of years prior to European occupation much of Australia’s environments were being shaped by traditional Aboriginal burning practices, which resulted in a fine mosaic of vegetation patches at various stages of post-fire recovery (Latz & Griffen 1978; Kimber 1983; Saxon 1984; Griffin & Friedel 1985; Payne 1991; Bowman et al. 2012). Traditional Aboriginal fire regimes across Australia were abandoned or modified post European settlement (Latz & Griffin 1978; Kimber 1983; Griffin & Friedel 1985; Burrows et al. 2006). This cessation of landscape-scale anthropomorphic burning has seen a shift towards infrequent, intense and broad-scale wild-fire events that result in vast tracts of modified habitat (Latz & Griffin 1978; Burbidge and McKenzie 1989; Morton 1990; Gill 2000; Allan & Southgate 2002; Burrows et al. 2006; Edwards & Allan 2009). Within these highly modified environments, invasive predators have the potential to threaten native fauna with extinction (Hobbs 2001).

The great desert skink (Liopholis kintorei) is an an internationally listed vulnerable species with a distribution confined to fire-prone arid environments of the western deserts of Australia (McAlpin 2001; IUCN 2016). This distribution overlaps with introduced mammalian predators, most notably feral cats and European red fox (Vulpes vulpes; Dickman 1996; Strahan & Van Dyck 2006). The known range of this species has contracted and localised population declines and extinctions have been documented (McAlpin 2001). Habitat modification caused by changes in recent fire regimes and increased predation by introduced mammalian predators have been previously identified as likely causes of great desert skink population declines (McAlpin 2001; Cadenhead et al. 2015; Moore et al. 2015).

The influence of fire on great desert skink populations has been investigated at different spatial scales. At a relatively small scale, fire was found to have a negative impact on occupancy rates at great desert skinks burrow-systems, along with rates of breeding success (Moore et al. 2015). At a larger spatial scale, fire regime was identified as a major determinant of great desert skink viability, with an increase in fire size and frequency predicted to drive this population to extinction (Cadenhead et al. 2015). However, in each of these studies, the mechanism by which fire is related to reduced burrow-system occupancy rates and the predicted local extinctions remained unclear.

Here we present the results of an observational study built opportunistically around a prior experimental burn study that focused on great desert skink burrow occupancy and breeding success post fire conducted on Newhaven Sanctuary (Moore et al. 2015). We aim to investigate the ecological mechanisms that underpin great desert skinks response to fire by determining: 1) the magnitude of predation on great desert skink by large mammalian predators generally across the sanctuary, 2) the level of potential predator pressure that exists at great desert skink burrow-systems, and 3) if predator pressure was influenced by the presence and type of fire.

Methods

Study site

The study was conducted at Newhaven Wildlife Sanctuary in central Australia, Northern Territory (22.72˚S, 131.17˚E; Fig. 1). This property is managed for conservation by the Australian Wildlife Conservancy. Newhaven has the largest known population of great desert skink, and here their preferred habitat is semi-saline spinifex sandplain (Latz et al. 2003). This community is typically dominated by needlewood (Hakea leucoptera), Inland tea-tree (Melaleuca glomerata) and the sub-shrub Pluchea ferdinandi-mulleri over hummock grass Triodia pungens (the stoleniforous growth form; Latz et al. 2003).

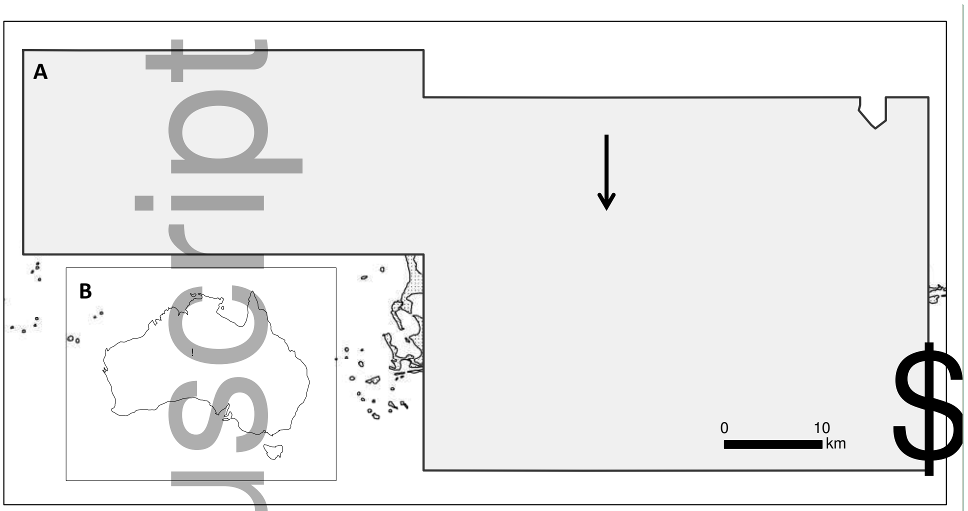

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Fig. 1. Newhaven Wildlife Sanctuary (A) showing the location of the three 1 km² sites from which predator scats were collected (closed squares). The arrow indicates the location of the study site at which predator tracking was performed. The shaded grey areas indicate potential great desert skink habitat and the hatched areas and small irregular shaped black areas indicate ephemeral lakes. The inset map (B) shows the location of Newhaven Wildlife Sanctuary within Australia.

Study species

The great desert skink grows to approximately 200 mm snout-vent length, can weigh up to 350 g, and is endemic to arid Australia (McAlpin, 2001; Chapple, 2003). It is an obligate burrower that constructs and maintains a complex burrow-system with multiple openings and interconnecting tunnels that can be up to 80 cm in depth. Burrows can be occupied continuously for up to at least 7 years and house close relatives, often consisting of the two parents and two age cohorts of their offspring (McAlpin et al., 2011; Dennison, 2015). It is crepuscular and nocturnal, spending the majority of its surface activity time at the burrow entrance and rarely foraging far from its burrow-system (Moore et al. in review).

Fire induced habitat modification at great desert skink burrow-systems and potential predator activity

Within a 75 ha focal study site, 30 burrow-systems were selected for a study on the impacts of fire on persistence of great desert skinks (see Moore et al. 2015 for detail). Three fire type treatments (with 10 replicates of each) were applied to an area approximately 0.25 ha (herein referred to as the experimental burn zone). This was the size required for the burn treatment to cover the extent of a single burrow system. The three fire treatments were: 1. clean burn—all ground cover was burnt within the experimental burn zone; 2. patchy burn—30% - 40% of ground cover was left unburnt within the experimental burn zone and the vegetation covering one to two burrow entrances was burnt and the latrine remained unburnt, and; 3. no burn—no experimental burn was conducted (Moore et al. 2015). The proportion of ground cover that remained at the burrow-systems after the experimental burns differed significantly when clean-burn and patchy-burn fire types were compared with no burn (Moore et al. 2015).

The cleared line that was created manually around each of the 30 burrow-system to help contain the experimental burns provided an excellent tracking surface to systematically monitor potential predator activity at each burrow-system. We used these cleared lines, (herein referred to as tracking ring), approximately 1.5 m in width, and the range of vegetation cover resulting from the experimental burns, to opportunistically collect data on potential predator visitation to the burrow-systems.

The following ground dwelling species, known to occur at Newhaven, were considered potential predators for great desert skink: feral cat, European red fox, dingo (Canisdingo), brush-tailed mulgara (Dasycercus blythi), woma python (Aspidites ramsayi), Stimson’s python (Antaresia stimsoni orientalis), mulga snake (Pseudechis australis) and Mengden’s brown snake (Pseudonaja mengdeni). Due to the difficulty in distinguishing between the tracks of mulga snake, Mengden’s brown snake and the woma python, all snake tracks greater than 2 cm in width were categorised as “large snake”. Although sand goanna could plausibly prey on juvenile great desert skink, we do not consider them a predator of this species. Goannas are strictly diurnal and forage at relatively high body temperatures, therefore they could only hunt great desert skink when it is inactive underground. In addition, the size and shape of great desert skink burrow-systems would usually preclude entry of adult sand goannas and restrict access to deep chambers within the burrow-system.

The day prior to tracking, the tracking ring was swept with a broom to remove all previous signs of animals and to create an even surface. In addition, all tracks (footprints) within 0.5 m of each burrow entrance were removed by sweeping. Potential great desert skink predators were detected by walking the tracking ring created around the burrow-system and searching for predator tracks. In addition, searches were made for predator tracks within 0.5 m of all entrances to each burrow. For consistency, only one of us (DM) made the tracking observations. Tracking took place between 7 am and 9 am when the sun was high enough to reach the surface of the ground but low enough to create shadows, therefore making tracks more obvious and keeping detection of tracks between burrow-systems equal. Potential predator tracks at each of the 30 burrow-systems were recorded daily for approximately one month beginning the day after the experimental burns were conducted. All tracks found on the tracking ring and at the burrow entrances were removed daily by sweeping.

Tracking was conducted during summer months (November and December) when great desert skink are active. Below average rainfall was recorded in the 12 months period to when scats were collected and conditions throughout the tracking period were dry.

Potential predator scat collection and dietary analysis

Feral cat, dingo and fox scats were collected over a fourteen month period (September 2013 to December 2014) from three 1 km² sites, separated by a minimum of 10 km. All sites were known to be inhabited by great desert skink, one of which included the focal study site (Fig. 1). On at least four occasions each of these sites was searched for predator scats. Scats were placed into paper bags and transferred to the laboratory where they were placed in nylon bags and soaked in hot water for a minimum of 12 hours and then washed through a regular cycle in a domestic washing machine. Scats were then air-dried in the nylon bags. Scat contents were sorted under a dissecting microscope to determine the presence of great desert skink which could be distinguished from blue-tongue lizards and other reptiles by their distinctive claws and jaw bones.

Analysis

The Kruskal-Wallis rank sum test (Quinn & Keough 2002) was used to compare predator activity levels at burrow-system entrances and to test for effects of the presence and type of fire on predator activity at great desert skink burrow-systems. A detection bias may have occurred as a result of the variation in vegetation cover across sampled sites post experimental burns. To account for this possibility, if a significant result was found when examining the predator occurrence at a burrow-system entrance, we also analysed observation data from the tracking rings, where detectability across all thirty sites was equal. Pearson's Chi-square test (Quinn & Keough 2002) was used to detect any significant difference in predation on great desert skink when examining the predator scat data. All analyses were performed using R version 3.0.2. (R Development Core Team 2011).

Results

Potential predator pressure at the burrow-system and the effect of fire on predator activity

Over the 4 week tracking period, 511 tracking surveys were conducted. From the seven potential predators identified, three species were recorded visiting great desert skink burrow-systems during the four weeks of intensive tracking. Two were native predators—dingoes, and large snakes as well as feral cats (Fig. 2). The level of feral cat activity at a burrow-system entrance (within 50 cm of at least one entrance to a burrow-system) was significantly higher than that of any other potential predator (Kruskal-Wallis rank sum test; df = 3; P < 0.001, χ^2= 45.6). Feral cat tracks were detected at a burrow-system entrance on 12.5% of the 511 track surveys, dingoes were only detected twice (0.39%) and large snakes were recorded on 1.2% of tracking surveys (Fig. 2). No European red fox or brush-tailed mulgara tracks were detected at burrow-systems, however tracks from each of these species were observed elsewhere (within 20 m of a tracking ring) within the focal study site.

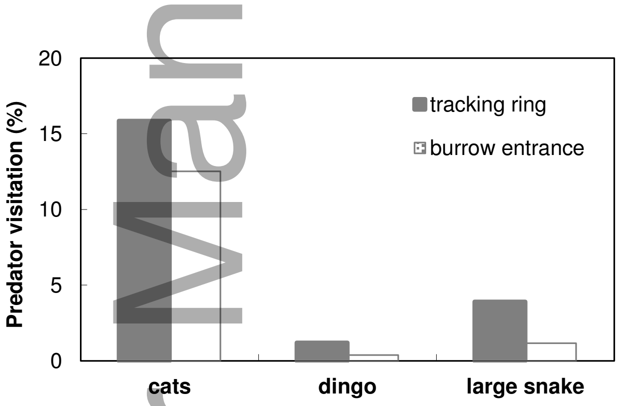

Fig. 2. The percentage occurrence of tracking surveys where predator tracks were detected at a great desert skink burrow-system entrance or on the tracking ring, irrespective of burn type.

There was no significant effect of the presence, or type, of fire on the frequency of cat, dingo and large snake visitations to a great desert skink burrow-system entrance. Feral cat activity at great desert skink burrow-system entrances was relatively high across all burrow-systems irrespective of burn type, with visitation ranging from 11.3% at clean burned sites to 14.6% at unburnt sites (Fig. 3). This equates to a burrow-system being visited by a cat every 7-9 days.

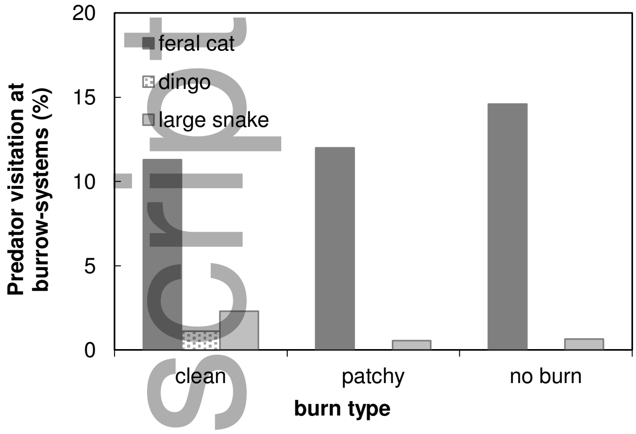

Fig. 3. The frequency of occurrence of feral cat, dingo and large snake tracks at great desert skink burrows across 3 burn types.

Large mammalian predator diet analysis

Over a 14 month period, 121 large mammalian predator scats were collected (39 feral cat, 65 dingo and 17 fox) from three 1 km² sites. The remains of great desert skink were confirmed in 49% of feral cat scats, 18% of fox scats and 14% of dingo scats (Fig. 4). The frequency of great desert skink remains occurring in feral cat scats was significantly higher than in fox and dingo scats (Pearson's Chi-squared test; $\chi^2 = 16.2$, d.f. = 2, $P < 0.001$).

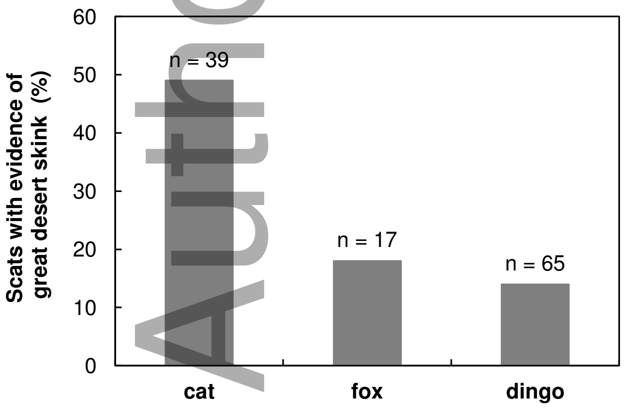

Fig. 4. The percentage of feral cat, European red fox and dingo scats that contained the remains of great desert skink. The number of scats sampled per predator, 'n', is also indicated.

Discussion

Relative predator impact on great desert skink

Results of this study strongly indicate that feral cats are the most significant predator of the nationally threatened great desert skink within semi-saline sand plains on Newhaven. Feral cats were the most frequently recorded predator at great desert skink burrow-systems and they had a significantly higher frequency of occurrence of great desert skink remains in their diets than dingo and European red fox. These results are consistent with the general conclusion in the literature that feral cats are a significant threat to Australian native fauna (Frank et al. 2014; McGregor et al. 2014; Woinarski et al. 2014).

The results of our tracking survey, in particular, highlight the increased predation pressure placed on this species by feral cats. Predator pressure, in this instance, refers to the pressure that might be experienced by an individual skinks or a family group inhabiting a burrow-system caused by the presence of a predator at the burrow-system. During the four week intensive tracking period we determined that a great desert skink burrow-system would be visited by a predator once every 7 days. If feral cats were removed from the ecosystem, this predator visitation would be reduced once every 67 days.

Several aspects of the behaviour of some native species have been identified as likely to increase their susceptibility to cat predation. These include being nocturnal, of colonial habit, utilising terrestrial areas and/or exhibiting conspicuous behaviour (Dickman 1996). Great desert skink show each of these traits—they are a crepuscular and nocturnal skink that spend a large proportion of their active time basking and hunting from a burrow-system entrance. In addition, they construct, maintain and occupy a family burrow-system for an average of four years (McAlpin et al 2011; Moore et al. in review). It is plausible that, because great desert skink burrow-systems are often tightly clustered and are a static feature within the landscape, individual feral cats may learn the locations of these burrow-systems and become specialist hunters of great desert skink. This specialisation is likely to magnify the impact of cat predation, in contrast to the impact caused by opportunistic hunting alone. Other studies have suggested that specialisation of hunting by feral cats has led to the local extirpation of native mammal species including the mala (Lagorchestes hirsutus) within the Tanami desert of Australia (Gibson 1994) and a captive colony of long-haired rat (Rattus villosissimus) within northern Australia (Frank et al 2014). On average three or four of the 30 burrows-systems monitored during this study were visited by a cat each day, and we observed the footprints of individual feral cats travelling directly from one active burrow-system to another, investigating numerous burrow entrances along the way, in a systematic and predictable manner. It is thus possible that particular individuals were targeting great desert skink in their hunting and concentrating their efforts on micro-habitats where prey capture is most likely. Despite regular dingo activity along roads traversing and adjacent to the study sites, dingo tracks were rarely detected at great desert skink burrows. In contrast to feral cat behaviour at a burrow-system, on the two occasions that dingo sign was observed at burrow-systems, the tracks indicated that the dingo walked directly over the burrow-system with no apparent change in direction or pace of travel. Despite this observation at the burrow-system, great desert skink still formed a relatively high proportion of dingo diet with 14 % of dingo scats containing the remains of this species. Although an analysis of 12,000 dingo scats over a 20 year period found that, across most of Australia, medium-sized mammals are the preferred prey of dingoes (Corbett 2001), within arid environments reptiles have been found to be a dominant part of the dingo diet. (Paltridge 2002; Newsome et al. 2014), In support of this, we found that 62.5% of scats contained reptile remains (25% goanna, 21% skink exclusive of great desert skink; 10% dragon, 1.5% snake, 3% other reptile) compared with 15% of scats that contained the remains of mammals. This result may be influenced by the collection of scats during summer months only and prevailing environmental conditions. Below average annual rainfall was recorded at the study site in 2013 (299.5mm; 12 months prior to the collection of scats) possibly reducing the numbers of small mammals available during the study period. Additionally, seasonal conditions are known to influence dingo diet in central Australia, where mammals form a larger part of dingo diets in the winter months when many reptile species are hibernating, with reptiles forming the majority of dingo diet in the summer months (Newsome et al. 2014).

Large snake tracks were observed at great desert skink burrow-systems, particularly after rain or when relative humidity was high. Although our tracking method was unable to distinguish between large diurnal elapids (Mengden's brown snake and mulga snake) and nocturnal pythons (woma python and Stimpson's python), we did directly observe a woma python to be a predator of great desert skink at the study site. Large diurnal elapids may be attracted to great desert skink burrow-systems for shelter or if led there by other hunting opportunities, including small mammalian prey, however, it remains unconfirmed if these species prey on great desert skink.

Effect of fire on predation pressure at burrow-systems

The experimental burns, though at a small scale in the immediate vicinity of the burrow-system, are ecologically significant because previous studies have shown that this species spends approximately 67% of its surface activity time at the burrow entrance (Moore et al. in review). Our results did not show a significant effect of fire on frequency of cat visitation to great desert skink burrow-systems. This is in contrast to a study from northern Australia that recorded cats travelling large distances to target their hunting in recently burnt habitat (McGregor et al. 2014). Our findings do not preclude cats targeting a recently burnt habitat following a more extensive wildfire, but in the current study the small area (approx. 0.25ha) of habitat modified by each experimental burn does not appear to have been sufficient to alter feral cat hunting preferences at great desert skink burrow-systems.

Regardless of how often feral cats visit a particular burrow-system, it is likely that their hunting success per visit is significantly influenced by the extent of vegetation cover at burrows. Feral cats usually detect prey by sight or sound—species that are conspicuous within an open burnt landscape are therefore at high risk of predation as the hunting efficiency of the feral cat increases under these conditions (Dickman 1996; McGregor 2014). It is thus plausible that a synergistic effect exists between habitat modification caused by fire and predation pressure whereby the effectiveness of cat hunting increases with the removal of vegetation cover following intense fire. This could explain the results of a concurrent study that found that, although great desert skink can initially persist their burrow-systems after fire, most burrow-systems become unoccupied between 1 and 4 months after the fire occurred (Moore et al. 2015). With no evidence that animals are dispersing from burnt burrow-systems, an alternative explanation for the disappearance of great desert skink from burnt sites is increased vulnerability to predation. If extirpations of individuals, or family groups, from burnt burrow-systems is driven by predation, the present study has revealed that cats are the main predator involved.

Conclusions

Predation by feral cats and inappropriate fire regimes have been recognised as key threats to extant Australian terrestrial mammals (Woinarski et al. 2014). These threats are potentially as critical for Australian terrestrial reptiles as they are for mammals, especially burrow constructing species with high burrow fidelity. Although, our results did not detect an increased presence of feral cats at fire-affected great desert skink burrow-systems, our data identified feral cats as their most significant predator, supporting the need for ongoing feral cat management at locations with vulnerable populations. Conservation management of great desert skink would benefit from further research that gains an understanding of predation pressure imposed by feral cats in habitat subjected to landscape-scale habitat modification caused by fire.

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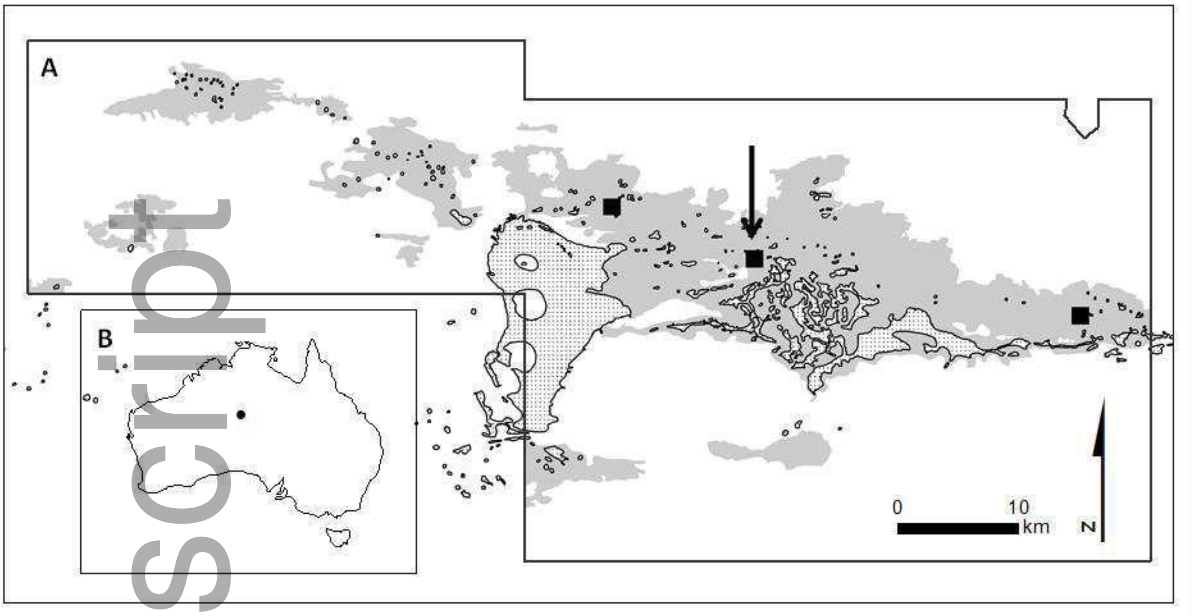
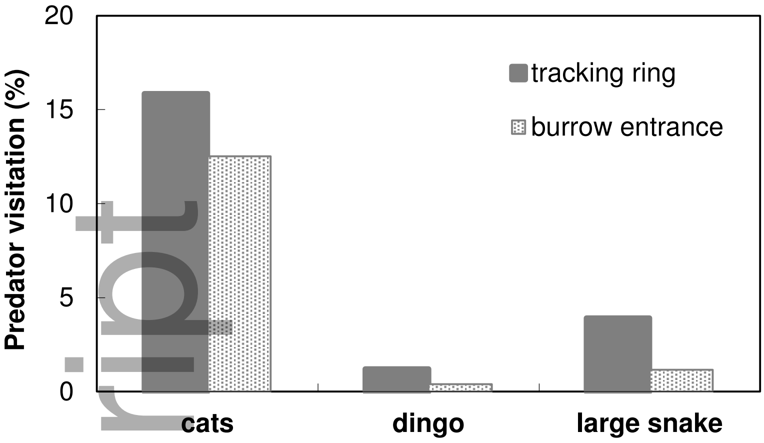
Fig. 1. Newhaven Wildlife Sanctuary (A) showing the location of the three 1 km² sites from which predator scats were collected (closed squares). The arrow indicates the location of the study site at which predator tracking was performed. The shaded grey areas indicate potential great desert skink habitat and the hatched areas indicate ephemeral lakes. The inset map (B) shows the location of Newhaven Wildlife Sanctuary within Australia.

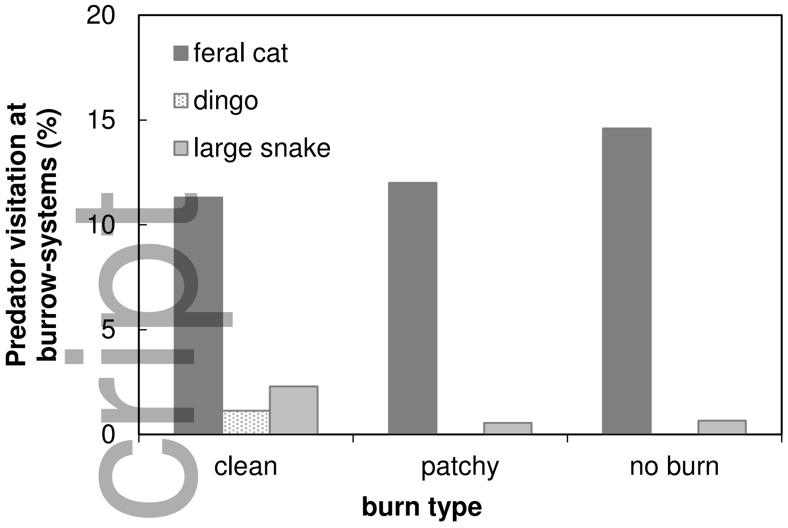
Fig. 2. The percentage occurrence of predator tracks detected at great desert skink burrow-systems irrespective of burn type.

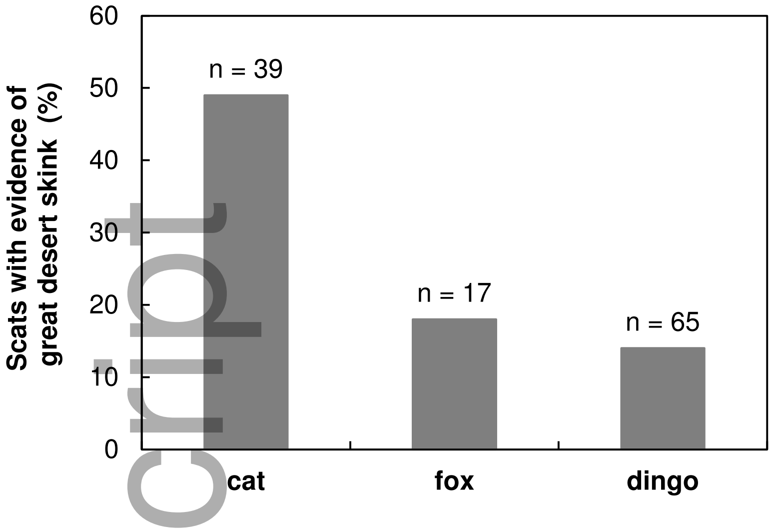
Fig. 3. The percentage of feral cat, European red fox and dingo scats that contained the remains of great desert skink. The number of scats sampled per predator, ‘n’, is also indicated.

Fig. 4. The percentage occurrence of feral cat, dingo and large snake tracks detected at a great desert skink burrow-systems across burn type.


A
B
0
10
km
N


Predator visitation (%)
20
15
10
5
0
tracking ring
burrow entrance
cats
dingo
large snake


20
15
10
5
0
Predator visitation at burrow-systems (%)
feral cat
dingo
large snake
clean
patchy
no burn
burn type


Scats with evidence of great desert skink (%)
60
50
40
30
20
10
0
n = 39
n = 17
n = 65
cat
fox
dingo