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Introduced predators and habitat structure influence range contraction of an endangered native predator, the northern quoll

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ABSTRACT

Introduced predators such as feral cats (*Felis catus*) are responsible for declines of many small mammals across the globe. The impact of cats can be exacerbated by mesopredator release, when larger predators (e.g. canids) are suppressed. In response to increasing predation threat from cats, native species may change their use of landscapes. We studied how interactions among native and introduced predators affect the decline of the largest native predator in northern Australia, the endangered northern quoll (*Dasyurus hallucatus*). The northern quoll is a carnivorous marsupial 'that is undergoing rapid population declines in most of its range, and is retreating to rugged, rocky parts of the landscape. Widespread dingo (*Canis dingo*) control has been hypothesized to lead to mesopredator release of cats in parts of the continent. Using camera trapping and GIS mapping methods, we determined the temporal activity and spatial distributions of sympatric northern quolls, dingoes and cats in the semi-arid Pilbara region of Western Australia. We found that dingoes were scarce, and their role as top predators in our study areas was weak. Cats avoided dingoes in time at a fine scale, but their spatial distribution was not affected by dingoes. Cats frequently used flat, open habitats. Quolls avoided areas used by cats. We suggest that introduced predators influence the use of landscapes by northern quolls at both local and larger scales. Predator avoidance is likely to be a major reason for the contraction of the distribution of northern quolls to rocky areas across northern Australia.

1. Introduction

Resource partitioning occurs in ecological time when smaller species from a given guild move to suboptimal habitat or alter their behaviour to avoid competition or predation from larger ones. For example, in the Panama Canal region, jaguars (*Panthera onca*), pumas (*Puma concolor*), and ocelots (*Leopardus pardalis*) exhibit resource partitioning (Moreno et al., 2006). Jaguars take large prey, leaving medium-sized prey to pumas and small prey to ocelots. In the absence of jaguars, pumas shift to large prey, and ocelots to medium-sized prey (Moreno et al., 2006). This is an example of mesopredator release, where the removal of a top-predator can alleviate top-down control for the remaining smaller predators, allowing them to increase in numbers or change their behaviour (Prugh et al., 2009). Mesopredator release often causes substantial declines of smaller prey species (Prugh et al., 2009), especially in areas where invasive predators affect native species.

Around a third of modern mammal extinctions have been Australian species. At least 24 species have become extinct since the mid-19th century (Woinarski et al., 2015) and a third of Australian marsupials have experienced range reductions (Fisher et al., 2014). Burbidge and McKenzie (1989) identified that species within a 'Critical Weight Range' (CWR), with a mass between 35 and 5500 g, were at most risk. Invasive predators are considered to be the main threat to CWR species (Johnson et al., 2007; Lawes et al., 2015). Introduced mammalian predators in Australia include the cat (*Felis catus*) and red fox (*Vulpes vulpes*). The dingo (*Canis dingo*, Crowther et al., 2014) is not a native mammal but arrived at least 3450 years ago (Wright and Lambert, 2015), and now has a role as top mammalian predator, perhaps having taken the ecological role of similar-sized extinct native carnivores (Johnson et al., 2007; Wallach et al., 2010). Changed fire regimes are also considered a threat to small and mid-sized mammals (Woinarski et al., 2015), potentially because intense fires interact with invasive predators, generating a 'multiplied' or synergistic negative effect (Doherty et al., 2015b). For example, in the Kimberley region of northern Western Australia, cats showed a strong preference for open habitats, especially areas burnt in intense fires, because fire simplified habitat structure, creating homogeneous open areas (McGregor et al., 2014). They also found that cats had a 30% hunting success rate, and 28% of the successful kills were not consumed (McGregor et al., 2015). CWR species are the preferred prey size of foxes and cats. Medium sized species have been identified as at higher risk in southern Australia where foxes and cats are prevalent. In northern Australia there are cats but no foxes, and species at higher risk are smaller (Fisher et al., 2014; Lawes et al., 2015). Frank

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et al. (2014) recently showed experimentally that cats are linked to declines of smaller mammals in northern Australia.

The northern quoll (*Dasyurus hallucatus*) is a medium-sized carnivorous marsupial (Dasyuridae), and is considered part of the CWR group. It is the largest native mammalian predator across most of its range. It was once distributed throughout the northern third of Australia (Hill and Ward, 2010), inland to about 200 km, but is now restricted to a few fragmented populations (Braithwaite and Griffiths, 1994; Oakwood and Spratt, 2000). The decline of the northern quoll has been more severe in flat, open habitats, than in elevated rocky areas (Hill and Ward, 2010; Oakwood, 2002; Oakwood and Pritchard, 1999), and it has disappeared from most of its former range in savannas and grasslands (Oakwood and Spratt, 2000). It persists in fragmented rocky areas and is now nationally and internationally listed as Endangered (Hill and Ward, 2010; Oakwood et al., 2008). Other than the toxic cane toad (*Rhinella marina*), which has not yet reached the Pilbara region, it is still unclear what factors threaten local survival of northern quolls in this region (Hill and Ward, 2010). It has been suggested that these factors include changes in fire regimes, land use changes due to cattle grazing and mining, and competition with and direct predation by introduced predators (Hill and Ward, 2010; Woinarski et al., 2007). In the National Recovery Plan for the species, Hill and Ward (2010) suggest that introduced predators are more abundant in flat grasslands, and that steep rocky habitats provide shelter where northern quolls are more protected from predators. The Pilbara region of Western Australia is an area where the top-down interactions of northern quolls and their introduced predators can be investigated without these being potentially obscured by the effect of cane toads.

The Pilbara is a semi-arid environment, where free water is limited. Many rivers in the Pilbara form sets of unconnected water pools for most of the year. Species respond differently to such limited water availability. Although water availability can be a crucial factor for dingoes because they need it to survive, they may not visit monitored water tanks daily (Allen, 2012). Cats can meet their water requirements through food, but free water might enhance their survival in arid environments (Brawata and Neeman, 2011). Water availability also seems to be important for northern quolls. This may be related to higher prey availability near water (Hill and Ward, 2010). Pollock (1999) found ~60% of recorded quolls within 200 m of permanent water, and Braithwaite and Griffiths (1994) have documented quolls drinking water. In addition to providing water, riparian areas are complex habitats that may provide shelter for cats from predators and humans (Doherty et al., 2014), while open habitats may allow them higher hunting success (Doherty et al., 2014; McGregor et al., 2015).

Regardless of their importance as top predators and the long time since they were introduced, dingoes are still considered an introduced pest and controlled by poison bait (sodium fluoroacetate, '1080') in many areas (Claridge et al., 2010; Johnson et al., 2007; Letnic et al., 2012). This poison affects foxes and cats as well, but because cats are less likely to consume 1080 bait, such control programs are ineffective for cats (Burrows et al., 2003), especially under high prey availability conditions (Burrows et al., 2003; Christensen et al., 2013). However, researchers have successfully controlled cats at site scale in southern Western Australia using the 'newly' developed Eradicat® which is also based on 1080 poison (Algar et al., 2013). Eradicat® has been tested in different parts of Western Australia (Morris et al., 2015) and was not found to have an effect on northern quolls in the Pilbara, so is now considered for programs at the landscape level (Morris et al., 2016). The role of dingoes as top predators is increasingly supported by evidence of their control of foxes and cats (Brook et al., 2012; Cupples et al., 2011; Johnson et al., 2007; Letnic et al., 2012). Thus, baiting programs facilitate mesopredator release where cats thrive in the absence of foxes and dingoes. Increased abundance of mesopredators translates into higher predation on their prey species, ultimately suppressing small and mid-sized native mammals (Johnson et al., 2007). On the other hand, Radford et al. (2014) show that the presence of top predators such as dingoes are related to a more complex composition and relative abundance of native mammals in the Kimberley. They suggest it can result from control on mesopredators and on 'dominant competitors of CWR mammals' such as macropods (Radford et al., 2014). Accordingly, we have observed dingoes predating on wallaroos (*Macropus robustus*) in our study area.

The overall goal of this study was to assess how interactions among predators might affect the decline of the northern quoll, particularly the contraction of its range to steep rocky areas and loss from flat arid grasslands. We analysed patterns of activity and distribution of northern quolls and introduced predators in the Pilbara to examine predator interactions, associations between predators and habitat structure, and associations between species distributions and water. We assumed that in this system, dingoes act as top predators, cats as mesopredators, and quolls, being the smallest species in this carnivore guild, as potential prey or competitors of the larger carnivores. We predicted the following. 1) Cats would avoid dingoes in space, and quolls would avoid cats in space. 2) Cats would avoid dingoes in time, and would quolls avoid cats in time (by shifting activity schedules in the presence of these predators). We hypothesized that mesopredators in our system prefer open habitats (grasslands and recently burnt areas) to rock outcrop areas, while quolls prefer rock outcrops to shelter from mesopredators among other potential benefits. So, we predicted that 3) cats would show greater use of open habitats than rock outcrops, and quolls would show greater use of rock outcrop areas than open habitats. In terms of associations between species distributions and water, reports in the literature suggest that dingoes, cats, and northern quolls may all prefer areas near water in the arid zone and seasonally dry tropics. Although the amount of drinking water needed by these species may differ, they likely all benefit from having drinking water readily available. If there were no interactions between predator species that affect their space use, and no associations between habitat structure and the presence of water, we predicted that dingoes, cats, and quolls would be associated with the spatial distribution of creek-lines. However, if quolls avoid cats, and cats avoid dingoes, we predicted that 4) dingoes and quolls would be positively associated with water, and cats would be negatively associated with creek-lines. Because this prediction assumed there are no associations between habitat structure and the presence of creek-lines, and to fully understand the habitat use of the species, we also tested relationships between habitat types or the presence of rock outcrops and the presence of water (Appendix A).

2. Materials and methods

2.1. Study area

The Pilbara is a semi-arid desert with high average temperatures of 38 °C during summer and 25 °C during winter (McKenzie et al., 2009; van Vreeswyk et al., 2004). The wet season is December to March (McKenzie et al., 2009). The region is remote with very low human population density, based on estimates of 2014, it has about 7.5 people per km^2 (REMPLAN, 2014). This research was carried out at two study sites in the Pilbara (Fig. 1): Millstream Chichester National Park (Millstream) and Indee Station (Indee). Millstream is south east of the coastal town of Karratha, and was a cattle property before it became a national park in 1982 (DPaW, 2011). Although Millstream does not poison bait dingoes, nearly all neighbouring properties bait every September. Indee Station, south of the coastal town of Port Hedland, is a cattle property and tourist park with mining activities inside and adjacent to the property. Indee Station baits dingoes every September. The mean monthly rainfall at the beginning of this study (2013) was 61.41 (SD = 89.15) for Millstream (recorded at Pyramid Station) and 48.68 (SD = 56.01) recorded at Indee Station (BOM, 2016).