Threatened species indicate hot–spots of top–down regulation

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Abstract

Threatened species indicate hot–spots of top–down regulation.— The introduction of alien mesopredators and herbivores has been implicated as the main driver of mammalian extinction in Australia. Recent studies suggest that the devastating effects of invasive species are mitigated by top–order predators. The survival of many threatened species may therefore depend on the presence and ecological functioning of large predators. Australia's top predator, the dingo (*Canis lupus dingo*), has been intensively persecuted across the continent and it is extremely rare to find dingo populations that are not being subjected to lethal control. We predicted that the presence of threatened species point out places where dingo populations are relatively intact, and that their absence may indicate that dingoes are either rare or socially fractured. A comparison of a site which harbors a threatened marsupial, the kowari (*Dasyuroides byrnei*), and a neighboring site where the kowari is absent, offers support for this suggested pattern.

Key words: 1080 poison–baiting, *Canis lupus dingo*, *Dasyuroides byrnei*, Invasive species, Predator control, Top predator.

Resumen

Las especies amenazadas son indicadoras de los puntos calientes de la regulación trófica en sentido descendente.— Se ha considerado la introducción de mesopredadores y herbívoros extranjeros como el principal desencadenante de la extinción de mamíferos australianos. Estudios recientes sugieren que los efectos devastadores de las especies invasoras quedan mitigados por los superpredadores. Por lo tanto, la supervivencia de muchas especies amenazadas puede depender de la presencia y funcionalidad ecológica de los grandes predadores. El superpredador australiano, el dingo (*Canis lupus dingo*) ha sido muy perseguido por todo el continente, y es extremadamente raro encontrar poblaciones de dingos que no estén sujetas a un control letal. En este estudio pronosticamos que la presencia de especies amenazadas señala los lugares donde las poblaciones de dingos están relativamente intactas, y que su ausencia puede indicar que los dingos son raros o que sus poblaciones están socialmente fracturadas. La comparación entre un lugar que alberga a un marsupial amenazado, el kowari o rata marsupial de cola de pincel (*Dasyuroides byrnei*), y un lugar vecino, de donde falta el kowari, es concordante con el patrón que sugerimos.

Palabras clave: Envenenamiento con 1080, *Canis lupus dingo*, *Dasyuroides byrnei*, Especie invasora, Control por predador, Superpredador.

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Introduction

In the past 200 years the extinction of mammalian species has been particularly severe in Australia. The invasion of exotic species such as foxes (*Vulpes vulpes*), cats (*Felis catus*) and rabbits (*Oryctolagus cuniculus*) has been implicated as the main driver of biodiversity loss (Johnson, 2006). Mammalian species of intermediate body mass (50–5,500 g, the 'Critical Weight Range', CWR) are most vulnerable to decline and extinction (Burbidge & Mckenzie, 1989), particularly in low rainfall areas (Johnson & Issac, 2009). Poison–baiting with sodium monofluoroacetate (1080) and other pest control measures have been intensively applied across the continent in an attempt to control invasives and enhance biodiversity. Poison–baiting is by far the most popular control method in use today (Reddiex & Forsyth, 2006), and approximately 200 kg of 1080 powder are used annually in Australia (APVMA, 2008).

Although wildlife managers commonly work under the accepted premise that pest control measures are beneficial and necessary, there is little, if any, reliable evidence in support of these practices (Reddiex & Forsyth, 2006; Warburton & Norton, 2009). Several authors have challenged the utility of wildlife population control for conservation (Goodrich & Buskirk, 1995; Zavaleta et al., 2001; Gurevitch & Padilla, 2004; Didham et al., 2005). Not only is pest control often highly ineffective but it may also be harmful (Bergstrom et al., 2009). The impact of pest control may be particularly severe when large (top) predators are indiscriminately affected.

Top predators have been recognized as keystone species in virtually all terrestrial and marine ecosystems worldwide (Terborgh et al., 1999). Both empirical and theoretical studies have shown that the loss of a top predator can trigger a cascade of extinctions through mesopredator and competitor release (Crooks & Soulé, 1999; Glen & Dickman, 2005; Borrvall & Ebenman, 2006; Ritchie & Johnson, 2009). Moreover, the reinstatement of top predators has been found to be a critical component of ecosystem restoration (Smith et al., 2003; Ripple & Beschta, 2003). For example, the reintroduction of wolves in Yellowstone National Park (USA) precipitated a trophic cascade whereby wolves caused a decrease of coyote (*C. latrans*) density, which in turn caused a four–fold increase in the survival rate of pronghorn (*Antilocarpa americana*) fawns (Berger et al., 2008). The scarcity of wolves on Isle Royale (USA) resulted in depressed growth rates of balsam fir due to high moose densities (McLaren & Peterson, 1994). Similarly, sea otters are the top predator in the kelp forests of the North Pacific. When they were hunted out, sea urchin populations exploded leading to severe deforestation of kelp forests (Soulé et al., 2003). Several authors have recently suggested that the preservation of large predators increases ecological resilience to perturbations such as climate change (Wilmers & Getz, 2005; Sandin et al., 2008).

The dingo (*Canis lupus dingo*) arrived in Australia about 5,000 years ago (Savolainen et al., 2004) and is the only large predator that has survived to this day. Replacing the thylacine (*Thylacinus cynocephalui*), the dingo has assumed the role of top predator across the continent (Johnson, 2006). Since European occupation, dingoes have been intensively persecuted over much of the continent (Fleming et al., 2001), and 1080 poison–baiting is the main method of control (Reddiex et al., 2006). Dingoes are controlled on pastoral stations because they are considered a threat to livestock (Allen & Sparkes, 2001), they are controlled in conservation designated areas (e.g. National Parks, Aboriginal Lands) because of a common belief that poison–baiting will assist the recovery of threatened species (Reddiex et al., 2006), and they are controlled around human settlements because of a perceived risk to human life and welfare (Burns & Howard, 2003; Peace, 2002). Dingoes are controlled in every State and Territory (Fleming et al., 2001), whether listed as pest or protected native species. Australia is thus unique in that it has a single large mammalian terrestrial predator, and that this predator is controlled on every major landholding type.

Evidence is emerging that the spread of invasive species and the loss of biodiversity in Australia are a direct consequence of dingo control (O'Neill, 2002; Glen & Dickman, 2005; Glen et al., 2007; Johnson et al., 2007; Wallach et al., 2009a; Letnic et al., 2009a, 2009b). The control of dingoes may result in the release of invasive mesopredators and generalist herbivores (Johnson & VanDerWal, 2009; Letnic et al., 2009b), leading to increased predation and grazing pressures (Glen & Dickman, 2005). Across the continent extinction of marsupials was most severe in area where dingoes were scarce (Johnson et al., 2007), and positive correlations between dingo abundance and the survival of threatened species are rapidly stacking up (e.g. rufous hare–wallabies *Lagorchestes hirsutus*: Lundie–Jenkins, 1993; spotted–tailed quolls *Dasyurus maculates*: Catling & Burt, 1995; bilbies *Macrotis lagotis*: Southgate et al., 2007; malleefowl *Leipoa ocellata* and yellow–footed rock–wallabies *Petrogale xanthopus xanthopus*: Wallach et al., 2009a; and dusky hopping mice *Notomys fuscus*: Letnic et al., 2009a).

Dingoes, like all wolf species, are socially complex predators. They form long–term social bonds that may persist for generations if human intervention is minimal (Haber, 1996). Pack stability and abundance are not linearly related. Lethal control severely fractures social groups, but abundance may increase or decrease following control (Wallach et al., 2009b). The effectiveness of dingoes as top predators may depend on the cohesiveness of their social structure. Fracturing of social groups may cause the loss of hunting abilities, alter demographic patterns, destabilize territory boundaries, reduce fitness, and increase the risk of hybridization (Haber, 1996; O'Neill, 2002). The extent of predator control in Australia implies that the vast majority of dingo populations in Australia are socially fractured (Wallach et al., 2009b) and their ecological functioning compromised (Johnson et al., 2007).

The ecological importance of top–down regulation suggests that species threatened with extinction (due to predation or competition) will only survive where top predators are present. In support of this proposed pattern, we located dingoes in areas where they have been presumed absent for several decades by following the trail of threatened species (Wallach et al., 2009a). We therefore predicted that the presence of threatened species points out hot–spots where top–down regulation is relatively functional, and their absence implies that top–down regulation is disrupted. In this short communication we provide preliminary evidence for this prediction, by comparing two sites: one which harbors a threatened marsupial, the kowari (*Dasyuroides byrnei*), and a nearby site where the kowari is absent.

Methods

Study animals

The kowari is a small carnivorous marsupial that is found in low densities across the arid gibber plains of the Channel Country in the north–eastern corner of South Australia and south–western corner of Queensland. They are listed as Vulnerable under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 due to considerable range reduction since European arrival in Australia. The kowari weighs 70–175 g (Lim, 2008) and is therefore one of the CWR mammals most vulnerable to predation by cats and foxes.

We surveyed relative abundance of dingoes, introduced mesopredators (fox and cat), introduced herbivores (rabbits and feral camel *Camelus dromedaries*), large native herbivores (kangaroos *Macropus* spp. and emus *Dromaius novaehollandiae*) and small native mammals. Small native mammals were assessed as a group, but we also separately analyzed the abundance of small mammals that fall within the CWR category (50 < 300 g). Direct observations were opportunistically used to assist in verification of some small mammal species or genera identification. CWR mammals included the kowari and ampurta (*Dasycercus* sp.); and small mammals (< 50 g) included dunnarts (*Sminthopsis* spp.), kultarr (*Antechinomys laniger*) and fawn hopping mice (*N. cervinus*). Of all species identified in this study, two (kowari and ampurta) are listed as threatened under the EPBC Act 1999.

Study sites

Surveys were conducted at two sites inside the historical range of the kowari. The site chosen where kowari were present was Pandie Pandie (PP) station (26º 33' S, 139º 42' E) and the site chosen for comparison was Mungerannie (MU) station (28º 00' S, 138º 35' E; following Brandle, unpublished data). PP was surveyed in July and MU in August 2007. Both pastoral stations are in the Sturt Stony Desert in north–east South Australia (ca. 150 km apart) where vast stretches of gibber plains, provide the habitat characteristic of kowari. Both stations are utilized for cattle (Hereford) grazing, and grazing pressure follows the South Australian Pastoral Board guidelines. Permanent water sources (mainly bores and dams) were available for every ~100 km^2 and the study sites encompassed an area of approximately 500 km^2. To the best of our knowledge, no barrier existed that may have halted the reinvasion of kowari back into MU station. We had no prior knowledge regarding dingo management practices or ecological conditions of the study sites. At the onset of each field survey we obtained information on predator control practices from the managers of these two stations.

Measuring abundance

Abundance of all species was estimated with a passive track survey method described previously in Wallach et al. (2009a). In short, an index of abundance for each species, or group of species (in the case of small mammals), was assessed by combining an estimate of relative density and relative distribution. Relative density was determined by dusting 500 m random transects and counting the number of animal crossings over three days, giving an average value of tracks / 500 m / day (10–12 transects / site, placed both on and off road). Relative distribution represents the proportion of the study site occupied, which was assessed by recording the presence or absence of fresh tracks in random 2–ha plots (20 plots / site). The Index of Abundance (IA) was calculated by multiplying relative density by the overall relative distribution of the site. The number of transects and plots needed in each site were determined according to a Coefficient of Variance (CV) test. All *Canis* tracks were assumed to be dingo tracks, as no domestic dogs (*C. familiaris*) were present and wild domestic dogs are presumably rare in remote regions (Daniels & Corbett, 2003).

Assessing social stability

We assessed the social stability of dingoes by monitoring scent–marking and howling activity (Wallach et al., 2009b). Predator scats, urine, and ground rakings are signs of scent–marking, and have a wide array of communicative purposes (e.g. Sillero–Zubiri & Macdonald, 1998). Scats are concentrated at distinct focal points (Barja, 2009) and are particularly useful as long–term visual cues which allow the assessment of social stability rapidly and non–invasively (Wallach et al., 2009b). The accumulation of dingo scat deposits at focal points is predicted by lethal control, rather than abundance, and linearly increases the longer an area is left undisturbed (Wallach et al., 2009b). Like dingoes, foxes scent–mark at distinct focal points (Henry, 1977; Wallach et al., 2009a). We conducted a survey of the most common resource points (water points, rabbit warrens and carcasses), and compared scent–marking rates of dingoes and foxes between the two study sites. In total, we surveyed 44 and 75 resource points in PP and MU, respectively.

Howling may also indicate pack stability, but is a less reliable method because it is strongly influenced

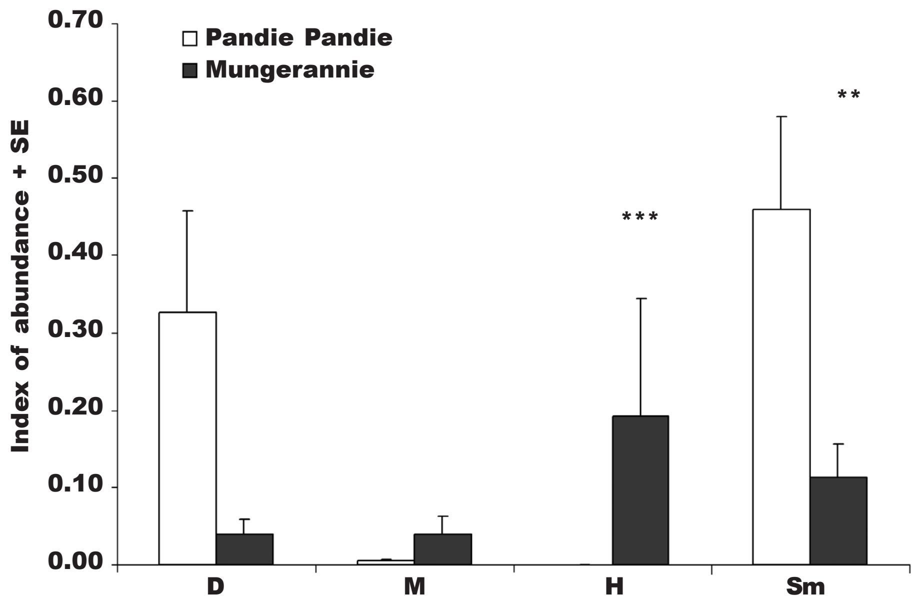

Fig. 1. Index of abundance of dingoes (D), mesopredators (M), generalist herbivores (H) and small native mammals (Sm) (full weight range included) in Pandie Pandie (kowari present) and Mungerannie (kowari absent). (Herbivore and small mammal abundances have been divided by 100 to allow for a comparable scale.)

Fig. 1. Índice de abundancia de los dingos (D), los mesopredadores (M), los herbívoros generalistas (H) y los mamíferos nativos de pequeño tamaño (Sm) (incluyendo el rango completo de pesos) en Pandie Pandie (kowari presente) y Mungerannie (kowari ausente). (Las abundancias de herbívoros y pequeños mamíferos se han dividido por 100, para permitir una escala comparable.)

by the presence and activity of people (Wallach et al., 2009b). Nonetheless, like scent–marking, howling is an indicator of pack activity (Corbett, 1995; Nowak et al., 2007) and is generally reduced where predator control is conducted (Wallach et al., 2009b). We therefore opportunistically recorded all howling events from the location of our field base at each study site.

A study conducted by Allen & Gonzalez (1998) indicates yet another possible symptom of pack disintegration. They found that, contrary to common expectations, attack rates on livestock may increase following predator control due to an increase in young unaffiliated dingoes. We therefore also surveyed cow and calf carcasses for signs of predation. We considered a carcass to have died from dingo predation if it was eaten while it was fresh, as determined by the condition of the hide. Stretched hide indicates that the carcass was eaten fresh, as dry hide will tear or break.

Results

PP station managers did not normally control dingoes and our study site was poison–bait–free for over five years. MU station, on the other hand, poison–baited all water points annually, and shot all dingoes on sight.

In PP dingoes were the most common predator (Wilcoxon $Z = 2.1$, $p < 0.05$; fig. 1), while in MU dingo and mesopredator abundance was similar (NS; fig. 1). Dingo abundance was not statistically different between the two sites despite the large effect size, which may be related to sample size (Mann–Whitney $Z = 1.3$, $p = 0.25$; fig. 1). On the other hand, scent–marking and howling rates were significantly higher at PP (Mann–Whitney scent–marking: $Z = 5.64$, $p < 0.001$, howling: $Z = 4.11$, $p < 0.001$; fig. 2). Also, in PP scent–marking was carried out almost exclusively by dingoes (Mann–Whitney $Z = 4.81$, $p < 0.001$; fig. 2), while in MU dingoes and foxes scent–marked at a similar rate (Mann–Whitney $Z = 0.99$, $p = 0.32$; fig. 2). We found no evidence of dingo predation on cattle in PP and no calf carcasses were found ($N = 56$), while in MU 14% ($N = 44$) of carcasses were calves, and all appeared to have been killed by dingoes.

Fox tracks were only found in two isolated locations in PP, while in MU we often found foxes walking along vehicle tracks, and we also located two fox dens in the gibber. Despite this, fox abundance was not significantly different between the sites (Mann–Whitney $Z = 1.99$, $p = 0.25$), but scent–marking was significantly higher in MU (Mann Whitney $Z = 3.43$, $p = 0.001$; fig. 2). Cats were similarly rare in both sites (Mann–Whitney $Z = 1.32$, $p = 0.54$).

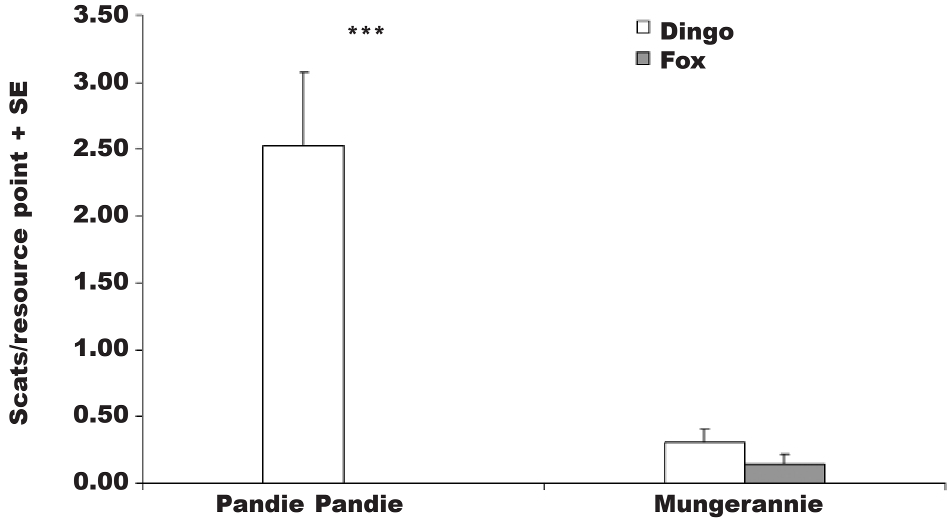

Fig. 2. Scent–marking of dingoes and foxes on resource points at Pandie Pandie (kowari present) and Mungerannie (kowari absent).

Fig. 2. Marcado por olor de los dingos y los zorros de los lugares con recursos en Pandie Pandie (kowari presente) y Mungerannie (kowari ausente).

Generalist herbivores (including rabbits, kangaroos, emus and feral camels) were significantly more common in MU (Mann–Whitney $Z = 3.74$, $p < 0.001$; fig. 1). In MU 91% of herbivores were rabbits, which accounts for the main difference in herbivore abundance between the two sites. Rabbits were unusually scarce at PP (Mann–Whitney $Z = 3.1$, $p < 0.01$), where we found a mere total of 13 warrens (seven warren clusters) across the study site during four weeks of extensive searches. In MU, rabbit warrens were commonly found in the gibber. Feral camels were found only in MU and were also located on the gibber.

The most remarkable difference between these two systems was the higher abundance of small native mammals at PP (Mann–Whitney $Z = 2.7$, $p < 0.01$; fig. 1); this difference was also significant for CWR mammals (Mann–Whitney $Z = 2.56$, $p = 0.01$). Small native mammal tracks identified to species or genera level (confirmed with direct observation) were kowari, kultarr and dunnart in PP, and ampurta, dunnart, and fawn hopping mice in MU.

Discussion

The presence of threatened species, particularly where they are surviving without human intervention, is the best indication of the ecological conditions required for their conservation. We found that kowari persisted where poison–baiting was minimal for several years, allowing dingo populations to reach a state of relative stability. The main difference between the dingo populations at the two sites was their social stability, as indicated by the higher rate of scent–marking and howling in PP. Also, similar to the results reported by Allen & Gonzalez (1998), we found a higher occurrence of calf losses at the site where dingoes were baited (MU).

The results of our study support the prediction that the presence of species threatened with extinction (due to predation or competition) indicate that top–down regulation is relatively intact. The area where kowari have persisted (PP) was characterized by a stable dingo population, scarcity of mesopredators and generalist herbivores and high abundance of small and CWR mammals. In PP dingoes regularly traveled across the gibber plains; while in MU, rabbits (including warrens), foxes (including dens) and camels were all commonly found in the open gibber, where kowari are no longer present. A notable exception was the presence of ampurta (a CWR threatened marsupial) in MU. A previous survey of ampurta distribution in this region found no correlation between ampurta presence and that of dingoes, mesopredators or herbivores (Southgate, unpublished report, 2006). However, all of the sites surveyed controlled dingoes. Future research is needed to compare ampurta abundance between sites with and without predator control to further test our proposed pattern.

Unlike the commonly accepted notion that poison–baiting benefits biodiversity (Reddiex & Forsyth, 2006), we found that where poison–baiting was applied (MU) the abundance of native small and medium (CWR) sized mammals were relatively low, and invasive mesopredators and herbivores were high. Although causation cannot be tested here, it is likely that the disruption of dingo populations in MU is the cause behind the increase in mesopredators and herbivores and the subsequent elimination of kowaris. Since there appears to be no barrier between PP and MU, kowari could presumably expand their range back into MU if predator control was to be relaxed in this area. We predict that if poison–baiting is to be initiated in PP, the kowari population will be reduced or lost.

Worldwide, research and conservation focus is turning towards wolves, lions, sharks and other large predators. The devastating consequences following their loss (Henke & Bryant, 1999; Borrvall & Ebenman, 2006), and the extraordinary ecological recovery that follow their reinstatement (Smith et al., 2003; Ripple & Beschta, 2003), is a pattern emerging globally. In Australia, where the vast majority of wilderness areas are subjected to wildlife control, threatened species may point out the rare places where dingo populations are relatively stable and ecologically functional.

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