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More buck for less bang: Reconciling competing wildlife management interests in agricultural food webs

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ABSTRACT

Mammalian top-predators can have positive, negative and negligible effects on economic, environmental and social values, which vary spatially and temporally. Harnessing 'pros' while mitigating 'cons' of top-predators remains a key management challenge, particularly outside reserves in agro-ecosystems. In this study, long-term (1972–2008) and broad-scale (250,000 km^2) datasets were used to explore co-relationships between rainfall, kangaroo abundance, beef-cattle calf production and dingo control effort in arid Australia. Best subsets and multiple regression analyses show that calf production fluctuates independently of dingo control, and kangaroo populations comprise 13–36% (mean 26%) of the combined kangaroo–cattle herd in any given year. Kangaroo abundance was associated most strongly with bottom-up forces (rainfall) as expected, but a combination of bottom-up (rainfall) and top-down (dingo control) processes best explained variation in kangaroo abundance trends. Supplementary economic analysis indicated that ongoing kangaroo competition with cattle is far more costly to beef producers than the occasional predation of calves by dingoes. These results suggest that lethal top-predator control practices in arid Australia may not be achieving their fundamental aim (to increase livestock production) because increased competition from native herbivores freed from top-predator suppression erodes the accrued economic benefits of a reduction in livestock predation. These data suggest that retaining top-predators outside reserves in agro-ecosystems may be advantageous to livestock producers and ecosystems where and/or when top-predators exert stronger effects on livestock competitors than they do on livestock. These data also highlight how increased knowledge of species interactions can reconcile competing wildlife management interests in agricultural food webs.

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1. Introduction

The distribution of many wildlife species is declining. Reserves are set aside for wildlife conservation, yet there is growing awareness that reserves alone are unable to prevent fauna decline in many cases (Woinarski et al., 2011; Li et al., 2014; Runge et al., 2014). The area of land used for agriculture is also increasing. Conserving wildlife populations outside reserves in agricultural areas is becoming increasingly difficult as the human need for agriculture increases. Finding ways to mitigate the impacts of wildlife on agriculture while enhancing the conservation of wildlife remains a key management challenge (McLaughlin, 2011; Phalan et al., 2011; Wright et al., 2012). Some of the most seemingly incompatible interests include the conservation or maintenance of large mammalian predators in places occupied by livestock (Treves et al., 2013; Kansky et al., 2014), which are used for producing meat, wool, leather and other commodities of great value to local, national and international economies.

Mammalian top-predators are ecologically important drivers of food web structure, yet they are rare or in decline in many places, particularly outside of reserves in ecosystems dominated by agricultural land uses (Estes et al., 2011; Ripple et al., 2014). Predation of livestock by terrestrial top-predators is a common source of human–carnivore conflict worldwide (Treves and Karanth, 2003; Graham et al., 2005), and top-predators are routinely killed in many places to protect livestock and managed game from real and/or perceived predation impacts. The fundamental purpose of top-predator control in ecosystems dominated by grazing livestock is to increase livestock production. However, the direct and indirect effects of predator control on livestock production have not been well-studied in many places (for examples, see Allen and Sparkes, 2001; Berger, 2006; Hebblewhite, 2011; Allen, 2014). Predators often kill both livestock and competitors of livestock alike, suggesting that there may be merit in investigating the indirect benefits that predators may provide to livestock producers. If the negative effects of predators on livestock competitors are greater than their effects on livestock, then livestock producers might achieve greater economic returns by retaining predators rather than killing them. Harnessing 'pros' while mitigating 'cons' of top-predators remains a key management challenge (Fleming et al., 2014); but if such could be achieved, it could be a

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win–win situation for both livestock production and top-predator conservation in livestock production areas.

Livestock production is one of the primary land uses across Australia (Hamblin, 2001; Allen, 2011), which is one of the world's largest beef, wool, sheep-meat and goat-meat exporters (www.fao.org; www.mla.com.au; accessed July 2014). Much of Australia is also arid or semi-arid, where viable livestock production is made possible only through the availability of artesian and sub-artesian water sources (Fensham and Fairfax, 2008; Allen, 2011). Such a system is typified by the arid beef-cattle (Order: Artiodactyla, Family: Bovidae; *Bos taurus*, *Bos indicus* and their crosses) production zone of northern South Australia (NSA). Cattle compete for pasture with a range of herbivores present within this area, including native kangaroos (Order: Diprotodontia, Family: Macropodidae; predominantly *Macropus rufus* and *Macropus robustus*) and exotic rabbits (Order: Lagomorpha, Family: Leporidae; *Oryctolagus cuniculus*), feral camels (Order: Artiodactyla, Family: Camelidae; *Camelus dromedarius*), feral horses and donkeys (Order: Perissodactyla, Family: Equidae; *Equus caballus* and *Equus asinus*) (e.g. Coman, 1999; Edwards et al., 2010). The extent to which these species compete likely depends on a range of factors including vegetation availability, and their daily water requirements and movement patterns. The only predator of calves in NSA is dingoes (Order: Carnivora, Family: Canidae; *Canis lupus dingo* and other free-roaming wild dogs; Fleming et al., 2012a) which, at 15.7 kg mean adult bodyweight (Allen and Leung, 2014), are the largest non-human terrestrial predators in Australia.

Dingoes are widespread and common across NSA and most of the continent (Allen and West, 2013), and many areas are subjected to broad-scale lethal control (primarily poison-baiting with sodium fluoroacetate, or '1080') in attempts to increase calf production (Eldridge et al., 2002; Allen, 2012; Fleming et al., 2012b). Due to reinvasion, dingo populations usually persist in areas subjected to contemporary control efforts (Allen et al., 2013a). However, periods of spatiotemporally intensive control efforts can temporarily suppress dingo population abundances (Fleming et al., 2001; Allen et al., 2013a). Importantly, dingoes are also thought to suppress kangaroos (Caughley et al., 1980; Pople et al., 2000; Fillios et al., 2010; Letnic and Crowther, 2013), one of dingoes' primary prey in arid areas (Corbett and Newsome, 1987; Thomson, 1992; Allen and Leung, 2012). Intensive dingo control is expected to free kangaroos from dingo suppression either by reducing dingo abundance or altering their social structure or group hunting abilities in ways that alleviate kangaroo predation (Allen, 2013; Choquenot and Forsyth, 2013; Prowse et al., 2014).

In this study, broad-scale historical datasets on rainfall, kangaroo abundance, beef-cattle calf production and dingo control effort from NSA are used to explore co-relationships potentially indicative of a trophic cascade from dingo control to beef cattle producers. It is hypothesized that dingo control suppresses dingoes and/or changes their function in a way that increases kangaroo abundance, that this leads to increased competition between cattle and kangaroos freed from dingo suppression, which may then constrain beef cattle production to levels lower than what might be achievable had dingoes not been controlled and kangaroos suppressed. Data demonstrating all of these processes are not presented. Rather, whether or not the available historical datasets support this hypothesis is investigated. Manipulative experiments are required to confirm causal factors for the relationships identified here (Barbosa and Castellanos, 2005; Hone, 2007).

2. Methods

Official calf production records (1976–2008) and dingo '1080' bait supply records (1972–2009) were obtained from each of the 39 beef-producing properties in the two cattle production regions of NSA, which encompass an area of ~250,000 km^2 (Fig. 1). For management purposes, NSA is divided into the northeast (NE) and northwest (NW) pastoral regions, which are broadly separated by the usually dry Lake Eyre and Simpson Desert. Official kangaroo abundance estimates derived from standardized aerial survey techniques were also obtained (DEH, 2008), but were available only after 1995 and for a selected core area within the NW region only (Fig. 1). For this reason, all analyses using data from the NW region were constrained to the 10 properties within and immediately surrounding this core area (hereafter 'NW core'). Calf production, 1080 baiting and kangaroo density datasets were sourced from the state government departments responsible for their collection and management. Historical daily rainfall records were obtained from the Bureau of Meteorology (www.bom.gov.au; accessed September 2013). Rainfall values for each region were derived from long-term weather stations at Cowarie, Clifton Hills, Innamincka, Marree and Frome Downs in the NE, and Coober Pedy, Marla and Todmorden in the NW core. Annual rainfall was calculated for the calendar year, January to December. Detailed descriptions of NSA, along with background information on contemporary dingo, kangaroo and cattle management practices are not described here, but can be found elsewhere (Wallis, 1997; DEH, 2008; Allen, 2012; Allen et al., 2013a; Allen et al., 2014a).

2.1. Dingo control (1080 baiting) data

Information on the dingo control history of each property in NSA was taken from official 1080 poison supply records (see Allen, 2010, available as supplementary material; and also Allen, 2012 or Allen et al., 2014b). These records showed the kilograms of meat injected with or tumbled in 1080 solution, which was converted to numbers of baits by dividing each kilogram of meat by seven, because approximately seven individual baits are cut from a kilogram of meat before being laced with 1080. Conversion from 'kilograms of meat' to 'number of baits' was necessary to incorporate recent records of manufactured 1080 baits, which are supplied individually. Thus, these records identified how many poison baits were supplied to each property each year between 1972 (when baiting dingoes with 1080 began in NSA) and 2008. Interviews with approximately half of the property owners or managers in NSA and the senior government staff responsible for bait supply verified that baits supplied were typically distributed within a few weeks of supply, usually in Autumn (April–May) and/or Spring (October–November) (Allen, 2010). Although other means of lethal dingo control (e.g. opportunistic shooting) are not accounted for with this dataset, 1080 baiting has been the principal dingo control tool used in NSA since 1972, and all other approaches combined were negligible contributors to overall dingo control efforts in the study regions during the study period (Allen, 2012). Bait supply records were used as a covariate of overall dingo control effort and its impact on extant dingo populations.

2.2. Calf production data

Annual calf production records for each property were collected from a property-specific 'Stock Return' detailing, amongst other things, the number of new calves branded and the number of branded cattle remaining on the property at the end of each year. Annual cattle data included all ages and both sexes, but did not include store cattle or those bought or sold, and as such, were unsuitable for calculating calf branding rates (i.e. the number of calves per cow), which could have been used as a coarse indicator of dingo predation of calves (e.g. Eldridge et al., 2002). Record collection methods also changed slightly during the period. Annual figures from 1976–2004 equate to 1st April to 31st March (i.e. calves branded between 1st April 1988 and 31st March 1989 are entered under the 1988 year). Whereas, 2005–2008 figures equate to the fiscal year 1st July to 30th June (i.e. calves branded between 1st July 2006 and 30th June 2007 are entered under the 2006 year). Peak calving in the study area occurs over the summer (Williams, 1989; B. Allen, unpublished data), which means that these changes to the reporting periods have minimal bearing on calf production data attributed to a given year. Changes of property ownership also

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