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Original Research

Profitable and Sustainable Cattle Grazing Strategies Support Reptiles in Tropical Savanna Rangeland☆

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ABSTRACT

Rangelands are areas used primarily for grazing by domestic livestock; however, because they support native vegetation and fauna, their potential role in conservation should not be overlooked. Typically, "off-reserve" conservation in agricultural landscapes assumes a trade-off between maintaining the ecological processes that support biodiversity and successful food production and profitability. To evaluate this potential biodiversity trade-off in rangelands, we need to understand the effect of different livestock grazing strategies on biodiversity, in relation to their performance in terms of profitability and land condition. We monitored reptile community responses to four cattle-grazing strategies (heavy, moderate, and variable stocking rates and a rotational wet season spelling treatment) in a replicated, long-term grazing trial in north Queensland, Australia. Simultaneously, measures of profitability and land condition were collected for the different grazing strategies. Overall, reptile abundance was not negatively impacted by the more sustainably managed treatments (moderate, variable, and rotational) compared with heavy stocking, although the effect of grazing treatment alone was not significant. Profitability and land condition were also higher in these treatments compared with the heavy stocking rate treatment. As drought conditions worsened over the 3 yr, the negative impact of the heavy stocking treatment on both profitability and biodiversity became more pronounced. Heavy stocking negatively impacted reptiles and was also the least profitable grazing strategy over the long term, resulting in the worst land condition. This suggests that in this tropical savanna rangeland there was no trade-off between economic performance and reptile abundance and diversity. Grazing regimes with a moderate stocking rate or flexible management strategies were better able to buffer the effects of climate variability. The consequence was a more resilient reptile community and better economic outcomes in dry years.

Introduction

Livestock grazing is the most widespread land use in the world, covering 25% of the global land surface (Asner et al., 2004). Most livestock grazing takes place on rangelands, generally defined as open landscapes with naturally occurring forage plants suitable for livestock, and millions of people in both the developed and developing world are dependent upon them economically and socially. In northern Australia, livestock grazing is the dominant land use across the 1.5 million km^2 of tropical savannas and many people depend upon this industry for their livelihood (Crowley, 2015). To ensure a sustainable grazing industry, we need to identify grazing strategies that minimize negative impacts on land condition and biodiversity.

Globally, the impact of livestock grazing on biodiversity is mixed. It can be either positive or negative and depends upon the evolutionary history of the system, its productivity, and the intensity of grazing disturbance (Milchunas et al., 1988; Cingolani et al., 2005). In Australia, grazing by domestic livestock is generally viewed as being negative for biodiversity (Eldridge et al., 2016) and is, in some cases, extremely detrimental (James et al., 1999). Under inappropriate management, particularly when coupled with drought, livestock grazing can lead to the loss of deeper-rooted perennial grasses and reduce ground cover and soil health, leading to increased runoff and reduced ecosystem services (Facelli and Springbett, 2009; McKeon et al., 2009; Eldridge et al., 2011). Subsequently, these changes to vegetation structure can affect the fauna using them as habitat. However, when managed appropriately, rangelands can be maintained in good condition (O'Reagain and Bushell, 2011). Ecological processes on rangelands are often relatively

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"intact" compared with those in more intensive agricultural areas, particularly when trees are not cleared and exotic pasture species are not introduced (McIntyre and Hobbs, 1999). Indeed, the extensive rangelands of northern Australia are largely dominated by native grasses, despite the ingress of exotic grasses like Buffel grass *(Cenchrus ciliaris)* and Indian Couch *(Bothriochloa pertusa)* in some areas. The relatively intact nature of these rangelands suggests that if managed appropriately, they can be used for food production and make a valuable contribution toward achieving landscape-scale conservation objectives (Neilly et al., 2016).

While nature reserves undoubtedly serve a critical role in conservation, they are inadequate on their own to conserve biodiversity into the future (Margules and Pressey, 2000). This is, in part, due to the social and economic limitations on their total area and subsequent management. Therefore, the importance of well-managed rangelands as complementary "off-reserve" conservation areas cannot be overlooked. Furthermore, due to the vast areas covered by rangelands, small management changes could have significant implications for conservation (Niamir-Fuller et al., 2012).

For "off-reserve" conservation to be a success, rangelands need to serve a dual purpose: economically viable animal production for the grazier and, simultaneously, maintenance of the ecological processes that support biodiversity. We need to understand the response of biodiversity to grazing and integrate this knowledge with an understanding of economic and social outcomes. Essentially, we must determine the relative trade-off between conservation and production objectives. In an industry that is facing severe financial challenges, with many operations struggling to remain viable (McLean et al., 2014), integrated information on biodiversity and profitability outcomes is needed to convince land managers to adopt wildlife-friendly practices and inform relevant incentive schemes. Unfortunately, there has been a limited capacity to accurately link measures of economic performance with measures of biodiversity, as a multidisciplinary approach to data collection is rare.

The basic principles of sustainable grazing management are relatively well known (i.e., stock around the long-term carrying capacity of the landscape, adjust stocking rates according to pasture (forage) availability, and regularly spell, or rest, paddocks to allow recovery from grazing (O'Reagain et al., 2014). In northern Australia, these kinds of conservative and flexible grazing strategies achieve the best land condition by maintaining healthy soil and vegetation communities, and they are also most profitable in the long term (O'Reagain and Scanlan, 2012). Therefore, it is reasonable to hypothesize that grazing strategies that maintain land in better condition and are most economically sustainable are also likely to have better biodiversity outcomes for both flora and fauna (Curry and Hacker, 1990).

We are, however, unable to directly compare animal production and biodiversity data unless we have studies designed to do so (Neilly et al., 2016). Rangeland scientists typically utilize grazing trials to assess animal production and land condition under different grazing treatments, and they usually focus data collection on important pasture species or soil characteristics (O'Reagain et al., 2011; Orr and O'Reagain, 2011). Conversely, ecologists often conduct biodiversity surveys in existing grazed environments, where floral or faunal communities in areas of different grazing intensity are compared (e.g., Landsberg et al., 2003; Dorrough et al., 2012). While biodiversity has sometimes been studied within experimental grazing trials (Kutt et al., 2012; Bylo et al., 2014; Villar et al., 2014), the opportunity to combine these data with simultaneously collected economic or land condition data has not been realized. Furthermore, few large-scale grazing trials are conducted over time periods long enough to adequately measure long-term profitability or to capture changes in land condition or biodiversity, particularly in areas with marked climatic variability.

In this study, we examined the effect of four cattle grazing regimes on profitability, land condition, and reptile abundance and species richness over 3 yr, on an existing long-term (19-year) grazing trial in an Australian tropical savanna rangeland. The specific aim of the trial is to assess the performance of different grazing strategies in relation to animal production, economic performance, and resource condition (O'Reagain et al., 2011). We selected reptiles as a biodiversity measure to assess grazing impacts due to their diversity in this location, the fact that their scale of movements are conducive to this grazing trial, and the responsiveness of reptiles to land-use type, compared with more vagile groups, such as mammals or birds (Woinarski and Ash, 2002). We predicted that overall reptile abundance and richness would be higher where profitability was higher and land condition was better. That is, we predicted there would not be a trade-off between biodiversity and profitability among the four grazing treatments, but instead that low profitability and poor biodiversity outcomes would coincide. Additionally, we predicted that season and vegetation type would strongly influence patterns of reptile abundance and richness.

Materials and Methods

Site Description

The grazing trial was established by the Queensland Department of Agriculture and Fisheries in 1997 at "Wambiana," a commercial cattle station (20°34′S, 146°07′E), 70 km south of Charters Towers, Queensland, in northeastern Australia. The property had been grazed by cattle, at relatively moderate stocking rates, since at least the 1870s. The study area was located on relatively flat, low-fertility, tertiary sediments within the greater Burdekin River catchment. The region has a distinct summer wet season and winter dry season. Average annual rainfall is 643 mm but is highly variable (historical range 207 − 1 409 mm) and includes regular droughts.

The 1 041-ha experimental site consists of 10 paddocks ranging from 93 − 115 ha in size, with five grazing treatments each replicated twice. Treatments were selected to reflect either typical or recommended management practices in northern Australian rangelands: 1) heavy stocking rate (H)—4 − 6 ha · Adult Equivalent-1 (AE, defined as 450-kg steer); 2) moderate stocking rate (M)—8 − 10 ha · AE-1; 3) variable stocking rate (V)—stocking rates adjusted annually on the basis of the end of wet season feed availability, range 3 − 12 ha · AE-1; 4) rotational wet season spelling (R)—a third of the paddock spelled each wet season 7 − 10 ha · AE-1 and; 5) Southern Oscillation Index strategy—stocking rates adjusted annually in November based on feed availability and the Southern Oscillation Index forecasts for the next wet season 3 − 12 ha · AE-1 (see O'Reagain et al., 2011 for detailed treatment descriptions). The effects of only the first four grazing regimes were quantified in this study. Following recommended practice, the entire site was burned in October 1999 and October 2011 to suppress woody growth.

The vegetation consists of open Eucalypt and Acacia savanna woodland underlain by C4 tropical grasses. The dominant vegetation communities are 1) Reid River Box *(Eucalyptus brownii)* on texture-contrast soils (sodosols; soil nomenclature follows Isbell and National Committee on Soil and Terrain, 1996), with a ground layer of *Bothriochloa ewartiana, Dichanthium fecundum, Chrysopogon fallax,* and various local *Aristida* species; 2) Silver Leaf Ironbark *(Eucalyptus melanophloia)* on yellow-brown earths (kandosols) with a ground vegetation of less palatable grass species *Eriachne mucronata* and *Aristida* species but also some areas of *C. fallax* and *Heteropogon contortus;* and 3) a small area of Brigalow *(Acacia harpophylla)* woodland on heavy clays (vertosols and gray earths). In the *E. brownii* and *A. harpophylla* vegetation types there is an irregular understory of currant bush *(Carissa ovata)*. All paddocks have similar proportions of the main soil types and vegetation communities.

Cattle Management

Experimental animals were Brahman-cross steers between 18 and 30 mo old, managed according to standard industry practice (O'Reagain et al., 2009). Profitability was calculated as the annual