Feral fuchsia eating: long-term decline of a palatable shrub in grazed rangelands

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Abstract

Long-lived palatable shrubs and trees in rangelands are particularly vulnerable to grazing impacts, with local extinctions and declines documented for numerous species. However, population trends can be difficult to detect due to longevity of individuals and poor understanding of regeneration patterns. We investigated the demography and conservation status of the Grey Range fuchsia (*Eremophila stenophylla* Chinnock), a geographically restricted and palatable shrub endemic to south-west Queensland. We documented 28 populations over 30,400 km^2, with an estimated total population size of 17,000 genetically distinct individuals. Populations tend to be geographically disjunct, and twelve populations contain <100 individuals. Seedling recruitment is rare and seedlings were only observed at six populations, all with low or intermittent grazing pressure. In contrast, vegetative recruits were recorded at 19 populations and comprised at least 28% of all plants measured. Resprouting ability confers some resilience to individuals, although repeated browsing restricts plant growth, limiting flowering and fruiting. Consistently heavily grazed populations also contain fewer plants. Goats and sheep are strongly associated with sites of high grazing pressure. Although *Eremophila stenophylla* is secure in numerous populations with low and intermittent grazing pressure, it qualifies as Vulnerable under IUCN criteria due to past and ongoing decline at more than half of the known populations. Grazing relief is necessary to ensure the long-term persistence of these populations. We predict that the same trajectory applies to numerous other semi-arid shrubs, and further research is required to elucidate the nature and extent of the problem and implement grazing management to avert local extinctions.

Keywords: Australia, browsing impacts, extinction, resprouting, threatened species, recruitment dynamics

1. Introduction

While emerging evidence suggests that arid zone ecosystems are more resilient to the effects of introduced herbivores than previously supposed (Oba et al. 2000, Batanouny 2001, Fensham et al. 2010, Bestelmeyer et al. 2013, Fensham et al. 2014), long-lived palatable perennial species are known to be especially vulnerable (Chesterfield and Parsons 1985, Hunt 2001, Nano et al. 2012, Auld et al. 2015). The adaptations of annual species and geophytes to unpredictable rainfall confer resilience to grazing, as they grow and set seed before grazing has severe impacts on populations (Sullivan and Rohde 2002, Silcock and Fensham 2013). Some perennial species have adaptations that deter grazing, such as chemical compounds rendering plants toxic or unpalatable (Robbins et al. 1987, Rebollo et al. 2002) or mechanical defences such as tough foliage or sharp spines at least when plants are young (Lucas et al. 2000, Burns 2014).

It is the long-lived, palatable species without such defences that are considered most vulnerable to sustained grazing pressure. Such plants are likely to be prevalent in ecosystems with low evolutionary grazing pressure like Australia (Fensham and Fairfax 2008). Grazing impacts and lack of regeneration have been documented for some of these species, mostly in southern Australian rangelands (Tiver and Andrew 1997, Watson et al. 1997b, Parsons 2000, Hunt 2001, Read 2004, Auld et al. 2015). The slow attrition and eventual loss of these keystone species would have severe and ecosystem-wide structural, functional and biodiversity implications (Denham and Auld 2004).

However, while the extinctions and ongoing declines of medium-sized mammals in the Australian arid zone are well recognised (McKenzie et al. 2007, Woinarski et al. 2015), the decline of long-lived elements of the flora are harder to detect. Suspected declines are masked by the longevity of individuals, meaning that they are persisting after 150 years of grazing, and any declines or extinctions may take centuries to play out. There is also a lack of data on the nature and extent of the problem. Recruitment dynamics for most species remain poorly understood, particularly in terms of disentangling the effects of climate and grazing regime (Crisp 1978, Gardiner 1986, Watson et al. 1997a). Numerous species are capable of both sexual and clonal reproduction and the relative importance and frequency of these reproductive modes, and how they are affected by grazing, are poorly-studied (O'Brien et al. 2014, Roberts et al. 2017). Are we witnessing slow but relentless extinction events across Australia's rangelands, or simply natural cycles that operate at temporal scales beyond our short observation span?

This study examines the demography and conservation status of a highly palatable, geographically restricted shrub, Grey Range fuchsia *Eremophila stenophylla* Chinnock (Chinnock 2007), in semi-arid south-western Queensland. The species is currently listed as Vulnerable in Queensland under the Nature Conservation Act 1992 and classified nationally as ROTAP 3K, with a geographic range of more than 100 km but occurring in small populations, poorly-known and suspected of being at risk of extinction (Briggs and Leigh 1996). We assess the stand structure of all known populations under a range of grazing management, and shed light on broader issues relating to the persistence of palatable perennials in grazed landscapes.

2. Materials and methods

2.1 Study area

Eremophila stenophylla is endemic to south-western Queensland. The Grey Range, together with smaller offshoot ranges, is the major topographic feature of the region. Comprised of Tertiary sandstone, the elevation falls from 450 m above sea level on tablelands in the north-east to just over 200 m in the south, drained by the Bulloo and Barcoo Rivers. Feral goats (*Capra hircus*) are patchily common and high numbers of native euros (*Macropus robustus*) occur throughout the area, with domestic cattle (*Bos taurus* and *B. indicus*) and sheep (*Ovies aries*) and native red (*M. rufus*) and grey kangaroos (*M. giganteus*) mostly restricted to the lower slopes and valleys.

The climate is semi-arid with average annual rainfall decreasing from 485 mm in the north-east to 300 mm in the south-west of the species' range. Most rain falls from December to March. Summer temperatures are hot, with maximums throughout December-February averaging 35°C and regularly exceeding 40°C, while short winters are characterised by cold nights often falling below zero and warm days. The study was preceded by exceptional rainfall in 2010 and 2011, during which much of the study area received more than double its average annual rainfall, followed by predominantly below-average rainfall totals from 2012-2016 (Bureau of Meteorology records, accessed September 2017). In the three months prior to survey, the southern sites received between 29-34 mm, central sites 31 mm and northern sites all <19 mm.

2.2 Field surveys and site measurements

Eremophila stenophylla was searched for throughout its range during rare and threatened plant surveys in western Queensland between 2009 and 2014 (Silcock et al. 2014). All populations were marked with a GPS, habitat described, population estimates made and browsing impacts noted. Areas of apparently suitable habitat where the species was absent were also marked.

In August 2017, we measured the stand structure and browsing impacts at all known populations excepting two: one with only two mature individuals found, and one with <100 individuals on the Blackall-Emmet road disturbed by contemporary road works. Transects were of variable length and width depending on density of plants, such that at least 30 plants were measured (except where total population size was <30, in which case all plants were measured). Sites were placed in areas representative of the density, stand structure and level of browsing of the population. Transects ranged in size from 0.04 to 8.76 ha.

The diameter (0.5 cm thence nearest 1 cm) of all living stems was measured at 0.3 m above the ground. Stems <0.5 cm diameter were assigned as either seedlings or vegetative re-sprouts. Each plant was assigned a browse category: 0 = unbrowsed, 1 = some stems browsed, or browsed in past (noted if historic browsing), 2 = all stems browsed to browse height, and often torn down to within reach. Presence of flowers and number of fruits were also recorded for each plant. We use the term ‘browsing’ to refer to herbivore impacts on *Eremophila stenophylla*, and grazing as a more general term when considering site-level pressure.

An index of recent grazing history was determined at each site using counts of herbivore dung in 50 x 2 m belt transects (Fensham et al. 2010), with dung not present on the transect but occurring within the site noted. Pellets of goats, sheep, cattle and rabbits were readily distinguishable in the field along with macropods (primarily the euro *Macropus robustus*, red kangaroo *M. rufus*, and eastern grey kangaroo *M. giganteus*). Dung was split into ‘old’ (still intact but dry and bleached) and ‘fresh’ (black) classes. Dung was considered ‘fresh’ if black or ‘old’ if dry and bleached but still intact. The presence of animal pads running through the site was also noted. Recent total grazing pressure at each site were grouped based on dung counts and pads into high, medium and low. Each site was also assigned a dominant historical grazing regime (consistently low, moderate, high or intermittent), informed through tenure, management information where available, and presence of deep animal pads that had clearly been used for numerous years.

Distance to water was measured using GPS points taken of the nearest water (where seen during field work) or by examination of Geoscience Australia data verified by Google Earth, and with reference to the mapping of Silcock (2009). Permanent and semi-permanent (defined as containing water for approximately >70% of the time) waters were included, encompassing bores, large dams and earth tanks (>30 m across), natural springs and waterholes.

2.3 Data analysis

Preliminary explorations revealed no consistent relationship between habitat and population size, or between habitat and demography. The proportion of fertile individuals across the sampling was ascertained for each size class. No data were normally distributed, even after log transformation, so non-parametric Wilcoxon tests were used to explore dung density of each main herbivore species, population size, and average number of plants per size class between grazing regimes. Influence of recent browsing on individual plants was explored using the proportion of individuals within each size class by browsing category (zero, some, all stems) across recent grazing history (low, medium or high). All analyses were performed using the R package (R Development Core Team 2015). Nomenclature follows Bostock and Holland (2007).

3. Results

3.1 Population survey

Eremophila stenophylla occurs patchily in a narrow band of south-west Queensland, with an extent of occurrence of 30 400 km^2 and estimated area of occupancy of 500 km^2. It occurs in four restricted areas: around the northern footslopes of the Grey and Gown Ranges south of Isisford (9 populations documented); on the footslopes and narrow bands of open grassland between the Grey and Cheviot Ranges south-west of Yaraka (15 populations); in a handful of small populations on the western footslopes of the Grey Range some 100 km to the south; and in two isolated southern populations in Walters Range west of Eulo (Figure 1). Extensive searches were conducted between these known populations and outside its known range, thus these seem to be true disjunctions. Records to the south-west of known populations previously identified as *Eremophila stenophylla* in the Queensland Herbarium were visited and determined to be the closely-related but distinct *Eremophila dalyana* (Chinnock 2007).

The species occupies three distinct habitats within its restricted range: rocky clay footslopes of Tertiary sandstone ranges (occasionally occurring to the upper slopes, where suitable clay soil habitat exists), low open gidgee (*Acacia cambagei*) woodlands on often rocky clay soil, and lightly wooded clay soil downs in broad valleys between ranges with scattered boree (*Acacia tephrina*) and/or gidgee. The far southern population is distinct in occurring on top of a low sandstone ridge, although also in open gidgee woodland. In the footslope habitat, abundance ranges from occasional to locally dominant over small areas (<10 ha), while in the other habitats the species typically occurs as isolated plants or in groups of <100 plants with occasional clusters of thousands of young plants. The 28 known populations range in size from two plants to >3000 (average estimated population size 400 plants), comprising nearly 11,000 plants in total. Our results show that at least 28% of all plants measured are resprouting from adult plants, thus the number of genetic individuals is likely to be closer to 8,500. Based on habitat mapping and search effort, we estimate that around 50% of suitable habitat has been surveyed, thus total population size is estimated at 17,000 plants.

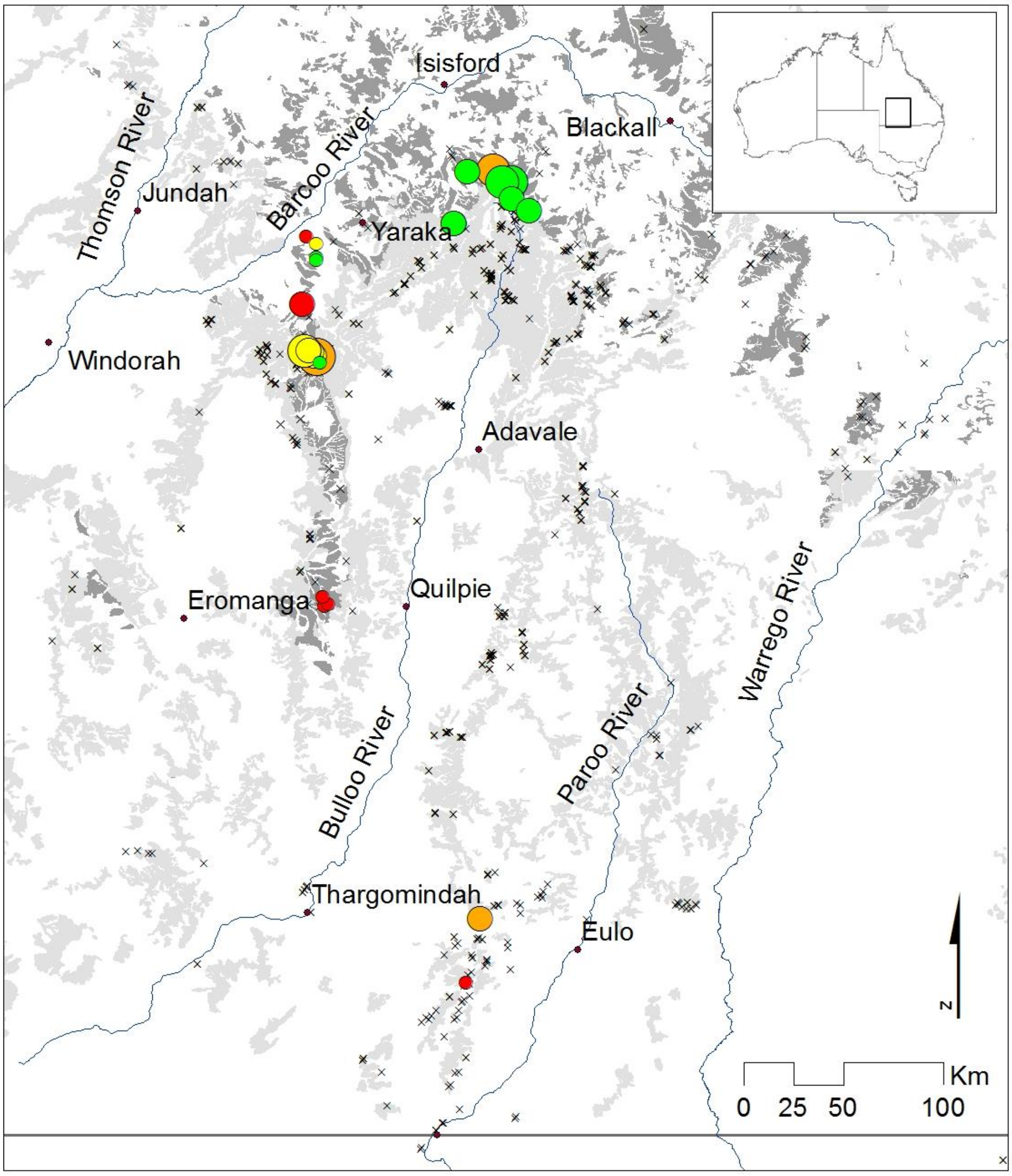

Figure 1. *Eremophila stenophylla* distribution, south-west Queensland. Tertiary sandstone range habitat is shaded light-grey, and lightly wooded downs shaded dark-grey. Sites with consistently high grazing pressure marked with a red circle; yellow, consistently moderate; green, consistently light; orange, intermittent grazing pressure. Population size indicated by size of circles: smallest circles <100 plants, medium 100-1000, large >1000. Sites of targeted search effort where the species was not found are marked with black crosses.

3.2 Plant traits and demographics

In total, 1084 plants were measured across 26 sites. Plants have a multi-stemmed habit when young even in the absence of browsing, such that four or five living stems are typical of a plant whose largest stem diameter is 4-5 cm. Excluding plants <30 cm tall, the average number of stems per individual was five and the highest 22 stems. Older plants tend to have fewer stems, apparently because some stems twine around each other and grow together as the plant ages. In other cases, some stems appear to die leaving only one or two main stems (Figure 2a). Old stems can die (sometimes due to browsing, other times apparently from drought) and new ones can resprout from the base, conferring some resilience to stem death. Excluding plants <30 cm high, 20% of plants had a mixture of live and dead stems, but only 19 dead plants were recorded across all sites; 11 of these were small plants (largest stem <2 cm diameter) that had been recently killed by heavy browsing. Plants can also resprout after anthropogenic disturbance including land clearing and mechanical disturbance, as evidenced at two sites.

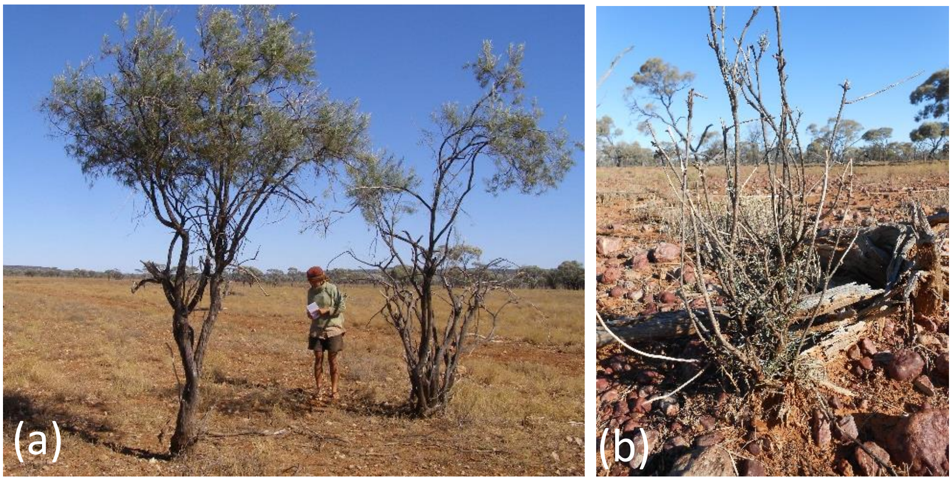

Figure 2. *Eremophila stenophylla*, showing (a) old plants (largest stem diameter >6 cm) in open downs habitat that have been browsed to herbivore height (in this case cattle); one or two stems have escaped browsing pressure while the ones within reach continue being defoliated and resprouting, and (b) a very woody plant about 1 m tall, that has resprouted repeatedly after

browsing, and is typical of plants with largest stem 1 cm diameter at moderately and heavily grazed sites.

Seedlings were difficult to separate from vegetative resprouts, but attributed to 31 individuals throughout six sites. Seedling recruitment is apparently a rare event but vegetative recruitment occurs readily. Almost one-quarter of total individuals recorded were <30 cm high resprouts, while an additional 6% >30 cm high (diameter of largest stem 0.5-2 cm) were also clearly resprouting from adult plants. Plants with a largest stem diameter of ≥3 cm accounted for just 22% of plants measured, and those ≥6 cm 10%. Only 33 very large adults (largest stem >10 cm diameter) were measured and these occurred across 11 sites. The largest stems recorded were 14-17 cm diameter, although there was an extreme outlier of 29 cm growing on the upper slopes of Mt Grey south of Isisford.

Flowering was observed at 18/26 populations (118 plants) and fruiting on 4/1084 plants at two populations. The most fruits seen on any plant was five. Flowering and fruiting were not related to recent grazing pressure, but appeared related to recent rainfall as most plants in southern populations were flowering and few flowers were observed at north-eastern populations. Presence of flowers was strongly related to diameter of the largest stem, with proportion of plants flowering increasing from 20% of plants at 2 cm diameter to 45% at 5 cm, where it remained consistent as plants grew (Figure 3). Negligible flowering was observed in plants with stem diameters <1 cm.

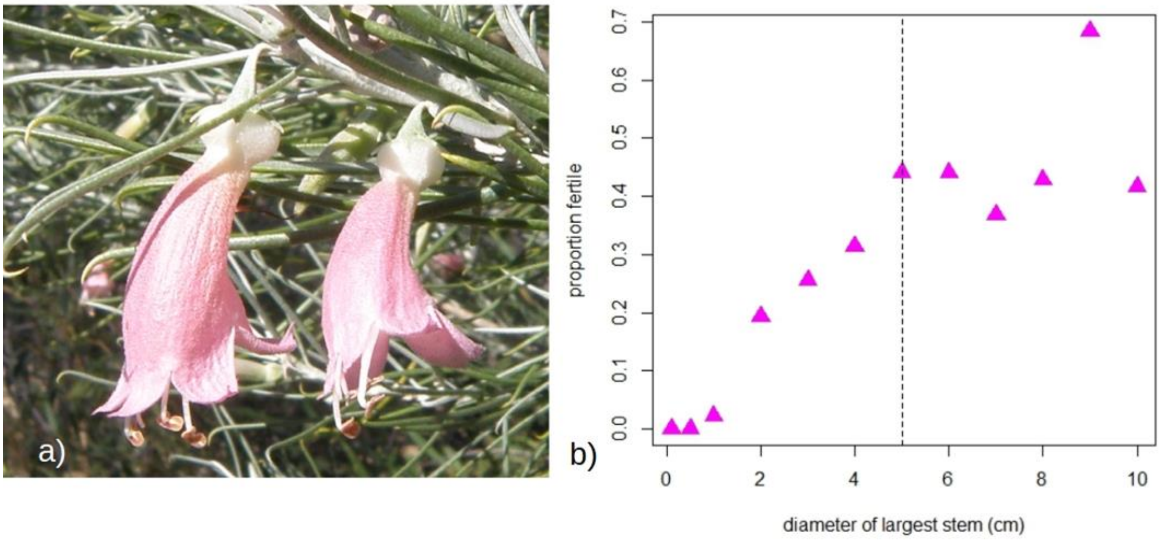

Figure 3. (a) Flowers of *Eremophila stenophylla*, and (b) proportion of sampled population fertile in August 2017 by stem size.

3.3 Browsing impacts

All populations occur within 3 km of semi-permanent or permanent water and almost 40% are within 1 km, reflecting the productive and heavily-utilised nature of the habitat by domestic, feral and native herbivores. There was no correlation between distance to water and dung counts (recent, old and combined), either in total or for individual herbivore species. Macropods were the most abundant herbivore and present at all sites, in significantly higher densities at medium and high compared to low grazing sites (Table 1). Cattle were present at 19 sites, goats at nine, sheep at four, and rabbits at two. Eleven sites had significantly lower recent grazing pressure, which was largely driven by an absence of sheep and goats and relatively low macropod and cattle abundance (Table 1). Ten sites had medium recent grazing pressure, generally comprised of cattle and macropods. Sheep and goats were restricted to sites of high recent grazing pressure, which typically also had cattle present at low densities (Table 1). Of the six sites with high recent grazing pressure, goats and/or sheep were the main herbivores at four, and cattle and macropods at two. Recent grazing pressure was generally similar to historic grazing pressure, except in three cases where grazing pressure based on dung counts and pads had been high in the past (due to goats at two sites and cattle at one), but was low (no recent evidence of grazing) at one site and medium at two at the time of sampling.

Table 1. Dung counts, proportion of size classes and total population sizes by grazing regime (consistently high, medium and low; three intermittently-grazed sites are not shown here). Stem diameters >5 cm are uncommon and are not shown here. Significant differences between grazing regimes are shown by superscripts.

	Low(n=9)	**Medium (n=8)**	**High (n= 6)**
Average dung counts (old and fresh)			
Cattle	1^{A}	2^{A}	2^{A}
Goats	0.1^{A}	1^{A}	68^{B}
Sheep	0^{A}	0.1^{A}	112^{B}
Macropods	34^{A}	190^{B}	195^{B}
Plant sizes (largest stem diameter)			
Average seedlings (% population)	3^{A}	0^{A}	0^{A}
Average resprouts (% population)	10^{A}	41^{A}	16^{A}
Average <1cm (% population)	28^{A}	23^{A}	23^{A}
Average 1-2 cm (% population)	33^{A}	15^{A}	32^{A}
Average 3-5cm (% population)	17^{A}	4^{B}	20^{A}
Average resprouts (number in population)	42^{A}	89^{A}	6^{A}
Average <1cm (number in population)	112^{A}	24^{B}	19^{B}
Average 1-2 cm (number in population)	177^{A}	116^{AB}	19^{B}
Average 3-5cm (number in population)	67^{A}	42^{A}	15^{A}
Average population size	420^{B}	285^{B}	65^{AB}

The influence of browsing on *Eremophila stenophylla* can be seen in Figure 4, showing an increasing proportion of affected individuals according to recent medium and high grazing pressure. Under high grazing pressure, 86% of plants measured were heavily browsed (browsing category 2), with resprouts and small plants (largest stem diameter <2 cm) particularly susceptible (Figure 2b). The foliage of larger plants tended to have grown beyond the reach of herbivores (Figure 2a), and these were assigned browsing category 1 for evidence of historic browsing. No plants in high grazing sites were ungrazed. Under medium grazing pressure, two-thirds of plants were heavily browsed, and a further 20% browsed to some degree (category 1). Smaller plants were also more likely to be heavily browsed under medium grazing pressure, with over 80% of resprouts and nearly 50% of plants with the largest stem diameter <1 cm assigned browsing category 2 (Figure 2b). Conversely, larger plants were more likely to have been moderately browsed (category 1) at sites with low recent grazing pressure, mostly due to historic browsing of stems, but overall 85% of plants at low grazing sites remained unbrowsed (Figure 4).

Over half of the 31 seedlings recorded occurred at a single site where past heavy grazing pressure had ceased (Mt Grey); most of the remainder occurred at two low grazing pressure sites on Idalia National Park. No seedlings were recorded at heavily grazed sites, and only a single seedling at consistently moderately-grazed sites (Figure 4).

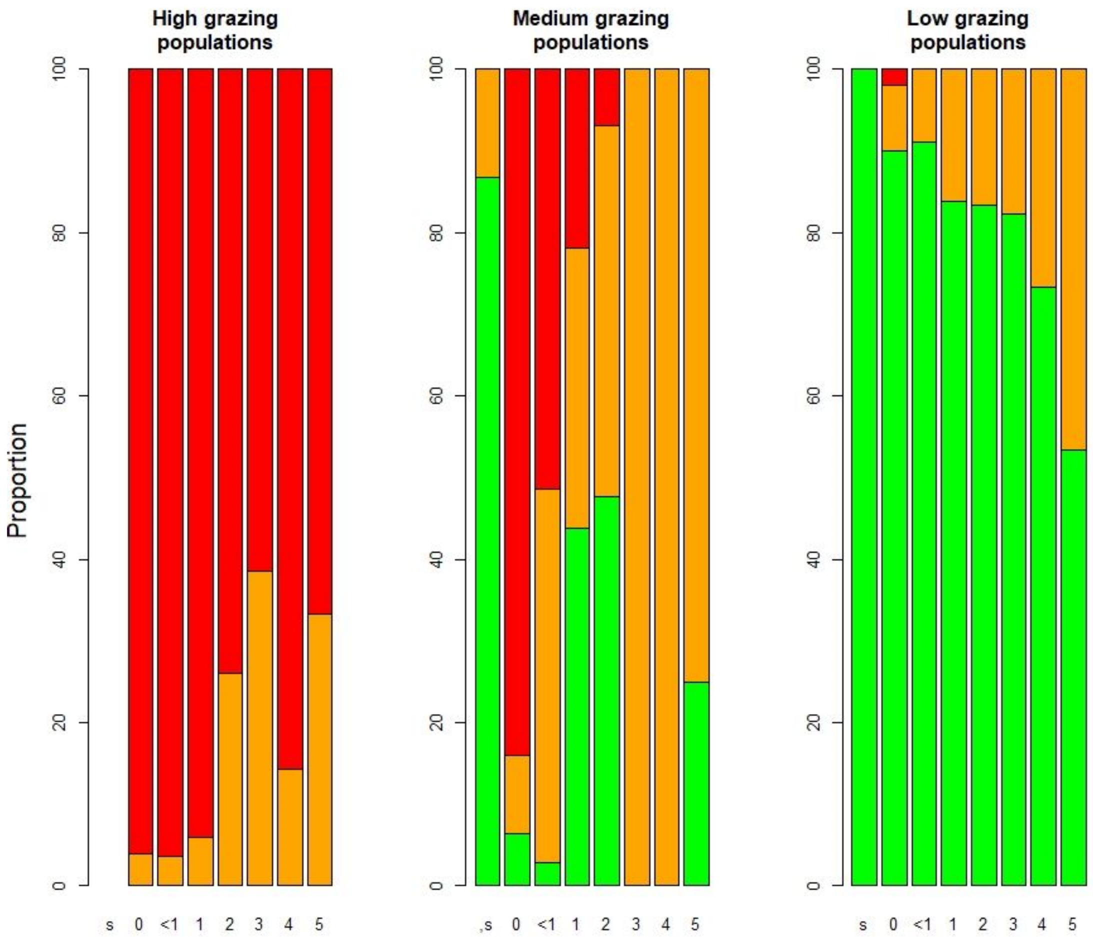

Figure 4. Proportion of stems browsed by size class between recent grazing regimes. Size classes: s=seedlings (none in high recent grazing), 0 = basal resprouts; <1-5 cm – diameter of thickest stem. Only stems up to 5 cm are shown. Red bars = all stems browsed (browsing category 2; see Methods), orange = some stems browsed or historic browsing (browsing category 1), and green = no browsing of plant evident (browsing category 0).

The effect of browsing translates to smaller proportions of smaller plants at the population scale, as well as smaller population sizes (Figure 5). Average population size was significantly lower in consistently heavily grazed sites compared to sites with low and moderate grazing pressure (Table 1). Consistently heavily grazed populations have an average population size of 65 plants, compared to 285 plants for consistent medium grazing pressure populations and 425 for consistently low grazing pressure populations. At the time of survey, around 4% of plants occur with high levels of grazing, 21% with moderate and 34% low. The three intermittently grazed populations together comprise 40% of the total known population. Populations with consistently low grazing pressure have higher numbers of plants with the largest stem diameter ≤1 cm (comprised of resprouts and seedlings), while consistently heavily grazed populations have relatively few small plants, and these are all heavily browsed (Figures 4 and 5).

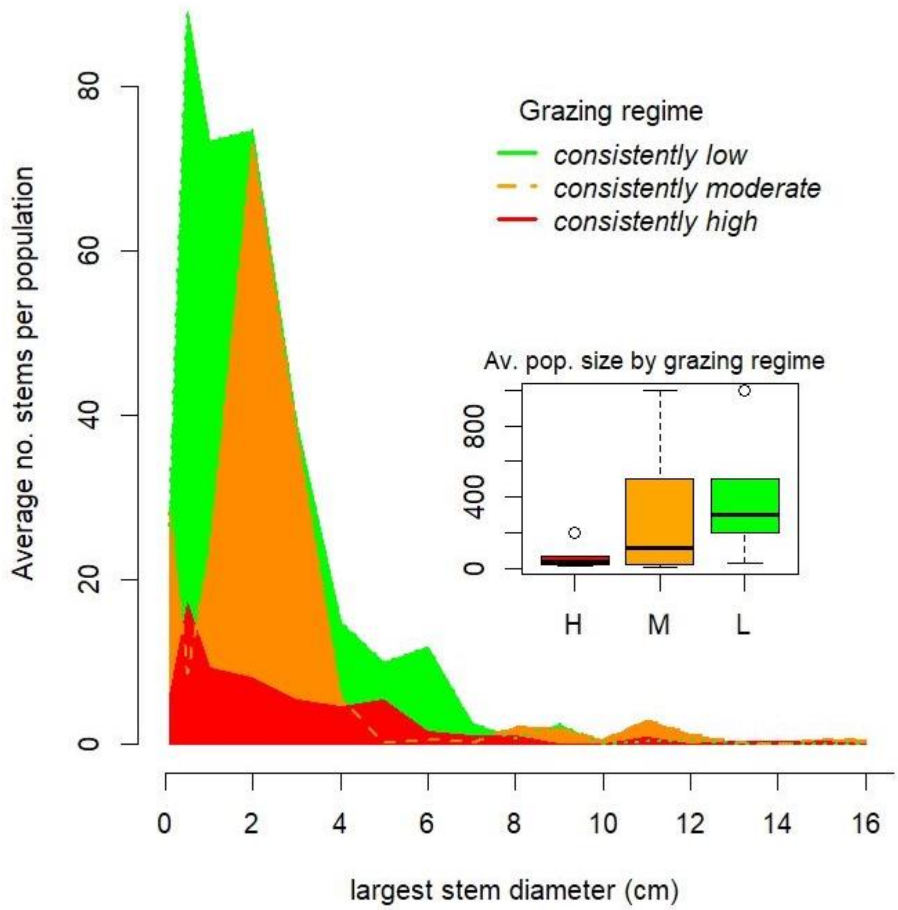

Figure 5. Average demographics and size of *Eremophila stenophylla* populations by grazing regime, showing average number of stems per diameter in each grazing regime. Intermittent grazing regimes were assigned to three populations, and are not included here.

4. Discussion

Our results show that heavy browsing has a negative impact on the Grey Range fuchsia. While re-sprouting may be promoted by browsing, any stem within herbivore reach is susceptible (Figure 4) and recruitment is hindered at least in part by preventing stems attaining a size capable of flowering (Figure 3). Despite this relatively short-term impact, populations in sites of high and medium grazing pressure are characterised by a greater proportion of larger plants and are significantly smaller than those under lower long-term grazing pressure. Unlike many studies of shrubs in Australian rangelands (Hall et al. 1964, Crisp 1978, Lange and Graham 1983, Denham and Auld 2004), rabbits are not suppressing recruitment, and were only present at two sites at low densities. While macropods occur at all sites and are often abundant, they do not seem to browse the species heavily, probably due to their general preference for grass and herbage (Dawson and Ellis 1994, Allen 2001). Sheep, cattle and especially goats graze the Grey Range fuchsia heavily. Similar impacts of sheep and goats on recruitment and growth of trees and shrubs are documented in rangelands of southern Australia (Lange and Purdie 1976, Harrington 1979, Tiver and Andrew 1997), but relatively few studies have shown negative effects of cattle on shrub recruitment and growth (Munro et al. 2009).

Eremophila stenophylla is capable of both sexual and vegetative reproduction, although the former appears to be rare. Fruits were observed on just four plants in two populations at the time of sampling, and 31 seedlings recorded across six populations. Natural attrition is common in arid zone seedlings (Lange and Graham 1983, Auld 1995a, Read 1995, Denham and Auld 2004, Tiver and Kiermeier 2006), although browsing has been shown to kill seedlings of some species (Auld 1995b). Seedling recruitment was only observed at populations with low recent grazing pressure, with the exception of one consistently moderately grazed site with a single seedling present. This is despite recent wet years, during which much of the study area received more than double its average annual rainfall in 2010 and well above-average totals for 2011 (Bureau of Meteorology records, accessed September 2017).

Vegetative recruits were recorded at 19/26 populations, and comprised at least 28% of all plants measured. This pattern of predominantly vegetative recruitment with occasional seedling recruitment has been documented for other arid zone shrubs (Auld 1995a, Denham and Auld 2004), and may be a strategy for reproducing under resource-limited conditions (O'Brien et al. 2014). In this case, it is probably partly due to the complex physical and chemical dormancy mechanisms common in the *Eremophila* genus (Richmond and Chinnock 1994). However, vegetative recruits were particularly susceptible to grazing, with 68% heavily grazed and 91% grazed to some extent across all populations (Figure 4). Only vegetative recruits in sites with consistently low grazing pressure were unbrowsed.

The prevalence of vegetative reproduction and the resprouting ability of the species confers substantial resilience to browsing at an individual plant level. Of the 486 plants that were experiencing heavy browsing pressure (category 2), only 11 had died, and plants can resprout under consistent browsing pressure for at least a decade (J. Silcock, pers. obs.). Most plants <30 cm tall were extremely woody at their bases indicating substantial age. When there is browsing relief (e.g. during periods of destocking, or when stock disperse or have an abundance of alternative food sources after rain), browsed stems shoot up and, if sufficient growth occurs, a single stem can exceed the reach of herbivores and become fecund. Such browsing-relief periods are critical to the long-term persistence of populations. There are also chance events such as fallen trees or seedlings germinating amidst unpalatable or spiny shrubs that can result in enough plants in a population escaping browsing pressure and becoming reproductive to ensure the long-term survival of the population, albeit as rare individuals. The ability to remain alive during, and resprout following, repeated heavy grazing is an adaptation that is well-recognised in fire-prone landscapes (Knox and Clarke 2004, Wright and Clarke 2007, Ondei et al. 2016) but has seldom been documented as a mechanism to survive herbivore browsing. Previous studies of arid-zone shrubs have shown that most repeatedly browsed vegetative resprouts die within one or two years (Auld 1993, Auld 1995b), with the notable exception of *Casuarina pauper* (Auld 1995a).

Despite this resilience at an individual plant level, the significant difference in population sizes between grazing regimes is instructive at the population scale. While browsed plants can persist for many years, if not decades, eventually they do die as evidenced from occasional dead plants observed at sites. In the absence of sufficient plants that ‘get away’, populations will be vulnerable to local extinction as older plants senesce and resprouts and seedlings are either eventually killed or remain stunted and infertile due to constant browsing pressure. The attrition of populations as grazing intensifies is reflected in the actual population sizes across these regimes (Figure 5). High stocking rates have resulted in population declines of *Eremophila* species elsewhere (Hacker 1984, Watson et al. 1997b).

Twelve of the 26 populations have all resprouts and plants within browse height heavily browsed and no seedlings. These populations are comprised of very small numbers of plants (average population size of 38 plants), suggesting they may not be viable in the long-term. There is little doubt that these populations have declined since pastoral settlement, and continue to decline. *Eremophila stenophylla* warrants its current Vulnerable listing under the Nature Conservation Act under IUCN criteria B2 (area of occupancy <2000 km^2 and severely fragmented with continuing decline projected) and A4 (projected population reduction in both the past and future where the causes of reduction have not ceased) (IUCN Standards and

Petitions Subcommittee 2017), and should be nominated for listing at federal level under the Environment Protection and Biodiversity Conservation Act.

Despite considerable resilience due to resprouting ability, the long-lived nature, palatability and disjunct occurrences in narrow patches of relatively productive habitat render *Eremophila stenophylla* especially vulnerable to declines due to overgrazing. Populations currently subject to consistent moderate and high grazing do not appear to be viable in the long-term without considerable rest periods during wet seasons to allow vegetative recruits, and seedlings where present, to escape browsing pressure. Long-term spelling at some sites will be extremely difficult to achieve, particularly where feral goats are difficult to control and where populations occur in highly productive grazing country, and we recommend that at least parts of these sites are fenced. Judicious fencing will also provide an opportunity to compare population dynamics under different grazing regimes and further inform recruitment dynamics. We predict that similar declines due to browsing are occurring for other palatable shrubs across the Australian rangelands, and further research is required to elucidate the nature and extent of the problem and implement grazing management to avert local extinctions.

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