Navigating the fiery debate: the role of scientific evidence in eliciting policy and management responses for contentious plants in northern Australia.

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Running Heading: Scientific evidence underpins invasive weed policy

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Abstract

Australia's vast tropical savannas contain outstanding biodiversity and cultural values. The region supports many industries, with broad-scale pastoralism being the most widespread. Hundreds of plant species were introduced into northern Australia to support the pastoral industry; some species have since been termed 'contentious' or 'conflict' species due to their perceived positive value for industry but negative impacts on non-pastoral values when they invaded non-pastoral landscapes. Heated political and public debate ensued about the appropriate policy and management response to these species based on people's perceptions of values being altered by invasion by these species, and conflicting views on what constituted appropriate management actions to control their use and spread. We share our insights into the role of scientific evidence in progressing this debate, by quantifying the impacts of species on environmental, socio-economic and cultural values. We reflect on the importance of science for underpinning evidence-based risk management tools, the outputs of which supported policy response by politicians and other policy decision-

makers. We also assess the gap in translation from policy to coordinated on-ground action at the national scale, and provide our insights into the contribution that science can make to bridge this gap.

Additional key words: conservation biology, conservation policy, invasive species

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Australia's tropical savannas are vast ancient landscapes containing internationally significant biodiversity and cultural values. Increasingly large areas are being invaded by non-native grass species, with consequential impacts being so substantial that they required significant policy and on-ground management response. In this paper, we share our insights into the role of scientific evidence in enacting policy guiding invasive grass management in tropical Australia.

Introduction

Australia's savanna woodlands and open forests cover the northern quarter of the mainland continent and contain internationally significant biodiversity and cultural values, the latter associated with the continuous Aboriginal culture for over 50,000 years (Roberts et al. 1993; Roberts and Jones 1994). Australia's savannas have seen significant change since European colonisation, with a strong focus on agricultural development from the late 1800's (Burrow 2014). This included major Government-supported programmes to increase agricultural productivity by importing potentially useful pasture plants into the country (Cook and Dias 2006; van Klinken et al. 2015). By the 1990's, concerns were being raised about the environmental impacts of the plant introductions. In this paper, we first provide some background on the reason for the large-scale introduction of non-native species into Australia's savannas, and share our insights into the role of environmental research, including our own, in providing evidence to alter policy and inform best-practice on-ground management of these species to protect the region's non-pastoral values. We consider this to be a timely contribution to the conservation science literature because there is currently a focus within the discipline on the gap between conservation research and policy and management responses (termed the 'research-implementation' gap; Toomey et al. 2016). We discuss success in bridging the research-implementation gap using the example of science affecting change in policy regarding risk management of introduced plants, in particular, invasive grasses. We also reflect on the current barriers limiting the implementation of effective on-ground management based on the changed policies. We focus on the introduction, use and management of *Andropogon gayanus* Kunth. (gamba grass), which arguably has the highest impact of the non-native grass species in Australia's savannas, and the species which we are most familiar with, having been a focus of our research for over two decades (Table 1).

Background: The agricultural imperative to alter Australia's tropical savanna flora

A characteristic feature of tropical savanna is the ground layer of continuous tall grasses (Gillison 1983; Hutley and Setterfield 2008). Since European colonisation, the vast area of tall grasses in northern Australia has led to the region being considered to have outstanding prospects for livestock production (Woinarski and Dawson 2002). Excellent insights into the views of Europeans since the late 1800's have been written by ecologists aiming to contextualise the consequences of plant introductions that are now apparent for the native biota (Woinarski and Dawson 2002; Cook and Dias 2006; Cook 2009). For example, Woinarski and Dawson 2002 noted that the mesic savanna area in the Northern Territory was lauded as "beautifully grassed"; the pioneer McDougall Stuart concluding "the country I have discovered … is more favourable than any other part of the continent" (McDougall Stuart 1863, cited in Woinarski and Dawson 2002). Cook (2009) outlines the range of economic and policy drivers that resulted in the strong promotion of agriculture in tropical Australia throughout the 19th and 20th Century, including the desire to substantially increase settler populations and defend the northern region.

Other characteristic features of Australia's savannas are the strongly seasonal climate and the limited areas of arable soils which limit the availability of highly palatable fodder grasses (Burrow 2014). This was recognised in the early 1900's as a significant limitation to primary production (Gramshaw and Walker 1988; Bortolussi et al. 2005) and a sustained period of planned plant introductions commenced in the 19th century through Government botanists and acclimatisation societies, followed by more intensive testing by Government agencies from the 1920s (Lonsdale 1994; Whitehead and Wilson 2000; Cook and Dias 2006). The Commonwealth Plant Introduction (CPI) scheme commenced in 1930; this marked the start of a more systematic record of plant introductions into Australia (although in their very thorough review, Cook and Dias (2006) noted that the record is an underestimate as many accessions were not recorded by the agencies that introduced them). Concurrently, there were well-resourced programmes within Australia's agricultural facilities to develop cultivars from the introduced plants that would be strongly suited to local conditions (Cook and Dias 2006; van Klinken 2015; see Box 1 Gamba grass introduction and spread). The cultivars were then trialled and promoted to agricultural producers, sometimes decades after the initial introductions of the source material (see Box 1).

Box 1: Gamba grass – its introduction and spread

Gamba grass (*Andropogon gayanus*. Kunth) is a perennial African tussock grass, growing up to 4 m tall (Fig 1a; Oram 1987). In northern Australia, widespread gamba grass is from the cultivar "Kent" (Cshures and Hannan-Jones 2008). This robust gamba grass cultivar was developed in the Northern Territory (NT) over several decades, starting at the Katherine Research Station in 1946 (Oram 1987). Kent was initially developed by crossing two varieties, one from Nigeria, and another from Africa via Brazil (Oram 1987; Grace et al.2004). During the 1960's and 1970's the establishment, growth and persistence of gamba grass in Northern Territory conditions was tested via a series of pasture trials (Grace et al. 2004). Gamba grass was officially released through the NT Herbage Plant Liaison Committee in 1978 (Oram 1987) and listed in the Register of Australian Herbage Plant Cultivars in 1986 (Grace et al. 2004). Kent gamba grass was considered to be well adapted to the adverse NT environmental conditions (Harrison 1998). It produced "green pick" throughout the dry season, and produced an "abundant amount of highly palatable, nutritious green feed" during the wet season (Harrison 1998).

The need for risk management should have been apparent from the time of release of the Kent cultivar. The information submitted for registration of the cultivar (Oram 1987) described unintended ‘‘spread downwind’’ at pastoral trial sites. Soon after, agricultural researchers noted the fire risk of gamba grass and that ‘‘the need for proper management cannot be overlooked with this species which restricts it to smaller more controlled areas’’(Andison 1990). However, the Kent cultivar was strongly promoted by the NT Government to agricultural producers, the cultivar was planted widely, as a pastoral grass and for minesite rehabilitation (Whitehead and Wilson 2000). In 1985 it was planted on several pastoral properties in the Litchfield, and Adelaide River region (~100 km south of

Darwin; Petty et al 2012) and also the Mary River region (~100 km south west of Darwin; Flores et al. 2005). By 1995 gamba grass had been documented in both Litchfield National Park (Petty et al. 2012), and also in Wildman Reserve (Barrow 1995; now Mary River National Park), both of which were adjacent to pastoral plantings of gamba grass. Spread models of gamba grass from the initial historical plantings in 1985 to its 2012 distribution demonstrated "explosive" rates of spread of gamba grass (Petty et al. 2014). Gamba grass spread rapidly along riparian corridors and this spread was accelerated by transportation of hay (Fig 1,b) and traffic along major transport routes (Petty et al. 2014). The rapid spread of gamba grass resulted in significant environmental impacts (Fig 1c,d), and quantifying these site-based impacts has been extremely powerful for informing its management including declaration (Australian Weeds Committee 2012).

Fig 1 (a-d). goes here

Recognising the off-site impacts on introduced plants: the role of ecological research

Concern for the natural environment as a consequence of plant introductions was of little or no consideration for most of the 1900's (Coombs 1977). It was in the late 1980's and early 1990's that ecologists and land managers became increasingly vocal, initially through grey literature (e.g. Cook 1991; Bowman 1999) and representation of conservation views at meetings (Clarkson 1991, 1995). Some of the cultivars of greatest concern had only been recently officially released (e.g. the Kent cultivar of gamba grass in 1986 (Oram 1987) and olive hymenachne (*Hymenachne amplexicaulis*) in 1988 (Wearne et al. 2010) but concerns were soon raised about their potential as invasive and environmentally damaging species (Whitehead and Wilson 2000). Nationally, the term 'environmental weed' was introduced as a new classification of non-native species (Humphries et al. 1991). The 1990's increasingly saw conflicting views between proponents of continued plant introductions, and those raising objections on the grounds of environmental concerns (Grace et al. 2004). As stated by Humphries et al. (1991), 'the conflict of interest between agricultural and conservation objectives is a policy and public relations issue which needs to be addressed immediately'.

An important contribution to the debate came when Lonsdale (1994) critically evaluated the environmental consequences of the programme of planned plant introductions in Australia, reporting that of the 466 pasture species were intentionally introduced into the region, only 21% came to be recommended as useful, and of these only 4 species (<1%) were useful pasture species without causing weed problems. This provided clear evidence that non-native pastoral species in northern Australia were problematic plants for other land uses, including conservation.

Despite this clear evidence, the debate continued to escalate driven by the entrenched differences in stakeholder values. To acknowledge the diversity of (and often conflicts between) stakeholder values, terms such as ‘conflict species’ and ‘contentious species’ were developed to denote species that had economic value for one or more land uses (e.g. agriculture) but negative impact on the values of others (e.g. environment) (Ferdinands et al. 2010, Friedel et al. 2010). Many introduced pastoral grasses come under the term ‘conflict species’, and the management of these grasses came to be recognised as the “single most controversial environmental issue’ in Australia’s Northern Territory” (Northern Territory Sessional Committee 2008a, p 66).

The role of conservation science in providing evidence about off-site impacts

The conflict over the use and management of non-native grasses in northern Australia was high profile, followed not only by the agricultural and conservation sectors, but covered in the public media (Fig 2). Cameron and Lemcke (1996) suggested that the conflict was continuing because “the nett positive and negative effects” of introduced pasture species had “not been objectively studied and documented’. Researchers, including ourselves, focussed on a range of species, and addressed critical questions to deliver the necessary evidence to underpin policy and management decision-making (Table 1).

Despite the growing scientific evidence, the conflict between the agriculture and conservation agendas remained strong and the accuracy and relevance of the science was often questioned (Northern Territory Sessional Committee 2008b). Peer-review was (and continues to be) critical for credibility of the research which was hotly contested (Whitehead and Wilson 2000). Whitehead and Wilson (2000) argued that there was an “ongoing campaign of denial” by northern Australian primary production authorities that some pasture grasses were causing adverse environmental effects, and the evidence was routinely ignored, denied or systematically undermined. The public and scientific pressures became so strong that in 2008 the Northern Territory Government Sessional Committee ran an inquiry into invasive species and management programs in the Northern Territory. The inquiry noted that “people working in government weeds control programs can feel ‘caught in the middle’ due to these pressures” and that due to “conflicting interests, a degree of paralysis has beset the management of these species” (Northern Territory Sessional committee 2008a, p. 42). An agreed pathway forward was needed and this was provided by the development of weed risk assessment (WRA) tools and associated policy to guide their use (Setterfield et al. 2010a; Adams and Setterfield 2016).

Importance of scientific evidence for weed risk assessment

Nationally and internationally, scientists and policy-makers collaborated to develop WRA tools in response to recommendations or requirements of governments and intergovernmental organizations (e.g., World Trade Organization) as part of trade or other transport of species (Adams and Setterfield 2016). WRA tools aim to provide a transparent method for assessing the risks associated with invasive species and prioritizing species for action given a set of comparable criteria (Groves et al. 2001). The most widely applied is a semi-quantitative assessment approach, such as the Australian WRA system used for pre-border screening (Pheloung et al. 1999; Anon 2006; Auld et al. 2012), and State specific post-border assessments and prioritization tools (e.g Anon 2006; Johnson 2009; Setterfield et al. 2010a). In the Northern Territory, we formed a collaborative team between University and Government-based scientists to co-lead the development of a WRA tool and policy framework (see Setterfield et al. 2010a; Adams and Setterfield 2016). Importantly, we undertook this process in collaboration with all key stakeholders groups (pastoral, horticulture, conservation, and Indigenous land users). This provided a transparent, evidence-based framework to assess risks and provide recommendations for management actions (Johnson 2009; Setterfield et al. 2010a).

The WRA tool and policy framework provides an excellent example, and reminder to scientists, of the importance that politicians and policy officials place on transparent decision-making frameworks and a clear evidence base to support resulting recommendations. The then NT Environment Minister, Len Kiely, underlined the importance of the evidence-based WRA tool to inform policy decisions about invasive plants, stating that “policy outcomes would wait on the results of the WRA” (NT News, 19/1/2008), valuing the "scientifically based assessment process that looks at how we can manage the problem weeds" developed "in conjunction with stakeholders and industry." (ABC News 18/1/2008).

Quantifying the costs of impact can be the key to policy and management action

Although the WRA outcomes provided clear management direction for high-risk introduced plant species, the strong pressure from interested parties continued to cause difficulties about the appropriate management response for some species. Again, gamba grass in northern Australia provides an example; despite ranking as one of the highest risk non-native species in the NT using the WRA, the policy-makers considered that an economic assessment of benefits and impacts of gamba grass was necessary before policy action was taken (Ferdinands et al. 2010). A partial BCA approach was therefore applied by a collaborative team of University and Government economists and scientists (Ferdinands et al. 2010). The costs associated with direct impacts, including the management costs on- and off-farm, infrastructure repair and maintenance due to the impacts of invasion, and changed fire management costs, were quantified. A number of secondary impacts, such as the loss of cultural values were reported but not assigned an economic value. We calculated the production benefits and management costs over a twenty-year time period, and this was sufficient to allow a comparison of private production benefits versus the mostly public costs of management and damage costs. We found that only the extremely optimistic and rarely realised 'optimal production scenario' produced nett benefits, estimated at $6.7 million, equal to the nett public management costs of $6.05 million (Ferdinands et al. 2010). In all other (more realistic) scenarios the costs far outweighed the benefits. The economic analysis therefore supported that policy action should be implemented to manage the risk of this species and in the case of gamba grass to ban further planting, transport and sale of gamba grass or gamba grass seed.

Environmental and socio-economic evidence underpins constructive debate and policy change

Comprehensive environmental and socio-economic evidence resulted in significant policy changes regarding invasive grasses in northern Australia. Based on evidence, gamba grass was declared a prescribed weed under Government policy in the three state jurisdictions that cover northern Australia: Western Australia (January 2008), Queensland (April 2008), and the Northern Territory (November 2008) (Australian Weeds Committee 2013). State-based management plans were released following declaration of gamba grass (see Box 1). Of the documented impacts of non-native grasses, particularly gamba grass, the most significant ecologically was the change in fire behaviour (Rossiter et al. 2003; Setterfield et al. 2010b, 2013b). Furthermore, this captured the most attention from the public and policy makers due to its potential for damage to property, infrastructure and human life (Neale 2017). We published research showing the average cost of managing a gamba grass wildfire ($25,609 ± $5,134) was 26 times higher than an equivalent native grass wildfire ($938 ± 252), which had substantial impacts on the regional fire budget (costs in 2017 dollars, Table 2; Setterfield et al. 2013b). We presented this research in many forums prior to and following publication, including to the politicians and policy-makers in charge of the relevant portfolios. The importance of documenting the costs of managing the more intense fires resulting from gamba grass invasion was important in demonstrating the ongoing risk and escalating costs of fire-management in the absence of policy to prevent further weed spread. As noted by Neale (2017), land management practitioners considered this research "crucial to eliciting action at the gamba-fire nexus", and was particularly powerful when it "scared the bejesus out of policy-makers'.

In 2009, the scientific evidence (Table 1) underpinned the listing of gamba grass and four other non-native grasses as a Key Threatening Process (KTP) under the Commonwealth *Environmental Protection and Biodiversity Conservation (EPBC) Act*. Consequently, in 2012, a Threat Abatement Plan (TAP) was completed by the Federal Environment Department, in consultation with key stakeholders, to provide guidance at national, state and local levels on activities and research needed to abate the threat. In 2012, Gamba grass was listed as one of Australia's 32 Weeds of National Significance (WoNS). A 'National coordinator' was assigned to develop and implement a national management strategy for gamba grass due to its status as a WoNS (Australian Weeds Committee, 2012). The WoNS strategy included a 10-year plan to ensure the most cost-effective use of limited 'national coordination' resources available from public funds (Australian Weeds Committee, 2012). The role of scientists to effect these changes was recognised, including by land management practitioners who considered that 'scientific evidence was instrumental in getting significant policy change' (Neale 2017).

A decade on… effectiveness of policy implementation and what further can conservation science contribute?

We have documented the significant contribution that science has made in underpinning a range of policies for the use and management of invasive grasses in tropical Australia. In considering the research-implementation gap, the historical perspective presented above presents a compelling case of how research has bridged the gap in policy implementation. However, a second step in implementation is moving from policy to nationally co-ordinated on-ground management. A decade has passed since the original declaration of gamba grass across the jurisdictions in northern Australia. We reflect here on progress over the past ten years in terms of the effectiveness of policy instruments in limiting spread; current impediments to achieving nationally co-ordinated management; and the contribution that science can make to further assist fire and weed management practitioners.

The impact of declaration as a policy instrument

An important consequence of the declaration of a suite of the invasive grasses (as State-listed weeds, WoNS and/or as a KTPs) was the limitations placed on their sale, planting and transport. The impact of these actions has not been quantified but based on our previous research, we suggest that the impact of declaration is likely to be significant in limiting the rate of spread. For example, we previously analysed the spread patterns of gamba grass from initial plantings to approximately 30 years later. Most of the rapid spread within the broader region resulted from new plantings and transport of the grass between properties (e.g. in hay bales) (Adams and Setterfield 2016). Declaration stopped this source of spread. Unfortunately there is currently little data available to assess the cost-effectiveness of such policy actions, or the prescribed activities within the associated management plans. Consequently, the effectiveness of declaration is sometimes questioned (Neale 2017).

Questions about the effectiveness of declaration as a policy measure likely reflect that individuals are confronted with the increasing visual reality of a gamba grass dominated landscape in northern Australia. Take a drive down Stuart Highway and into Litchfield Park and you can easily spot the astonishingly tall (4m+) gamba grass stands. What is absent from these arguments is the alternative reality of what would this landscape look like in the absence of gamba grass declaration? We estimate that Litchfield Park is 18% invaded by gamba grass (Adams and Setterfield 2016) but using counterfactual thinking (i.e. what would have happened in the absence of declaration) we estimate this would likely be much greater. For example, our analysis of the effectiveness of mimosa management in Kakadu, using counterfactual thinking, estimated that management avoided 58km^2 of infestations across the floodplains (Adams et al. 2015). This type of rigorous counterfactual policy assessment is currently missing for declaration and other policy activities, but would provide cutting edge analysis of the impact of policy measures and the ability to compare the cost-effectiveness of these measures to alternative management options.

The gap between policy directing and achieving nationally co-ordinated on-ground action

In addition to limiting deliberate spread, the declaration of gamba grass as a State-listed weed and a WoNS should have led to co-ordinated and dedicated on-ground management that prioritised control to prevent spread and eradicate outlying infestations. However, this is where the gap between policy and appropriate on-ground action is most evident, that is, there is a lack of co-ordinated action across the invasion range despite the recognised need by Governments (Invasive Plants and Animals Committee 2016). A major set-back occurred in July 2013 when it was announced that the funding for Australia's WoNS programme would transition to a 'new phase' that included the cessation of funding for the position of 'National Co-ordinator' for each WoNS species, with no alternative funding source allocated to ensure implementation or co-ordination of the national weed management strategies (Australian Weeds Committee, 2012). The timing of this announcement was unfortunate for gamba grass management as it had only just been added to the WoNS list (April 2012). Consequently, publication of the first national strategy for Gamba grass management coincided with the removal of resources for national strategy co-ordination (Australian Weeds Committee, 2013). The gap between policy and action is particularly apparent when a Government endorsed strategy prioritising evidence-based best-practice management is released without funds or other commitments to implement it. As of November 2013 (Phase 3 of the WoNS program), National WoNS co-ordination became the responsibility of the state and territory jurisdictions (Australian Weeds Committee, n.d.), although there was no stated pathway for how this would occur. Where (limited) government-supported control is occurring, there is no evidence that the funds are allocated as part of a national or regional strategy.

The role of science to progress cost-effective action

With a clear gap between policy and nationally co-ordinated on-ground action on invasive tropical grasses, there is a need to re-assess the situation and what role additional science can play in overcoming the gap. Weed and fire management practitioners recently suggested that evidence-based science will be critical in progressing action, suggesting that the discipline should "do what has been successful previously, that is, document impacts and take the findings to policy-makers" (quoted in Neale 2017). This, much like our example of the role of the WRA tool in informing policy, is a strong reminder to scientists of the importance of scientific evidence in holding policy makers accountable for implementing change. Based on our experiences, we recommend the following are important lines for scientific evidence:

- *Updated assessments of the current and predicted future cost of impacts of invasion*. For example, the increased cost of fire management between native grass fires and gamba grass wildfire (Table 2; Setterfield et al. 2013b) provided powerful evidence for increased funding for fuel and fire management, and was critical for the policy initiatives for weed management (Setterfield et al. 2010b; Setterfield et al. 2013b). The need to update this became evident in October 2017, when high intensity, high risk gamba-fueled fires occurred on five consecutive days in the Darwin rural area, capturing the attention of the public and media. We collated the fire management costs for five wildfire events, occurring in areas in which the cover of gamba grass was ~80% and where fire authorities to responded strongly to the community risk by deploying large amounts of personnel and equipment. Consequently, the costs of managing these gamba grass wildfires in 2017 was substantially higher than any previously reported, with the most expensive wildfire costing $102,130 (Table 3) compared to the previously highest cost wildfire of $50,558 that we reported in Setterfield et al. (2013b) (cost in 2017 dollars; Table 2). This is powerful information for reassessing the relative costs and benefits of implementing coordinated on-ground control across the invasion region.
- *Evaluation of currently funded management programmes, and research on alternative control methods*. Independent and transparent assessment of the effectiveness of weed management programmes will require significant effort by scientists and economists in order to first collect data on the actions and funds expended and then estimate the impact of these investments using counterfactual approaches (see above). In addition, research is needed into more effective control

methods that maximize local eradication of the invasive species and rehabilitation of the native community. Projects assessing control methods are commencing, in north Queensland and the Northern Territory (NESP 2018).

- *Development of innovative cost-effective approaches to prioritize regional or property scale actions*, which maximize the returns on investment in terms of assets saved. Tools such as forecasting, scenario planning (Adams et al. 2018) and optimization are at the forefront of these developments, and can be applied to consider range of assets to be protected, such as cultural values (Januchowski-Hartley et al. 2018).

Concluding remarks

In this paper, we've shared our insights into the importance of peer-reviewed science in the development and implementation of policies governing the management invasive grasses in tropical Australia. However, there is still a lack of adequately-resourced, on-ground action across the region of potential invasion. There is a clear role for conservation science in bridging the policy-action gap. Particularly important will be updating the evidence database from past site-based impacts to the regional-scale impacts that have more recently occurred, and the application of scenario modelling to temporally and spatially extrapolate the cost of impacts across the invasion region if effective on-ground management does not commence. The earlier evidence that was sufficient to enact policy change requires revision to kick-start co-ordinated national action.

Conflicts of interest

The authors declare no conflicts of interest

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Box 2. Reflections on a career as a female ecologist– Associate Professor Samantha Setterfield

I've certainly had a rewarding, exciting and challenging career as an ecologist. I've been able to work in the beautiful landscapes with interesting people, and travel to many parts of the world. However, reflecting on my life as a female scientist would not be complete without acknowledging the feeling of isolation that is quite typical of being in the minority. Gender inequality in Australian sciences has improved slightly since I began my PhD, but certainly not as much as I would have imagined or hoped for. Women are still in the minority in the sciences (Johnston 2016); there is a 'leaky science pipeline' (McGuire et al. 2012) with few women able to fly high in the profession compared to men, and certainly few women with children (McGuire et al. 2012; Grover 2017). The reminders of the lack of diversity are evident daily, not just in the obvious ways such as being the only female in meetings or work teams, but in many more subtle reminders. Personally, I think that it is very important to acknowledge the reminders that gender inequity has and does exist, and may continue to impact females entering the discipline or forging their way through mid- and late-career.

As an example, I'm now based in a lovely sandstone building in the picturesque campus of UWA in Perth. Over the years the building has been the home of geology, geography, and more recently, environmental science. As I enter each day, I walk along a corridor with a line of photographs of the past leaders of the geography and (more recently) environmental science department. At the other end of the building is a line of photos of the past leaders of the geology department. All are men. All were photographed in their younger years with the promise of long careers ahead. This is similar to other departments at many universities around the country. Many of these men became highly esteemed in their fields, have been honoured by having buildings, lecture theatres, seminar series and awards named after them. But, to me, the most eye-catching and important photo on those walls is of Lucy F. V. Hosking, the first female lecturer in geology, a position she held between 1931 and 1933. She was a pioneer being one of the few female lecturers in science in Australia at that time. The photo caption tells us that she published 5 papers and co-authored two books. Then, flying high in her career, what was her next step in academia? Well, she resigned 'on marriage', as was the custom for the time. Amazingly, the next female lecturer in geology *was not appointed until 1996*. A 60-year gap! How different things may have been if Lucy Hosking and her female peers had been able to continue. Up until 1966, women in the public service *had* to resign when they married and this including many women who started scientific careers with outstanding potential. It is these women whose names we would now be honoured on buildings, awards and the like. Certainly, there are examples of this type of public recognition for female scientists but it's going to take some time before we catch up, and until then, it contributes to the feeling of isolation that we should all be mindful of it.

The impact of these policies resulted in a lack of female colleagues and role models in the sciences. In the early 1990s, I moved to Darwin to start my PhD. This provided the opportunity to work with many great ecologists employed in ongoing positions at the University, CSIRO and Government, although none were female. There wasn't a female ecologist to provide the role model of navigating the work/life balance, juggling remote ecological field work with family duties, or providing the female voice in meetings, lectures and seminars. In an attempt to build a network with female scientists, to overcome the isolation and seek out potential role models in our broader discipline, a few of us organised a regular event - an evening meal to share experiences with other females working across any organisation in town in any field related to biology. It was a great experience but I look back and think of our precious PhD time spent trying to build a female network in our profession because one did not exist for us. The male researchers didn't need to do this; that network was the system already in place for them. In this competitive environment when we report our research outputs relative to our time in the workforce, there is little to adequately acknowledge the many extra efforts that minority groups put in over the years.

As my career progressed, I found that having female postgraduates, research associates and postdoctoral fellows in my lab team helped reduce the feeling of isolation. Sharing experiences directly, or through other avenues such as this journal issue or similar articles (Grover 2017), is all part of building a supportive network. I wanted to contribute to this issue with Natalie and Vanessa because my career is certainly the better for having had them in my lab team, watching them build their own successful careers, navigate their way through the similar life-work balance, and being role models for students in their teams. Indeed, I am glad that we can contribute to ensuring that the next generations of female researchers can experience a more diverse environment. I am heartened by the fact that the next generation will be exposed to an increasing number of role models of successful women in science – such as the other authors of this special edition.

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Figure Captions

Fig 1. (a-d) Photos of (a) 4m high dense stand of Gamba grass (*Andropogon gayanus*) in the Northern Territory dry season (NB: this stand was not planted but was the result of spread from one of the original pastoral plantings in 1985; Rossiter-Rachor) (b) Gamba grass baled for Hay in northern Queensland (Setterfield), (C) High intensity gamba grass fire (Setterfield) and (d) Tree decline in the Northern Territory due to high intensity gamba grass fires (Rossiter-Rachor).

Fig 2. Montage of selected Northern Territory and Queensland newspaper headlines documenting the public gamba grass debate (2000-2008)

Fig 1.

Fig 2

Gamba fuels hot debate

AT A GLANCE

- Scientists and ecologists want gamba grass to be labelled a weed.
- But graziers say a code of practice is the best option for management.
- They argue that it is an important tool that can be properly managed.

By ALYCE PEARSON and BRAD PFEFFER

CATTLEMEN and seed suppliers are shaking their heads in disbelief at calls for the Queensland and Northern Territory Governments to declare gamba grass a weed.

On Monday, almost 200 weed scientists and ecologists signed the so-called Gamba Declaration, seeking an outright ban on the planting and sale of the popular North Queensland and Northern Territory pasture species.

They claim the tropical grass is difficult to contain in fenced paddocks, and

Why scientists want it banned . . . a high-temperature gamba fuelled fire in the Northern Territory.

Why graziers love it . . . cattle grazing happily on gamba at Mareeba.

Govt seeks weed ban

GAMBA grass may be declared a weed in the Territory – but not until the middle of next year.

Environment Minister Marion Scrymgour said experts were assessing the effects of the exotic grass on the environment.

Independent MLA Gerry Wood said gamba was still being baled and sold at a property on the Stuart Highway.

Urgent call for NT to ban gamba grass

THERE are calls for the Northern Territory Government to ban gamba grass after a similar move in WA.

World Wildlife Foundation northern landscapes manager Stuart Blanch said the grass was the "green bulldozer" of northern Australia.

The WA Government banned the introduced African plant on Thursday, saying it posed a fire risk and affected biodiversity.

"The NT and Queensland governments must also ban gamba grass ... to support landholders struggling to stop this destructive weed spreading," Dr Blanch said.

"Gamba grass is one of many high risk weeds that must be subject to much stronger regulation and proactive management action."

NT Environment Minister Len Kiely said he would wait for the results of the weeds' risk assessment.

Bushfire sparks gamba grass battle

FUEL FOR THOUGHT: John Earthrowl says his house was almost burnt down because of gamba grass. Picture: JULIANNE OSBORNE

Both parties dithering

WHICH political party is going to have the guts to do something about gamba grass? Whichever does will get my vote.

I'm sick of the dithering over this weed, which is a real threat to everything we hold dear as Territorians.

The Government needs to ban all gamba plantings and ramp up the eradication programs. Anyone still planting this evil weed needs their backside kicked and a hefty fine to boot.

Someone will get killed in a gamba grass-fuelled fire. I've seen them and they are scary. Or is this going to be the next cane toad Territory-style?

Jim "Chooka" Dempsey
Humpty Doo

Tables

Table 1: Critical research questions examined by conservation biologists to underpin policy and management decision-making about invasive grass management in northern Australia, with examples of relevant peer-reviewed evidence.

	Research questions	References
Invasion	Can the species naturalise and then invade relatively undisturbed vegetation?	Knerr et al. 1998; Flores et al. 2005; Setterfield et al. 2005; Ens et al. 2015
	What is the preferred habitat for establishment?	Flores et al. 2005; Setterfield et al. 2005; Petty et al. 2012
	How long does the seed remain viable in the soil seedbank?	Knerr et al. 1998; Setterfield et al. 2004
Spread	What are the pathways of spread?	Petty et al. 2012
	How far can the seed spread?	Barrow 1995
	What is the potential distribution of the species? How will climate change impact on the potential distribution of the species?	Ferdinands 2007; Petty et al. 2012
Impacts	What are the impacts on native flora and fauna?	Ferdinands et al. 2005; Douglas et al. 2006; Parr et al. 2010; Beggs 2012
	What are the impacts on community and ecosystem structure (trees and grasses)?	Ferdinands et al. 2006; Brooks et al. 2010; Levick 2015; Parr et al. 2010; Setterfield et al. 2018
	How do these species impact ecosystem processes (e.g fire regimes, nitrogen cycling, carbon cycling, hydrology)?	Rossiter et al. 2003; Rossiter et al. 2004; Douglas et al 2006; Rossiter-Rachor et al. 2008; Setterfield et al. 2008; Rossiter-Rachor et al. 2009; Setterfield et al. 2010b; Rossiter-Rachor et al. 2017

	Research questions	References
Policy and Management	What at the optimal ways to manage invasions, and how can managers prioritise management?	Drucker and Setterfield 2008; Ferdinands; Setterfield 2008; Brooks et al. 2010; Ferdinands et al. 2010; Setterfield et al. 2010a; Setterfield et al. 2013b; Adams et al. 2015; Adams and Setterfield 2013; Adams and Setterfield 2015; Adams and Setterfield 2016; Adams et al. 2018

Table 2. Comparison of costs (in 2017 dollar values) from six paired fires in (a) native grass, (prior to gamba grass invasion) and (b) Gamba grass fuelled fires. Paired fires were selected based on the closeness of site of ignition, therefore the staff and resource response would be expected to be similar over time.

Reproduced from Setterfield et al.2013. Data in Setterfield et al. (2013b) were provided in 2010 AUD dollars and are reported here in 2017 AUD (based on average annual inflation rate of 2.1% between 2010 and 2017 reported by RBA; https://www.rba.gov.au/calculator).

Fire Location	**Cost**	
	(a) Native grass	**(b) Gamba grass**
Rum jungle	$868	$23,338 (70% cover)
Tortilla	$434	$27,406 (70% cover)
Batchelor	$434	$7,166 (70% cover)
Batchelor mine	$868	$37,802 (90% cover)
Darwin River	$1,735	$31,481 (80% cover)
Lake Bennett	$2,169	$50,588 (35% cover)

Table 3. Wildfire response costs from five gamba grass fuelled fires over a five-day period in August 2017. The fires occurred in the Darwin rural area in sites with 70-80% gamba grass cover. Data are provided in 2017 AUD dollars.

Fire	Grassland Fire Danger Index	Gamba grass cover	Area burnt	Total Cost	Cost per km^2 burnt
1	72 (Severe)	70% cover	3.6 km^2	$55, 394	$15, 387
2	97 (Severe)	80% cover	98.5 km^2	$102, 130	$1, 037
3	42 (Very high)	80% cover	3.2 km^2	$40, 637	$12, 860
4	82 (Severe)	80% cover	6.7 km^2	$90, 533	$13, 472
5	55 (Severe)	80% cover	1.3 km^2	$16, 576	$12, 751
		Total	**113.3 km^2**	**$305, 273**	