An inventory of Queensland prioritised invasive plant species for management and research

Olusegun O. Osunkoya[1], Christine Perrett[1], Kerri Moore[2], Sam Nicol[2], Jens Froese[2], Kristy Gooding[3] and Shane Campbell[4]
[1] Invasive Plant and Animal Science Unit, Biosecurity Sciences, Department of Agriculture and Fisheries, Eco-sciences Precinct, Brisbane, Queensland 4102, Australia
[2] CSIRO, Eco-sciences Precinct, Brisbane, Queensland 4102, Australia
[3] Local Government Association of Queensland, PO Box 230 Fortitude Valley, Brisbane, Queensland 4006, Australia
[4] Invasive Plant and Animal Science Unit, Biosecurity Sciences, Department of Agriculture and Fisheries, Tropical Weeds Research Centre, Charters Towers, Queensland 4820, Australia
(Olusegun.osunkoya@daf.qld.gov.au)

Summary There are currently ~300 declared weeds in Queensland (QLD), Australia, but this list requires a review as the last known exercise dealing with weed risk assessment and prioritisation was undertaken about two decades ago. In this paper we propose an updated list of invasive alien (plant) species of significant concern in QLD, based on information derived from pest management plans of local governments, herbarium records and published/grey literature, expert knowledge, and opinion from diverse groups of stakeholders. Weed diversity varies significantly between local government areas and regions. Regions on the mainland eastern seaboard of the State share similar weed communities, unlike western regions and the Torres Strait islands, which share fewer, weed species. Stakeholders identified the top research and management priorities for the weed list. These were: studies involving biological control options (34.8% of respondents), public awareness and education (18.5%), effective herbicide-use and application techniques (15.2%), ecology, taxonomy and risk analysis (11.5%), and adaptive pasture management (9.3%). Based on occurrence and distribution across local government areas/regional jurisdictions and on-ground stakeholders' perceived weed severity, a weed priority list of high-medium and-low impact scores for policy, research and management was compiled for each region and State-wide.

Keywords Biological invasions, stakeholder elicitation, weed risk assessment, weed impact, weed prioritisation, weed spread.

INTRODUCTION

Biological invasions, a key component of global change, have significant environmental and economic impacts worldwide (McGeoch *et al.* 2016). Due to increasing globalisation, most geographical regions or ecosystems have numerous candidate invasive alien species (IAS) in need of attention. Given the large number of problematic introduced pest plants and animals and limited resources for their management, it is necessary to prioritise them for adaptive research and strategic control options. For example, in Australia there are currently 3100+ alien plants with a broad range of environments and industries affected (AG 2018). Prioritisation of IAS requires information on abundance (density), extent of spread (current and potential distribution), socio-economic-ecological impact, and management achievability of candidate species (Parker *et al.* 1999, McGeoch *et al.* 2016, Booy *et al.* 2017).

We define pest species prioritisation as the process of ranking environmental IAS (including those impacting the grazing industries, but excluding those exclusive to cropping ecosystems) to guide policy, research and management. Here we focus on prioritisation of established invasive plants of Queensland (QLD), Australia using data obtained from the grey literature, herbarium records and stakeholders elicitation. Bebawi *et al.* (2002) did a similar exercise, but restricted the exercise to plants of the tropics. Our aims are to:

1. describe variations in QLD invasive flora that are of great concern across all regions of the State; and
2. develop a prioritised IAS list at regional and whole State levels based on spread and perceived impact.

MATERIALS AND METHODS

Pests are managed at a regional level in QLD by local government (LG) authorities, and consequently each LG has a different list of IAS. Each LG belongs to one of 10 Regional Organisations of Councils (hereafter 'regions'), which are administrative groupings of nearby LG councils that share relatively similar geographic and climatic features. To examine the full list of IAS at a statewide level, we accessed QLD LG pest management plans (PMPs) during February to June 2016 by *e*-downloading or requesting via email from the appropriate authority (74 LGs in all). For each LG PMP, IAS lists were extracted and entered into a relational database. Each IAS was recorded together with information about its priority listing for perceived threats and management need (rated: high, medium or low). Across LGs, The IAS and associated ecological data (e.g. life form, habitat invaded, date of first record in the State [i.e. time since invasion/residency time] based on QLD herbarium records (HERBRECS) etc.) were aggregated into regional lists based on their regional affiliations.

From October 2016 through to March 2017, we convened a round of regional stakeholders' workshops around the State for each of the 10 regions using the platform of Local Government Association of QLD. Participants (n ≥15) were made up of LG officials tasked with pest control and management, farmers, elected council officials, and State Government biosecurity officers. At each workshop, the region's established weed list (extracted and aggregated from LG PMPs), together with identified State emerging IAS, was presented to the group. We made initial presentations and discussions around the scoring methods (see below) and terminology to reduce the potential for language-biased misunderstanding, followed by open, facilitated discussions. Finally, through deliberation and consensus-building, each species was assigned a single priority opinion (high, medium or low) on 'perceived' pest impact and management expediency. Research and management needs for each species were also recorded. In the process, some species were added, removed from the regional list, or changed rank/rating compared to what was in the LG PMPs.

For each region, LG pest lists were aggregated by summing the number of LG that listed and/or rated a given IAS as a significant concern and therefore requires management. The IAS qualitative ratings and distribution derived from LG PMPs and from the elicitation workshops were converted to numerical (given arbitrary values of 8, 5, and 2 for high, medium and low ratings, respectively) or absence-presence values (1 for presence of a given rating, e.g. high, and 0 for its absence) for further analyses (see below).

To explore similarities between IAS lists at a regional level, the data were subjected to multivariate analyses of non-metric multidimensional scaling (NMDS) in two dimensions using Bray-Curtis dissimilarity measure. The Primer software (ver. 6) was used with region as the main factors. Responses to open-ended questions (e.g. research needs for management) were summarised by grouping major opinions or answer types, and recording the number of respondents (i.e. region) that mentioned each opinion.

A plethora of indices exist for estimating pest spread (invasiveness) and impact (see Barney *et al.* 2013). We used the framework of Parker *et al.* (1999) to quantify regional spread and impacts of invaders based on the linear equation $I = A \times R \times E$, where I is the invader's impact, A is the invader's mean local abundance (density), R is the range or area occupied by the invader (i.e. its distribution), and E is the invader's per unit effect. We used the proportion of LGs within each region that listed and rated a given invader as our estimate of A and proportion of regions within QLD with the weed as the estimate of R. Note that we assume that if the weed is listed then it will be abundant, now or in the near future, so listing by LG serves as a crude proxy for mean spread (see Kumschick *et al*. 2012, Panetta 2016 for a similar approach). As in many IAS assessment reports (e.g., McGeoch *et al.* 2016, Pearson *et al.* 2016), quantifying E (i.e. per unit weed effect) is untenable due to the large number of species screened for. Thus we used, as a proxy, the mean of the consensus ratings generated at the regional stakeholders' meetings as a measure of effect (E) of each listed weed. This involved conversion of priority ratings generated from qualitative, three point state [high-medium-low] to quantitative values- assigned 8, 5 and 2, respectively (see Kumschick *et al.* 2012, McGeoch *et al.* 2016) with the average regional priority rating values as input to derive a final impact (I) score.

RESULTS

In all, a total of 295 species were identified from the LG PMPs of which only 107 species (36.3%, range 13.6–90.9%) were of significant concern at the regional stakeholders' workshops (Figure1). Queensland invasive flora is taxonomically diverse, representing 161 genera and 64 families. The five most important families based on number of species assessed and prioritised were: Fabaceae (16 species), Asteraceae (13 species), Poaceae (12 species), Cactaceae (10 species), and Verbenaceae/Amaranthaceae (5 species each).

NMDS ordination of QLD IAS based on presence-absence data indicated that range of pest plant species varied widely across the inland regions and the Torres Strait islands, while those of coastal regions appeared homogenous (Figure 2). These variations (of 25.0–90.0% dissimilarity) reflect roughly the geographical continuum of the State, consisting of (a) northern, (b) southern, and (c) western regions.

Using the invasiveness index in Parker *et al.* (1999) (a product of $A*R$), the twenty most highly ranked pest plant species in QLD in decreasing order

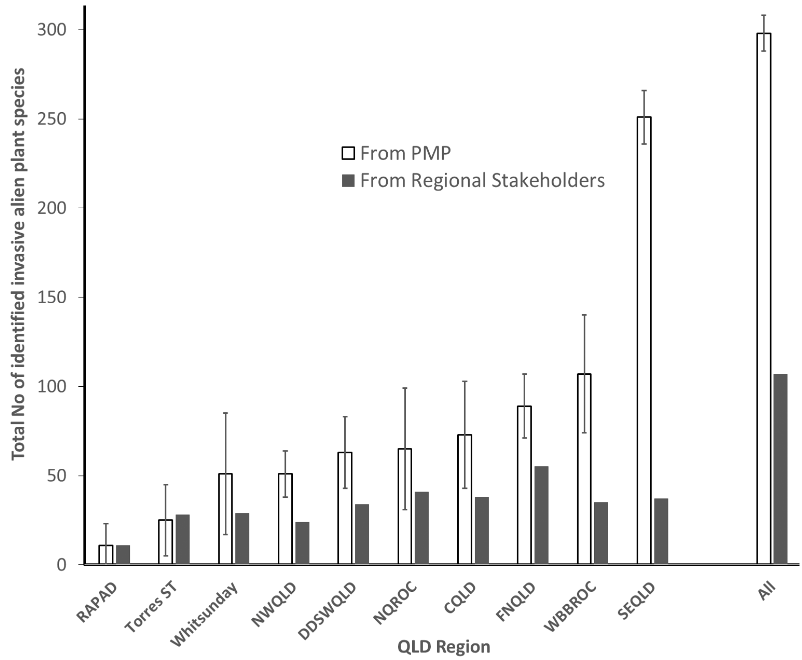

Figure 1. Number of IAS (±SE) across regions of QLD identified from scoping of LG pest management plans (PMP) and by stakeholders at regional workshops. Regions are: RAPAD – Remote Area and Planning Authority Development [Central West]; Torres ST – Torres Straight Islands; NWQLD – North West QLD; DDSWQLD – Darling Downs QLD [South West]; NQROC – North QLD; CQLD – Central QLD; FNQLD – Far-North QLD; WBBROC – Wide Bay Burnett region; and SEQLD – South East QLD.

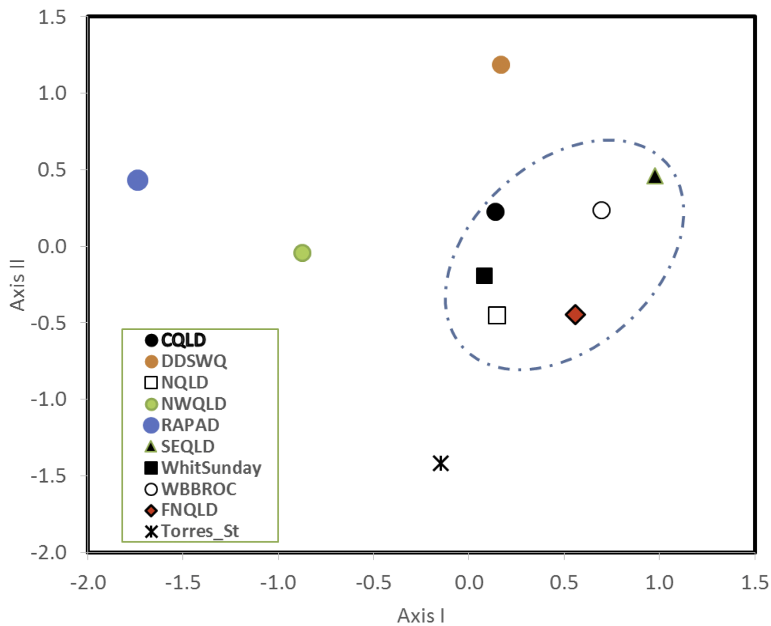

Figure 2. NMDS ordination of ten regions of QLD, Australia based on presence-absence data of IAS. Dashed circle indicates similarity in IAS for the eastern regions. Region abbreviations as in Figure 1.

with estimated residency time (years.) based on the date of first appearance of the IAS in the QLD herbarium records are: *Parthenium hysterophorus* L. (parthenium – 62 yr); *Bryophyllum delagoense* (Ecklon and Zeher) Schinz (mother of millions – 104 yr); *Cryptostegia grandifilora* (Roxb.) R.Br. (rubber vine – 157 yr); *Parkinsonia aculeata* L. (parkinsonia – 157 yr); *Vachellia nilotica* (Benth.) Brenan (prickly acacia – 117 yr); *Sporobolus pyramidalis* P. Beauv., *S. natalensis* (Steud.) Dur and Schinz (giant rat's tail grass – 57 yr); *Salvinia molesta* D.S. Mitchell (Salvinia – 64 yr); *Jatropha gossypifolia* L. (bellyache bush – 129 yr); *Eichhornia crassipes* (Mart.) Solms (water hyacinth – 127 yr); *Harrisia martini* (Labour.) Britton (harrisia cactus – 59 yr); *Lantana camara* L. (lantana – 176 yr); *Prosopis glandulosa* Torr. (mesquite – 117 yr); *Ziziphus mauritiana* Lam. (chinee apple – 101 yr); *Hymenachne amlexicaulis* P. Beauv. (Hymenachne – 44 yr); *Pistia stratiotes* L. (water lettuce – 71 yr); *Dolichandra unguis-cati* (L.) L.G. Lohmann (cat's claw creeper vine – 70 yr); *Leucaena leucocephala* (Lam.) de Wit. (leucaena – 96 yr); *Opuntia* and *Cylindropuntia* spp. (e.g., *Cylindropuntia rosea* (DC.) Backeb. Hudson pear – 44 yr); *Xanthium strumarium* L. (Noogoora burr – 90 yr); and *Senna obtusifolia* (L) Irwin and Barneby (sicklepod – 146 yr). If regional impact score ($I=A*R*E$) rather that mean regional invasiveness (spread) score is used, the order of ranking of pest species changed somewhat but not significantly, with *Senecio madagascariensis* Poir. (fire weed – 99 yr) and *Tecoma stans* (L.) Kunth (yellow bells/tecoma – 93 yr) coming up on the list. Other pest species making up the prioritised list and their scores can be requested from the senior author.

At the stakeholders' workshops, research and management needs for prioritised IAS were identified, and they include needs on: (i) biological control options (34.8% of respondents); (ii) public awareness and education (18.5%); (iii) effective herbicide use and application techniques (15.2%); (iv) ecology, taxonomy and risk assessment (11.5%): (v) pasture and integrated management (9.3%); and (vi) eradication of outliers (4.4%).

DISCUSSION

The weed flora of QLD is diverse within and between regions, with greater variation between regions in western QLD and that of coastal eastern part of the State (Figure 2). The coastal similarities in IAS composition suggest that QLD eastern regions have shared challenges and may benefit from working cooperatively as a single unit (with the exception of Torres Strait, a top end region, which tends to have its own distinctive weed assemblage). In contrast, weeds in the western regions and the Torres Strait are largely disparate; while there are still benefits from cooperating on individual shared species, it may be necessary to develop region-specific management strategies.

The use of biological control agents, including their redistribution and efficacy, was the most frequent requirement of stakeholders' research and management needs. This suggests that there is strong community support for the QLD and Australian governments in continuing investment in biocontrol ventures, including fund provision to prospect for agents to combat prominent emerging invaders, including grasses such as *Sporobolus pyramidalis* and *S. natalensis* (giant rat's tail grass).

The quest to find the best procedure for pest prioritisation continues. Currently there are over 30 procedures published and recommended (see the comprehensive list in Nentwig *et al.* 2016). However, many have argued that there is no objectively correct way to carry out pest species prioritisation, as long as certain guidelines are met. These guidelines include: the provision of a logical scientific basis for the approach, transparency; generality of questions that are applicable to a range of situations; minimisation of subjective views; relatively few questions; and ability to aggregate all available data into a single index (Kumschick *et al.* 2012, McGeoch *et al.* 2016). In this study we have fulfilled these criteria. We initially extracted weed lists from PMPs of LGs, aggregated the LG data into a regional list and presented the weed lists to stakeholders, followed by the use of a single stakeholders' consensus rating per candidate weed to ensure that subjective views are minimised. Finally the qualitative ratings were converted to quantitative data that serves as input in the estimation of the Parker *et al.* (1999) weed invasiveness and impact indices. These are steps that are transparent, traceable and repeatable. The next phase is to explore how the prioritised target species list can be refined further to account for management achievability. This step, the pest risk management scenario, calls for another round of stakeholder elicitation to examine the probability of IAS eradication and/or control. Combining risk assessment and risk management creates a matrix that defines the final IAS list – thus ultimately influencing policy in terms of adaptive weed research and management options.

ACKNOWLEDGMENTS

We thank many stakeholders across the state of QLD who participated in the regional workshops.

REFERENCES

AG, Australian Government (2018). Weeds in Australia. http://environment.gov.au/biodiversity/invasive/weeds (accessed 4 April 2018).

Barney, J.N., Tekiela, D.R., Dollete, E.S. and Tomasek, B.J. (2013). What is the "real" impact of invasive plant species? *Frontiers in Ecology and the Environment* 11, 322-9.

Bebawi, F., Campbell, S. and Stanley, T. (2002). Priority lists for weed research in the wet-and dry-tropics of north Queensland. *Plant Protection Quarterly* 17, 67-73.

Booy, O., Mill, A.C., Roy, H.E., Hiley, A., Moore, N., Robertson, P., Baker, S., Brazier, M., Bue, M. and Bullock, R. (2017). Risk management to prioritise the eradication of new and emerging invasive non-native species. *Biological Invasions* 19, 2401-17.

Kumschick, S., Bacher, S., Dawson, W., Heikkilä, J., Sendek, A., Pluess, T., Robinson, T. and Kühn, I. (2012). A conceptual framework for prioritization of invasive alien species for management according to their impact. *NeoBiota* 15, 69-100.

McGeoch, M.A., Genovesi, P., Bellingham, P.J., Costello, M.J., McGrannachan, C. and Sheppard, A. (2016) Prioritizing species, pathways, and sites to achieve conservation targets for biological invasion. *Biological Invasions* 18, 299-314.

Nentwig, W., Bacher, S., Pyšek, P., Vilà, M. and Kumschick, S. (2016). The generic impact scoring system (GISS): A standardized tool to quantify the impacts of alien species. *Environemtal Monitoring and Assessement* 188, 315-28.

Panetta, F.D. (2016). Dealing with 'new' alien plants: Risk assessment and risk management. Proceedings of the 20th Australasian Weeds Conference, eds R. Randall, S Lloyd, and C. Borger, pp. 183-9. (Weeds Society of Western Perth, Australia).

Parker, I.M., Simberloff, D., Lonsdale, W., Goodell, K., Wonham, M., Kareiva, P., Williamson, M., Von Holle, B., Moyle, P. and Byers, J. (1999). Impact: Toward a framework for understanding the ecological effects of invaders. *Biological Invasions* 1, 3-19.

Pearson D.E., Ortega Y.K., Eren Ö. and Hierro J.L. (2016) Quantifying "apparent" impact and distinguishing impact from invasiveness in multispecies plant invasions. *Ecological Applications* 26, 162-73.