Meetings

‘Raising the bar’: improving the standard and utility of weed and invasive plant research

A workshop held at B-Bar Ranch, Emigrant, Montana, USA, June 2012

Weedy and invasive plants currently cause globally significant environmental and economic impacts in agricultural and natural ecosystems (e.g. Pimentel *et al.*, 2005). The extent and impact of invasive plants will become increasingly variable with climate change, while the evolution of herbicide resistance is increasingly thwarting current agricultural weed management approaches. In short, weedy and invasive plants need to be a major consideration in efforts to enhance global food security, maintain biodiversity and reduce environmental degradation. Recently, commentators have started to question if the substantial effort and investment in ‘weed science’ and ‘invasion ecology’ is moving in the right direction (Davis *et al.*, 2009; Vanderhoeven *et al.*, 2010). This meeting was planned to ‘raise the bar’ in these important areas of plant ecology by attempting to encourage active, critical debate about current approaches and conceptual frameworks for research. In particular, there was a strong desire amongst participants to facilitate a greater integration and cross-fertilization of ideas between weed science, invasion ecology, and other fields of biology. The meeting was organised around three major themes: plant invasions, herbicide resistance, and climate change impacts. The mountains of southern Montana provided an inspiring setting to bring together an international cast of leading and emerging scientists in those disciplines to deliberate on the critical challenges and knowledge gaps within each theme. Below, we present some of the more broadly relevant topics of discussion from these themes and reflect on the future challenges for the fields involved.

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How do we advance invasion ecology?

Invasive plants are a global concern, and the causes and consequences of invasions continue to be intensely studied. Predicting invasions, understanding their drivers, and evaluating impacts were major issues spanning the expertise of researchers attending the workshop. Two key challenges with research on these issues were identified as: i) the plausibility and efficacy of species distribution models (SDMs), and ii) identifying and measuring the multitude of ways invasive plants may cause impacts at different scales.

Invasion biology has been a prominent focus of recent publications on the modelling of species' potential distributions, and the usefulness of SDMs invited heated debate among participants. As a tool for underpinning management decisions, policy change, and the allocation of financial resources, projected maps from SDMs will continue to be an important tool for invasion biologists (Lindgren, 2012). However, incorrectly applied modelling methods with poor techniques remain common in the literature. Moreover, many modelling techniques applied are correlative and, therefore, are not recommended for extrapolation. Participants discussed the need to overcome these shortcomings by using appropriate modelling techniques, having a better appreciation of model limitations, and ensuring the publication of enough information to allow for interrogation and method repeatability (Kriticos *et al.*, 2012).

Regarding invasive species impacts, the discussion focused on the necessity of moving beyond simple impact measures such as reduced diversity. However, it was acknowledged that assessing impacts was complicated by the difficulty of knowing invasive species' roles in, and responses to, ecosystem change. That is, are they drivers or passengers (MacDougall & Turkington, 2005), or perhaps even backseat drivers (Bauer, 2012)? Within this context, the approach of comparing invaded and non-invaded ecosystems was discussed, as was the need for cross-discipinary collaboration, such as with entomologists and soil ecologists, to address complex interactions driving invasions (e.g. Stanley *et al.*, 2012) and resulting in impacts.

Resistance is futile?

Current management of agricultural weeds is dominated by herbicide use despite calls for a more integrated approach (e.g. Mortensen *et al.*, 2011). Inevitably, this has resulted in the widespread and continuing evolution of herbicide resistance in weedy plants. A good deal of high-impact research has adopted physiological approaches to establish the molecular mechanisms that underpin resistance evolution. However, there has been relatively little focus on the eco-evolutionary dynamics that drive selection for resistance and that will underpin management interventions (Neve *et al.*, 2009). Workshop participants were asked to identify critical challenges for herbicide resistance research that might enable the retardation or even prevention of herbicide resistance evolution. Broadly speaking, two (non-mutually exclusive) schools of thought emerged: greatest advances will arise from a better understanding of the eco-evolutionary dynamics of resistance evolution; research needs to focus on the design and implementation of cropping systems that minimise selection for resistance. Interestingly, a view was expressed amongst some participants that resistance is an inevitable consequence of herbicide use and that there should be no publically-funded research into herbicide resistance.

Participants voted for their top three research challenges. There was strong support for efforts to design 'evolution-free' management systems (e.g. Koella *et al.*, 2009) underpinned by research to better understand the ecological and evolutionary drivers of selection for herbicide resistance (population, meta-population and seed bank dynamics, fitness costs and trade-offs, modes of inheritance). Designing diverse cropping systems and integrated weed management strategies that identify synergies between control tactics and may even exploit potential trade-offs between herbicide resistance and other weed life history traits were seen as crucial to these efforts. The development of modelling frameworks and risk assessment tools for herbicide resistance was a unifying theme and concluding discussions focused on establishing methods and collaborations to integrate genetic, evolutionary, ecological, agronomic and socio-economic perspectives and considerations into these models.

What changes with rapid climate change?

Global climate change is recognised as a significant driver of species biogeography and ecosystem change. Humans have ramped up this rate of change via greenhouse gas emissions, which are combining with other aspects of global change (e.g. land use change, urbanisation) to fundamentally change the dynamics of plant invasions and weed infestations. How we frame these changing dynamics was one of the core issues identified that sets climate change apart from other aspects of research on weeds and invasive plants. As climate change increases the likelihood of range shifts in all species, determining appropriate baselines against which to assess change is essential, particularly when these baselines are shifting at an unprecedented rate. For example, having a clear understanding of how to differentiate between range-shifting natives and invasive non-natives will become more complicated, particularly with adaptation options that include managed relocation of species well beyond their known range (Webber & Scott, 2011). It was noted that the increasing prevalence of novel environments, such as those created by land use change, further complicates the matter.

Additional challenges were identified for integrating climate change drivers into existing invasion ecology and weed related research. A hierarchy of processes operating at different spatial and temporal scales (e.g. dispersal) control the population dynamics of weeds and invasive plants (Pysek & Hulme, 2005). Most research projecting the effects of climate change with weed and invasive plant models are based on climate averages, when it is often climate extremes that limit the range of many species. With greater climatic extremes forecasted across the globe, modelling that includes these extremes is becoming increasingly important to gain a broader understanding of climatic impacts across trophic levels (e.g. Diez *et al.*, 2012). There has also been little focus on the ecological processes behind the observed and projected patterns, or on the potentially significant changes to demography, phenology, and community assembly (Walck *et al.*, 2011). It was

emphasised that these new insights must be used to update policy to provide a stream-lined system of understanding and adoption for efficient adaptation to and mitigation for climate change.

Conclusions and future challenges

The focus on three research themes engendered active debate amongst participants from weed science and invasion ecology backgrounds. Inevitably, perspectives and challenges were somewhat different between these sub-disciplines, but the overall sense was of considerable overlap in research questions, approaches, underlying principles and management options. However, to what extent are these overlaps being recognised? There was an overall agreement between weed and invasion ecologists of the need for better framing of our research. This will primarily be achieved by better formulation of hypotheses to recognise the wider ecological and evolutionary context in which we do our research. We 'raise the bar' by more clearly framing our research in the context of eco-evolutionary principles, not being too inward-looking and parochial (particularly in weed science) and seeking to collaborate more widely with those working in related disciplines. We need to become better at communicating the fundamental and applied importance of our study system through recognising the power of these economically important species to inform about the consequences of human-induced environmental change. In doing so, weed and invasion ecology will contribute to fundamental advances in plant ecology and evolution. There is an emerging literature in eco-evolutionary dynamics – weeds and invasive species can be at the heart of this. Improved management follows from improved science. Tackling the knowledge gaps and challenges identified in this workshop within an integrated and holistic approach will undoubtedly improve future research into the ecology and evolution of weedy and invasive plants.

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