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Planning for metapopulation persistence using a multiple-component, cross-scale model of connectivity

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ABSTRACT

Reducing fragmentation and habitat loss by restoring or maintaining connectivity has been promoted as a way to mitigate the negative impacts of human activities on biodiversity. This study is an example of collaboration between spatial researchers and on-ground practitioners, to deliver better informed management options for investment in connectivity and biodiversity outcomes. Using the Border Rivers-Gwydir catchment revegetation programmes in New South Wales, Australia, we describe a fit-for-purpose, cross-scale methodology consisting of multiple-component models, where each component reflected varying spatial scales. The methodology was based on the concepts of metapopulation ecology and landscape ecology and used least-cost paths analyses. At the wider scale, native vegetation extent and condition were used as a surrogate for all biodiversity; at the finer scale, landscape structure and generalised movement parameters related to a focal woodland species group were used to derive least-cost paths. The output from the analyses provided spatially explicit management action zones that were used to prioritise areas for revegetation investment. Combining local priority zones for linking habitat with regional-scale and broad-scale zones should increase access to resources for biota, increase dispersal potential and thereby enhance biodiversity persistence. Promoting connectivity is a global concern. Our approach could be relevant in other geographical settings where the implementation needs of NRM practitioners can be assisted through the application of scientific knowledge.

1. Introduction

Loss of habitat connectivity is a global threat to biodiversity (MEA, 2005). Translating connectivity goals into on-ground conservation actions is a complex challenge in natural resource management. The difficulty is compounded by the need to reconcile potential conflicts between alternative land uses (Hobbs and Kristjanson, 2003), which can be particularly challenging in agricultural landscapes. Connectivity can be defined as the degree to which the landscape facilitates movement of fauna (foraging, dispersal and migrations) or flora (dispersal and pollination via vectors such as wind, water or fauna) (Nathan et al., 2008) among resource patches (Taylor et al., 1993). Poor connectivity compromises the conservation of plant and animal species by impeding access to resources and movement between local populations (Hanski, 1999). Connectivity can, however, be improved by the creation of habitat corridors and stepping stones (such as small habitat fragments or paddock trees) (Baguette et al., 2013; Beier and Noss, 1998; Fischer and Lindenmayer, 2002a, 2002b). Measures aimed at increasing connectivity have been promoted in plans and policies at continental, regional and local scales by both government and non-government agencies, and as a way to mitigate reduced biodiversity and declining populations arising from inadequate and deteriorating connectivity (Fitzsimons et al., 2013; Soule et al., 2004; Worboys et al., 2010; Wyborn, 2011).

In Australia, biodiversity and habitat loss are severe in agricultural regions where land is largely privately owned and regional-scale conservation planning is undertaken by state-administered natural resource management (NRM) agencies (Robins and Dovers, 2007). In New South Wales, these agencies are known as Local Land Services (NSW Government, 2015). Local Land Services aim to deliver regional-scale NRM outcomes, delivered through actions implemented by individual landholders at the farm scale (Zerger et al., 2011). These outcomes are often phrased in terms of targets (Zerger et al., 2009), such as hectares of revegetation. NRM agencies are confronted with trade-offs between achieving targets, allocating funds among competing projects, working with limited time and resources, and the willingness or ability of landholders to participate. Transparency, defensibility and achieving maximum benefit from investing funds should guide an NRM agency's response to these conflicts (Maxwell et al., 2014; Wintle, 2008; Torrubia et al., 2014).

The global literature is replete with methods for connectivity or restoration planning using a variety of assessments or frameworks (Lethbridge et al., 2010). They vary in approach, metrics and the spatial

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scale of concern. Published techniques range from stakeholder preferences (Zerger et al., 2011), to landscape metrics that describe the spatial arrangement of habitat patches (Westphal et al., 2007), to more complex computations such as circuit theory (Lechner et al., 2015), graph theory (Bergsten and Zetterberg, 2013; Cushman et al., 2013) and integer programming (Crossman and Bryan, 2006), as well as planning tools such as Zonation (Thomson et al., 2009) and OPRAH (Lethbridge et al., 2010). Key conceptual variables used include habitat suitability, habitat reachability, restoration cost and biological behaviour (e.g. dispersal). The focus may be single species or groups of species (Alagador et al., 2012; Bryan, 2010; Crouzeilles et al., 2015; Polyakov et al., 2015; Tambosi et al., 2014; Watts et al., 2010). Planning scales range from continental (e.g. YYCI, 2015), national (GER, 2015) to local (Davidson et al., 2011; Lechner et al., 2015). The final choice of approach depends, in part, on the goal of the planning activity and the capacity of stakeholders to implement the approach (Bergsten and Zetterberg, 2013). However, the decision must ultimately be to serve the primary purpose of conserving or restoring viable populations, ones that are resilient to current and potential future conditions (Noss et al., 2009).

Despite the availability of technical knowledge, few studies actually lead to on-ground implementation. Bryan (2010) described an environmental investment plan, developed in collaboration with a South Australian NRM agency, which was used to guide strategic investment. The work was aimed at managing natural capital (such as water, land and biota) and ecosystem services rather than metapopulation persistence, and the selection of alternative management actions was based on comparative cost-effectiveness and the agency's budget rather than biological processes. The task of effectively integrating scientific knowledge with implementation is characterised by: a complex mix of competing approaches, limited biological information about species, processes and landscapes; and intractable technical limitations. This can challenge NRM agencies that are responsible for implementing programmes (Crossman et al., 2007). In particular, data about habitat connectivity at scales relevant to biodiversity conservation is often absent or incomplete (Henle et al., 2010). However, this lack of knowledge and expertise can be overcome through the collaboration of NRM practitioners and science organisations (Whitten et al., 2011).

We present a new methodology aimed at addressing these knowledge and extension gaps for a region administered by two NRM agencies in NSW, the Northern Tablelands and North West Local Land Services (LLS) (with a combined jurisdiction of 13 million ha). The methodology encompassed different spatial scales by combining (1) a new, rapid assessment method to evaluate local-scale and regional-scale connectivity with (2) a pre-existing broad-scale mapping of depleted habitats and wildlife corridors at the state scale (Native Vegetation Management Benefits Analyses, NVMBA; Drielsma et al., 2013). The methodology was a response to the decision-support needs of the LLSs to maintain and restore landscape connectivity in their regions. It was subsequently used to guide the planning of actual on-ground revegetation works as part of the Brigalow–Nandewar Biolinks Project (BNB Project) (http://www.agbiolinks.com.au). The project was instigated in 2012 with AU$5 million of Australian Government funds to invest with landholders to improve connectivity for biodiversity. The project's targets included 1550 ha of revegetation of cleared farmland. A significant challenge for the project was to identify places where investment would achieve the best returns for biodiversity.

Our goals were to (1) develop a spatially explicit methodology for identifying and improving connectivity and (2) provide the NRM agencies with the knowledge base for implementing revegetation actions for maximum biodiversity benefit. Our new local-scale and regional-scale analyses employed ecologically informed least-cost paths analysis to derive connectivity networks based on vegetation structure and generalised estimates of species movement for woodland fauna and fauna-assisted plant species, since the predominant vegetation formation across the study region was woodland. The NVMBA assessed benefit in terms of predicted persistence of biodiversity arising from alternative management actions. It was based on habitat configuration, quality and quantity, and generalised estimates of species movement. With this approach, we identified existing connectivity linkages and gaps across the landscape, where targeted revegetation activities could provide multiple-scale benefits for biodiversity. Woodlands across the globe are under pressure from various anthropogenic and natural threats (MEA, 2005) and while our particular focus was woodland and region-specific, the methodology can be adapted to other biogeographic regions, socio-political systems, datasets and vegetation types.

2. Methods and materials

2.1. Study region

The study was conducted in the Border Rivers-Gwydir (BRG) catchment (51,100 km^2) (Fig. 1), which straddles the jurisdictions of two state NRM agencies, the Northern Tablelands and the North West LLSs, in northern NSW, eastern Australia. Six woodland communities in the BRG catchment are listed as threatened under state and national legislation (OEH, 2015). Originally covering 56% of the catchment, woodland now covers less than 25% with <1% comparatively unmodified (unpubl. data, 2011). Additional details about the study region are provided in the supplementary data online (Appendix A.1).

2.2. The methodological approach, outputs and advantages

Using an integrated multi-scale modelling approach, we identified candidate revegetation areas for improving habitat connectivity and biodiversity persistence. The component models focus on different spatial scales and different biological processes at each scale.

We defined local scale as the area approximating a single field or farm (i.e. from several hectares to hundreds of hectares), which is the level at which restoration activities are planned, implemented and paid for in our study region. Regional scale approximates the scale of the NRM agencies' planning, investment and administration (i.e. from 10^4–10^7 ha). Broad scale aligns with the area of the state of New South Wales (i.e. ~10^8 ha), and is important for contextualising decision making at a national or continental scale. These terms also reference the differing scale of species' movements, bridging the gap between day-to-day foraging movements (local scale) and the larger movement distances undertaken for occasional dispersal and seasonal migration at regional and continental scales, as well as the potential response to climate change at these larger scales (Angelone et al., 2011; Werner et al., 2014). The methodology can therefore be viewed collectively as a 'cross-scale' approach, one which combines horizontal (across space) and vertical (across management level) interactions (Wyborn, 2011).

We developed two connectivity models for the scale of implementation, local-scale and regional-scale (first and third components, respectively; Fig. 2), using vegetation structure and estimates of dispersal distances. We then integrated the regional-scale model with existing NVMBA layers (second component; Fig. 2) that represent a connectivity- and complementarity-based perspective of revegetation

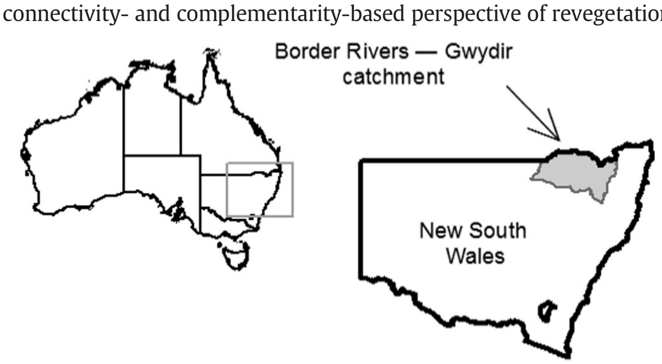

Fig. 1. Border Rivers-Gwydir catchment, New South Wales, Australia.