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Review

A review of fauna in mine rehabilitation in Australia: Current state and future directions

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A B S T R A C T

Restoration of degraded land has been identified as a top research priority in conservation. Fauna plays a critical role in the re-establishment of a functional ecosystem, yet fauna recolonization of restored areas is less studied than flora. We reviewed the findings of 71 publications on fauna recolonization, through the example of mining rehabilitation in the Australian continent, a global stronghold of large-scale mining.

Species densities and richness were frequently lower in rehabilitated compared to undisturbed areas, even more so when only native species were considered. Amongst all criteria used to measure success, recovery of the pre-mining fauna community composition was the hardest to achieve. Introduced species were often found in rehabilitated areas but further research is needed to determine the duration of this association. Meta-analyses of the factors influencing mining rehabilitation success for fauna revealed that fauna groups recolonized heterogeneously. Recolonization was dependent on the methods used to rehabilitate and the number of years since rehabilitation. Notably, methods combining the use of fresh topsoil with the addition of seeds and seedlings were most successful for fauna recolonization, both in term of fauna density and richness.

Limitations to this review included strong biases toward certain mining companies, as well as missing data, which decreased the power of meta-analysis. Available publications did not evenly represent all fauna taxa and studies were short when compared to the time needed to re-construct whole ecosystems. We consider the development of comprehensive fauna standards for assessing rehabilitation success critical. This could be the next challenge in restoration ecology.

Contents

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1. Introduction

With the growing demands of an ever-increasing human population, all ecosystems on the planet are now under anthropogenic pressures (Vitousek et al., 1997). Habitat degradation, driven by land clearing for agriculture, urbanization, logging and mining, is recognized as a leading cause of biodiversity loss worldwide (Dobson et al., 1997). As a result, restoration of degraded land has become a priority for conservation (MacMahon and Holl, 2001). In this review, we outline some of the successes and short-comings of habitat rehabilitation (sensu Hobbs, 1998, see also: Cairns and Heckman, 1996; Davis, 2000; Hobbs and Norton, 1996) in the context of mining. Mining provides an ideal environment to study habitat rehabilitation, as one of its by product is bare land that needs to be rehabilitated before the end of mine life, i.e., mine closure.

While mining may not have the largest physical footprint in comparison to other anthropogenic disturbances (<0.1% in Australia for instance, Bell, 2001; Hobbs and Hopkins, 1990), it is recognized to have a significant and growing environmental impact (IUCN and ICMM, 2004; Sutherland et al., 2011; Walker and Willig, 1999). The number of mine closures around the world is expected to substantially increase in the near future (World Bank and the International Finance Corporation, 2002). It is thus worrying that the vast majority of mining countries lack appropriate legislative and policy frameworks in regards to mine closure (Clark and Cook-Clark, 2005). Exceptions include North America and Australia where a heavy legacy of abandoned mines has resulted in mine closure being closely regulated (World Bank and the International Finance Corporation, 2002). These countries will therefore be at the fore-front of setting worldwide standards of environmentally and socially appropriate procedures for mine closure.

A critical part of mine closure is ensuring that mined sites are rehabilitated in accordance with public interest (Wilson, 1999). To assess the success of mining rehabilitation, it is therefore important to establish performance standards and monitor the progress of rehabilitated habitats against such standards (Smyth and Dearden, 1998). To date, the measures of physical factors (e.g., water quality, land topography) and flora (e.g., plant density, richness) are most commonly the basis of monitoring standards. Fauna, on the other hand, is infrequently monitored (Smyth and Dearden, 1998) because animals are assumed to return following the re-establishment of flora (Block et al., 2001; Thompson and Thompson, 2004). Few empirical studies have, however, demonstrated that restoring flora leads to restoring fauna (as noticed in Bisevac and Majer (1999b), Clewell and Rieger (1997) and Majer (1990)). This remains an important gap in research on habitat restoration, as fauna return is essential in more than one way. Not only is fauna an integral component of an ecosystem, but it also plays a key role in many processes that would enhance restoration success. These include nutrient cycling, soil aeration and structure, plant composition and productivity, pollination, dispersion of seeds and spores or control of insect pests (Frouz et al., 2006; Majer, 1989; Nichols and Nichols, 2003; Topp et al., 2001).

Here, we review the current state of knowledge in fauna recolonization of rehabilitated mine sites. We used the Australian continent as an example of what mining companies can hope to achieve in a context where legislative and social frameworks are promoting good environmental practices. Australia is recognized as a worldwide leader in managing mine closure (for instance, see the work on mining certification in Rae and Rouse (2001)). Australia also has a booming mining industry, thus the interactions between fauna and mining rehabilitation are of growing importance for fauna conservation at a continental scale. We aimed to extract information on how successful rehabilitation is in regards to fauna and to identify predictors of rehabilitation success. We also highlight potential limitations of fauna research and future directions worth investigating. We conclude by underlining the importance of developing a relevant assessment of fauna success in mining rehabilitation. This is applicable to all restoration projects and is becoming a crucial part of our conservation effort.

2. Methods

We undertook a detailed search of peer-reviewed literature relating to fauna recolonization after mining activities. We used every combination of "fauna", "animal" OR "recolonization" AND "mine", "mining", "rehabilitation", "restoration" OR "mining disturbance" as search terms in ISI World of Science and Google scholar (last searched in March 2011), then subsequent reference lists, as well as author bibliographies. We kept only publications with study sites in Australia and rejected one publication on the basis that no rehabilitation was performed at the study site (Fletcher, 1987) and three that were focusing on the interaction between mining rehabilitation and an unrelated industrial pollution (Letnic and Fox, 1997a,b; Madden and Fox, 1997). We kept all other references: 71 publications in total, consisting of 39 journal articles, 13 proceedings of conferences and workshops, 10 published bulletins and government reports and 9 book chapters (Appendix A).

First, we summarized the general characteristics of each publication (e.g., type of mines used as study site, taxa studied) and the criteria used by these publications to measure how successful mining rehabilitation was in regards to fauna. Secondly, we described the level of rehabilitation success as assessed by each fauna criterion.

Thirdly, we identified the most frequent predictors of rehabilitation success for fauna. Many publications assessed fauna criteria at the scale of rehabilitation blocks of given age or methodology. This allowed them to compare the influences of different predictors on rehabilitation blocks and we present a summary of these results. A smaller number of publications also gave details of success in fauna criteria at the plot level. This enabled us to further investigate the success of each plot as a function of the predictors (i.e., explanatory variables) identified in the first step (at the rehabilitation block level). Density and richness were used as response variables for measuring fauna success because they were the only success criteria presented frequently enough to be studied with precision. The following five explanatory variables were available: two quantitative variables: (1) time since rehabilitation (in years) and (2) rainfall at the study site, and three qualitative variables: (3) method of rehabilitation [0: no rehabilitation performed, 1: topsoil only, 2: topsoil and plantation (plantation refers to the addition of one type of plant, usually for stabilization purpose), 3: topsoil and mixed seeds, 4: topsoil, mixed seeds and seedlings], (4) quality of the topsoil (0: stockpiled, 1: fresh) and (5) taxa concerned by the study (taxa1 = Formicidae, taxa2 = invertebrates, taxa3 = Coleoptera, taxa4 = *Orthoptera caelifera*, taxa5 = Termitoidae, taxa6 = Aves, taxa7 = Mammalia, taxa8 = invasive species, taxa9 = Collembola, taxa10 = Amphibia, taxa11 = Reptilia, taxa12 = Arachnida, taxa13 = Crustacea, taxa14 = Chilopoda).