Mining and biodiversity: are they compatible?

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Abstract

The growth and success of the Western Australian mining, oil and gas industries has brought massive financial benefits to the state, and to the nation as a whole. But what has been the impact on Australia's biodiversity? Application of the Biodiversity Integrity Index (BII) to five major land uses in Western Australia (namely, agricultural clearing, rangeland grazing, urbanisation, transport corridors and mining) results in a figure that indicates the degree of alienation ('product of loss times area affected') caused by each type of land use. An examination of the extent of this land alienation indicates that mining has by far the least impact (the state being considered as a whole). However, it should be remembered that there are multiplier effects impacting outside the mined area, and that mining also repeatedly targets particular geological formations with their associated ecosystems. This means that impacts are cumulative through time, and points to the fact that certain ecosystems will increasingly be threatened. These factors, and the escalating pace of minesite development, suggest that it is time to ask: what is important to us in Australia?

Introduction

Western Australia (WA) is 'the mining state' of Australia, with its minerals and other natural resources meeting peak demand in recent times, largely due to the emerging strength of the Chinese economy. As an official state government pamphlet explains, WA "is one of the great mineral provinces of the world and hosts an impressive 540 commercial mineral projects with 968 operating mine sites that produce over 50 different minerals. It [mining] is the largest contributor to the WA economy, representing around 30 per cent of Gross State Product and is a key driver of economic growth in Australia. As a result, WA was Australia's largest exporter in 2010/11, contributing 46 per cent ($112.5 billion) to Australia's total Merchandise Exports" (Department of Mines and Petroleum 2012). There is no doubt that this demand has been a bonanza for the Australian economy, but is this happening at the expense of our biodiversity? If this is shown to be the case, we should discuss and possibly re-think our priorities.

This chapter examines the impact of the WA mining, oil and gas industries on Australia's biodiversity. Most members of the public would be concerned to hear if our 'charismatic megafauna' – birds, mammals, reptiles and amphibians – are being adversely impacted by mining. However, any development that threatens a species with extinction, be it a vertebrate, invertebrate, plant or fungus, is regarded as causing significant environmental harm under the WA Environmental Protection Act 1986. Furthermore, if the organism is a listed species, it will prompt special protection under the WA Wildlife Conservation Act 1950, and the matter would be considered of national significance under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. There is also the importance of biodiversity in ecosystem functioning. Without the presence of certain organisms, our ecosystems would not function or could even face collapse (Wilson 1987). There is plenty of scope for mining to inadvertently, or due to misfortune, fail to meet the requirements of these Acts or to interfere with the functioning of our ecosystems. A topical example of this comes from Queensland, where the recent flooding has resulted in the release from mine dumps of toxic minerals and acidic materials into rivers, despite these dumps having been designed to prevent this from happening. How great is the impact of mining likely to be? It has been determined that around 1500 – 2000 square kilometres of land surface have been disturbed by mining and associated infrastructure (Department of Mines and Petroleum personal communication, November 2012). Although this is minute when compared with a total land area of around 2.5 million square kilometres for the entire state (Geoscience Australia 2013), there could be unexpected and unwanted consequences.

Biodiversity integrity

We can quantify the impact of mining by measuring the reduction in biodiversity from a particular land use and multiplying this by the extent of that type of disturbance. Majer and Beeston (1996) developed a biodiversity integrity index (BII) to provide a measure of the intactness or integrity of the original species richness or species composition associated with a particular land use. This can be summed up over a range of regions to obtain overall impact, which can be compared with other land uses. Imagine a hypothetical region divided into four habitat units. Biodiversity is set at unity if it is in a 'pristine' condition, and all habitat units are assigned 100 area units, with no additional weighting being assigned to large regions. Thus, habitat unit 1 is in a pristine state and receives a BII value of 100 x 1 = 100. Habitat unit 2 contains a mine that occupies 10 per cent of the area, and biodiversity has dropped to 0.5 in the mined and subsequently rehabilitated area; the remainder of the habitat is pristine. Thus, BII is (10 x 0.5) + (90 x 1) = 95. Habitat unit 3 is also mined over 10 per cent of its area but has also been cleared for farming over 45 per cent of the area, wherefore its diversity value drops to 0.33. Thus, BII is now (10 x 0.5) + (45 x 0.33) + (45 x 1) = 65. The final habitat unit is totally cleared for farming, so BII drops to (100 x 0.33) = 33. The resulting figures can be used to compare biodiversity loss in different regions and also to assess the contribution of different land uses to the loss of this biodiversity.

Majer and Beeston (1996) used Beard's (1990) 24 WA phytogeographic regions as the habitat units and ascribed 100 area units to each, with no weighting for differing sizes of each region. The major land uses were determined as agricultural clearing, rangeland grazing, urbanization, transport corridors, mining and uncleared. The latter was assumed, albeit simplistically, to be in a pristine state. The proportion of each phytogeographic unit under each land use was determined from various data sources. Ants were selected in order to provide a metric of biodiversity because they have been well studied in WA, and information on the impact of the various land uses on their diversity is available. A problem arose because diversity (when measured as species richness) actually increased above unity in the rangeland grazed areas. This is probably because the original vegetation was still largely intact, thereby supporting much of the original fauna, but had been sufficiently disturbed to allow a number of opportunists and disturbance specialists to enter the area; thus two faunal components existed side-by-side. To resolve the problem of disturbance apparently 'improving' biodiversity, Majer and Beeston (1996) used an additional approach of measuring the degree of change in species composition from the pristine state. This was achieved by the use of multivariate analyses of similarity of species composition between the various land-uses, whereby branching tree-like diagrams were produced which show the affinity of the fauna within each of the different land uses. The length of the branch between the pristine uncleared areas and the respective land use was taken as a measure of the degree of alteration of the faunal assemblage due to that particular land use. The response values obtained by this method suggest a more intense alteration in ant fauna values under all land uses than that suggested by reductions in species richness alone. Using this metric, negative effects of rangeland grazing were also evident.

Figure 13.1 below shows the BII values of each land use on the phytogeographic regions, derived using the change in the ant species composition metric, with decreasing tone representing progressive loss of biodiversity integrity. It clearly shows that loss is greatest in the Wheatbelt region, with additional moderate losses on the Swan Coastal Plain and in the Southern Kimberley. The interior of the state is relatively intact as far as biodiversity integrity is concerned, although reductions can be seen in the mining-intensive regions of the Pilbara (predominantly iron ore) and in the Goldfields (predominantly gold and nickel). Although these values have been derived using ants, the exercise was repeated using reptiles (Bracken 1985) and similar results were obtained. Thus, losses in biodiversity of vertebrates and invertebrates reveal similar trends, and the results probably apply to other components of the biota as well.

The procedure can also be used to provide a statement on the relative impact of different land uses on BII (Figure 1 inset). State-wide, agricultural clearing, followed by rangeland grazing, have the greatest impact on loss of biodiversity integrity, with lower losses due to urbanization and transport corridors and, lastly, mining. Although this puts mining in perspective against other land uses, its impact on biodiversity is nevertheless appreciable, and there are other implications that are explored below.

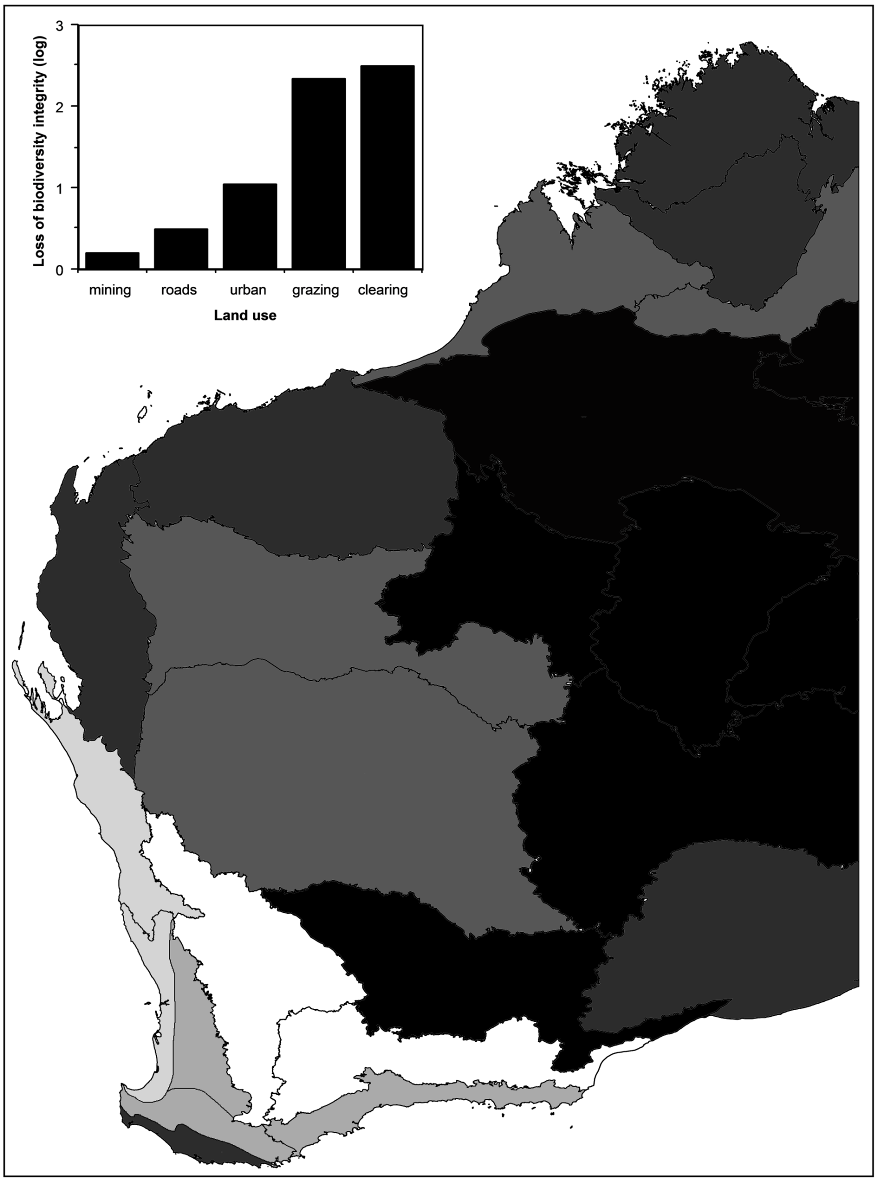

Figure 1. Biodiversity Integrity Index (BII) values in the 24 phytogeographic regions of Western Australia.

Lighter colours signify greater losses of biodiversity integrity, with the greatest loss being in the WA Wheatbelt. Inset shows loss of biodiversity integrity (BII) values across all 24 regions (maximum loss = 24 x 100 BI units = 2,400) as a result of five broad land uses in Western Australia. Source: Based on data in Majer and Beeston (1996).

Ecosystem services

The various components of biodiversity provide essential ecosystem services, the value of which to the environment and to humans can be enormous (Daily 1997). This point can be illustrated by reference to certain groups of invertebrates. Changes in soil fauna, such as ants, termites and beetles, can interfere with soil formation and porosity, reduce water infiltration and possibly cause sheet flooding (Andrés and Mateos 2006). If these groups are eliminated, their loss could also be associated with reduced nutrient cycling (Ward et al. 1991), which may impede plant growth. Changes in the ant fauna could disrupt the important ant-mediated seed dispersal process (Bakker et al. 1996), leading to failures in the next generation of plants. Losses of certain species-specific pollinators, including certain wasps and flies, could similarly interfere with the reproductive processes of plants, possibly leading to a failure of certain plant species to reproduce themselves in rehabilitated areas (Dixon 2009). These are just a few examples of the vital importance of fauna in ecosystem functioning and the ecological services they provide; there are many more. This highlights the fact that it may not just be a matter of considering losses or changes in diversity; there may be unexpected flow-on effects, which may result in unexpected and far-reaching changes in the environment.

Multiplier effects

Additional factors that should also be considered in relation to the resources industries include the multiplier impacts of exploration, haul-roads, general edge-effects and the impact of town sites, infra-structure, and so on. Of course, the land-take of below-ground mining may differ from mining at the surface, but even below-ground mining has substantial space requirements due to the need for spoil and overburden dumps, as well as the usual mining infra-structure. In 1991, Majer and Athanasoff performed a spatial analysis of Alcoa's Jarrahdale mine sites number 1 and 2, both of which are pod-type surface mines, whereby scattered, discrete patches of high level ore are mined. The researchers measured the area mined (both rehabilitated and unrehabilitated) and also the area cleared for haul roads and railways. Taking a one-kilometre boundary around the entire mining area, they found that 37.8 per cent of the area had been mined but, significantly, almost half as much again had been cleared for transport corridors. Furthermore, 59.5 per cent of the forest in the mining envelope was represented by fragments of less than 5 hectares and 74.9 per cent by patches of less than 10 hectares. The existence of forest in such small patches is likely to affect the composition of species occurring there, possibly in detrimental ways (Harris 1984). For instance, movement of small, desiccation-prone animals such as snails and millipedes may be prevented by the surrounding open roads, and the confining of organisms to small fragments of habitat may result in sizes of their population being below the minimum that will guarantee long-term survival (Parker and MacNally 2002). Thus, although the area of a mine can seemingly be quite restricted, the impact of its operation in the region can be diffuse and can change the ecological characteristics and general ambience of the region considerably.

In addition to the physical installations associated with a mine, there are also other implications of the associated workforce being brought into the area. Workers require recreational facilities, and the use of off-road vehicles is common. Anyone who has flown over the Pilbara near mine sites will have seen the criss-crossing of tracks through the mulga and spinifex. This can cause a multitude of environmental impacts, including soil compaction, death of plants and animals and fragmentation of habitat (Webb and Wilshire 1983). As well as this, mine personnel may bring pets such as dogs and cats, which might pose particular problems in newly opened up areas, which have been relatively free of such animals. Both types of pet have the capacity to become feral, and both, but cats in particular, are extremely effective predators of wildlife (Bradshaw et al. 2007). Fortunately, re-strictions or bans are now generally placed on pets and off-road vehicle use in sensitive regions as part of the current environmental approval process; however, the problem persists in older areas where mining takes place.

Impact on specific ecosystems and species

Mining in WA tends to be concentrated in particular regions, most notably the Pilbara, Murchison, Coolgardie, Jarrah Forest and Swan Coastal Plain regions, so it is here that the greatest threat to biodiversity exists. Compounding this, minerals tend to be deposited in or beneath particular geological features, such as banded iron-stone formations, which often support a characteristic flora and fauna. If all of these areas were ultimately to be mined, this could threaten or lead to the loss of entire ecosystems associated with these formations. This may not be so much of a problem in the Pilbara, where such formations are extensive. However, it could be a more serious issue in the Mid-West, where banded ironstones are sparse but conspicuous features in a more subdued landscape, but still a target for mining activity (Gibson et al. 2012). This is of additional concern, since areas of elevated topography may provide a more mild, or buffered climate, and hence act as refugia and safe havens for biodiversity during future changes in climate (Keppel et al. 2011).

In some areas, such as the limestone formations of the Cape Range or the ironstones of the Pilbara, there is a threat to short-range endemics (SREs), for example subterranean fauna living in water or air spaces. According to Harvey (2002), SREs are species whose range is less than 10,000 square kilometres. Eberhard et al. (2007) outline an even more restricted criterion of range that is less than 1,000 square kilometres. Whichever criterion one accepts, it follows that species in such localised areas are particularly vulnerable to extinction if their range is impacted by human development. This would be an unacceptable outcome under the State and Commonwealth Acts mentioned earlier in this chapter.

The presence of a SRE posed an obstacle in 2007 to a proposed iron ore mining site in the Pilbara region of WA. The area concerned contains a series of flat-topped mesas, which represent patches of the original land surface, separated from each other by eroded land surfaces. The company concerned wished to mine banded ironstones in a particular mesa, and was first required by the WA state government to carry out a survey of subterranean fauna. In this case the fauna were present in air filled spaces and, like cave fauna, these are referred to as troglo-fauna. Bore holes were drilled and a range of invertebrates were found, including a spider-like schizomid arachnid that was subsequently described as *Paradraculoides anachoretus* (Harvey et al. 2008). Most mesas in the chain had their own species of schizomid and, unfortunately for the company, *D. anachoretus* was only present on this mesa, the proposed site for mining. In view of the obvious threat to this species, the Environmental Protection Authority recommended against the company's application to mine in this area until evidence could be provided that the schizomid occurred elsewhere or mining could be carried out without threatening the species. This represented a threat to $12 billion of revenue from the proposed mine. The company employed consultants to carry out further surveys and, although the schizomid was not found outside of the mesa, mapping of its distribution in a series of purpose-drilled boreholes enabled a new mining footprint to be designed that would hopefully allow for the survival of a subset of the population. After expenditure well in excess of $1 million, approval was eventually granted to mine this mesa.

Biodiversity and people

Most WA resource-based projects take place in remote parts of the state, areas that attract tourists due to their landscape, biodiversity or wilderness values. The general public tends to judge a landscape in terms of human disturbance and presence of built structures more than the ecological integrity or status of biodiversity, two features which they do not necessarily understand or have the ability to detect (Ergin et al. 2004, Moore and Polley 2007). Therefore, those seeking wilderness- or nature-based experiences react most negatively to human generated disturbance and built structures like buildings, roads, open cut mines and litter. They also tend to react negatively to ordered landscapes – for example where forest blocks of trees are of the same age and/or have been planted in rows as part of certain types of mine site rehabilitation (Hughes 2013). The loss of, or changes in, biodiversity may well reduce the attraction of the area to tourists. However, the overall effect on tourism remains to be quantified, although it cannot be denied that the existence of mining or other resource industries in these areas would detract from the wilderness qualities of such areas, a feature that is of considerable attraction to some visitors and no doubt to the income from national and overseas tourists (see Chap. Nine and Ten).

Cumulative impacts

The impact of mining and associated aspects of resource development present even more cause for concern if we consider the long-term cumulative impacts of certain types of mining. We tend to consider the current extent of mining, all of which has been carried out in the past 250 or so years, and most of which has been carried out only in the past 50 years. When thinking about impacts, we tend not to take into account the fact that the impact of mining will continue to spread, or new areas might be opened up for mining for scores or even hundreds of years. Scaling the area mined in the past 50 years to that which might be mined during the next five centuries makes it clear that, although an impact at the moment may appear quite localised, it could one day affect an entire region.

Amelioration of impacts

All of this assumes that mining and other resource developments irreversibly change the ecological characteristics of an area. As outlined in the response to Majer and Athanasoff's (1991) paper, the mining industry thinks otherwise (Nichols and Slessar 1991), stating that quality rehabilitation can lead to levels of biodiversity comparable with the pre-mining situation. Is this a correct assumption? There are certainly documented instances of fauna diversity in rehabilitation reaching, or even exceeding, levels in the undisturbed vegetation (e.g. Nichols and Nichols 2003). This claim needs to be tempered by the fact that the presence of pioneer or generalist species in the rehabilitation tends to mask losses in species that can only be found in undisturbed areas. Therefore, claims that rehabilitation results in return of the original biodiversity levels can only be validated if species composition, as well as diversity or richness, are taken into account. That said, it must be acknowledged that the standard of some mine site restoration in this state is world-class, as exemplified by Alcoa being listed on the United Nation's Environment Programme Global 500 Roll of Honour in 1990 for its rehabilitation work. Throughout the state, restoration technology is continually improving, with efforts being made to facilitate the return of as much of the biota as possible, often with outside assistance from universities and organisations such as Perth’s Kings Park and Botanic Gardens. However, there are still companies who do the bare minimum or who do not have the expertise to carry out quality restoration. This is particularly the case with smaller companies or those with low-value mineral mines: both situations prevent the employment of teams of environmental staff. Such companies, and the environmental staff or consultants they employ, are also vulnerable to downturns in the economy, such as we saw with the intermittent downturn in the iron-ore price in 2012. The resulting redundancies provide cause for concern that companies may not honour their environmental responsibilities during times of financial stress.

This situation is about to change, as the state government has recently introduced a requirement for proponents of new mine developments to produce mine closure plans prior to commencement of their projects (Department of Mines and Petroleum and Environmental Protection Authority 2011). These plans will require close evaluation before approval, hopefully meaning that only mines that promise to be adequately rehabilitated will be approved. In addition to this, companies are required to outlay bonds, based on the areas mined or disturbed by other means (Department of Mines and Petroleum 2010). These bonds are not returned until certain completion criteria have been met, providing an additional incentive for companies to rehabilitate to the required standard. Whether this proves to be an effective measure for ensuring effective restoration is too early to say.

Completion criteria are metrics for assessing the end product of rehabilitation (Mills et al. 1992) and are defined as rehabilitation performance objectives (Tacey and Treloar 1994). In WA, completion criteria are not formally nominated, but appear in various conditions of project approval under three classes of controlling acts, namely: the Environmental Protection Act - 1986; the Mining Act 1978 and various agreement acts which pertain to the project being developed (Mills et al. 1992). Because of the wide range of possible final land uses and of variation in soil conditions and climate, there are no general standards for creating such performance objectives (Waggitt and McQuade 1994). The performance indicators, therefore, are site-specific, and include physical and biological factors, as well as water quality and safety measures. Such indicators should allow government and other agencies, as well as mining companies, to evaluate the quality of rehabilitation techniques employed. They also allow an evaluation of the success of the rehabilitation in reaching a self-sustaining ecosystem that is suitable for the agreed final land use, hopefully with conservation of biodiversity in mind. To assist with this process, the Environmental Protection Authority has produced a draft guidance statement on rehabilitation of terrestrial ecosystems (Environmental Protection Authority 2006).

Conclusions

On the face of it, the Biodiversity Integrity Index values portray mining as a relatively benign land use when matched up against other uses such as agriculture. However, Australia has the seventh highest per capita ecological footprint of any country in the world (WWF 2000) and the continuation of a vigorous mining industry is an essential cornerstone for sustaining the Australian economy. The impacts of mining are cumulative, despite the extensive and sophisticated measures that are taken to restore the impacted areas. Although high standards of restoration are often achieved, the full range of biodiversity is not necessarily returned and full ecosystem functioning is not necessarily guaranteed. Government initiatives, such as mine closure plans, completion criteria and rehabilitation bonds will contribute to ensuring that the best possible environmental outcomes are achieved, but it is too early to say whether some of the objectives of rehabilitation are achievable or whether these initiatives will be adhered to. For these reasons, we need to intensify our research efforts to understand the impacts of mining and its associated infra-structure on biodiversity and find ways to protect and restore biodiversity in ways that all companies, not just the largest ones, can put into practice. If this is not done, extensive areas of WA could become denuded of much of the biodiversity that gives it its charm and which provides the essential ecosystem services that are vital for its sustainability.

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References

Andrés P, Mateos E (2006) Soil mesofauna responses to post-mining restoration treatments. Applied Soil Ecology 33:67-78
Bakker JP, Poschlod P, Strykstra RJ, Bekker RM, Thompson K (1996) Seed banks and dispersal: Important topics in restoration ecology. Acta Botanica Neerlandica 45:461-490
Beard JS (1990) Plant life of Western Australia. Kangaroo Press, Perth
Bracken D (1985) An evaluation of the biodiversity integrity index using reptiles as an indicator. Graduate Diploma in Natural Resources Thesis, Curtin University of Technology, Perth
Bradshaw CJA, Field IC, Bowman DMJS, Haynes C, Brook BW (2007) Current and future threats from non-indigenous animal species in northern Australia: a spotlight on World Heritage Area Kakadu National Park. Wildlife Research 34:419-436
Daly GC (ed) (1997) Nature's services: Societal dependence on natural ecosystems. Island Press, Washington, DC
Department of Mines and Petroleum (2010) DMP bond policy. Government of Western Australia, Perth
Department of Mines and Petroleum (2012) Fact sheet: Western Australia's resource industry. Government of Western Australia, Perth
Department of Mines and Petroleum and Environmental Protection Authority (2011) Guidelines for preparing mine closure plans. Government of Western Australia, Perth
Dixon K (2009) Pollination and restoration. Science 325 (5940):571-573
Eberhard S M, Halse SA, Williams MR, Scanlon MD, Cocking JS, Barron HJ (2007) Exploring the relationship between sampling efficiency and short range endemism for groundwater fauna in the Pilbara region, Western Australia. Freshwater Biology 54:885-901
Environmental Protection Authority (2006) Guidance for the assessment of environmental factors. Draft guidance statement No. 6. Rehabilitation of terrestrial ecosystems. Government of Western Australia, Perth
Ergin A, Karaesmen E, Micallef A, Williams T (2004) A new methodology for evaluating coastal scenery: fuzzy logic systems. Area 36:367-386
Geoscience Australia (2013) Area of Australia - states and territories http://www.ga.gov.au. Accessed 5 June 2013

Gibson N, Meissner R, Markey AS, Thompson WA (2012) Patterns of plant diversity in ironstone ranges in arid south western Australia. Journal of Arid Environments 77:25-31
Harris LD (1984) The fragmented forest. University of Chicago Press, New York
Harvey MS (2002) Short-range endemism among Australian fauna: some examples from non-marine environments. Invertebrate Systematics 16:555–570
Harvey MS, Berry O, Edward KL, Humphreys G (2008) Molecular and morphological systematics of hypogean schizomids (Schizomida: Hubbardiidae) in semiarid Australia. Invertebrate Systematics 22:167-194
Hughes M (2013). Ecotourists and views of nature. In Ballentyne R, Packer J (eds) International handbook on ecotourism. Edward Elgar, UK, pp 108-116
Keppel G, Van Niel KP, Wardell-Johnson GW, Yates CJ, Byrne M, Mucina L, Schut AGT, Hopper SD, Franklin SE (2011) Refugia: identifying and understanding safe havens for biodiversity under climate change. Global Ecology and Biogeography 21:393-404
Majer JD, Athanasoff M (1991) The impact of bauxite mining and other land-uses on fragmentation of the jarrah forest. Land and Water Research News 10:3-6
Majer JD, Beeston G (1996) Biodiversity integrity index: an illustration using ants in Western Australia. Conservation Biology 10:65-73
Mills C, Chandler R, Caporn N (1992) Completion criteria. Proceedings of Conference on Management and Rehabilitation of Mined Lands. Curtin University of Technology, Perth
Moore S, Polley A (2007) Defining indicators and standards for tourism impacts in protected areas: Cape Range National Park, Australia. Environmental Management 39:291-300
Nichols OG, Nichols FM (2003) Long-term trends in fauna recolonization after bauxite mining in the jarrah forest of southwestern Australia. Restoration Ecology 11:261-272
Nichols OG, Slessar G (1991) Alcoa's response to article by J. Majer and M. Athanasoff. Land and Water Research News 10:6-7
Parker M, MacNally R (2002) Habitat loss and the habitat fragmentation threshold: an experimental evaluation of impacts on richness and total abundances using grassland invertebrates. Biological Conservation 105: 217-229
Tacey W, Treloar J (1994) What do we want completion criteria to achieve? Proceedings of the 19th Australian Mining Industry Council Environmental Workshop. AMIC, Canberra, pp 246-256
Waggitt OW, McQuade CV (1994) Mine close-out criteria - present guidelines and future trends in Australia. Proceedings of the AusIMM Annual Conference. Darwin, pp 407-410
Ward SC, Majer JD, O'Connell AM (1991) Decomposition of eucalypt litter on rehabilitated bauxite mines. Australian Journal of Ecology 16:251-257
Webb RH, Wilshire HG (1983) Environmental effects of off-road vehicles. impacts and management in arid regions. CABI, Wallingford
Wilson EO (1987) The little things that run the world (the importance and conservation of invertebrates). Conservation Biology 1:344-346
World Wide Fund for Nature (WWF) (2000) Ecological footprint by country. Living Planet Report. Switzerland, Gland