BEYOND SREs: INVERTEBRATES HAVE THEIR PLACE IN ENVIRONMENTAL ASSESSMENT AND MANAGEMENT

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Western Australia (WA) can probably pride itself as the only state in Australia where invertebrates are specifically addressed in environmental impact assessment (EIA) studies through the consideration given to terrestrial short-range endemics (SREs) (EPA 2016c) and subterranean fauna (stygofauna and troglofauna) (EPA 2016a, d). Queensland also has a high-level guidance documents on stygofauna, but refers to WA guidelines for methodology (DSITIA 2014). The concentration on invertebrate SREs, both terrestrial and subterranean, is based on their vulnerability to extinction due to their often relative inability to disperse as a result of specific habitat preferences, and to their tendency to be genetically isolated and of very limited distribution.

Fauna surveys, including those focusing on invertebrates, are mainly conducted pre-disturbance to inform the EIA process, consistent with the Western Australian Environmental Protection Authority's (EPA) objective to protect terrestrial fauna so that biological diversity and ecological integrity are maintained (EPA 2016b). These surveys largely concentrate on conservation-significant species, particularly those listed at both State and Federal level. In some instances, ministerial conditions may dictate for the monitoring of conservation-significant fauna populations during construction and operation of a proposed development, generally to assess if disturbances exceed those identified and accepted during the EIA process. Exceeding pre-determined values of population decline generally triggers a management response.

Fauna surveys currently do not form part of compliance monitoring during rehabilitation, which concentrates on completion criteria identified for flora and vegetation and, to a decreasing amount, on Ecosystem Function Analysis (EFA) with its core element Landscape Function Analysis (LFA). The almost complete lack of consideration of the fauna in the rehabilitation of mine sites is perplexing, since regulatory documents, in particular EPA Guidance Statement 6 (EPA 2006), provides ample provision to do so. Whilst the primary concern of rehabilitation is the management of biodiversity, especially terrestrial vascular plants, it also concerns the re-establishment of habitats for animals, fungi and microorganisms. The EPA therefore realised the importance of flora and vegetation as matrix for other organisms. We believe that, completion criteria for fauna diversity should be included and that these should be based on the diversity of indicative groups of animal species such as birds, herptiles, mammals and certain invertebrate groups, especially for extensive rehabilitation projects. Long-term monitoring of animal diversity is also an important research objective. Monitoring of faunal diversity requires accurate pre-disturbance species lists, as recommended in EPA's Technical Guidance: Terrestrial Fauna Surveys (EPA 2016e).

The Western Australian Department of Mines and Petroleum (DMP) guidelines for mine closure plans (DMP 2015) also specifically refer to fauna in rehabilitation, i.e. that rehabilitated areas provide appropriate habitat for fauna. Fauna utilization, abundance and diversity should be present in appropriate proportions given the specified post-mining land use. However, our information indicates that surveys of the use of rehabilitated

areas by fauna are generally not being conducted and therefore the success of closure objectives remain largely untested.

There is ample evidence that sites fulfilling completion criteria based on flora and vegetation values are not necessarily used by fauna. One of the most striking studies, which was conducted on North Stradbroke Island (Queensland), showed that that rehabilitation success based on flora criteria did not correlate with presence of Koalas (*Phascolarctos cinereus*) (Cristescu et al. 2013).

At a world-wide scale, completion criteria for rehabilitation are largely based on flora and vegetation, but invertebrate species diversity is used in about a third of the cases studied (EPA 2006), despite the fact that some groups have been shown to be excellent indicators of environmental condition (Majer et al. 2007). This is inconsistent with the important part that invertebrates play in terrestrial ecosystems and the fact that they comprise 99% of all animal species (Ponder & Lunney 1999).

A comprehensive survey for terrestrial SREs in Western Australia often incorporates wet pitfall traps as a survey component, in particular in regions with poorly documented invertebrate fauna. This survey method is well established and its usefulness for documenting ground-dwelling invertebrates recognized and has been widely applied in regional surveys of the WA Department of Parks and Wildlife (DPaW) and the WA Museum (WAM), such as the Avon Wheatbelt ('Salinity Action Plan'), and the Pilbara, Carnarvon, and Goldfields surveys. Within the WA EIA framework, data analyses of wet pitfall trap catches concentrate on the few SRE target groups, in particular mygalomorph spiders, pseudoscorpions, scorpions, harvestmen, millipedes and sometimes slaters. The reminder of the by-catch, including other prolific epigean invertebrate groups such as ants, beetles, cockroaches, grasshoppers and crickets invariably end up in the bin. The appropriate identification and curation of these groups to WA Museum standards (http://www.museum.wa.gov.au/consultation/home) can currently not be competitively costed. Furthermore, DPaW Regulation 17 collecting permits, required for collection of fauna in WA, generally do not stipulate lodging all specimens with the WAM.

One has to repeat this to appreciate it: We are collecting a perfect snapshot of the epigean (above ground) invertebrate fauna as part of an environmental assessment process pre-disturbance, picking out a few specimens presumed rare (many of these target animals are not...) and then throwing away the bulk of the specimens that would provide the perfect benchmark to assess faunal rehabilitation success post-mining! In addition, we lose biodiversity information for often poorly collected areas of the State. As an example, a recent pitfall trap study in the Great Victoria Desert targeting mygalomorph spiders detected a total of nine spider species within the target group of trapdoor spiders (Mygalomorphae), but 62 other species of spiders, only 11 of which scientifically described. Therefore, most of these species were new to science, have potentially never been collected before due to the remoteness of the study area, but would never see the petri-dish under the microscope of a taxonomist for formal description if treated with current practice.

The focus on SREs and subterranean fauna is important because they are vulnerable to extinction as a result of coincident and unplanned development; our State and Commonwealth legislation is designed to prevent this from happening. What puzzles us, however, is the widespread tendency to overlook the remaining invertebrates of the area when environmental surveys are carried out. Troglofauna surveys in WA, on average, yield less than one specimen and only between 0.1 an 0.25 species per sample, although species accumulation curves rarely approach an asymptote (Halse & Pearson 2014). By comparison, approximately 1,000–2,000 invertebrate species occur in the soil and litter and on the vegetation of the corresponding area anywhere throughout the State (see for example Majer et al. 2002).

The developments that we see in this State, most conspicuously agriculture and mining, have an enormous capacity to destroy or change invertebrate communities, with unpredictable consequences. Since invertebrate herbivores, seed dispersers and pollinators can have profound influences on plant species composition, they can have a pivotal role in rehabilitation outcomes. Industrial infra-structure can be damaged by insects attracted to lights or attacking wooden structures. Accidental introduction of new species, such as invasive ants, can alter the entire ecology of a region. Whilst compliance conditions in remote areas often include the control of weeds, no such requirements exist for invasive invertebrates. These are just a few examples of problems that can arise if invertebrates are not considered, although surveys of certain groups, such as ants, spiders, beetles or sucking bugs can provide an excellent bioindication of the 'condition' of the environment or how well different rehabilitation options are performing (Majer et al. 2007). So why are we generally ignoring them?

Rhytidoponera ant, an important agent in seed dispersal. Ants can be considered the indicator 'champions' within terrestrial invertebrates in Australia, with many studies showing a change of ant communities with habitat modification and/or regeneration (e.g., Majer et al. 2007) (photo by Rebecca Graham)

One underlying reason is the lack of appreciation of the ecological importance of invertebrates – 'they are so small and inconspicuous that they probably don't matter' – despite an abundance of keystone species within the invertebrate fauna. Another common reason that is advanced is that we don't know how to sample and measure them. This is unjustified, since various sampling protocols have been designed, often so that the relative novice can use them (e.g., Allen 1989). Another frequent comment is that there are so many species that consideration of them is overwhelming. This can be overcome by focusing on certain taxa, such as the bioindicator groups already mentioned. Also, there is the possibility of considering invertebrates at the level of functional group. Another excuse for not considering invertebrates that is often heard is the cost that is likely to be involved. While we do not deny that invertebrate surveys can be relatively expensive, they need cost no more than a typical subterranean fauna survey and the yield of useful information is many-fold greater.

Many of the methodological uncertainties could be addressed in a technical guidance document for terrestrial invertebrates. This could detail specific methods for invertebrate surveys dependent on the objective (i.e. rehabilitation monitoring, including pre-disturbance surveys, or more specific methods for targeted surveys for conservation-significant species or SREs). It is clear that without the establishment of a regulatory framework, terrestrial invertebrate surveys will not happen. Incidentally, comprehensive invertebrate surveys are generally part of limnic or lotic aquatic systems, although similarly, an appropriate technical guidance by regulators for such surveys does not exist (but see DoW, 2009).

Lycosa australicola, a common semi-arid zone wolf spider. Wolf spiders are abundant ground-dwelling predators and have been shown to positively correlate with salinity in the Western Australian Wheatbelt (McKenzie et al. 2003) (photo: V.W. Framenau)

There are some encouraging trends emerging. Papers that consider terrestrial invertebrates are steadily increasing in applied scientific journals, such as *Restoration Ecology* (Majer 2009). There are a number of high-profile examples in Western Australia where invertebrates have been considered to the advantage of the development concerned. Examples include Alcoa of Australia, who committed themselves to long-term vertebrate and invertebrate monitoring as a result of the 1978 Wagerup Environmental Review and Management process (Gardner & Bell 2007), and Chevron Australia, who were obliged to monitor flora and fauna, both vertebrates and invertebrates, to ensure that they could detect whether any species have been introduced during the Gorgon Gas Project on Barrow Island (Gunawardene et al. 2013). These are both cases where surveys have been conducted as a result of ministerial directives. There are cases where companies have voluntarily conducted invertebrate surveys, such as the flora and fauna studies for the Worsley bauxite mine (Worsley 1985) and also for the Boddington gold mine (Worsley 1999). However, there are dangers of inconsistencies in the approaches that are taken, dangers of money-wasting 'rediscovering the wheel' when designing surveys, and losses of opportunity to compare data between developments if comparable techniques are not adhered to. All of this could be avoided if the EPA would commission a suitable, well-informed technical guidance on the consideration and sampling of terrestrial invertebrates.

As initial step, appropriate fauna groups, both vertebrate and invertebrate, need to be monitored in rehabilitation, driven by appropriate interpretation of regulatory requirements, which clearly addressing fauna values of rehabilitated sites (DMP 2015; EPA 2006). Secondly, the choice of faunal indicators should be elucidated, which is dependent on location, logistics, and efficiency (money). We argue, based on long-term research, that several invertebrate groups fulfill the necessary criteria in WA.

We hope that this contribution will stimulate readers to appreciate the importance of including terrestrial invertebrates in environmental assessment and management procedures, giving them equal consideration to that afforded to plants, vertebrates and subterranean fauna. As the famous sociobiologist, Ed (E.O.) Wilson (1987) has said, invertebrates are 'the little things that run the world'. This is a delicate way of saying that our world, as we know it, would cease to exist if it were not for the function of invertebrates. The majority of our crops would not be pollinated, leading to widespread famine, dead vegetation and animal waste would not decompose so rapidly, leading to a build up of semi-decayed material, and many of our vertebrate animals would not survive without an adequate supply of invertebrate food. Just as importantly, inclusion of invertebrates in the environmental appraisal and management processes would lead to better-informed decisions and more effective outcomes. As a stimulus to this, the WA EPA, and similar organizations throughout Australia and New Zealand, should give priority to developing guidance documents for surveying terrestrial invertebrates, using a format that is consistent with guidelines that have already been produced for other components of the biota. We also urge proponents of major projects, and the environmental consultants that work for them, to take our message onboard and routinely incorporate terrestrial invertebrates into their assessments.

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