Grassland Invertebrates of the Western Victorian Basalt Plains: Plant Crunchers or Forgotten Lunches?

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Native grasslands and invertebrates both share one common factor: a low public profile and lack of public awareness. There is now a realisation that the Victorian western basalt plains grasslands have been drastically altered, but one of the major ecological components — the invertebrates — has been totally overlooked. Some of the issues regarding the public perception of invertebrates are discussed as well as the practical issues involved in working with invertebrates. The meagre amount of information on Victorian grassland invertebrates is discussed, as well as current projects. The future requirements for invertebrate research, grassland management, and public education on the value of grassland invertebrates are outlined in a strategy that involves maintenance of a Victorian western basalt plains grasslands invertebrates reference voucher collection, database, and the eventual preparation of a user-friendly field guide.

1. Introduction

Most of the people interested in conservation have some experience in the identification of plants and vertebrate animals. Botanists and zoologists would be used to undertaking field work where a large proportion of the species that are observed or collected can be identified in the field — either through personal expertise or through the use of field guides — and those that cannot be identified with certainty can be brought back to herbaria or museums for checking. New distributional records are often made, and the discovery of an undescribed species is a major event. For vertebrates and vascular plants, complete species identifications and site inventories are achievable.

With this background in scientific methodology, many people are taken aback with the replies they receive when they ask invertebrate zoologists for a species identification or information on what species occur at a particular site. If the questioners are lucky, they may get an immediate species identification. More often they will get an identification after the specimen has been keyed out in the laboratory or compared with some reference collection. However, they are often surprised when they are told that the specimen can only be identified to the order, family level, or else that no identification beyond order is possible because the specimen is immature and that only the taxonomy of adults is known.

With regard to the second question as to what species of invertebrates are found at a particular site, the answer is generally, “We don’t know.”

Why bother about invertebrates?

Invertebrates are seldom considered as animals in their own right. They are usually considered as a adjunct to botanical or vertebrate studies. The title of this paper reflects the only published information about western Victorian grassland invertebrates that was available until recently. The “plant crunchers” refers to the species of cecid fly found on Kangaroo grass by McDougall (1989), and the “forgotten lunch” refers to the diet analysis of *Delma impar* Fischer by Coulson (1990). The title is not meant to reflect adversely on either McDougall (1989) or Coulson (1990), because without their support, none of the invertebrate work that has recently started would have got under way. It does, however, reflect a greater community attitude towards invertebrates, namely they are important when they attain potential status or are essential for the survival of a species of vertebrate.

The primary reason why it is necessary to consider invertebrates is simply because, in terms of number of species, they dominate faunal species richness on this planet, and their diversity is reflected in the ecological roles they undertake.

There are also secondary, but still important, reasons why invertebrates need consideration. One is the value of invertebrates for environmental education when the general public will see fewer birds, mammals, reptiles and amphibians, especially in habitats that have fewer species of vertebrates such as in the grasslands. Although plants are readily available for environmental education, the use of invertebrates will help to stress the fact that plants and animals are interacting and dependent components of an ecosystem. The use of invertebrates as readily collected “indicator taxa” is also an area of immense potential.

What are invertebrates?

Unfortunately, there is a lack of realisation on the diversity of invertebrates, both in form and function. In fact, some people do not even realise what invertebrates are. Invertebrates are animals without backbones, and in Australia, there are an estimated 275,000–300,000 species in 21 phyla of non-marine invertebrates (of which under 50% have been described) compared to the 2,500 species of non-marine vertebrates, which are found in one sub-phylum (Table 1).

These species of invertebrates are involved in essential ecological functions such as herbivory, decomposition, predation, parasitism, pollination, and numerous other functions such as occupying vital positions in food chains as a food source for vertebrates.

In summary, invertebrates are a major component of all biological systems, and for long term viability of these systems, it is essential that we have an adequate understanding of the components of these systems and how they operate.

The native grasslands and grassy woodlands are the most threatened ecosystems in Victoria (Department of Conservation and Environment, 1992). The following discussion will focus on the grasslands of the Victorian western basalt plains because it is the area in which some recent invertebrate projects have been initiated. The grasslands of the northern and Gippsland plains will not be included, although these latter areas are just as important. The grassy woodlands, with their tree cover, add an extra dimension to the complexity of the ecosystem, and are not included in this discussion.

A discussion on the invertebrates associated with the western Victorian basalt plains grasslands should outline information regarding invertebrates found there, their ecological functions, and information about threatened species. However, as very little information of this sort is available, it would be timely to discuss why this information has not been collected, and what needs to be done to overturn the problem.

2. Why is there so little information about western plains grasslands invertebrates?

The lack of information regarding invertebrates of the Victorian western basalt plains is due to factors inherent with invertebrates themselves, social and cultural factors, and lack of administrative willingness and resources.

2.1 The problem of scale

Invertebrates are generally small in body size relative to vertebrates and vascular plants. Most people are unaware of the existence of the diverse invertebrate fauna found in most habitats, and it is difficult to appreciate and understand something that one is not aware of its existence.

2.2 Lack of knowledge

The amount of information available on Australian non-marine invertebrates is meagre. It is not possible to provide formal scientific names to a large proportion of the fauna. Possibly only half of the Australian species of non-marine invertebrates have been formally named. Others are known in collections and have not yet been described, but many species have probably not yet been collected. However, this is not a reason to ignore invertebrates because sound scientific decisions can still be made if a judicious choice is made as to which invertebrates are studied and if reference voucher specimens are collected and stored in an accessible collection.

There is also a lack of biological information on many species, little distributional information even for well known species such as butterflies (New, 1991), and certainly a lack of information about invertebrate/invertebrate interactions, invertebrate/plant interactions, and invertebrate/vertebrate interactions.

2.3 Preference for cute and cuddly vertebrates

Invertebrates are discriminated against in the popularity stakes because of the preference for cute and cuddly vertebrates, especially birds and mammals. There is even a pecking order; within the vertebrates, fish and reptiles are not as popular as birds and mammals, and among the invertebrates, butterflies are preferred over other groups.

2.4 Bad public image

Undoubtedly, one of the reasons for the unpopularity of invertebrates is the bad public image associated with the small number of venomous, disease-transmitting, and agricultural pest invertebrate species (Yen, in press).

2.5 Preference for more charismatic habitats

A preference for more charismatic habitats focuses attention on the components of those habitats. There is more interest in habitats such as rainforests and old growth forests, both overseas and in Australia, to the detriment of less charismatic habitats. The western Victorian basalt plains certainly fall into the latter category, and there has been little interest in its invertebrate fauna in the past.

2.6 Lack of resources

Flora and fauna conservation is dominated by priorities towards vertebrates and vascular plants. This is reflected in funding priorities, but more importantly, the fact that most of the staff employed in conservation agencies have either a vertebrate or vascular plant background, and very few people with invertebrate (or even non-vascular plant) expertise are employed to use their areas of expertise (Yen & Butcher, 1992).

2.7 Different approach to studying invertebrates

The approach to studying invertebrates is different from that required for studying vertebrates or vascular plants, and few conservation administrators and land managers understand the difference. Most invertebrates are easily collected, and usually less time is required for field work. This is offset by the greater amount of laboratory time required for sorting and identifying specimens. Furthermore, a high proportion of the specimens may be immatures that have no resemblance to the adult stages, and as taxonomy is based primarily on adults, this slows the identification process (Yen *et. al*., 1990). Identification guides do not exist for many groups of invertebrates, and invertebrate zoologists are required to make up their own reference voucher collections, based on morphospecies delineation.

2.8 Lost opportunity

The Victorian western basalt plains grasslands are an example of a habitat that has been nearly destroyed before an opportunity to conduct a baseline inventory of the invertebrate fauna.

3. What information is available about Victorian western basalt plains grassland invertebrates?

By structural definition, grassland habitats are very different from other habitats, but are the associated grassland invertebrates different from those found in other habitats? There is insufficient information to answer this question with any certainty at this stage.

When initial drift-fence pitfall trap samples of ground-dwelling invertebrates from the Derrimut Grassland Reserve were compared with samples from similar traps in Central Victoria and in the Victorian Mallee, there appear to be a lower diversity of invertebrate groups at the ordinal (or higher) level in the grasslands: specimens from 13 orders were collected at Derrimut (Yen, unpublished data), 18 orders were collected in the Central Victorian Mallee (Yen, unpublished data) and 20 orders were collected in the Victorian Mallee (Robertson et al., 1989).

However care has to be taken in interpreting these data because of differences in the nature of the three areas and in methodologies adopted in their study. The Central Victorian and Mallee habitats have tree cover, and in the studies on both these areas, a greater range of habitats were sampled over a longer period, and they involved many more sites over a broader geographical area compared to Derrimut. They do illustrate that the perception that grasslands are “depauperate habitats” and are less diverse than other habitats.

Willis (1964) stated that the basalt plains flora was less species rich than most other Victorian floral associations, and initial invertebrate samples suggested that the invertebrate fauna follows the same trend. In the long term, the number of species is not the major scientific priority, but the degree of dependence of invertebrates to the grasslands is.

The ground-dwelling invertebrates at the ordinal level collected in drift-fence pitfall traps in the summers of 1989 and 1991 at the Derrimut Grassland Reserve are presented in Table 2. It is interesting to note that certain groups, such as slaters (Isopoda), millipedes (Diplopoda), and ants (Hymenoptera), differ considerably in percentage composition between 1989 and 1991, emphasising the importance of long-term monitoring to take account of population fluctuations.

Furthermore, pitfall traps do not sample all invertebrate groups; for example, the noctuid larvae found in the faecal pellets of *Delma impar* were rarely found in pitfall traps (Coulson 1990).

There has not been a systematic survey of the native invertebrates of the Victorian western basalt plains grasslands. Published references to invertebrates have included them as secondary issues or as part of a broader study.

McDougall (1989) refers to an unnamed species of gall midge fly (Cecidomyiidae) that is found on the spikelets of *Themeda*. This species of fly has been found on *Themeda* in Victoria, the ACT, New South Wales and in Tasmania, and it may also be the same species that infests species of *Stipa* in parts of Victoria. Some larvae of the cecid fly are parasitised by an unidentified species of wasp (McDougall, 1989).

There have been two assessments, based on faecal pellet analyses, on the food of the legless lizard *Delma impar* (Coulson, 1990; Wainer, 1992). In faecal pellets collected in the summer of 1989, the items found included the common black field cricket, *Teleogryllus commodus* (Walker) (Orthoptera: Gryllidae) and spiders, but the predominant food were the larvae of a species of noctuid moth (Noctuidae: Lepidoptera) (Coulson, 1990).

In a subsequent study based on faecal pellets collected from late spring 1991 through summer 1992, Wainer (1992) found that most of the invertebrate food items ranged from 10–30 mm in length, and included spiders (Araneae), a cockroach (Blattodea), locusts (Orthoptera: Acrididae), the common black field cricket, an earwig (Dermaptera), an ant (Hymenoptera: Formicidae), and the noctuid moth larvae, as well as some adult moths; the predominant foods were field crickets and noctuid moth larvae. Wainer (1992) suggests that there is some prey selectivity by *Delma impar* in that invertebrates in the preferred size range were collected in pitfall traps and not found in the faecal pellets. These included millipedes (Diplopoda), slaters (Isopoda), slugs (Gastropoda), bugs (Hemiptera), and beetles (Coleoptera).

Some of the invertebrates trapped in the drift fence pitfall traps used to collect *Delmar impar* have been collected and are housed at the Museum of Victoria until funding is available to sort and identify the material to a more refined level.

Horne (1992) studied the comparative biology of *Notonomus* species (Coleoptera: Carabidae); one species, *Notonomus gravis* (Chudoir), is widely distributed across the Victorian western basalt plains grasslands and is a major predator of moth larvae.

Most of the invertebrate work in the Victorian western basalt plains have involved pasture pest species. Schroder (1983) reports 12 species of pasture pests from the Hamilton region, the most common ones include the Red-legged earthmite (*Halotydius destructor*), and black field crickets (*Teleogryllus commodus*).

Although not directly associated with basalt plains grasslands, invertebrate research has been conducted on the aquatic macroinvertebrates in the western wetlands region of Melbourne (Cameron, 1992), where 114 taxa of invertebrates were identified. Crosby (1990) reported on the Altona Skipper Butterfly. *Hesperilla flavescens flavescens* Waterhouse, which is found on *Gahnia* associated with swampy areas in western Victoria.

From a conservation perspective, the first question that is asked is how many species are threatened and how many have become extinct. For the western Victorian basalt plains grasslands, the answers are not known. If the record of presumed extinct, endangered, vulnerable, depleted or rare vertebrates and vascular plants in Victorian native grasslands and grassy woodlands is any indication (Department of Conservation and Environment, 1992), then just because there are probably many more species of invertebrates, then the number of species threatened or lost may be very high.

There are 131 rare, threatened or extinct plants in Victorian native grasslands and grassy woodlands, and if they are host plant species with dependent invertebrate herbivores (and associated parasitoids), then these invertebrates may also be categorised in similar categories. In the western plains grasslands, there are 8 species of vertebrates and 29 species of plants that are extinct or at risk (Craigie & Stuwe, 1992).

Information is available about threatened or possibly threatened grassland invertebrate species from outside Victoria. These include the castniid moth *Synemon plana* (Lepidoptera: Castniidae), the morabine grasshopper *Keyacris scurra* (Rehn) (Orthoptera: Eumastocidae) and the wood cricket *Cooraboorama canberrae* (Orthoptera: Gryllacrididae) in the ACT (Driscoll, 1991; Falconer, 1991).

Synemon plana is a day-flying moth, and inhabits native grasslands dominated by *Danthonia carphoides* and *D.auriculata*, along with many other species of moths and butterflies that may also be dependent upon the *Danthonia* grasslands (Edwards, n.d.). The females of *Synemon plana* have reduced wings and have very limited ability to fly and thus to disperse actively to recolonise distant suitable habitat.

Synemon plana was once widespread in Victoria (Bright, Tatong, Eildon, Tallarook, Burrumbeet, Riddell’s Creek, Broadmeadows, Kiata, and near the Grampians), in South Australia, in the ACT and in NSW, but its range has been severely reduced (Edwards, n.d.). It is now only known from eight sites in the ACT and one site in Victoria (Kiata) (Driscoll, 1991). The main threat to *Synemon plana* is conversion of its native grassland habitat to pasture, the destruction of *Danthonia* by fertilisers, altered hydrology regimes, exotic weed invasion, and even replacement by more aggressive native grass species (Edwards, n.d; Falconer, 1991).

4. What is being done and what needs to be done on western plains grassland invertebrates?

4.1 Objectives

The first step in any biological decision making process is to determine what is there, followed by discovering what they do. With regard to the Victorian western plains basalt grasslands, habitat identification on the basis of the flora, has been underway for many years (Willis, 1964; Stuwe & Parsons 1977; Stuwe, 1986), although habitat factors relevant to invertebrates have not been identified. As already mentioned, these grasslands were severely destroyed and fragmented before any baseline inventory of invertebrates was undertaken. This does not negate the need for such an inventory, and in fact places more importance on undertaking such an inventory before further deterioration of grassland habitats to assist development of management plans for remnant grassland habitat.

As management decisions affecting native grasslands need to be decided in the very near future, it would be impractical to attempt to compile a list of all invertebrate species that are found on the Victorian western plains basalt grasslands in a short period of time. The main aim would be to determine priority taxa that can be used as indicators of grassland habitats and that can be used to monitor environmental changes to these habitats.

An inventory involving these selected priority taxa can be used to determine:

1. The composition of the invertebrate fauna in relation to floristics and vegetation structure;
2. Species of grassland-dependent invertebrates;
3. Species of introduced invertebrates; and
4. Rare and threatened invertebrate species.

4.2 Invertebrate information strategy

It is essential that information collected on Victorian western basalt plains grasslands invertebrates is safely stored in for long-term access. A strategy for information gathering and storage that is both collection-based (1–4) and ecologically-based (5–9) is proposed. However, it is important to remember that research on invertebrate ecology ultimately relies on good collections and taxonomy.

1. Check museum collections to determine, if possible, invertebrate species that were collected in Victorian western basalt plains grasslands. This may assist determination of grassland-dependent invertebrates and possibly rare and threatened species.

2. Set up a reference voucher collection of Victorian western basalt plains grasslands invertebrates for ready access.

3. Set up a data-base of Victorian western basalt plains grasslands invertebrates that can be used to assist management decisions.

4. Prepare preliminary identification guides of Victorian western basalt plains grasslands invertebrates, using the reference voucher collection, with the eventual preparation of a user-friendly field guide to macro-invertebrates of the Victorian western basalt plains grasslands.

5. Adopt similar standard collecting techniques for use in grassland invertebrate assessments. Encourage other researchers in grasslands to adopt the same collecting regimes so that results will be comparable. Entomologists at the Plant Research Institute have adopted similar standard collecting techniques in grassland invertebrate assessments pastures at Horsham to those being used by the Museum of Victoria in their work on native invertebrates.

6. Using information from the database, undertake a multivariate analysis to ascertain the effects of land use on the invertebrates found in Victorian western basalt plains grasslands.

7. Seasonal monitoring of priority invertebrate taxa in selected permanent representative grassland sites to:
   a. Determine seasonality of the fauna;
   b. Determine habitat requirements of selected key invertebrate taxa from the major habitat components: the soil, the litter, the plants, etc.;
   c. Determine phenologies of selected key invertebrate taxa;
   d. Determine population dynamics of selected key invertebrate taxa;
   e. Determine if species assemblages can be used to characterise grasslands
   f. Obtain information on the functioning of the fauna by examining trophic relationships.

8. Determine the relationship between invertebrates and habitat factors such as floristics, grass phe-

nology, soil type, soil moisture, and soil surface characteristics such as cracks, microtopographic features such as rocks, and if relevant, plant litter.

9. Prepare recovery plans for threatened species; genetics; captive breeding

4.3 Management issues and grassland invertebrates

Management of native grasslands involves two main objectives:
1. the control of threatening processes, and
2. management regimes that simulate past natural processes to maintain the grasslands in a natural state for long term survival.

The primary issue is conservation of native grassland habitat as a functioning entity. While recognising that invertebrates are an integral part of this entity, the first consideration should be, in this case, maintenance of the grassland habitat, and management decisions on the plants may take priority over invertebrates. However, some baseline information on invertebrates is necessary, and the monitoring of the fauna to ascertain the effects of the management programmes is required.

Some threatening processes are readily apparent, and the effects are immediate. These include alienation of native grasslands by total vegetation clearance and replacement. With other threatening processes, the effects are more subtle, and it is often difficult to differentiate the effects of each threatening process because each type of land use activity usually involves several inter-related processes. For example, grazing by introduced stock results in soil disturbance, vegetation disturbance, vegetation removal, introduction of exotic weeds, and increased nutrient levels.

The following is a brief resume of the main management issues associated with western Victorian native grasslands with emphasis on invertebrates. Many of the issues overlap.

4.3.1 Alienation of remnant grasslands

Total vegetation clearance will be disastrous for invertebrates, through removal of food plants for dependent herbivores, destruction of habitat, or removal of food sources for predators and parasites. Remnant grasslands are alienated for urban development, or for pasture improvement; the latter will be considered separately.

Urban development will, at worst, result in the total destruction of native grasslands, and at least, result in further fragmentation of an already very much decimated vegetation type and alteration of the floristics. As most grasslands have been fragmented, the effects of the size and shape of remnant patches on the invertebrates is important from two aspects: the long term viability of grassland fragments as habitat for native invertebrate species, and the invasion of remnant patches by invertebrates adjacent to these patches. One aspect that can be looked at simply is the trophic relationships of invertebrates in remnant patches to ascertain whether there has been a reduction of specialist species and an increase of generalist species.

Some species of invertebrates exist as metapopulations. The populations of these species may be locally small and may become locally extinct as a natural part of their ecology. They rely on recolonisation from surrounding populations (Harrison et al., 1988), and habitat reduction and fragmentation reduces the chances of recolonisation because it increases the distances between populations.

Other management issues associated with fragmentation that are very relevant to invertebrates include the edge effect, and whether the fauna at the edges is different from that in the centre of remnant fragments, the use of buffer zones to protect remnant habitat, and the viability of corridors to connect remnant habitat.

4.3.2 Pasture improvement

Alienation of native grasslands by introduction of exotic pasture plants results in immediate loss of invertebrate species that are directly dependent on native grassland plant species as food or as habitat. Some native invertebrates may survive pasture improvement and may adapt so well as to become pasture pests. King et al. (1985) found that fertilised improved pastures (for sheep grazing) had a higher proportion of exotic invertebrates compared to natural pasture. Other factors involved with pasture improvement include soil disturbance and increased nutrient input.

Soil disturbance can be caused by ploughing, ripping and the movement of vehicles or other machinery. The degree to which these practices are conducted will influence the invertebrate fauna. In conventional tillage (ploughing), the soil is inverted and no remnant plant material left on the surface; while minimum tillage (discing) or no tillage leave much of the remnant plant material on the surface and maintain soil structure. The effects on invertebrates vary depending on crop type, geography, but some species of pests increased, some decreased, and there were no effects on the remainder; there was a general increase in soil and litter inhabiting predatory species (Stinner & House, 1990).

Direct application of fertilisers can be detrimental to native flora and encourage exotic flora (Lunt, 1991). They can also result in an increase in the proportion of exotic invertebrates in pastures sown with exotic plants (King et al. 1985).

4.3.3 Grazing by introduced stock

The effects of grazing by domestic stock on flora is outlined by Lunt (1991). *Themeda* grasslands require periodic disturbance of the vegetation (but not of the soil) to prevent smothering of smaller plants by the more vigorous Kangaroo Grass (Lunt, 1991). Grazing and trampling by introduced hard-hoofed animals such as sheep and cattle, results in the removal of plants, the introduction of exotic weeds, damage to both vegetation and soil, and increased nutrient input (through urine, faeces and carcasses) (Craigie & Stuwe, 1992).

From an invertebrate perspective, sheep grazing can alter the microclimate, vegetation, litter and soil structure resulting in a significant reduction in the abundance of litter and topsoil microinvertebrates (King & Hutchinson, 1983). It can destroy the habitat of dependent species, such as trap door spiders, which rely on ground litter cover to provide material for construction of their burrows (Main, 1991).

Native grasslands have historically been grazed by native mammals (Lunt, 1991), but the importance of herbivorous invertebrates as grazers has not been assessed.

Mowing has sometimes been advocated as a management tool to simulate grazing, but it is different from grazing because it adds to the plant litter.

4.3.4 Other factors resulting in soil and vegetation disturbance

Soil and vegetation disturbances caused by vehicular traffic has already been mentioned, but it can also occur with activities associated with recreation, scientific research, and even management such as intensive pedestrian access, rock removal, and maintenance works such as fencing (Craigie & Stuwe, 1992). Trampling (and vehicular traffic) can adversely affect the flora (Lunt, 1991), but the effects on western Victorian native grassland invertebrates are not known.

4.3.5 Altered fire regime

The major management issue is the role of fire. The importance of fire in maintaining floral diversity, by preventing formation of dense swards of *Themeda triandra* and associated build up of plant litter, is outlined by Stuwe and Parsons (1977) and McDougall (1989).

While the effects of fire on plant-dependent invertebrate species, the ground dwelling fauna and the soil-litter fauna are not known, the recolonisation and recovery of burnt areas is also important in relation to the fauna in adjacent areas and the timing of the fire. While fire is such an important ecological factor in Australian environments, most of the work on fire and invertebrates has been associated with forests, and there is no information on fire and invertebrates in native grasslands. Mowing is sometimes advocated as a less favourable alternative to fire (Department of Conservation and Environment, 1992), but it is clearly different from fire because, unless the mowed plant material is removed, it results in a build up of plant litter. The effects of mowing as an alternative to fire on Australian invertebrates are unknown.

However, fire is clearly one of the important management issues, both in terms of maintaining floral diversity and as a possible weapon in the reduction of introduced weeds, and the major issue for invertebrates is their inclusion in experiments on fire frequency and timing.

4.3.6 Weed control

The invasion of native grasslands by exotic weeds is a major threat. It generally occurs after soil disturbance, intensive grazing, or fertiliser use (Craigie & Stuwe, 1992). It can affect invertebrates adversely by elimination of native plant species, habitat alteration, and it may encourage the spread of species of exotic invertebrates.

Weed control can be physical or chemical. The indiscriminate use of herbicides can be detrimental to native flora, although selective application can be an important management option (Lunt, 1991). The effects of control methods on native invertebrates is not known. There may be scope for biological control of the weeds, but this should only be undertaken after thorough testing of the biological control agents on native plant species that they may colonise.

4.3.7 Pest animal control

The control of pest animals, both invertebrate and vertebrate, is an issue that concerns both the remnant grasslands and the areas adjacent to them.

For invertebrates, the definition of “pest” is more controversial. In some cases, such as the Red-legged earthmite (*Halotydius destructor*), the definition is clear cut because the species has been introduced from overseas. In other cases, such as the field cricket *Telegryllus commodus*, native species have become economic pests, and this is more difficult when considered from a conservation aspect.

Drift into adjacent grasslands from the broad scale application of insecticides to control pasture pests would be a major threat to native invertebrates.

As with possible biological control of weeds, any attempts to use biological control for pest invertebrates will require testing on potentially susceptible native species.

While some pasture pests are restricted to pastures, the danger of control, whether chemical or biological, there is the danger of their influence extending beyond the pasture boundaries. This is more important for small, especially narrow linear, remnants.

4.3.8 Restoration

The issues associated with the restoration of grasslands are discussed by Scarlett et al. (1992). In the case of grasslands, the important issue for invertebrates is to create the habitat first; monitoring colonisation by invertebrates and their subsequent succession is important to determine if exotic species are involved. While restoration is a management option, it is more important to conserve and manage the remnants.

One of the dangers to grasslands is tree planting in areas that naturally have few or no trees. If native tree species are planted outside of their natural range, it is likely that associated host specific insects may colonise them.

4.4 Current Victorian grassland invertebrate projects

Since 1989, the Museum of Victoria has been associated with three projects that have involved invertebrates in the Victorian western basalt plains grasslands.

The first project involves participation in the research on the Legless Lizard *Delma impar* conducted by Graham Coulson. Some of the macro-invertebrates trapped in the drift fence pitfall traps have been deposited in the Museum. Although some samples have been sorted to the ordinal level (Table 2), the invertebrate aspect of this project has had no funding, and material will not be identified to the species level unless future resources are found.

More recently, in a project on sites of invertebrate significance in the western region of Melbourne, Beverley Van Praagh has some grassland sites included as part of the project. This work has been funded by the Western Regions Commission, the Australian Heritage Commission, and Melbourne Water, and is due for completion during 1993.

In the largest project conducted on Victorian western basalt plains grasslands invertebrates, Amanda Kobelt and Richard Kay are employed by funds from the Endangered Species Unit of the Australian National Parks and Wildlife Service in a 12 month project. The main aim of this project is to determine whether ranking sites for conservation on the basis of their invertebrates will yield similar results compared to using flora. In a project funded by the Australian Heritage Commission, western Victorian basalt plains grassland sites have been ranked on the basis on the occurrence of rare plant species (McDougall, unpublished data).

The criteria selected for invertebrates in this project cannot be the same as chosen for plants because of the lack of information available for invertebrates. To overcome the lack of knowledge that hinders short-term invertebrates projects, the following standards were adopted:

1. In general, only adult macro-invertebrates are involved. Macro-invertebrates are defined as specimens with a body length of at least 0.5 cm. Besides practical reasons, macro-invertebrates are selected because they are the ones that landowners and managers will be able to identify in the future.

2. Only a subset of known grassland sites are sampled for invertebrates. In this project, 12 sites have been selected from the 40–50 sites available across the western plains on the basis of geography, size, and land use.

3. The project has adapted a set of standard techniques. Three techniques (pitfall trapping, sweeping, and direct searching) were selected on the basis of simplicity, replicability, and effectiveness. A fourth technique (suction trapping) has only been included because it is an effective method to detect one of the exotic invertebrates, the Red-legged earth mite.

To establish a conservation ranking, the following criteria were applied:

1. Species richness of selected macro-invertebrate groups including beetles (Coleoptera), grasshoppers and crickets (Orthoptera), and ants (Hymenoptera);
2. A preliminary assessment of rarity based upon the number of sites at which each species is found; and
3. The number of exotic invertebrate species.

Other outcomes of the project include:

1. Classification of invertebrates to find characteristic species assemblages of grassland communities;

2. Establishment of a grassland invertebrates reference voucher collection so that invertebrates from other grassland sites can be identified;
3. Establishment of a database of grassland invertebrates; and
4. Material upon which to base preparation of a popular field guide to grassland invertebrates.

The project began in mid 1992. At this stage, preliminary results are only available for the first half of the project, and the invertebrates collected are presented at the ordinal level (Table 3). There are two interesting results:

1. The effect of collecting techniques in collecting efficiency; and
2. The greater diversity of invertebrates orders in grasslands that originally thought when compared to results based purely on drift-fence pitfall traps at Derrimut Grassland Reserve (Table 2).

There are major differences in the number of invertebrate orders and the composition of the orders collected by each of the four collecting techniques adopted (Table 3). Sweeping is the least effective method in that only 9 orders were collected, with spiders (Araneae) and flies (Diptera) dominating the catch. The suction trap collected representatives from 14 orders, with spiders, mites (Acarina), springtails (Collembola), bugs (Hemiptera), beetles (Coleoptera), flies, moth larvae (Lepidoptera), and wasps and ants (Hymenoptera) dominating the catch. Both these techniques are effective in collecting invertebrates found on plants and flying insects.

Pitfall trapping is effective in collecting ground-dwelling invertebrates, including spiders, mites, millipedes (Julida), springtails, crickets and grasshoppers (Orthoptera), beetles, flies, wasps and ants. Direct searching is the most effective technique, yielding 26 orders, with spiders, slaters (Isopoda), centipedes (Scolopendrida), beetles, and ants dominating the catch.

The four collecting techniques produced a total of 29 invertebrate orders, which is over double the number collected in the drift-fence pitfall traps collected at the Derrimut Grassland Reserve (Table 2).

In terms of species richness, results from autumn and winter samples reveal 42 species of beetles (including 16 species of carabid beetles), 9 species of crickets and grasshoppers, 28 species of ants, and spiders from 15 families.

While these results are preliminary, they indicate that the Victorian western basalt plains grasslands invertebrate is richer and more diverse than previous impressions.

4.5 Future value of grasslands

Native grasslands have many important values that include scientific, economic, and educational. As most of the western plains grasslands exist as small remnants, information obtained from the conservation and management of these remnants will be applicable to many other threatened and fragmented ecosystems.

The grassland invertebrates will also be important. Research is required to determine the value of remnant grasslands as reservoirs of native biological control agents. For example, studies in the United Kingdom indicate that carabid beetle predators of a pest weevil of field beans (*Sitona lineatus*) are capable of reducing populations of the weevils by more than 30% (Hamon et al. 1990). Further, motorway verges have the potential to act as reservoir habitat for beneficial insects such as pollinators and predators (Free et al., 1975).

The widespread notion that most invertebrates are pests needs to be countered. Unfortunately, information on the number of pest species in relation to the number of beneficial species is sparse in the scientific literature. Although not related to the native Western Victorian basalt plains grasslands, a study on insecticide-free potato crops in south-east Queensland found 28 species of potato feeding invertebrates and 204 species of beneficial invertebrates (Cantrell et al. 1983).

An education programme on grasslands and their associated invertebrates is possibly the major exercise in conservation, but with invertebrates, a minimum level of knowledge is required before such a programme can be effectively mounted.

Invertebrates are important in education because:

1. In some grassland remnants, they may represent the main, and most obvious, faunal element;

2. Their diversity and abundance lend themselves as ideal indicators of biological diversity;

3. They can, once field guides are available for the common macro-invertebrates, be readily used by landowners, land managers, and amateurs to obtain more information on distribution;

4. Their diversity and abundance lend themselves as ideal educational tools at the local level; and

5. Their value in schemes such as Land for Wildlife, as already underway with the Giant Gippsland Earthworm (Van Praagh, 1991).

If this is to happen, the following will be required in the immediate future:

1. Completion of the survey of Victorian western basalt plains grasslands invertebrates already initiated;
2. Maintenance of the Victorian western basalt plains grasslands invertebrates reference voucher collection and database;
3. Preparation of a simple field guide to common, interesting, and threatened macro-invertebrates of the Victorian western basalt plains grasslands; and
4. Development of an invertebrate awareness campaign.

5. Conclusion

All of this needs additional resources. There is no doubt that relative to vertebrate and vascular plant research, invertebrate research is very under-resourced. One of the mythical fears that many botanists, zoologists and administrators hold is that resourcing for invertebrates needs to be on a similar per species level as applied to vertebrates and vascular plants. This is clearly impractical, and it must not be used as a reason for not adequately funding invertebrate studies. Due to their diversity and abundance, studying species assemblages of invertebrates and their habitat requirements may provide a greater insight into how species interact within a biological system and would be more valuable for conservation of ecosystems than the single species approach adopted for vertebrates (Yen et al., 1990).

To conclude, if the conservation of biological diversity is to be taken seriously, then the major contributors to species biological diversity, namely the invertebrates, need much more consideration than they are currently getting. The days when invertebrates are only considered as plant crunchers or forgotten lunches are over, and they need to be considered in their own right.

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