# DIET AND FEEDING ECOLOGY OF THE STRIPED LEGLESS LIZARD *DELMA IMPAR* (FISCHER, 1882) WITHIN THE AUSTRALIAN CAPITAL TERRITORY

by

**Donna Nunan, B. App. Sci. (Hon.)**

**Applied Ecology Research Group**
**University of Canberrra**
**P.O. Box 1, Belconnen ACT 2616.**

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The Striped Legless Lizard
*Delma impar*

The current study investigated the dietary ecology of the nationally vulnerable pygopodid, *Delma impar*, which inhabits isolated patches of grassland within the ACT. sites through the use of scat (faecal pellet) analysis, together with the collection of invertebrates. Scats were also used to examine temporal variation in diet, geographic variation between ACT and Victorian populations, as well as dietary overlap between *D. impar* and the closely related species, *D. inornata*, which also occurs within the ACT.

Results suggest that *D. impar* is a selective arthropod feeder which utilises surface active and sedentary prey types. Spiders, crickets, Lepidoptera larvae (caterpillars) and cockroaches were common in the diet of the species at most study sites. Spider families identifiable from scats included Lycosidae (wolf spiders) and Salticidae (jumping spiders). Trophic niche breadth varied between sites, although all values were found to be closest to the specialised end of the scale, with common invertebrates such as Isopoda (slaters) and Hemiptera (true bugs) and Formicidae (ants) lacking from the diet.

Predominant prey types of the species in Victoria have previously been found to be crickets and noctuid moth larvae, while spiders were found to be predominant in the diet within the ACT. A number of known *D. impar* prey types were also found within *D. inornata* scats, with wolf spiders commonly occurring. This suggests that there is evidence of trophic resource overlap between the two species, although the current study could not quantify the magnitude. While no strong evidence of seasonal variation in diet was apparent in the diet of *D. impar*, these results were not conclusive, due to low sample sizes and a lack of data on prey availability.

Differences between sites in the number availability as a prey type varied, with numbers highest at the study site dominated by the non-native grass species *Festuca elatior*. The proportion of scats containing spiders was also significantly different between sites, and was shown to increase with spider availability. No consistent trend was found between native and non-native sites in terms of prey availability or relative abundance of *D. impar*, while lizard body condition did not vary between sites. A significant positive relationship was found between the relative abundance of *D. impar* and the relative abundance of Lepidoptera larvae, however results of the current study could not conclusively determine the cause and effect of this relationship. Considering the predominance of this prey type in the diet of the species in Victoria, as well as at ACT sites in previous years, it is possible that this prey type may have some affect on the abundance of *D. impar*.

Prey types taken by *D. impar* suggest that the species participates in periods of active foraging, but may also utilise sit and wait predation. Composition of the diet is consistent with that of a species which is a surface active predator. With flexibility in the degree of specialisation and prey selectivity, currently the diet of *D. impar* does not appear to be limiting the distribution of the species within the ACT, allowing it to persist and reproduce over a range of native and non-native grassland sites. In consideration of this, the role of non-native grasslands in aiding to conserve this species, at least in the short term, should not be underestimated.

# MANAGEMENT RECOMMENDATIONS AND FUTURE RESEARCH

## Management recommendations

From the results of the current study the following management recommendations should be considered for the conservation of *D. impar*:

1 Considering that the availability of Lepidoptera larvae may possibly limit the abundance of *D. impar*, in any situation requiring the translocation of *D. impar* individuals, the availability of Lepoidoptera larvae at the site of translocation should be comparable with that of their original habitat.

2. The biomass of Lepidoptera larvae may be used as a habitat indicator to focus survey effort on those sites most likely to contain *D. impar* in high abundance. Naturally this indicator would be applied after the initial selection of possible survey sites had been made, with the biomass of Lepidoptera larvae at a site known to support high numbers of *D. impar* used as a comparative measure.

3. Hadden (1995) considered exotic perennial pasture as marginal habitat for this species, with such sites non-viable for supporting populations in the long term. However, the role of such sites should not be underestimated in terms of aiding in the conservation of the species. *Delma impar* does appear to persist and reproduce in highly disturbed and non-native grassland sites, with no evidence of a reduction in body condition. These sites may therefore be of use to the species at least in the short term. The flexibility in diet which is shown by *D. impar* may allow it to utilise any disturbed grassland areas which surround native sites, particularly as refuge during and after fire. Furthermore, the ability to move between native sites, through the use of disturbed roadside verges, does not appear to be limited by dietary requirements of the species. Until long term monitoring of *D. impar* at disturbed and non-native sites is undertaken, the full potential of such areas in aiding in the conservation of this species cannot be realised.

4. Until the specific dietary requirements of captive individuals is determined, it is highly recommended that any captive *D. impar* should have access to the range of prey types known to be taken by the species in the wild. These include specifically: spiders (wolf spiders if possible), Lepidoptera larvae of the families known to inhabit grasslands, crickets, cockroaches and grasshoppers.

5. Although based on as yet limited results, there is evidence that the two species of *Delma* overlap in their food resources. Until the extent and nature of this potential competition is quantified, translocation of *D. impar* into areas occupied by *D. inornata* is not advised. It is also possible that in such situations behavioural interactions between the taxa may also occur.

## Future research

While little evidence of seasonal variation in diet was apparent from this study, the topic does require further attention. Any variation in the composition of the diet occurring within the activity period of the species would be more evident with larger sample sizes, allowing the comparison of diet between individual months. Furthermore, the collection of invertebrates throughout the activity season would be beneficial in providing a more accurate picture on seasonal variation in diet. Such continuous invertebrate trapping would also provide details on peaks in invertebrate abundance, pinpointing the best time to relocate, or reintroduce individuals in terms of prey availability. The highly seasonal period of trappability for *D. impar* will, however, continue to restrict the availability of dietary samples from other periods and provides a challenge to future research.

The difficulties associated with catching high numbers of *D. impar* does limit the ability to obtain an accurate estimation of diet within a discrete time period. Considering the variation in invertebrate availability which occurred within the 1994 *D. impar* trapping period (see Appendix D), the collection of scats over a time period shorter than three months may provide a better "snapshot" of diet selectivity. However, until a more successful trapping technique is discovered for this species, the collection of adequate sample sizes within a shorter time frame, remains difficult.

Although stomach analysis is commonly used to determine diet for lizards, the development of scat analysis for small species with conservation status, such as *D. impar*, would be beneficial. Studies on differences between the composition of scat and stomach contents for common species could aid in quantifying bias associated with this technique, providing a more useful tool with which to determine diet, without the need for killing specimens.

At least one site utilised in the current study was located in what was thought to be unsuitable habitat. Therefore, the presence of *D. impar* at all 1994 study sites was unexpected. As a result, the current study did not quantify differences between the invertebrate fauna at sites where *D. impar* occurred and sites where *D. impar* were nearby, but did not occur. Although the results obtained suggest that dietary requirements are not limiting species distribution, a comparison between two such areas would be required to provide more substantial evidence, and would be a useful direction for further research.

Trends within the diet of *D. impar* can only give inference to spatial and temporal movement patterns, as well as foraging activity. Tracking the lizards with fluorescent dye was not particularly successful (Kutt 1994), and a more accurate picture could be obtained through the use of radio tracking. Although size constraints currently inhibit its utilisation, such a technique would more effectively address questions on the behaviour and movement patterns of this species.

# ACKNOWLEDGMENTS

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# CHAPTER 1

# INTRODUCTION

## General

**• Dietary attributes of reptiles as ectotherms**

When compared to mammals and birds, reptiles and amphibians are unique in their approach to terrestrial life. Differences between these vertebrate groups stem from the source from which energy to regulate body temperature is obtained. While mammals and birds generate most of the energy required for thermoregulation internally and are classed as endotherms, herpetofaunal species generally obtain this energy from outside their bodies and are called ectotherms (Pough 1980).

Ectotherms differ from endotherms not only in the source from which energy is obtained, but also in terms of their relatively low energy demands (Reichenbach and Stairs 1985, Pough 1980). Although considerable benefits are associated with ectothermy (Pough 1983a, Pough 1980), maintenance of these low energy demands does involve costs. Reptiles have a limited capacity for aerobic exercise (Regal 1978), which can result in exhaustion after only one or two minutes of intense activity for some lizard species (Bennett 1983).

As a consequence of their low energy demands, reptiles can convert energy into tissue with great speed and efficiency (Pough 1980). This is of particular benefit during peaks in food abundance and provides them with the ability to fully utilise ephemeral food sources. This in turn enhances individual survival and can increase reproductive output. The Komodo dragon (*Varanus komodoensis*) for example, is an opportunistic carnivore that is highly adapted to ingesting as much food as possible in the shortest amount of time (Auffenberg 1978). Together with the ability to efficiently convert these large stores of food into fat, the Komodo dragon can fully capitalise on ephemeral resources, such as carrion.

Owing to their ectothermic attributes, reptiles also have the ability to withstand long periods without food (Zug 1993) and are therefore more resilient to fluctuations in prey availability than endotherms. This allows reptiles to specialise on seasonal or unpredictable food supplies that are only available periodically (Pough 1983a, Pough 1980). *Dasypeltis*, for example, are egg-eating snakes that only feed during the two annual breeding periods of the birds upon which they prey, and then fast for the rest of the year (Gans 1952). Another example is the file snake (*Acrochordus arafurae*) which is an exclusively piscivorous predator with an unusually low rate of metabolism (Shine and Lambeck 1985). While this limits the species to predating only upon slow moving fish, feeding may only be required a few times a year (Shine 1986a). Such examples show that while ectothermy may limit the diet of reptiles through their inability to sustain activity, low feeding rates reduce dependence upon the availability of prey. Such attributes may allow reptiles to persist not only where prey is most abundant, but also where prey is at the limits of its distribution, or fluctuating in abundance.

To retain their internally produced energy, endotherms must minimise any loss of heat from the body. This requires a body shape that does not have a high surface area to mass ratio, as is shown by elongated body forms. Unlike endotherms, ectotherms are free of heat-conserving constraints and a trend towards body elongation is seen in snakes (Greer 1989) and several lineages of lizards (Shine 1986b). Body elongation allows reptiles to utilise foraging areas that would otherwise be unavailable, such as crevices (Shine 1986b) and burrows (Gans 1975), as well as trees (Pough 1983b). Reptiles can therefore exploit types of prey and methods of hunting that are not available to birds and mammals (Pough 1983a). The large surface area to mass ratio of a snake, for example, would result in extreme heat loss for an endotherm. As a result endotherms rarely display body elongation beyond that shown by mammals such as the weasel (Brown and Lasiewski 1972).

Ectotherms possess a number of interdependent physiological and ecological features which have traditionally been interpreted as "primitive" (Shine 1986a), but may alternatively be viewed as adaptations to low rates of energy flow (Pough 1980).

Ectothermy provides reptiles with dietary opportunities and trophic niches unavailable to mammals and birds, and is the basis for their success in areas that are too harsh and unpredictable for endotherms (Pianka and Schall 1981).

- **Specialisation and selectivity**

Specialisation and selectivity are terms commonly associated with dietary studies, although there is a lack of consistent usage within the literature, particularly in regard to the former (Fox and Morrow 1981, Drummond 1983). Defining these terms is therefore essential to avoid ambiguity or misinterpretation. The current study follows Morse (1980) in defining specialisation as the utilisation of a subset of resources which is narrower in range than that of the potential resources available, while selectivity is defined as resource use which is disproportional to availability (Manly *et al.* 1993). While both processes may influence the composition of the diet simultaneously, their affects may also be considered separately (Figure 1).

With respect to the above mentioned definitions of specialisation and selectivity, it may be argued that if a particular organism is unpalatable to a species, then it does not classify as a potential food item and therefore should not be considered when examining these attributes of the diet. However, it may be difficult to determine whether a potential prey type is actually unpalatable to the species in question. Furthermore, if potential prey types are absent from the diet, this does suggest that an evolutionary response has been made in relation to the resources available. Thus, the absence or disproportionate use of any potential prey type within the diet should be considered when examining specialisation and selectivity, regardless of suspected unpalatability.

- **Foraging behaviour**

As predators, reptiles are commonly described as either sit-and-wait or active, wide foragers. While such a dichotomous view is widely accepted, (see McLaughlin 1989, Pietruska 1986, Huey and Pianka 1981), others have proposed the existence of an intermediate mode (O' Brien *et al.* 1990, Perry *et al.* 1990, Regal 1983, Regal 1978) or a foraging continuum, along which each species has a place (Magnusson *et al.* 1985). Regardless of whether there is a continuum or gradation, sit-and-wait and widely foraging represent the extremes in foraging behaviour and are therefore of use in examining the consequences of foraging mode.

Within the literature there is an apparent trend between the foraging mode of reptiles and the type of prey taken, with sit-and-wait foragers tending to take active prey and widely foraging species most commonly taking sedentary prey (Bergallo and Rocha 1994, Magnusson *et al.* 1985, Henderson 1982, Huey and Pianka 1981, Pianka 1977). Differences in foraging mode will influence the type of prey encountered (Huey and Pianka 1981) and can therefore affect the composition of the diet (Pianka 1977).

- **Importance of lizard dietary studies**

Dietary habits of lizards may be paralleled by adaptations of behaviour and morphology (Patchell and Shine 1986), and can provide information on the evolutionary divergence of lineages within common taxa (Webb and Shine 1994). Studies examining diet contribute to theories on optimal foraging (e.g. Paulissen 1987), energetics and metabolism (e.g. Grimmond *et al.* 1994, Karasov and Anderson 1984, Pough 1973), prey selection (e.g. Webb and Shine 1993, Pough and Andrews 1985, Stamps *et al.* 1981) as well as theories on foraging strategies (e.g. Huey and Pianka 1981) and inter-specific sympatry and parapatry (e.g. Klawinski *et al.* 1994, Huey 1979, Huey and Pianka 1977).

Obtaining information on diet may be useful for pinpointing habitat requirements, and is often considered as valuable ecological knowledge for the management of species with high conservation status (Fellers and Drost 1991, Osborne *et al.* 1991, Coulson 1990). As the fulfilment of dietary requirements may be considered a prerequisite of survival, dietary information may also contribute to the understanding of processes that govern species decline. In cases where individuals of a species are to be relocated to previously occupied habitat, knowledge on diet may be considered essential, due to possibilities such as the elimination of essential food sources through a change in plant species composition (Caldecott and Kavanagh 1988).

- **The species - *Delma impar***

The striped legless lizard, *Delma impar*, is a pygopodid with characteristic longitudinal body stripes, found in south eastern Australia (Cogger 1992). It is believed that the species has suffered a substantial contraction in geographic range and abundance over the last 100 years (Coulson 1990) with recent survey evidence suggesting the continuation of this trend (Hadden 1995). Currently the species is considered as vulnerable nationwide (ANZECC

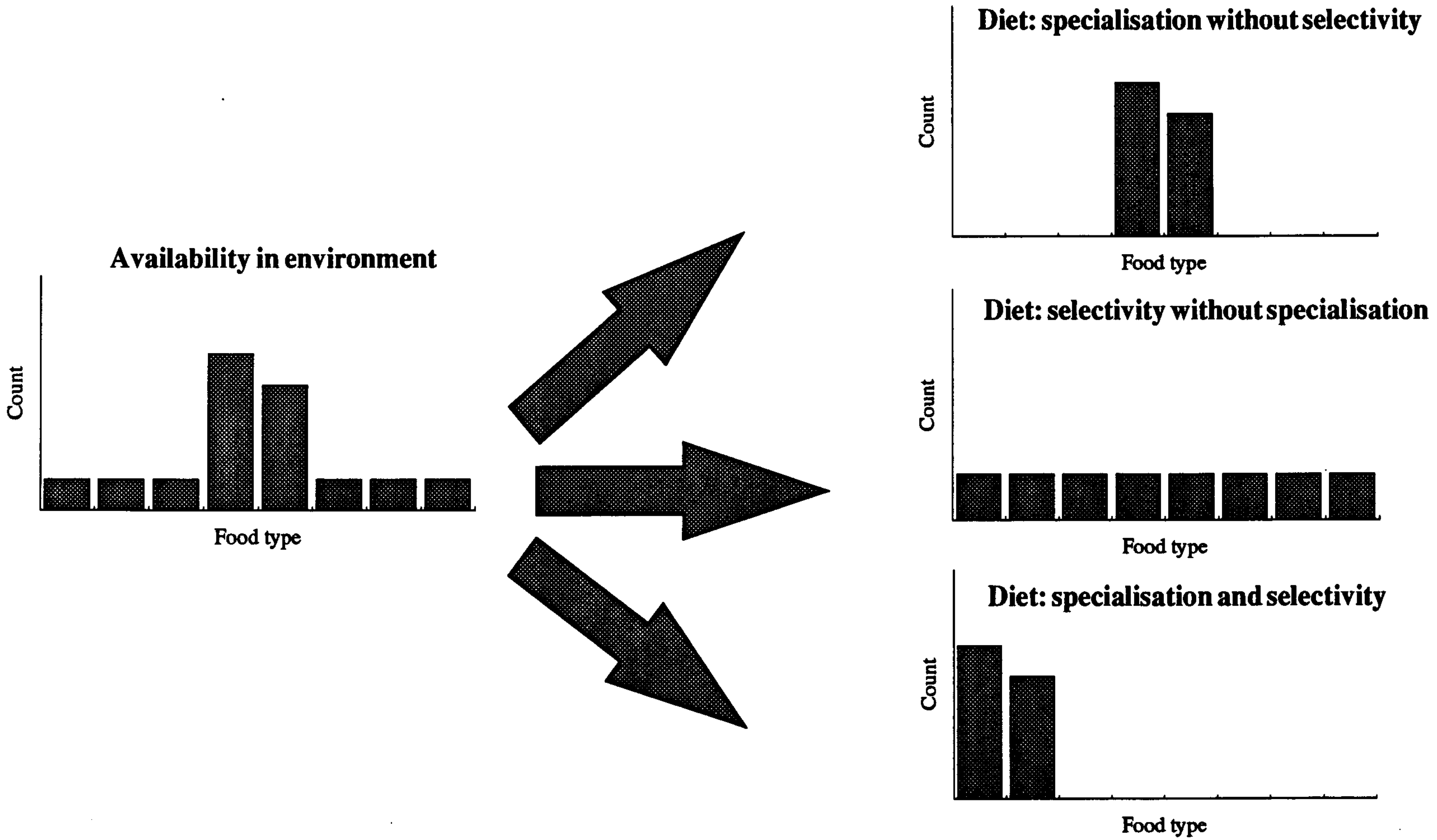

Figure 1. Graphical representation of the definitions for dietary specialisation and selectivity.

1991). Within the ACT, *D. impar* occurs in remnant native grasslands (Osborne *et al.* 1994), but there is also evidence that the species may be utilising introduced grasses (Kukolic *et al.* 1994).

Survey work undertaken within the ACT has revealed four disjunct populations (M. Rauhala pers. comm. 1995) with no known populations occurring within conservation areas. Considering what is thought to be the former extent of grassland plains within the ACT, and the number of surveyed sites within this area where *D. impar* has not been found to occur (Osborne *et al.* 1994), the distribution of this species may be considered somewhat limited. While a comprehensive base study on the distribution, morphology and general ecology of *D. impar* has been previously undertaken in Victoria by Coulson (1990), this was considered preliminary and highlighted the need for further research into aspects such as the dietary attributes of the species. This was also recommended in the Draft Conservation Strategy for *D. impar* within the ACT (*Delma impar* Working Group 1994).

Previous dietary analysis by Coulson (1990) and Wainer (1992) found that *D. impar* scats predominantly contained noctuid moth larvae and crickets, with the latter study describing the species as an opportunistic insectivore, or arthropod feeder, with some evidence of food selectivity. However, considering the wide range of resources available to *D. impar*, Kutt (1992) suggested that *D. impar* may be considerably more selective than previously thought, with the main prey types consisting of only four invertebrate taxa; noctuid moth larvae, crickets, spiders and locusts. Although providing initial insight into the dietary preferences of *D. impar*, both Coulson (1990) and Wainer (1992) relied upon very small sample sizes and did not examine seasonal variation in diet. Furthermore, geographic variation in diet and the availability of prey were not addressed. Thus, conclusions on the dietary preference of this species to date have been somewhat preliminary.

The closely related pygopodid, *D. inornata*, inhabits open savannah woodlands within the ACT (Jenkins and Bartell 1980) but also occurs within some isolated grassland patches. *Delma inornata* has been trapped not only at sites where *D. impar* occurs, but also at sites where habitat appeared suitable for the latter species, but no evidence of occurrence was found (Kukolic 1994). While there may be a number of plausible explanations, the possibility of trophic resource overlap should be considered. If the potential for inter-specific competition for trophic resources was identified, then it may be a possible factor determining the limited distribution of *D. impar* within the ACT.

## Scope

By sampling the prey available to *D. impar*, and focusing on a more quantitative and comparative approach, the present study aims to provide more specific details on the feeding ecology of this species. Furthermore, by comparing the invertebrate fauna between sites dominated by native grasses and sites dominated by introduced grasses, this study aims to determine whether non-native grasslands provide *D. impar* with suitable habitat, in terms of dietary requirements. The possibility of trophic resource overlap between *D. impar* and *D. inornata* will also be examined, as well as the effects of diet on distribution and abundance. Possible links between the diet of *D. impar* and behaviour and activity of the species will also be explored.

## Objectives

The main objectives of the study are:

1. To determine the diet of *D. impar* within the ACT and document any seasonal variation.
2. To quantify the degree of dietary selectivity and specialisation displayed by the species within the ACT.
3. To determine if there are any links between the diet of *D. impar* and its restricted and patchy distribution, with comparisons between native and non-native grasslands.
4. To compare the dietary preferences of *D. impar* and *D. inornata* and determine if there is dietary overlap between the two species.
5. Contribute management recommendations for *D. impar* in relation to its dietary requirements and distribution of prey.

## Approach-scat analysis

Studies concerning the diet of lizards generally utilise the technique of stomach analysis, which requires lizard mortality (e.g. Brown and Perez-Mellado 1994, Brown 1991, James and Losos 1991, Avery 1981, Crome 1981, Robson and Lambert 1980). Heatwole and Taylor (1987) noted that dietary studies of reptiles usually involve the destructive sampling of a large number of animals, but considered this appropriate when numerous aspects of the animals ecology are to be examined simultaneously. However, they stressed that the use of such techniques is inappropriate in the case of threatened or endangered species. Considering its current conservation status, *D. impar* is one such case.

Other, techniques used to examine lizard diets include stomach flushing (e.g. James 1991, Lewis 1989, Shine 1986c), examining museum specimens (e.g. Webb and Shine 1994, Patchell and Shine 1986), and field observations (e.g. Jones 1983). While stomach flushing has been refined for small scincid lizards, initial attempts can result in mortality, with respiratory failure and deep shock also occurring (James 1990). Museum specimens do not always provide suitable samples as they may have empty stomachs as a result of being held captive prior to mortality. Furthermore, field observations are limited to those species which are relatively slow moving within open habitat that allows for ready visibility.

Studies utilising scat analysis are rare for reptile species, with the technique generally applied secondarily as a result of incidental scat collection (Fellers and Drost 1991, Lewis 1989). While the potential biases associated with scat analysis have been determined for insectivorous mammals (Dickman and Huang 1988, Kunz and Whitaker 1983), little is known on how differences in prey retention and digestion affect the contents of scats for lizards. The technique is considered traditional for determining the diet of bats (McAney and Fairley 1989) and has also been used to examine the diet of a range of other insectivorous and herbivorous mammals (Morten 1992, Green 1989, Dickman *et al.* 1983, Churchill 1994, Marti 1982). Before scat analysis can be used more widely in lizard studies, the technique does require further refinement and quantification. However, considering the conservation status, small body size and cryptic nature of *D. impar* habitat, scat analysis was considered the most appropriate dietary analysis technique for this species.

## Project significance

As a consequence of the gross alteration and severe fragmentation of native grasslands within Australia (McDougall and Kirkpatrick 1994), protection and management of such areas are essential components of the conservation program for *D. impar*. However, management planning is limited by a lack of biological and ecological knowledge of the factors that limit the distribution of this species. The dietary requirements of *D. impar* are not well documented and such knowledge may aid in locating suitable habitat, and explain the limited distribution of the species within the ACT.

There is a paucity of knowledge on the dietary habits of the pygopodid family, with incidence of published data sparse and anecdotal (Patchell and Shine 1986). Due to its virtually continent-wide distribution and striking adaptations for lizard predation, the pygopodid *Lialis burtonis* has received the most research attention, but it is not a species which is characteristic of the entire family. While diet has also been examined for a number of species of *Aprasia* (Jones 1992, Webb and Shine 1994), considering the diversity of morphological features and ecological niches displayed by pygopods (Webb and Shine 1994), this lizard family has received little research attention.

# CHAPTER 2

## METHODS

### Study area

The ACT lies 130 km from the east coast of Australia with an altitude within Canberra of about 600m above sea level. With a latitude of 30° south of the equator, the region experiences distinct temperature variation between seasons. From 1939 to 1994 the lowest temperature recorded within the ACT was -10°C with a high of 42°C and an average annual temperature of 12.9°C (Bureau of Meteorology 1995). The region experienced below average rainfall from June through to November of 1994, with above average rainfall recorded for December of 1994 and January of the following year (Figure 2).

Although there are a number of plant associations characteristic of the ACT region (NCDC 1984), all study sites were within the area generally considered to be lowland native grassland prior to European modification. Typical species of lowland grasslands include tall spear grass (*Stipa bigeniculata*), kangaroo grass (*Themeda australis*), wallaby grass (*Danthonia spp.*) and redleg grass (*Bothriochloa macra*) (Sharp 1994). Study sites (see Table 1 and Figure 3) were all located in relatively treeless areas, with flat to gently undulating topography. A detailed analysis of the vegetation present at these sites was undertaken within the current study (see below).

### Fieldwork

- **Floristics**

Point line transects were used to determine the predominant plant species and levels of introduced species invasion. At each site, four, 20 m long transects were laid. At each metre interval, the plant species occurring directly below the transect line was recorded. If bare ground occurred at any metre interval, the closest individual plant was recorded. At each point, species were identified to genus and grouped as native or introduced. Eighty points were recorded for each site. Plant lists were also compiled for each site with identification to species level. After transects were completed, a further 10 min were spent at each site to search for the presence of additional plant species. Nomenclature follows Harden (1990-1993).

- ***Delma impar* trapping techniques**

To examine diet, lizards were trapped during the main activity period of October, November and December of 1994. Trapping methods used previously by ACT Parks and Conservation Service to capture *D. impar* (e.g. Kukolic *et al.* 1994) were employed to maintain comparability between trapping results. This involved the use of two lines of drift fencing, with pitfall traps set at five metre intervals along each, intersecting at a 90° angle to form a cross-shaped design (Figure 4). Each line of drift fencing contained ten pits with a total of twenty at each site. Pitfall traps consisted of metal, 11 litre ice cream containers, and the drift fence was made from heavy-duty shade cloth approximately 30 cm high and buried 5 cm into the ground. Each pitfall trap had holes for drainage, with a small length of pipe placed in the bottom to provide shelter for any animals that were caught.

Lizards were collected from six sites (Figure 3) which varied in floristic structure (Table 1) but were all fenced to exclude stock. Names given previously to these sites by the ACT Parks and Conservation Service were retained in the current study (Table 1). Lizards were kept at room temperature, and held until a faecal pellet was passed. Directly after capture, body length and weight measurements were taken, with lizards heat branded before release (see Lizard measurements, page 11). Lizards that had been recaptured numerous times, and were losing body weight, were released within two days of capture, even if a scat had not been passed. Any lizards that had not passed a scat after five days were also released. The presence of other reptiles species, as well as frogs, were recorded for each site, with immediate release after identification. Traps were checked every second day and were continuously supplemented with water at sites where frogs were caught regularly.

Owing to the limited duration of this study, the trapping period could not encompass the entire activity period of *D. impar*. Therefore, to analyse seasonal variation in diet, 63 scats were kindly provided by the ACT Parks and Conservation Service. These scats

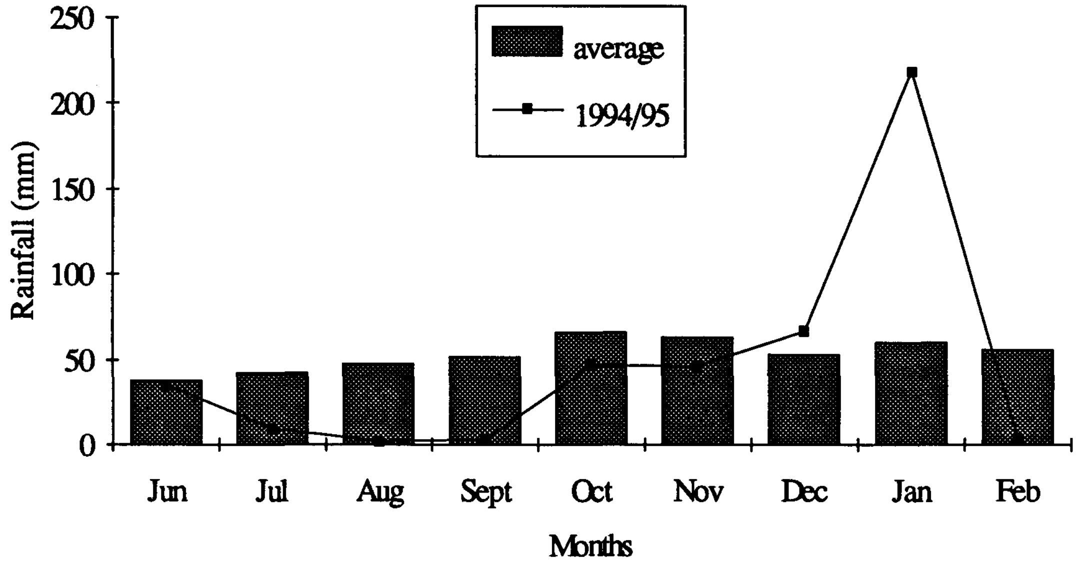

Figure 2. Average monthly rainfall and recorded rainfall figures for the ACT from June 1994 through to February 1995 (Bureau of Meteorology 1995).

Table 1. Site details. For location of sites, refer to Figure 3.

| Site number | Site name | Grassland type | Grid reference |
|---|---|---|---|
| 1 | 2CY1 | *Themeda* | 928007 |
| 2 | 2CY2 | *Themeda* | 930005 |
| 3 | 2CY3 | *Phalaris* | 927006 |
| 4 | CSIRO1 | *Stipa* | 935010 |
| 5 | Stockpound | *Phalaris* | 943990 |
| 6 | Kaleen3 | *Festuca* | 926994 |
| 7 | Majura1 | *Themeda* | 995933 |
| 8 | Mitchell | *Stipa* | 938025 |
| 9 | National Museum | *Themeda* | 893924 |
| 10 | Lake Ginninderra | *Stipa/Themeda* | 894997 |
| 11 | Jerramalee | *Themeda* | 824034 |

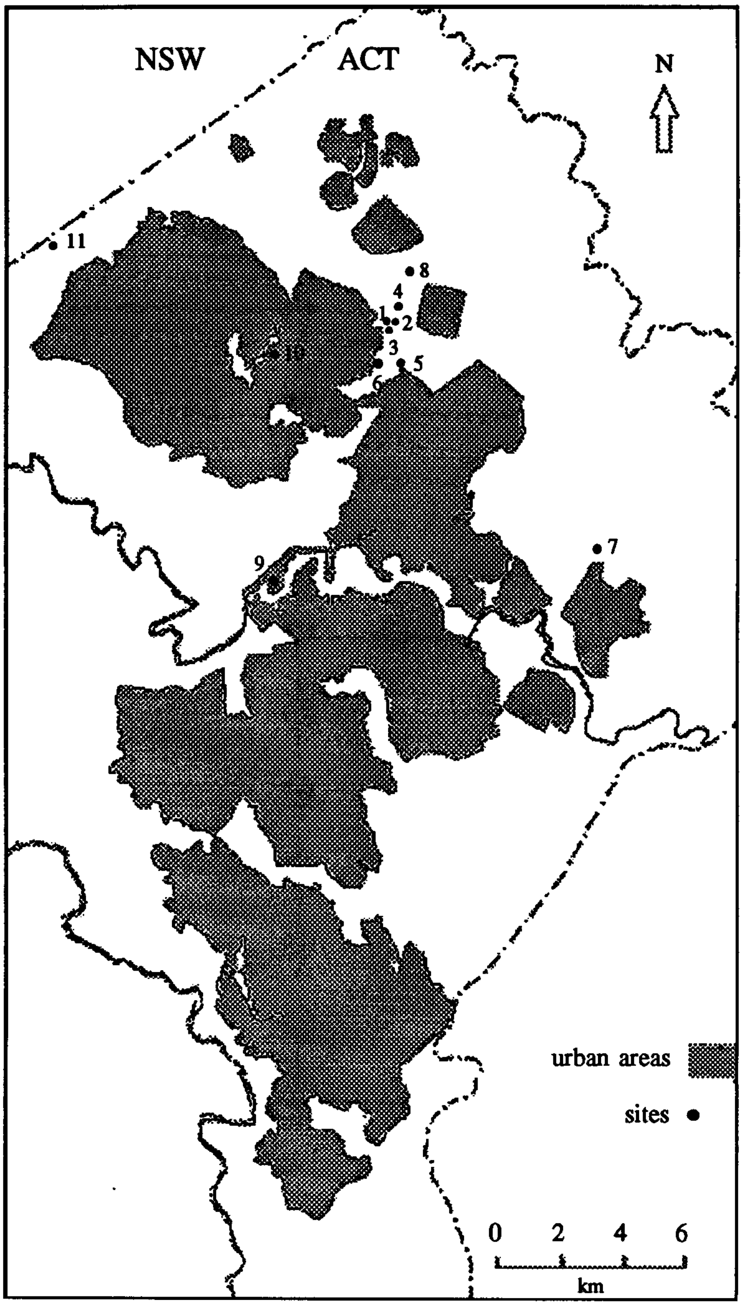

Figure 3. Map showing urban areas and site localities within the ACT. Site 1=2CY1, 2=2CY2, 3=2CY3, 4=CSIRO1, 5=Stockpound, 6=Kaleen3, 7=Majura1, 8=Mitchell, 9=National Museum, 10=Lake Ginninderra, 11=Jerramalee. For grid references refer to Table 1.

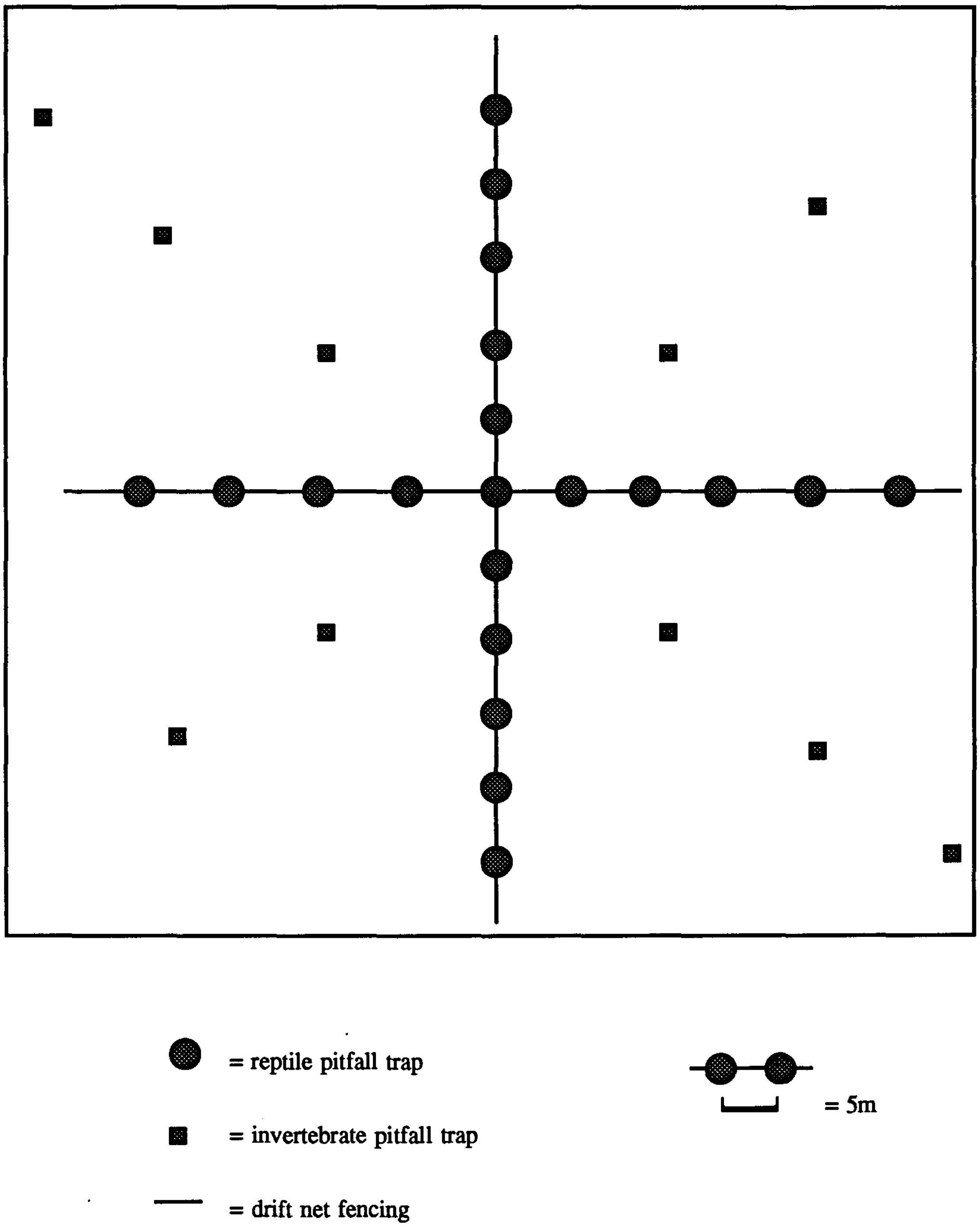

Figure 4. Trap layout used for reptile and invertebrate pitfalls

were obtained from three native grassland sites, 2CY1, Majural and Mitchell (Figure 3). Traps were open at these sites from October 1991 through to March 1992, with a good record of trapping success at all three sites. Scats collected from Majural during October to December of 1992 were also analysed to allow a dietary comparison between years for this site. Victorian data on the diet of *D. impar* at the Derrimut Grassland Reserve was obtained, with permission, from the unpublished work of John Wainer (1992), for a geographic comparison of diet between populations.

Additional scats provided by the ACT Parks and Conservation Service included 17 *Delma inornata* scats, which were collected during November and December of 1991. While a number of these scats were obtained from sites near the National Museum, where both *Delma* species occurred, *D. inornata* scats from Jerramalee and Ginninderra sites (Figure 3) were also analysed, to provide a broader picture on the diet of the species. An indice of niche overlap was not calculated for the two *Delma* species as adequate sample sizes were not available from sites where both species occurred.

- **Invertebrate sampling.**

To determine the range of prey available to *D. impar* and how selective the lizards are in what they eat, invertebrates were sampled in conjunction with scat collection. Invertebrate samples must represent what prey are available to ensure that the most accurate estimation of trophic niche is determined. Therefore, since *D. impar* is known to take active and relatively sedentary prey types (Wainer 1992), vacuum sampling was originally chosen in an attempt to measure absolute rather than relative abundance, and to cover all potential prey types. However, initial trials proved vacuum sampling to be inefficient at collecting a range of invertebrate types and size classes known to occur at the study sites. For these reasons, pitfall trapping was chosen in preference.

At each site, ten cups with a diameter of 9 cm were placed between the arms of the reptile drift fencing (Figure 4). Cups were first filled with water for a period of one week to determine the risk of incidental vertebrate captures. As no vertebrates were caught during this period, cups were then filled with 20 ml of 70% ethanol and 5 ml of glycerol. Cups were left open for two, seven day periods starting 24-Nov-94 and 16-Dec-94, with alcohol supplemented every second day.

Invertebrates were also sampled through the use of Agrisense LO-LINE sticky traps to compare differences in diurnal and nocturnal availability, and also to compare differences in the activity of invertebrate types between the litter and grass tussocks. At each site, on 29-Dec-94, eight 19.5×9.5 cm sticky traps were randomly placed on the litter within inter-tussock spaces, with eight 9.75×4.75 cm traps placed within the base of randomly chosen grass tussocks. Sticky traps sampling diurnally active prey were set at all sites within the first hour after sunrise and retrieved in the last hour before sunset. For sampling nocturnally active prey, sticky traps were laid in the first hour after sunset and retrieved in the last hour before sunrise.

Before setting sticky traps, trials were undertaken to determine if vertebrates could be removed from the sticky traps and released. This was to ensure that if any reptiles or amphibians were caught, they could be removed from the traps without harm. The addition of vegetable oil onto sticky traps was found to be suitable for this purpose. All traps placed within the litter were sheltered from direct sunlight to avoid any risk of vertebrate mortality and also to reduce interference from predators, particularly birds.

Lists of the invertebrate orders present at each site were compiled through the use of all sampling techniques employed. These included sticky traps, invertebrate pitfalls, with alcohol and water, as well as the collection of invertebrates from reptile pitfall traps and vacuum sampling trials.

## Laboratory work

- **Lizard measurements**

Within the laboratory each lizard was weighed to the nearest 0.01 g, with snout to vent length and tail length recorded to the nearest millimetre. To measure length, each lizard was placed within a bag made of stiff, transparent plastic. The body of the lizard was then traced on the plastic with a water soluble marker. The resulting line was then measured through the use of a planimeter. Lizards that were less than 65 mm in snout to vent length were classed as juveniles. Body weight and total body length were used as a measure of body condition. Lizards were marked using heat branding, to give an indication of recapture numbers and also to monitor movement between adjacent sites. Each lizard was not given an individual marking, but was branded on the basis of site of capture. Individual scars and colouration were also recorded to aid in the identification of recaptured individuals. As it was not possible to accurately identify the sex of individuals, determination of lizard sex was not attempted, except for cases where individuals were obviously gravid females.

- **Scat analysis**

Scats were preserved within 70% ethanol, with the site, trap number and date of lizard capture recorded for each (see Plate 1). The analysis of scats collected previously by ACT Parks and Conservation Service, from sites not included within the study, provided a preliminary opportunity to resolve any difficulties associated with invertebrate identification. Invertebrates caught within reptile pitfall traps were utilised as a reference collection. This collection included invertebrates that were intact, to distinguish characteristic features, as well as crushed, to aid in identifying fragments within scats.

All distinguishable prey items were identified at least to the taxonomic level of order, with spiders, grasshoppers and crickets identified to family where possible (see Plates 2-5). For each scat the presence of prey types was recorded, as well as the minimum possible number of prey items. The latter was determined through the number of heads, legs, wings, mandibles and palps within each scat.

- **Invertebrate analysis**

Invertebrates collected through all sampling techniques were also identified at least to the taxonomic level of order, with grasshoppers and crickets identified to family level. For both alcohol pitfalls and sticky traps the presence, and number, of each invertebrate type caught was recorded. The presence of different families of Lepidoptera larvae was recorded for each site, although all families were grouped when recording counts. The occurrence of invertebrates less than 3 mm in length were not recorded as potential prey items as Wainer (1992) found the average size of *D. impar* prey types ranged from 30 to 3 (with the only prey type smaller than 10 mm on average based on a sample size of one).

## Data analysis

The diet of *D. impar* was determined by considering the number and proportion of scats containing each prey type, as well as the number and proportion of individual prey items consisting of each prey type. While the latter is biased towards the consumption of large numbers of social insects, which may not contribute much in terms of energy intake (James 1991), the former gives a measure of the proportion of the population that are consuming a prey taxon. As scat analysis is biased against soft bodied prey (Dickman and Huang 1988), with energy intake underestimated as a result, prey proportions by volume were not calculated from scats.

Diet was summarised through this technique for scats collected during the course of this study, as well as for *D. impar* and *D. inornata* scats collected previously by the ACT Parks and Conservation Service. For comparisons between sites, main prey types were defined as those occurring within at least 15% of scats at any site. Although occurring within 20% of 2CY2 scats, Lepidoptera adults (butterflies and moths) and Coleoptera (beetles) were excluded from this definition, due to low scat sample size at this site (only five scats were collected).

The degree of specialisation shown within the diet of *D. impar* at each site was calculated using Levins' standardised measure (Levins 1968), expressed as

$$B = \frac{1}{\sum_{j=1}^{n} p_j^2} \qquad j = 1....n$$

where

B = Levins' measure of niche breadth
pj = proportion of the food items in the diet that are of category j
n = number of possible food categories

which is standardised to a 0 to 1 scale by

$$B_A = \frac{B-1}{n-1}$$

where

$B_A$ = Levins' standardised niche breadth
B = Levins' measure of niche breadth
n = number of possible food categories

Levins' standardised niche breadth is actually a measure of the spread of foods taken over the observed categories of potential foods. A value of one indicates a dietary generalist, with an even spread of potential foods found

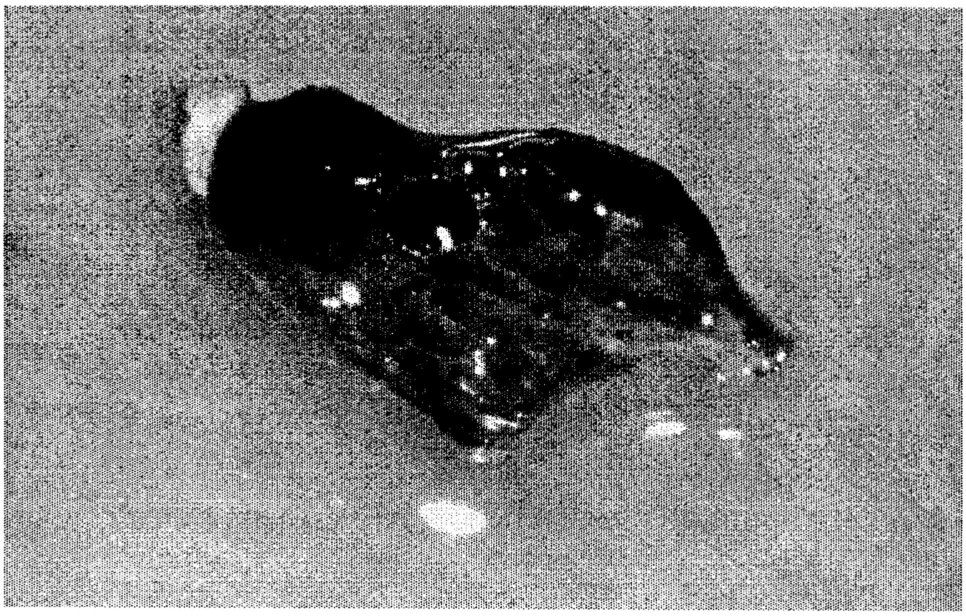

Plate 1. Faecal pellet (scat) of *Delma impar*. Magnification × 7

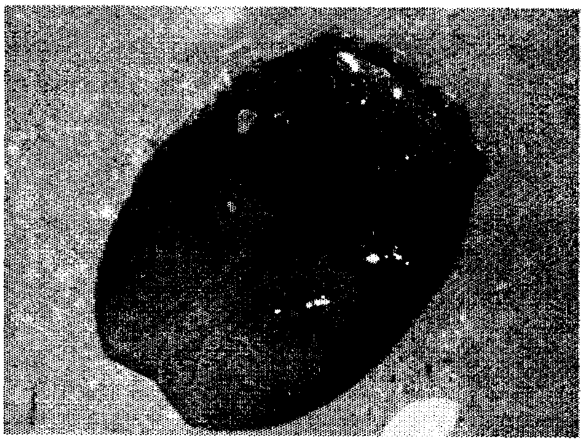

Plate 2. Head of a spider from the family Salticidae identified from within a *Delma impar* scat. Magnification × 20.

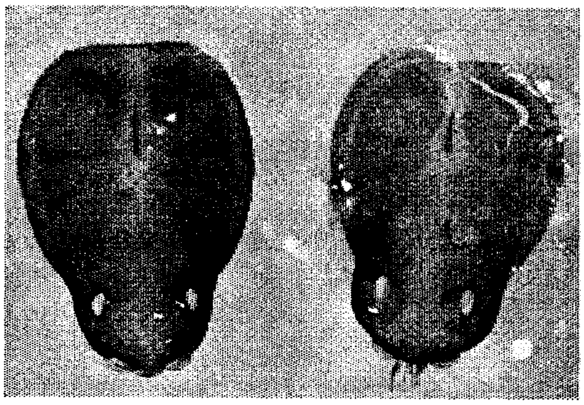

Plate 3. Heads of spiders from the family Lycosidae identified from within a *Delma impar* scat. Magnification × 17.

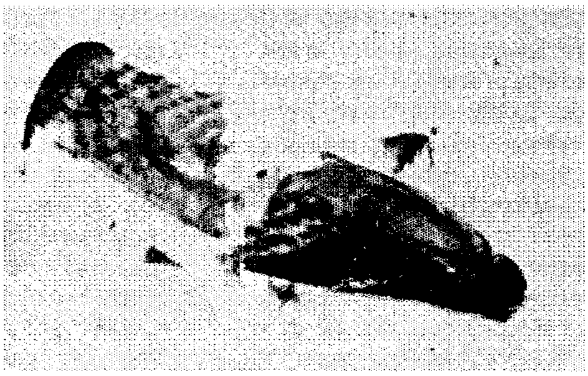

Plate 4. Cricket femur identified from within a *Delma impar* scat. Magnification × 9.

Plate 5. Cricket wing identified from within a *Delma impar* scat. Magnification × 10.

within the diet, while a value close to zero indicates a dietary specialist with most of the food eaten falling into only one of the available potential food categories. Potential food categories correspond to the different categories of invertebrates obtained from all methods of invertebrate sampling.

The use of Hurlbert's modification of Levins' measure was originally intended, as it scales resources in relation to availability and is therefore more sensitive to the selection of rarer resources (Hurlbert 1978). However, since pifall trapping is a biased method of sampling invertebrate availability (Greenslade and Greenslade 1971) and vacuum sampling proved ineffective, Hurlbert's measure could not be used. Invertebrate data collected from sampling with sticky traps could not be substituted, due to the complete absence of a range of invertebrate types from these traps.

Although invertebrates and scats were collected during the 1994 study period, selection indices were not calculated due to the unquantifiable bias between invertebrate types associated with pitfalling (Luff 1975, Greenslade and Greenslade 1971). However, qualitative comparisons were made between sites by comparing difference in availability and utilisation, with the assumption that invertebrates were equally trappable at all sites. As the invertebrate sampling techniques used were not designed to catch aerial prey, incidence of aerial invertebrates within pitfalls and scats were removed from selection comparisons.

Analyses of all statistical data were conducted using SAS (SAS Institute Inc. 1989) with the level of significance set at 0.05. Underlying assumptions associated with data analysis were that invertebrate pifall trapping measured relative availability of prey, percentage occurrence of prey types within scats was an accurate measure of prey utilisation and that the number of *D. impar* caught within pitfall traps measured relative abundance.

Within scats used in the analysis of seasonal variation in diet, invertebrate fragments required to distinguish between grasshoppers and crickets were often absent. Both were therefore grouped as Orthoptera. Due to low numbers of available scats for certain months, seasonal variation could not be examined on the basis of the traditional spring, summer and autumn periods. Maximum sample sizes were achieved by using the following groupings: October, November, December and January, February, March.

For between site comparisons of the number of spiders caught within alcohol pitfalls, before performing an analysis of variance, spider numbers were square root transformed to meet the assumption of normality. Values for the mean, range, and the mean ± two standard errors were then back-transformed when presented on box plots. Owing to differences in trap size, numbers of invertebrates caught on sticky traps within the litter and tussocks were both converted to count per 100 $cm^2$. However, statistical comparisons between the two were not made due to the possibility of differences in invertebrate trappability with trap size.

# CHAPTER 3

## RESULTS

### Site floristics

Floristic sampling undertaken to determine the native or non-native status of 1994 study sites revealed that all sites were dominated by tussock forming grasses, including *Themeda australis*, *Stipa bigeniculata*, *Phalaris aquatica* and *Festuca elatior*. Point line transects revealed differences in the dominant grass species occurring at each site (Table 2). Transects were characterised by only one of the above mentioned grass species at all sites but one. The exception was the CSIRO1 transect where points were characterised by a mix of both native *Stipa* and introduced *Phalaris* (Table 2). Both introduced dicots, *Hypochoeris* and *Plantago*, either occurred along transects, or were present at each site (Table 2). Transect points at 2CY1 and 2CY2 most commonly intercepted native plant species, while transect points at 2CY3, Stockpound and Kaleen3 predominantly intercepted introduced species (Table 2). Although a majority of transect points at CSIRO1 also intercepted introduced species, they did not predominate to the degree shown at other sites.

Introduced species were present on transects at all sites, while native species were present along transects at all sites except Kaleen3 (Table 2). This was also reflected in the total species list for each site with no native species found to occur at Kaleen3 (Table 3). Total species lists showed variation in plant species diversity between sites, with the highest number of plant species, and the highest number of native species, occurring at 2CY2 (Table 2 and Appendix A). Transects at each site indicate that 2CY1 and 2CY2 may be characterised as primarily native grassland sites with 2CY3, Kaleen3 and the Stockpound primarily non-native grassland sites. With a relatively equal mix of native and introduced species, CSIRO1 does not fit into either category, and may therefore be considered as a highly disturbed native grassland.

### Diet

#### • Prey types

From the six sites trapped for *D. impar* a total of fifty individuals were caught. Capture dates, and individual measurements taken for each lizard, are summarised in Appendix B. All other reptile and amphibian captures were recorded and are summarised in Appendix C. From the fifty *D. impar* caught, a total of sixty two scats were available for analysis, with the additional scats obtained through recaptures at least two weeks apart.

Apart from Collembola (springtails), which may have been accidentally ingested with dirt, Araneae (spiders) were the most frequently occurring prey item within scats at each site. However, the prey type found to occur in the most number of scats varied between sites (Table 4). Gryllidae (crickets), Lepidoptera larvae (caterpillars) and Blattodea (cockroaches) were also main prey types at most sites, with Acrididae (grasshoppers) only occurring as a main prey type at the Stockpound (Table 4). Although often unidentifiable from fragments, Araneae families found to occur in scats were commonly Lycosidae (wolf spiders) and Salticidae (jumping spiders). Lepidoptera larvae could not be identified to family level owing to the lack of adequate information obtainable from a majority of scats. However, evidence of the consumption of different Lepidoptera families was apparent, with colouration and pattern differences occasionally occurring within scats. Other less frequently occurring prey types included Lepidoptera adults (butterflies and moths), Coleoptera (beetles), Diptera (flies) and Formicidae (ants), with the average number of prey items per scat ranging from 1.1 to 2.8 (Table 4). Of all prey taken, Araneae (spiders) and Collembola (springtails) were the only prey types found to occur in multiple numbers within single scats (Table 4).

Owing to their very small body size (< 2 mm), the occurrence of springtails within scats was originally considered as accidental ingestion, and therefore they have not been considered as a main prey item. However, frequent occurrence within scats at CSIRO1 places doubt upon this assumption and warrants the inclusion of springtails within Table 4. While grass occurred within a number of scats at all sites, its presence primarily as single fragments suggests that the ingestion of grass as a food item is unlikely. Numerous, small

Table 2. Percentage of transect points intersecting plant genera at each site. For specific species see Appendix A. * indicates genus was present at site but not recorded along transect. For location of sites, refer to Figure 3.

| | | | Site | | | |
|---|---|---|---|---|---|---|
| Genus | 2CY1 | 2CY2 | 2CY3 | CSIRO1 | Stockpound | Kaleen3 |
| MONOCOTYLEDONS | | | | | | |
| *Danthonia* | 0* | 0* | 0 | 0 | 1 | 0 |
| *Festuca* | 0* | 0 | 0 | 0 | 0 | 81 |
| *Holcus* | 6 | 0 | 0 | 0 | 0* | 0 |
| *Juncus* | 1 | 3 | 4 | 0 | 0* | 0 |
| *Nasella* | 0 | 0 | 0 | 0* | 0 | 3 |
| *Phalaris* | 0* | 1 | 71 | 36 | 63 | 10 |
| *Poa* | 6 | 5 | 0 | 0 | 0 | 0 |
| *Stipa* | 0 | 0 | 0 | 39 | 3 | 0 |
| *Themeda* | 70 | 74 | 0 | 0 | 0* | 0 |
| Other | 6 | 2 | 4 | 4 | 3 | 5 |
| DICOTYLEDONS | | | | | | |
| *Hypochoeris* | 8 | 10 | 13 | 20 | 8 | 1 |
| *Plantago* | 0* | 3 | 6 | 0* | 23 | 0* |
| Other | 3 | 2 | 2 | 1 | 1 | 0* |
| TOTAL | | | | | | |
| Native | 81 | 85 | 4 | 39 | 5 | 0 |
| Introduced | 19 | 15 | 95 | 61 | 95 | 100 |

Table 3. Total number of plant species found to occur at each site. For location of sites, refer to Figure 3.

| | | | Site | | | |
|---|---|---|---|---|---|---|
| Species | 2CY1 | 2CY2 | 2CY3 | CSIRO1 | Stockpound | Kaleen3 |
| Native | 15 | 26 | 5 | 5 | 12 | 0 |
| Introduced | 14 | 19 | 6 | 9 | 12 | 13 |
| Total | 29 | 45 | 11 | 14 | 24 | 13 |

Table 4. Diet and trophic niche breadth of *Delma impar* at all study sites during October, November and December 1994. No. prey denotes the number of prey items consisting of each prey type. No. scats denotes the number of scats each prey type occurred within. Numbers in parentheses are percentages. L=larvae. A=adult. For location of sites, refer to Figure 3.

| Site | 2CY1 | | 2CY2 | | CSIRO1 | |
|---|---|---|---|---|---|---|
| Taxon | No. prey | No. scats | No. prey | No. scats | No. prey | No. scats |
| Araneae | 9(36) | 4(24) | 9(64) | 4(80) | 18(86) | 8(89) |
| Gryllidae | 2(8) | 2(12) | 0 | 0 | 2(10) | 2(22) |
| Acrididae | 1(4) | 1(6) | 0 | 0 | 0 | 0 |
| Lepidoptera L | 3(12) | 3(18) | 0 | 0 | 1(5) | 1(11) |
| Lepidoptera A | 1(4) | 1(6) | 1(7) | 1(20) | 0 | 0 |
| Blattodea | 7(28) | 7(41) | 3(21) | 3(60) | 0 | 0 |
| Coleoptera | 1(4) | 1(6) | 1(7) | 1(20) | 0 | 0 |
| Diptera | 1(4) | 1(6) | 0 | 0 | 0 | 0 |
| Formicidae | 0 | 0 | 0 | 0 | 0 | 0 |
| Collembola | 2* | 1(6) | 0 | 0 | 0 | 0 |
| Total | 25 | 17 | 14 | 5 | 21 | 9 |
| Mean no. prey per scat | | 1.5 | | 2.8 | | 2.3 |
| Levin's standardised measure of niche breadth | | 0.29 | | 0.08 | | 0.03 |

| Site | 2CY3 | | Stockpound | | Kaleen3 | |
|---|---|---|---|---|---|---|
| Taxon | No. prey | No. scats | No. prey | No. scats | No. prey | No. scats |
| Araneae | 4(33) | 4(36) | 15(71) | 9(69) | 6(60) | 3(50) |
| Gryllidae | 2(17) | 2(18) | 0 | 0 | 3(30) | 3(50) |
| Acrididae | 0 | 0 | 3(14) | 3(23) | 0 | 0 |
| Lepidoptera L | 1(8) | 1(9) | 2(10) | 2(15) | 0 | 0 |
| Lepidoptera A | 0 | 0 | 0 | 0 | 0 | 0 |
| Blattodea | 3(25) | 3(27) | 1(5) | 1(8) | 0 | 0 |
| Coleoptera | 1(8) | 1(9) | 0 | 0 | 0 | 0 |
| Diptera | 0 | 0 | 0 | 0 | 0 | 0 |
| Formicidae | 1(8) | 1(9) | 0 | 0 | 1(10) | 1(17) |
| Collembola | 7* | 2(18) | 146* | 5(38) | 0 | 0 |
| Total | 12 | 11 | 21 | 13 | 10 | 6 |
| Mean no. prey per scat | | 1.1 | | 1.6 | | 1.7 |
| Levin's standardised measure of niche breadth | | 0.35 | | 0.07 | | 0.11 |

* not included in prey total due to suspected accidental ingestion.

fragments of grass were found occasionally inside the remains of Lepidoptera larvae within scats, however this was an uncommon occurrence. Scats contained soil particles infrequently, and only at 2CY1, CSIRO1 and the Stockpound, with a majority of the latter also containing springtails.

• **Specialisation**

Calculation of the Levins' standardised measure of niche breadth at each site showed the diet of *D. impar* to vary in breadth from 0.03 at CSIRO1 to 0.35 at 2CY3 (Table 4). With all values for niche breadth not exceeding 0.5, the diet of *D. impar* at all sites may therefore be considered closest to the dietary specialised end of the niche breadth scale, consisting of a range of resources that is narrower than the range that is available. When interpreting these values of niche breadth it is essential that the limitations of Levins' measure are considered. Levins' measure does not take into account differences in availability and therefore does not address the question of whether *D. impar* is selecting the most common or least common resources. It is merely a measure of the spread of potential food resources within the diet, regardless of differences in availability. To examine both the range and availability of potential food resources when calculating niche breadth, the use of a modification such as Hurlbert's (1978) is required.

One might expect the rarer resources taken by *D. impar* to occur within scats as sample size increases. Differences in niche breadth between sites may therefore merely be a result of variation in scat sample size. However, a linear regression analysis found niche breadth at each site was independent of the number of scats analysed (F=1.56; df=1, 4; p= 0.28). This therefore suggests that there is evidence of true variation in the degree of dietary specialisation shown between sites. No consistent trend between native and non-native sites was apparent in relation to this variation.

• **Selectivity**

Accepting that bias may have affected the sampling of different invertebrate types, there was little evidence of a relationship between the availability of invertebrates (percentage count of invertebrates at each site) and the selection of invertebrates (percentage occurrence within scats) (Figures 5 to 7). At sites where ants and slaters were the most common invertebrate types within pitfalls, this was not reflected by percentage occurrence within scats. Furthermore, at sites where cockroaches and Lepidoptera larvae (caterpillars) occurred within scats, these prey types were almost completely absent from invertebrate pitfall samples (Figure 5 to 7). This suggests that *D. impar* are not selecting the most readily available prey items, with the assumption that all invertebrates collected were actually available to the lizards.

Apart from possible bias between the trappability of different invertebrate types, further difficulties in extracting trends in prey selection arise through variation in invertebrate availability throughout the scat collection period. This is evident from differences in the percentage count of invertebrate types within pitfalls between sampling periods (Figure 5 to 7) and also from differences in the total number of invertebrates caught (Appendix D). This problem could be overcome by dividing scats into groups, based on collection date, and comparing to the nearest invertebrate sampling period, however this option was not available owing to the resulting low scat sample sizes.

An examination of presence and absence of prey types within scats revealed that the proportion of lizards selecting particular prey types varied between sites (Table 4). These differences were found to be significant for spiders (Fisher Exact Test, 6×2 contingency table: $p<0.001$; $n=61$) and also for cockroaches ($p=0.02$; $n=61$). The proportion of scats containing other main prey types was not found to be significantly different between sites (for crickets: $p=0.08$; $n=61$; for grasshoppers: $p=0.3$; $n=61$; for Lepidoptera larvae: $p=0.99$; $n=61$).

Regression analysis showed a significant positive relationship between the percentage occurrence of spiders within scats and the abundance of spiders within pitfalls ($F=5.05$; $df=1,10$; $p=0.049$) with a trend of increasing occurrence within scats with increasing availability (Figure 8). No significant relationship was found between percentage occurrence within scats and percentage count of spiders within pitfalls ($F=0.80$; $df=1,10$; $p=0.39$). This suggests that the selection of spiders is influenced by the number available, but not by their abundance relative to other available invertebrate types. For all other main prey types no significant relationship was found between percentage occurrence in scats and number, or percentage count, within pitfalls (crickets by number: $F=0.13$; $df=1,10$; $p=0.72$; by percentage occurrence: $F=0.45$; $df=1,10$;

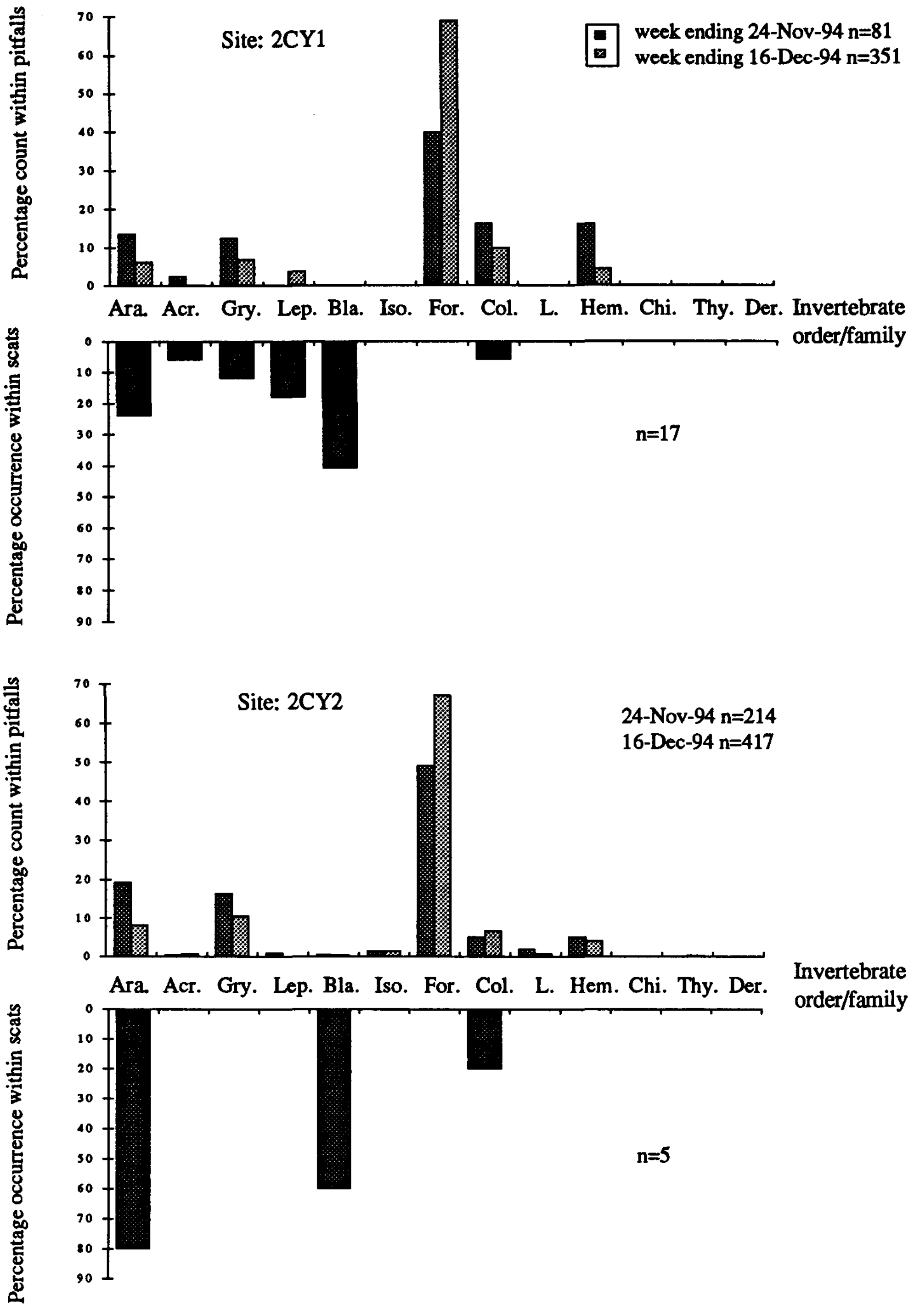

Figure 5. Percentage occurrence of terrestrial invertebrate orders/families within *Delma impar* scats collected from October to December 1994, as well as percentage count of invertebrates caught in pitfall traps for weeks ending 24-Nov-94 and 16-Dec-94 at sites 2CY1 and 2CY2. Ara.=Araneae; Acr.=Acrididae; Gry.=Gryllidae; Lep.=Lepidoptera larvae; Bla.=Blattodea; Iso.=Isopoda; For.=Formicidae; Col.=Coleoptera; L.=Coleoptera larvae; Hem.=Hemiptera; Chi.=Chilopoda; Thy.=Thysanura and Der.=Dermaptera. For location of sites, refer to Figure 3.

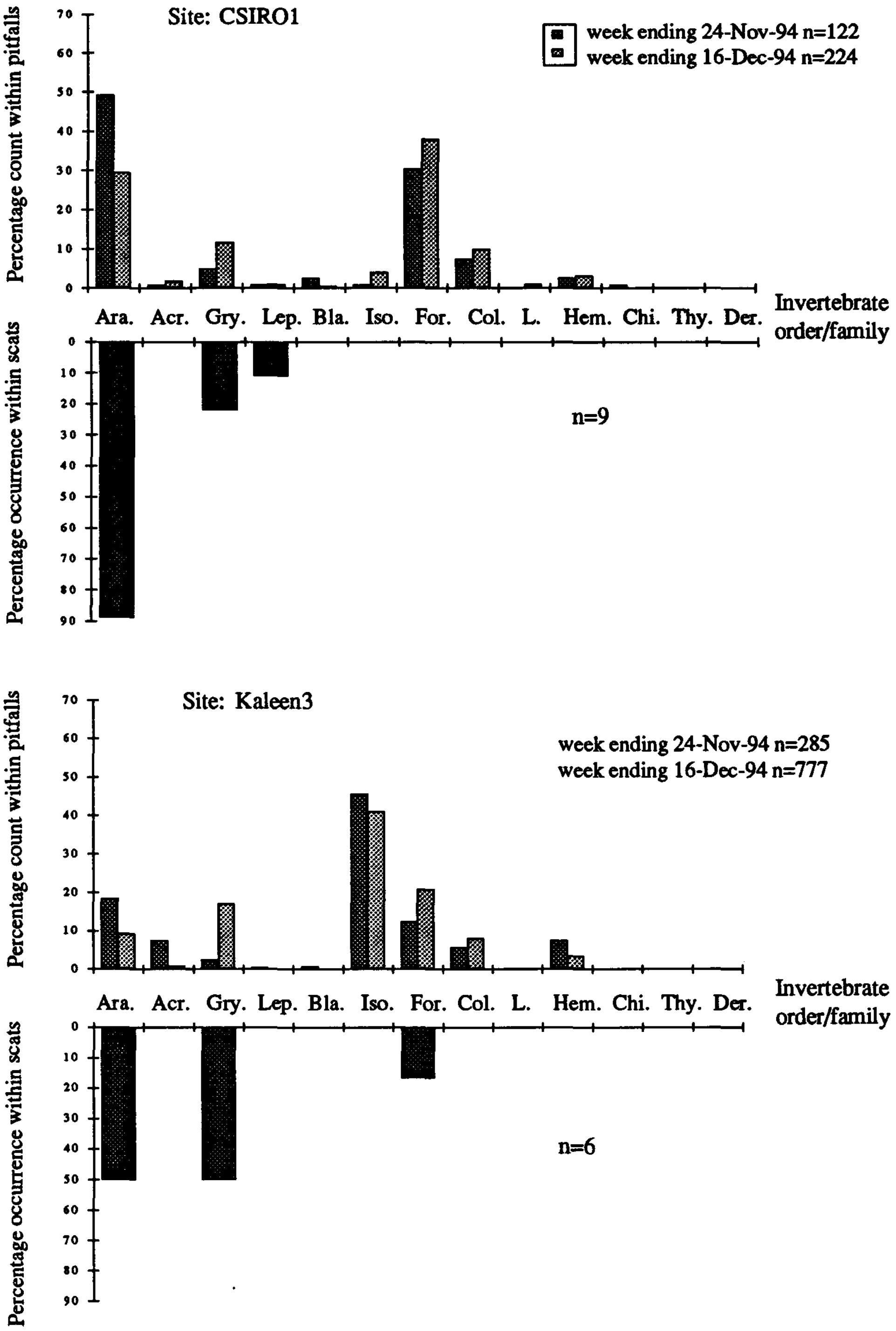

Figure 6. Percentage occurrence of terrestrial invertebrate orders/families within *Delma impar* scats collected from October to December 1994, as well as percentage count of invertebrates caught in pitfall traps for weeks ending 24-Nov-94 and 16-Dec-94 at sites CSIRO1 and Kaleen3. Abbreviations for prey taxa are shown in Figure 5. For location of sites, refer to Figure 3.

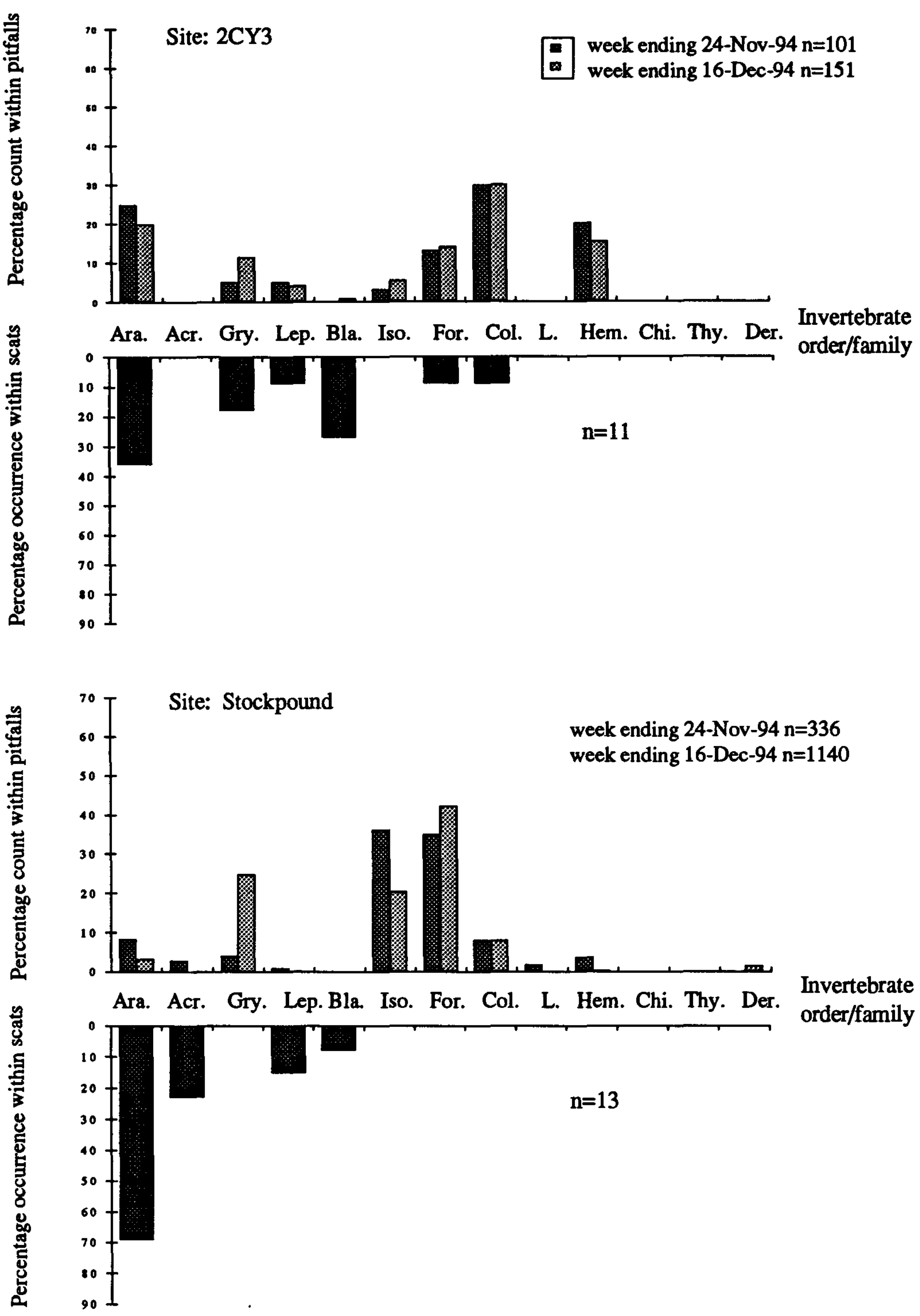

Figure 7. Percentage occurrence of terrestrial invertebrate orders/families within *Delma impar* scats collected from October to December 1994, as well as percentage count of invertebrates caught in pitfall traps for weeks ending 24-Nov-94 and 16-Dec-94 at sites 2CY3 and the Stockpound. Abbreviations for prey taxa are shown in Figure 5. For location of sites, refer to Figure 3.

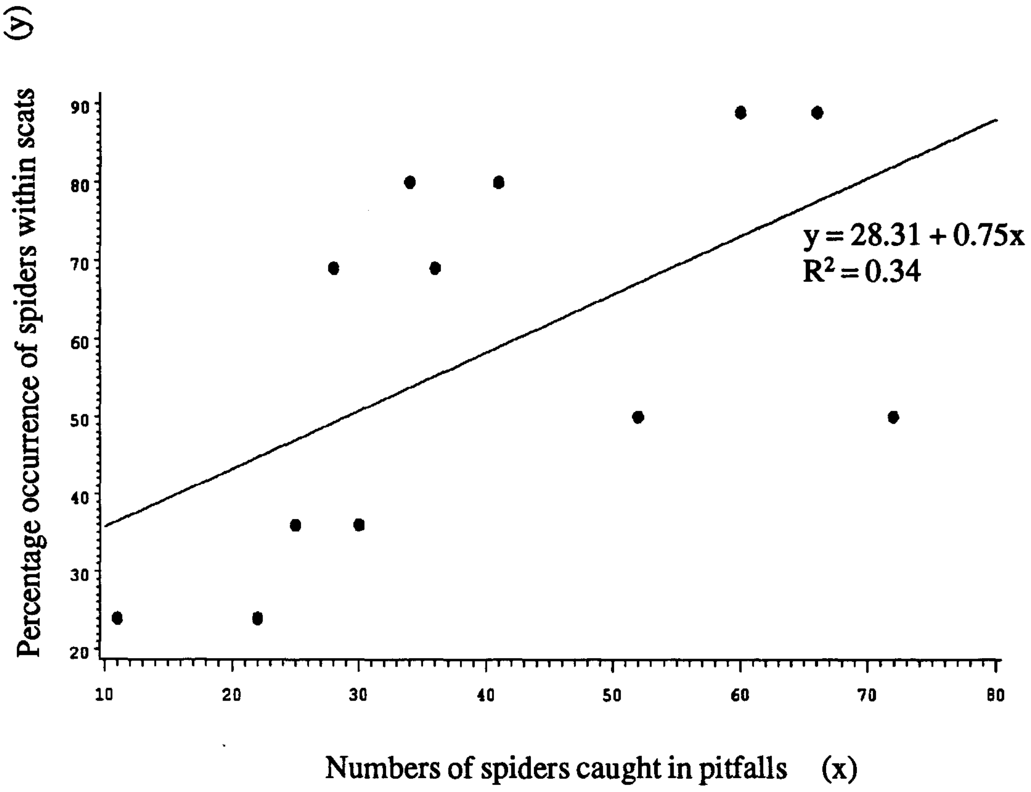

Figure 8. Plot showing percentage occurrence of spiders within scats against total numbers of spiders caught in pitfalls at all sites.

p=0.52; cockroaches by number: F=0.79; df=1,10; p=0.39; by percentage occurrence: F=0.25; df=1,10; p=0.63; Lepidoptera larvae by number: F=2.22; df=1,10; p=0.17; by percentage occurrence: F=0.64; df=1,10; p=0.44; grasshoppers by number: F=0.001; p=0.97; by percentage occurrence: F=0.003; p=0.96). This suggests that selection of these resources does not vary with availability, or that pitfalling is not an accurate measure of availability for these prey types. The latter is most likely the case for cockroaches. As their occurrence within scats was found to be significantly different between sites, some other factor, apart from availability through activity, may be affecting their selection as a prey item.

## Invertebrate fauna

The range of invertebrate types caught at each site exceeded the range that was identified within *D. impar* scats in 1994. Formicidae were the most common invertebrates in pitfalls at 2CY1, 2CY2 and 2CY3, with ants and slaters the most common at the Stockpound. Ants, as well as spiders, were the most common invertebrates at CSIRO1, while at Kaleen3 slaters occurred in the highest numbers (Appendix D).

Lepidoptera larvae of the family Anthelidae (genus *Pterolocera*) were found at all sites except Kaleen3 where only one Lepidoptera larvae was caught. This specimen could not be identified to family level, owing to poor condition. Noctuidae larvae were found at all other sites but 2CY2, while larvae of the family Arctiidae were found at 2CY1, 2CY3 and CSIRO1.

Invertebrate lists compiled through the combination of all trapping techniques revealed minimal differences between sites in the invertebrate families present (Appendix E). However, numbers of invertebrates caught in alcohol pitfalls varied between sites, with numbers of spiders significantly different between sites for both sampling periods (week ending 24-Nov-94: F=7.17 df=5, 54; p<0.001; week ending 16-Dec-94: F=5.04; df=5, 54; p<0.001). A TUKEY's test (SAS Institute Inc. 1989) showed that those sites that were significantly different in spider numbers varied between the two sampling periods. For the week ending 24-Nov-94 numbers of spiders at 2CY1 were significantly lower than at 2CY2, Kaleen3 and CSIRO1, with 2CY3 and the Stockpound also significantly lower in spider numbers than CSIRO1 (Figure 9). For the week ending 16-Dec-94 the number of spiders at 2CY1 was significantly lower than CSIRO1 and Kaleen3, with 2CY2 and 2CY3 also significantly lower than Kaleen3 (Figure 10). For both sampling periods spider numbers were lowest on average at 2CY1, while sites CSIRO1 and Kaleen3 showed the highest average numbers of spiders for both sampling periods (Figure 9 and 10).

Numbers of crickets caught in invertebrate pitfalls were also significantly different between sites (week ending 16-Dec-94: F=40.17; df=5,54; p<0.001). Pitfalls at the Stockpound caught significantly higher numbers of crickets than at Kaleen3 while both these non-native grasslands were found to have significantly higher numbers in pitfalls than all other sites (TUKEY's test). Numbers were lowest on average at 2CY1 and 2CY3 (Figure 11). Owing to low numbers in pitfalls, cricket numbers were not compared between sites for the week ending 24-Nov-94 (see Appendix D).

While low numbers of all other main prey types did not allow comparisons between sites, differences in the number of spiders and crickets caught within invertebrate pitfalls suggests that their availability as a prey type varied between sites. Numbers for both prey types were lowest at the native *Themeda* site, 2CY1, while the non-native *Festuca* site Kaleen3 was characterised by high numbers of both spiders and crickets, however, this trend was not found to be consistent between native and non-native study sites in general.

Comparisons between the invertebrates collected within the litter and grass tussocks showed that spiders occurred on sticky traps within both microhabitats at all sites (Figure 12 and 13). Cockroaches also occurred on sticky traps within both microhabitats at all sites except 2CY3. At sites where they occurred on sticky traps, both grasshoppers and Lepidoptera larvae were found only within the litter. At sites where crickets occurred on sticky traps, all individuals were also found within the litter, except at 2CY2 where individuals occurred in both microhabitats (Figure 12 and 13). As a consequence of high numbers at some sites, ants were not included in graphs to allow better comparisons between main prey types. Accepting that differences in the presence of invertebrate types within tussocks and litter may be a reflection of differences in trappability, the presence of grasshoppers, Lepidoptera larvae and crickets primarily

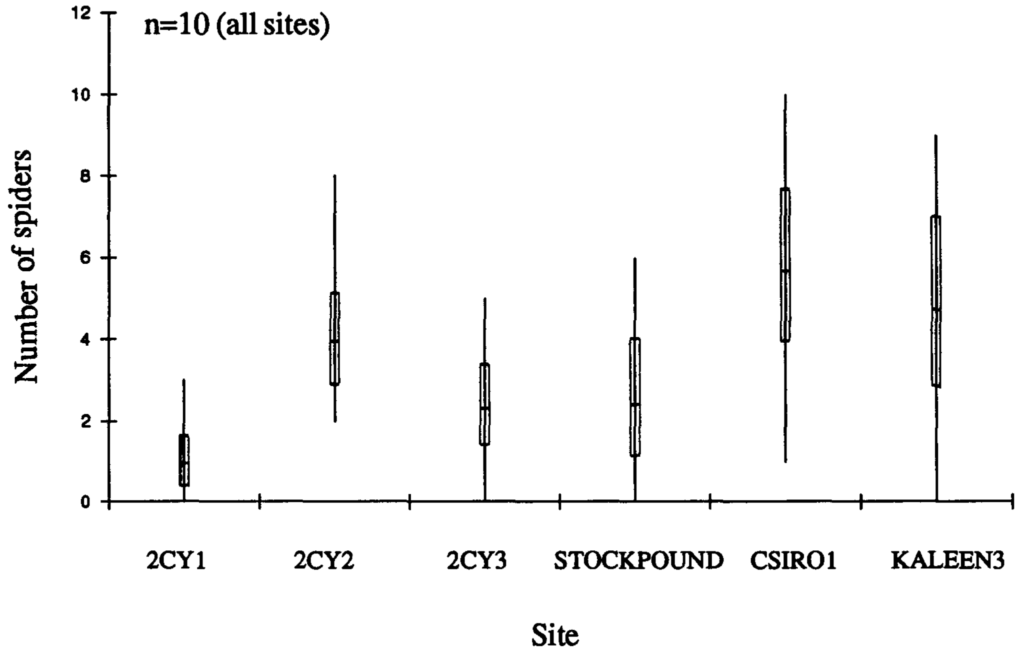

Figure 9. Numbers of spiders caught in pitfall traps at all sites for the week ending 24-Nov-94. Bar denotes mean. Box denotes mean +/- 2 standard errors. Line denotes range.For location of sites, refer to Figure 3.

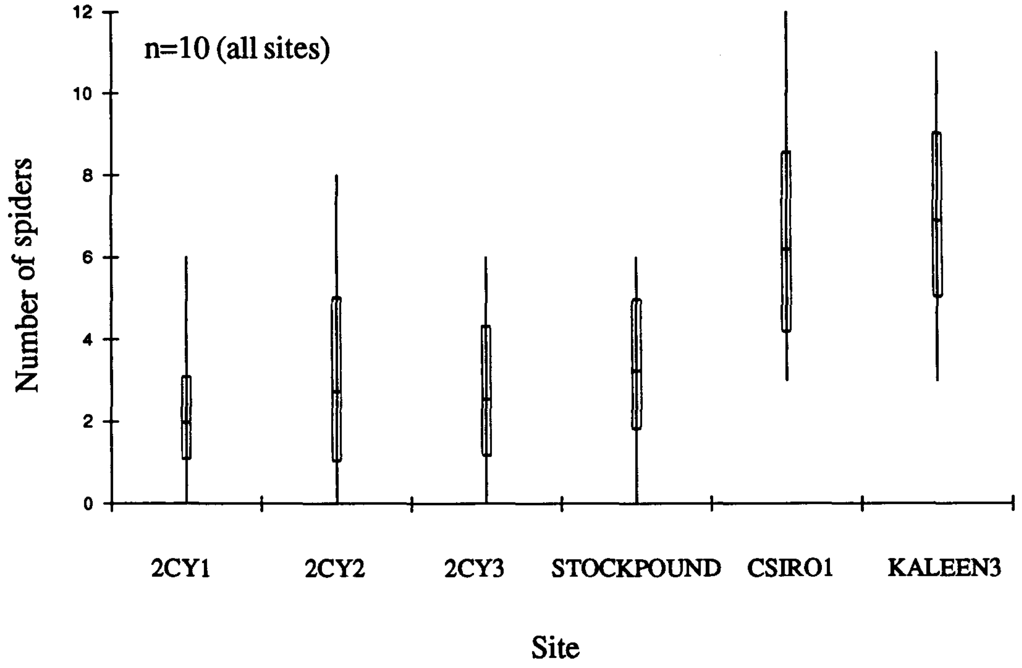

Figure 10. Numbers of spiders caught in pitfall traps at all sites for the week ending 16-Dec-94. Bars denote mean. Box denotes mean +/- 2 standard errors. Line denotes range. For location of sites, refer to Figure 3.

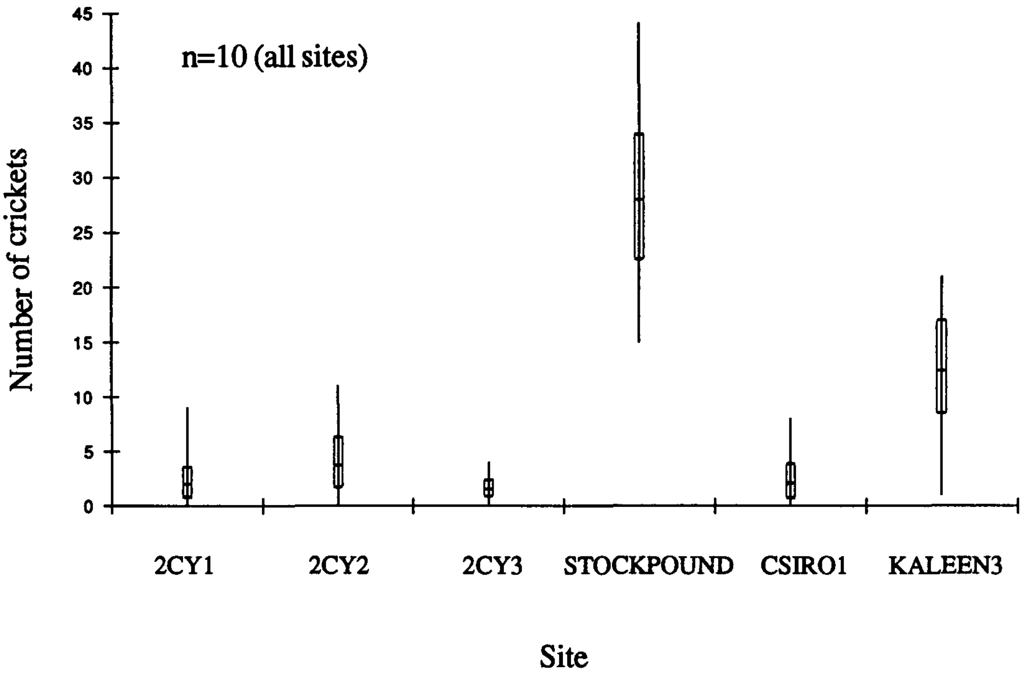

Figure 11. Numbers of crickets caught in pitfall traps at all sites for the week ending 16-Dec-94. Bar denotes mean. Box denote mean +/- 2 standard errors. Line denotes range. For location of sites, refer to Figure 3.

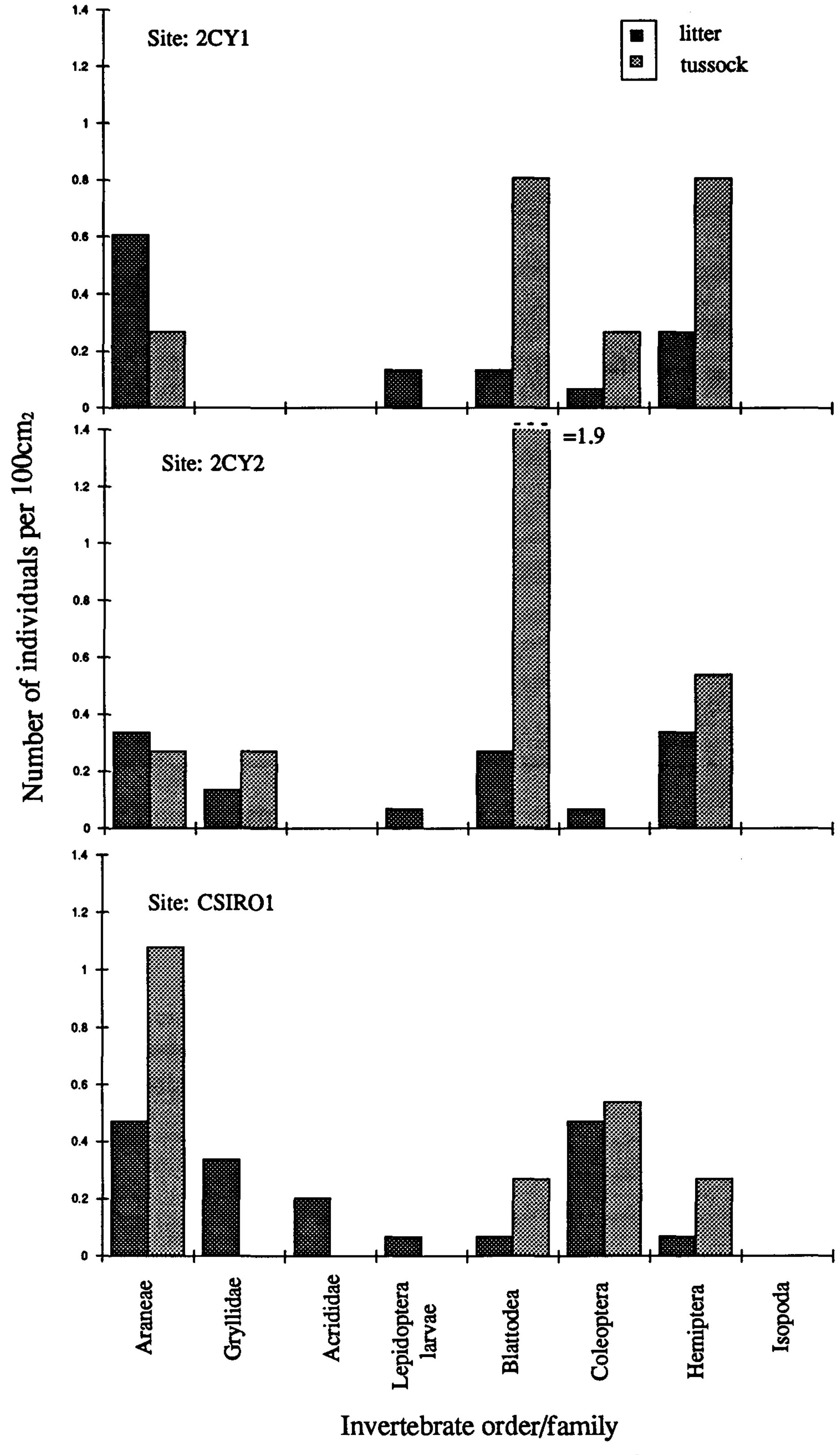

Figure 12. Number of individuals per 100 cm$^2$ for invertebrate orders/families captured by sticky traps in litter and tussock microhabitats on 29-Dec-94 at sites 2CY1, 2CY2 and CSIRO1. For location of sites, refer to Figure 3.

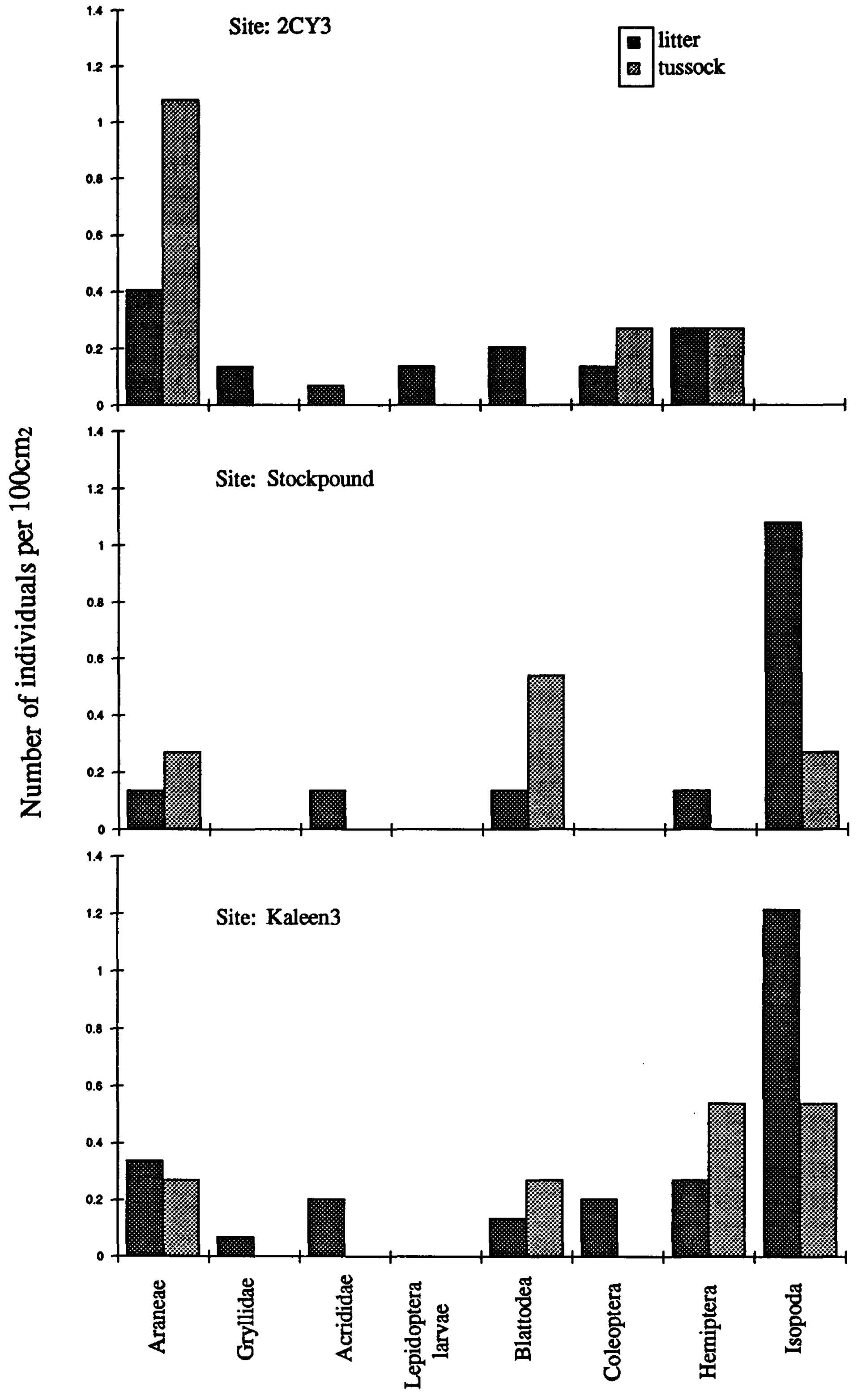

Figure 13. Number of individuals per 100cm$^2$ for invertebrate orders/families captured by sticky traps in litter and tussock microhabitats on 29-Dec-94 at sites 2CY3, Stockpound and Kaleen3. For location of sites, refer to Figure 3.

within the litter suggests that *D. impar* would be required to forage within the litter to access all main prey types while they are active.

At all sites spiders were caught both during the day and night, with a predominance of nocturnal captures occurring at Kaleen3 and 2CY2 and a predominance of diurnal captures occurring at other remaining sites (Figure 14 and 15). At sites where slaters occurred on sticky traps, all individuals were caught at night. Cockroaches were also caught on sticky traps predominantly at night, while the time of Lepidoptera larva and cricket captures varied between sites. All occurrences of grasshoppers on sticky traps were during the day, except at the Stockpound where individuals were caught during both times (Figure 14 and 15). As cockroaches occurred as a main prey type within the diet of *D. impar*, their primarily nocturnal activity suggests that *D. impar* are either feeding nocturnally, or that they are actively searching out cockroaches during the day. The latter supports the earlier stated hypothesis that activity (captures in pitfalls) is not reflecting the availability of cockroaches to *D. impar*.

## Body condition and abundance

*Delma impar* was found at all sites trapped during the current study. At the predominantly *Themeda* sites, 14 lizards were from 2CY1 with 5 from 2CY2. At the predominantly *Phalaris* sites, ten lizards were caught at 2CY3 and eight were from the Stockpound. At the *Stipa/Phalaris* mixed site, CSIRO1, nine lizards were caught, while four lizards were caught at the predominantly *Festuca* site, Kaleen3. Gravid females were caught at all sites except 2CY2. Juveniles occurred at all sites but 2CY2 and Kaleen3. Recaptures occurred at all sites except 2CY2 (see Appendix B) with no evidence of movement of marked individuals between adjacent sites.

After removing lizards with obvious dropped tails, a regression analysis showed a significant relationship between snout to vent length (as a proportion of total body length) and total body length (F=12.81; df=1,27; p=0.0013). Body weight and total body length were then plotted for these lizards with a significant relationship shown between the two at: 2CY1 (F=6.32; df=1,7; p=0.04), 2CY2 (F=150.87; df=1,2; p=0.007), 2CY3 (F=19.61; df=1,5; p=0.007), Stockpound (F=38.04; df=1,3; p=0.009) and CSIRO1 (F=38.35; df=1,4; p=0.004). Kaleen3 was not included in this analysis as all but one lizard showed evidence of tail loss at this site. Regression analysis comparing body weight plotted against body length showed no significant difference between sites in terms of slope (F=0.62; df=4,19; p=0.65) or elevation (F=0.72; df=1,19; p=0.72) (Figure 16). There is therefore no apparent evidence that body condition of lizards varied between sites.

Although the number of spiders caught in pitfalls was found to be significantly different between sites (Figure 9 and 10), and the number of *D. impar* caught at each site varied, no positive relationship between lizard abundance and spider availability was found for either invertebrate pitfalling period (Spearman Rank Correlation Test: for week ending 24-Nov-94 Rs=-0.66; p=0.156; for week ending 16-Dec-94 Rs=-0.77; p=0.07). This was also the case for crickets (week ending 24-Nov-94 Rs=-0.37; p=0.47; week ending 16-Dec-94 Rs=-0.77; p=0.07), cockroaches (on sticky traps: 29-Dec-94 Rs=-0.029; p=0.96) and grasshoppers (week ending 24-Nov-94 Rs=-0.49; p=0.32; week ending 16-Dec-94 Rs=-0.55; p=0.26.

While not significant, the predominance of negative correlations does suggests a negative relationship between prey availability and lizard abundance, implying that diet is not determining the abundance of *D. impar*. However, while a negative, but non significant, Rs value also occurred between the abundance of *D. impar* and the number of Lepidoptera larvae caught during the week ending 24-Nov-94 (Rs=-0.55; p=0.26), a significant positive correlation was found between the abundance of *D. impar* and the availability of Lepidoptera larvae at each site during the week ending 16-Dec-94 (Rs=0.99 p<0.001) (Figure 17). This illustrates the variability in prey abundance that occurred within the three months of the current study. Considering that an extended period of below average monthly rainfall was broken within this period (Figure 2), such variability is not surprising.

The positive correlation found between lizard abundance and Lepidoptera larva availability suggests a number of relationships. Firstly, the availability of Lepidoptera larvae may have an effect on lizard abundance. Secondly, lizard abundance may have a positive effect on the abundance of Lepidoptera larvae, through the lizards feeding on predators of the

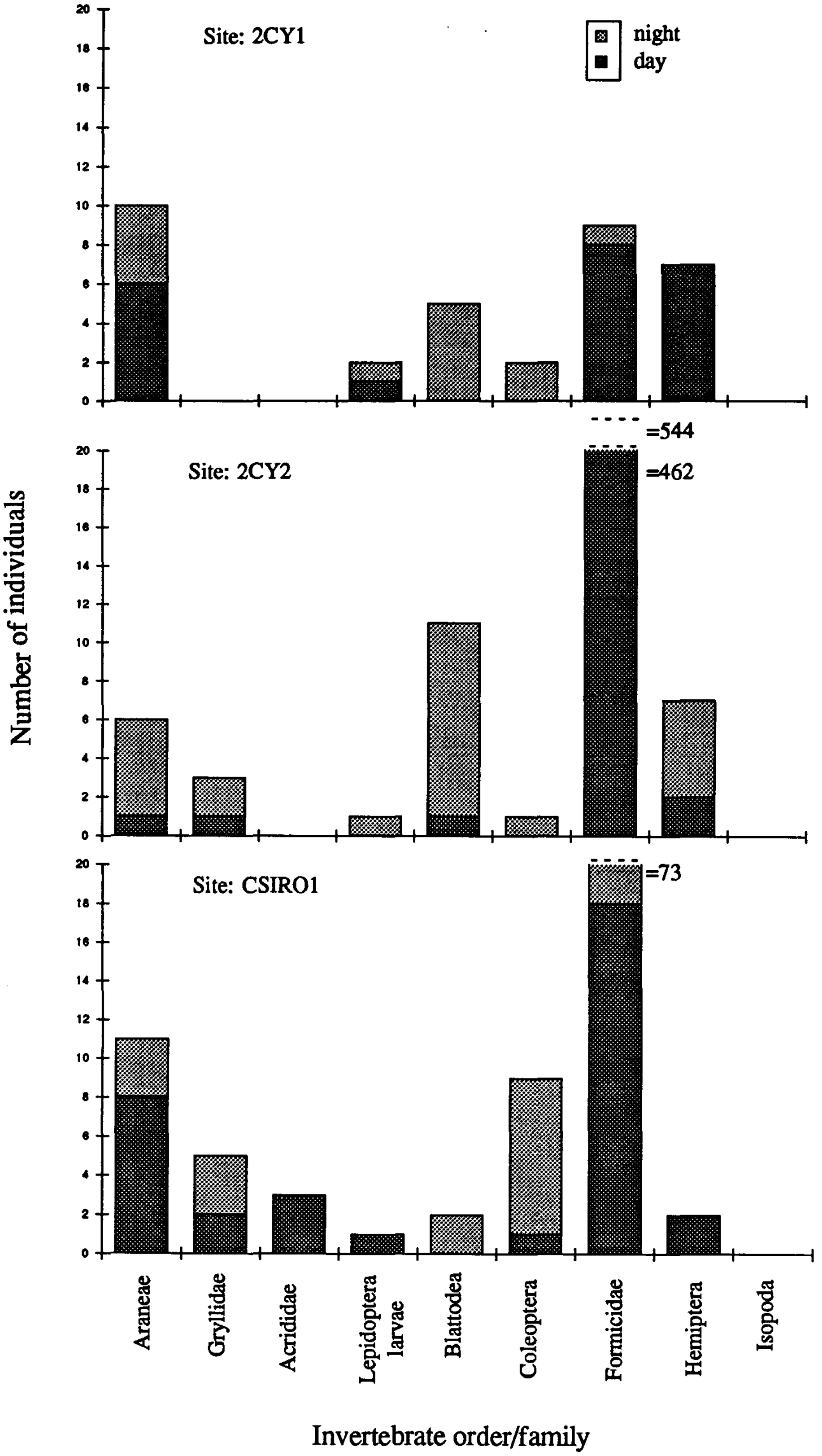

Figure 14. Number of individuals of different invertebrate orders/families captured by sticky traps during the day and during the night on 29-Dec-94 at sites 2CY1, 2CY2 and CSIRO1. For location of sites, refer to Figure 3.

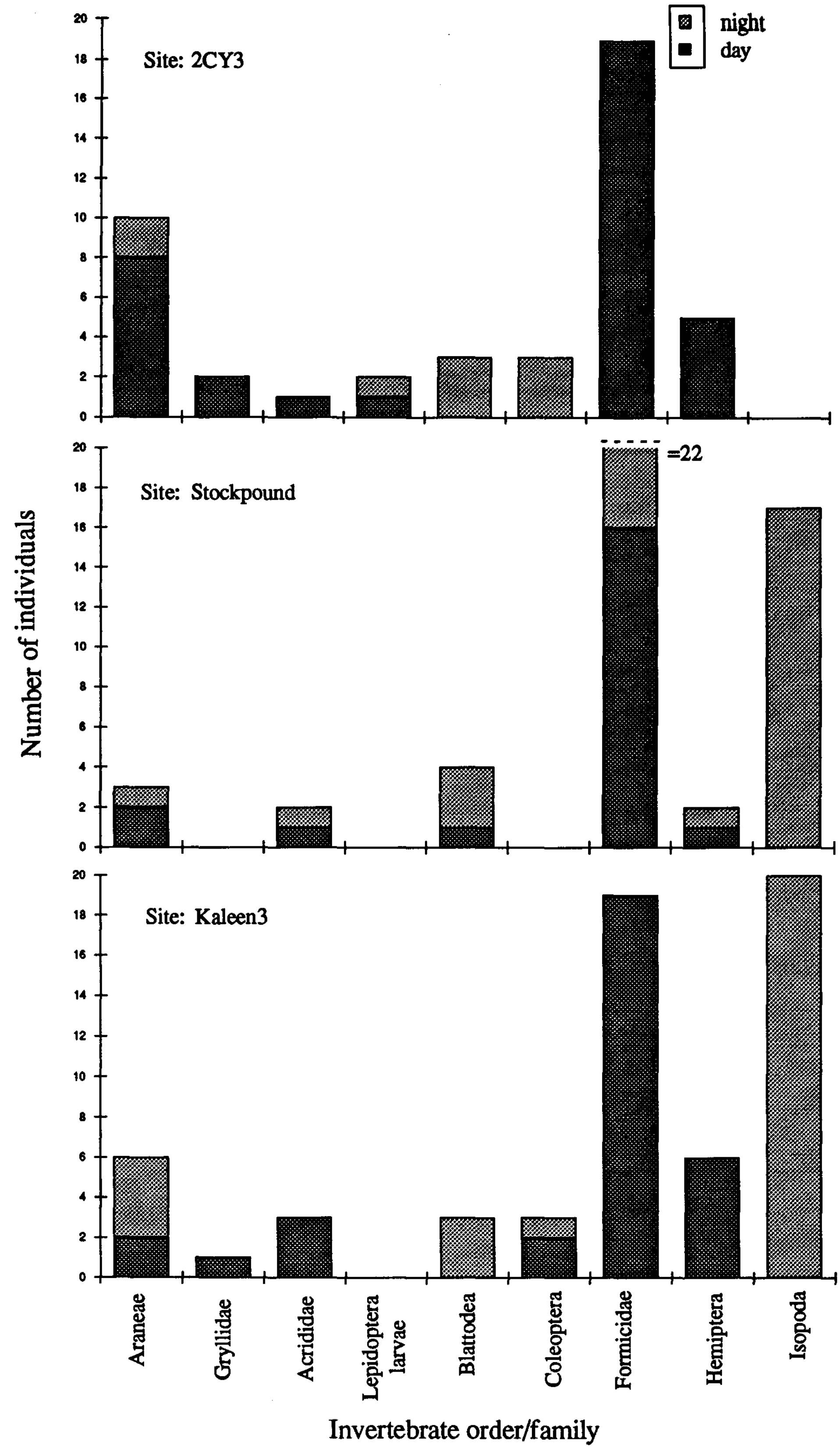

Figure 15. Number of individuals of different invertebrate orders/families captured by sticky traps during the day and during the night on 29-Dec-94 at sites 2CY3, Stockpound and Kaleen3. For location of sites, refer to Figure 3.

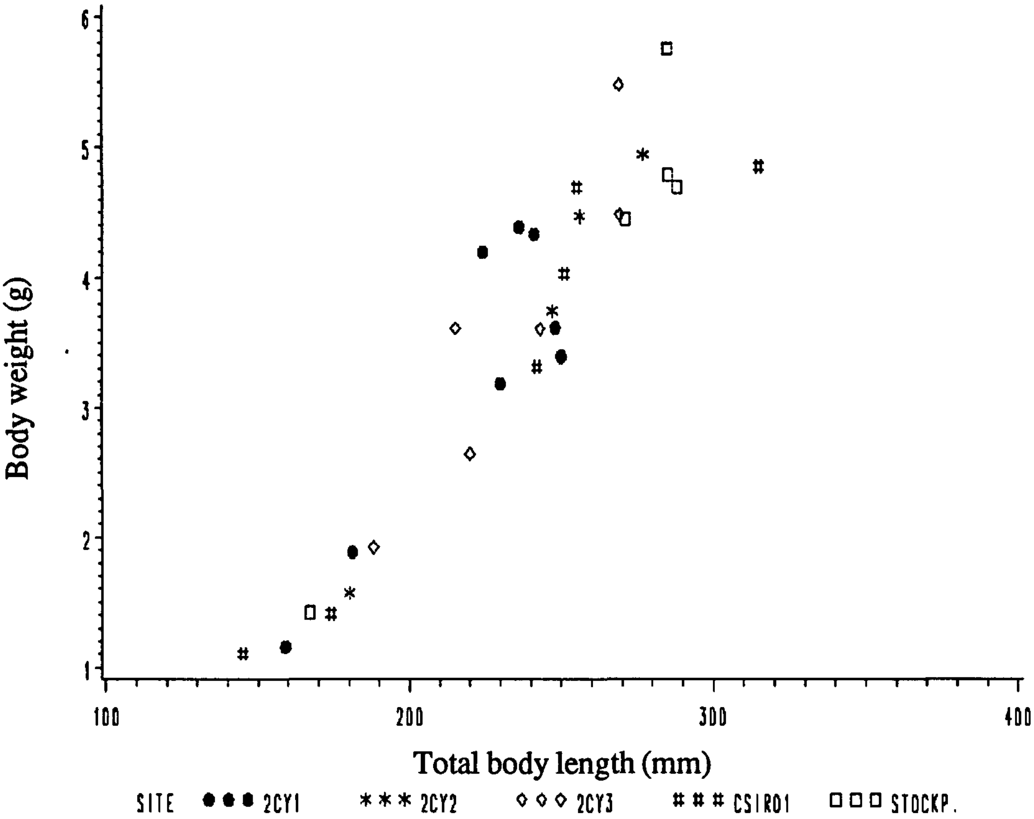

Figure 16. Plot showing body weight against total body length for all *Delma impar* without dropped tails at all sites. For location of sites, refer to Figure 3.

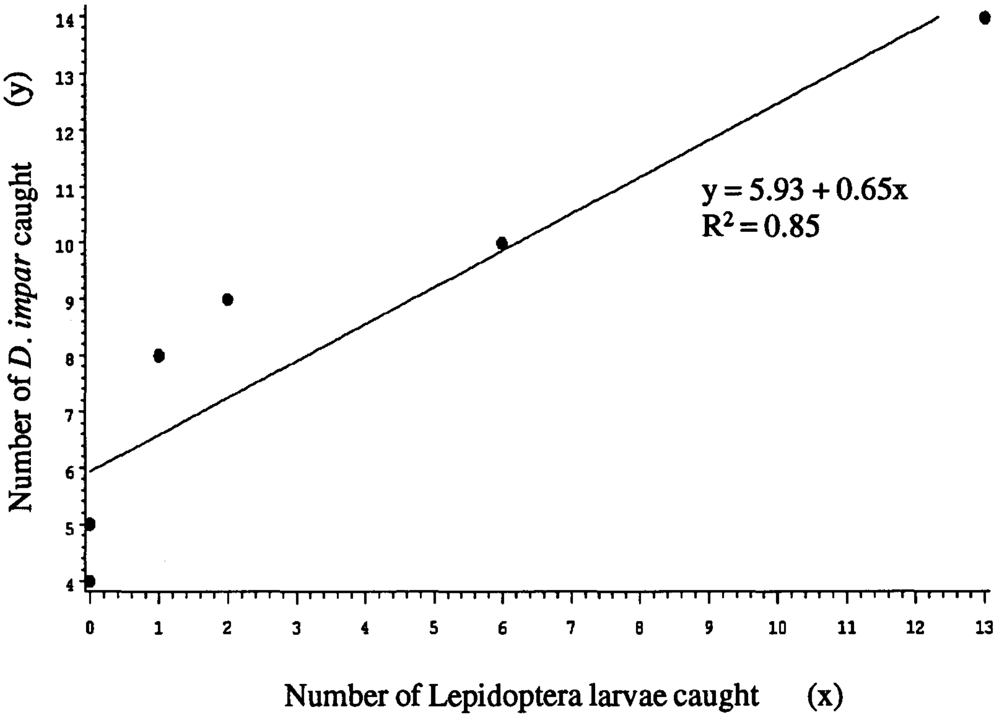

Figure 17. Plot showing total number of *Delma impar* caught against number of Lepidoptera larvae caught in pitfalls during the week ending 16-Dec-94 at all sites.

larvae. Thirdly, lizard abundance and Lepidoptera availability may not be directly related, but jointly influenced by some other factor, i.e. they both prefer the same conditions. Considering that Lepidoptera larvae are a main prey type of *D. impar,* the first relationship appears most likely. While the results of the current study cannot conclusively determine the cause and effect of this relationship, it does appear that high lizard abundance can be predicted from high Lepidoptera larva availability.

## Geographic and temporal variation in diet

Seasonal changes in the average number of prey per scat were not consistent between all sites. The average number of prey per scat was highest during January, February and March of 1992 for the Mitchell site, while at Majural the highest average was shown during October, November, December Of 1991. Minimal change in the average number of prey per scat was shown at 2CY1 between the two seasons. For both seasons spiders were the only prey type found to occur in multiple numbers within one scat (Table 5).

Although the proportion of scats containing each prey type was similar between seasons at Majural, this trend was not apparent at 2CY1 or Mitchell (Figure 18). This was reflected by a significant difference in the ranking of prey types between seasons for 2CY1 and Mitchell (Spearman Rank Correlation Test: Rs=0.41; p=0.41 and Rs=0.94; p=0.06 respectively), with no significant difference found at Majural (Rs=1.00; p=0.0). However, spiders did remain as a predominant prey type within scats during both seasons at all sites (Figure 18).

Regardless of differences in the ranking of prey types, the proportion of lizards feeding on spiders, Lepidoptera larvae, Orthoptera (grasshoppers and crickets) and cockroaches was not significantly different between seasons for all sites (Fisher Exact, for Majural: spiders p=1.00; n=24, grasshoppers and crickets p=1.00; n=24, Lepidoptera larvae p=1.00; n=24 and cockroaches p=1.00; n=24, for 2CY1: spiders p=0.655; n=22, grasshoppers and crickets p=0.169; n=22, Lepidoptera larvae p=0.616; n=22 and cockroaches p=1.00; n=22, for Mitchell: spiders p=0.294; n=17, grasshoppers and crickets p=1.00; n=17, Lepidoptera larvae p=0.101; n=17 and cockroaches p=1.00; n=17). While selection may vary in terms of the ranking of prey types, no evidence of extreme prey switching to utilise seasonally available prey is evident. This finding is somewhat speculative, however, as it assumes that invertebrates do vary in availability within the activity period of *D. impar*, for which there is no supporting data.

Ranking of prey types was found to be significantly different between years at 2CY1 (Spearman rank Correlation Test: Rs=0.68; p=0.14), with spiders and Lepidoptera larvae the predominant prey types within scats from 1991 and cockroaches the predominant prey type in scats from 1994 (Figure 19). The proportion of lizards feeding on spiders, grasshoppers and crickets, Lepidoptera larvae and cockroaches, however, was not significantly different between years (Fisher Exact Test, for spiders: p=0.274; n=37, for grasshoppers and crickets: p=0.618; n=37, for Lepidoptera larvae: p=0.136; n=37, for cockroaches: p=0.723; n=37). Both Lepidoptera adults and flies were not found to occur within scats from 1991 (Figure 19).

For Majural a significant difference was also found between different years for the ranking of prey types (Rs=0.59; p=0.22). But there was no significant difference between years in the proportion of scats containing spiders (p=0.644; n=26), grasshoppers and crickets (p=1.00; n=26), Lepidoptera larvae (p=0.136; n=26) or cockroaches (p=1.00; n=26). Spiders were the predominant prey type within scats for both 1991 and 1992. Although present within 25% of scats from 1991, Lepidoptera larvae were absent from all 1992 scats (Figure 20). While proportions within the diet did not differ significantly between years, variation in the presence and predominance of main prey types does suggest the presence of a slight variation in the diet on a broad temporal scale.

Geographic variation in the diet of *D. impar* is evident through differences in the percentage occurrence of prey types within scats between sites in the ACT and Victoria for 1991/92. While spiders were the most common prey type within scats at both ACT sites, crickets and Lepidoptera larvae were the most common prey type in Victorian scats (Figure 21). A 2x2 contingency table showed that the proportion of scats containing spiders was not only significantly different between states (for Majural and Derrimut: $\chi^2$ =12.02; df=1; n=45;

Table 5. Diet of *Delma impar* at sites Majural, 2CY1 and Mitchell for October, November, December 1991 and January, February, March 1992. No. prey denotes number of prey items consisting of each prey type. No. scats denotes the number of scats each prey type occurred within. Numbers in parentheses are percentages. L= larvae. For location of sites, refer to Figure 3.

Site: Majural

| Season | O/N/D | | J/F/M | |
|---|---|---|---|---|
| Taxon | No. prey | No. scats | No. prey | No. scats |
| Araneae | 21(62) | 13(81) | 6(55) | 6(75) |
| Orthoptera | 2(6) | 2(13) | 1(9) | 1(13) |
| Lepidoptera L. | 4(12) | 4(25) | 2(18) | 2(25) |
| Blattodea | 5(15) | 4(25) | 2(18) | 2(25) |
| Coleoptera | 1(3) | 1(6) | 0 | 0 |
| Diptera | 1(3) | 1(6) | 0 | 0 |
| Total | 34 | 16 | 11 | 8 |
| Mean no. prey per scat | | 2.1 | | 1.4 |

Site: 2CY1

| Season | O/N/D | | J/F/M | |
|---|---|---|---|---|
| Taxon | No. prey | No. scats | No. prey | No. scats |
| Araneae | 11(48) | 6(38) | 3(38) | 3(50) |
| Orthoptera | 1(4) | 1(6) | 2(25) | 2(33) |
| Lepidoptera L. | 6(26) | 6(38) | 1(13) | 1(17) |
| Blattodea | 4(17) | 4(25) | 2(25) | 2(33) |
| Coleoptera | 1(4) | 1(6) | 0 | 0 |
| Diptera | 0 | 0 | 0 | 0 |
| Total | 23 | 16 | 8 | 6 |
| Mean no. prey per scat | | 1.4 | | 1.3 |

Site: Mitchell

| Season | O/N/D | | J/F/M | |
|---|---|---|---|---|
| Taxon | No. prey | No. scats | No. prey | No. scats |
| Araneae | 5(42) | 5(42) | 6(50) | 4(80) |
| Orthoptera | 2(17) | 2(17) | 1(8) | 1(20) |
| Lepidoptera | 3(25) | 3(25) | 4(33) | 4(80) |
| Blattodea | 2(17) | 2(17) | 1(8) | 1(20) |
| Coleoptera | 0 | 0 | 0 | 0 |
| Diptera | 0 | 0 | 0 | 0 |
| Total | 12 | 12 | 12 | 5 |
| Mean no. prey per scat | | 1 | | 2.4 |

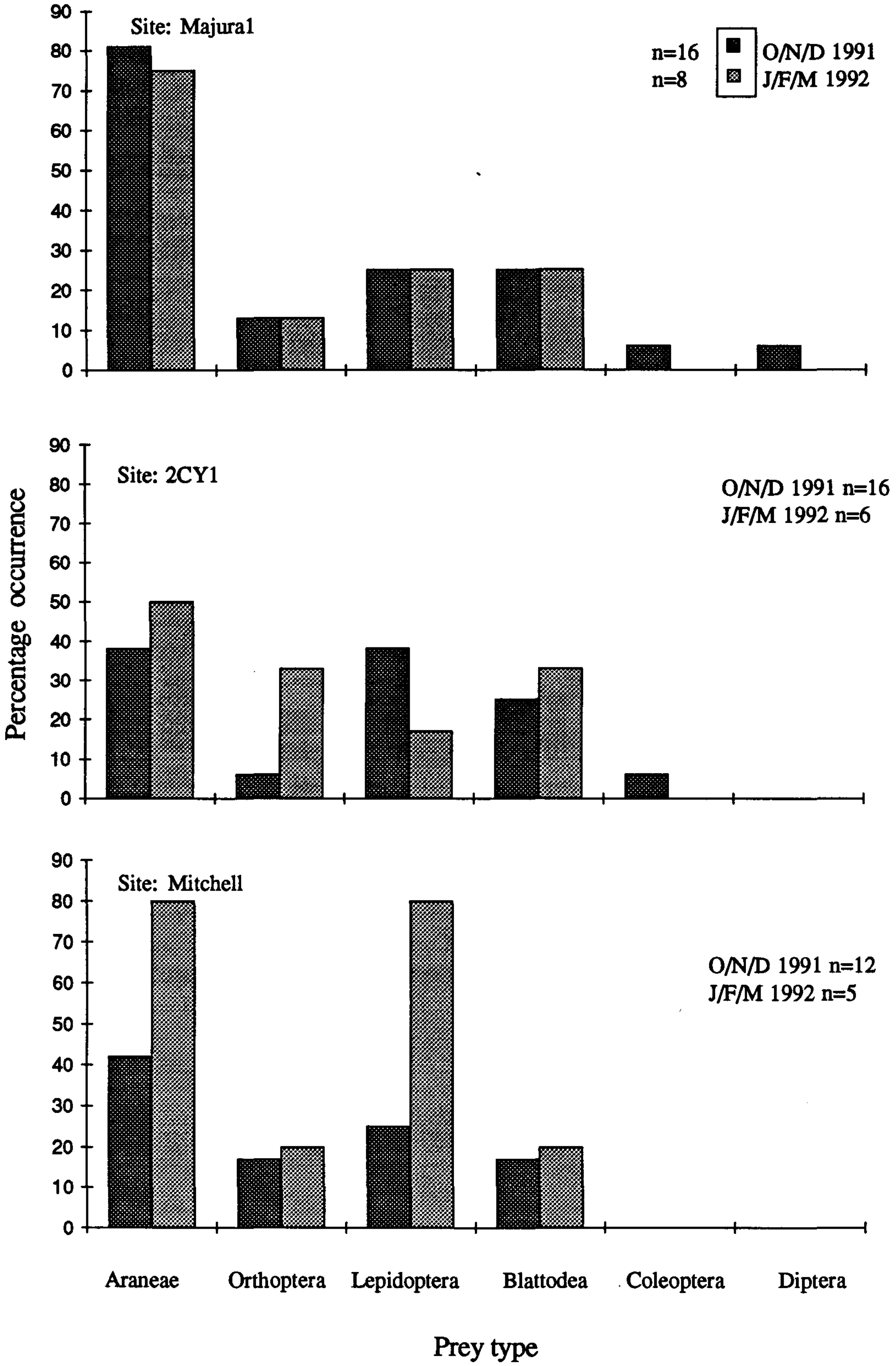

Figure 18. Seasonal changes in *Delma impar* diet from October, November, December 1991 to January, February, March 1992 as percentage occurrence within scats at each site. For location of sites, refer to Figure 3.

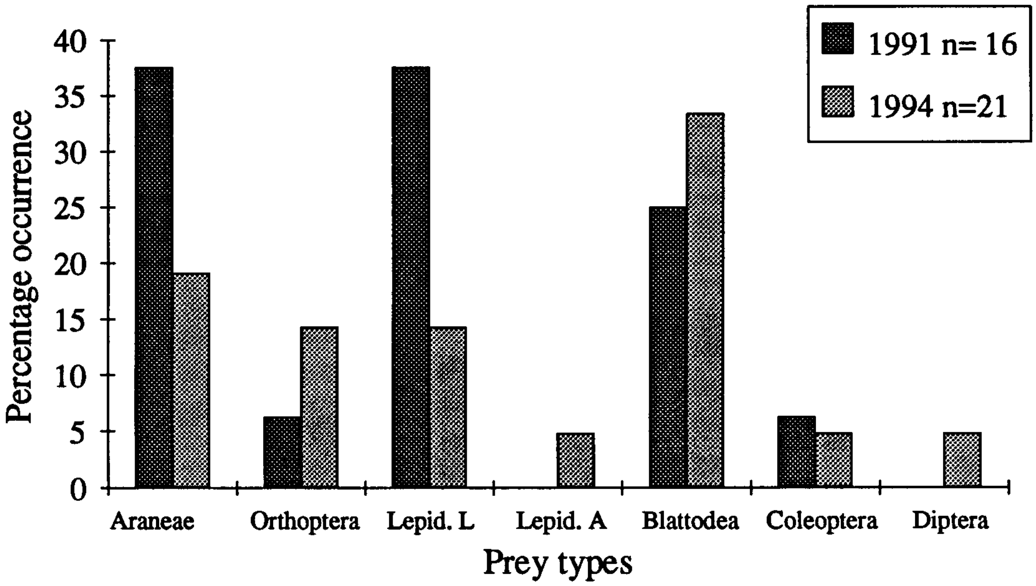

Figure 19. Percentage occurrence of invertebrate prey types within *Delma impar* scats at site 2CY1 for October/November/December of 1991 and 1994. Lepid L=Lepidoptera larvae. Lepid. A=Lepidoptera adult. For location of sites, refer to Figure 3.

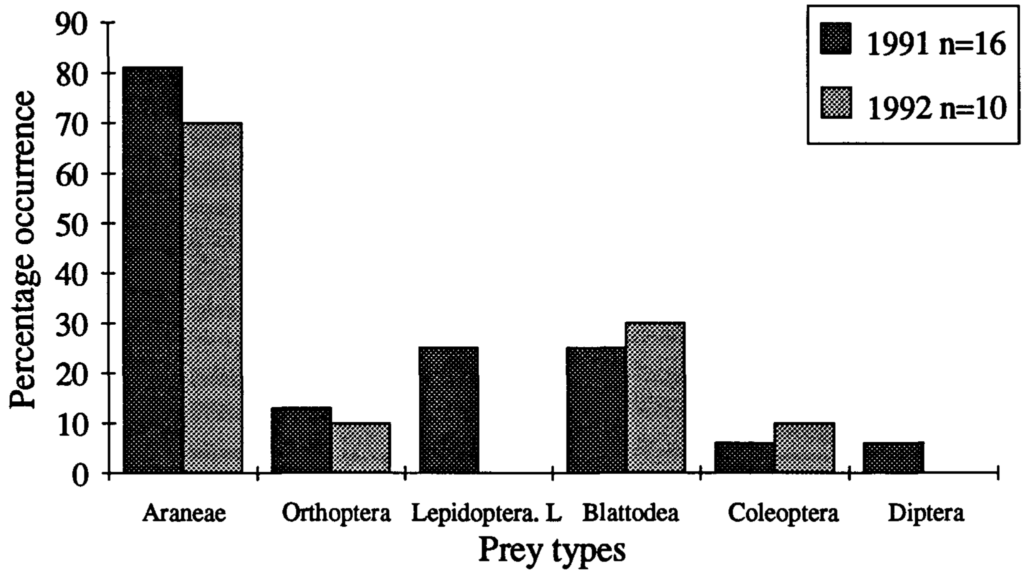

Figure 20. Percentage occurrence of invertebrate prey types within *Delma impar* scats at site Majural for October/November/December of 1991 and 1992. L=larvae. For location of sites, refer to Figure 3.

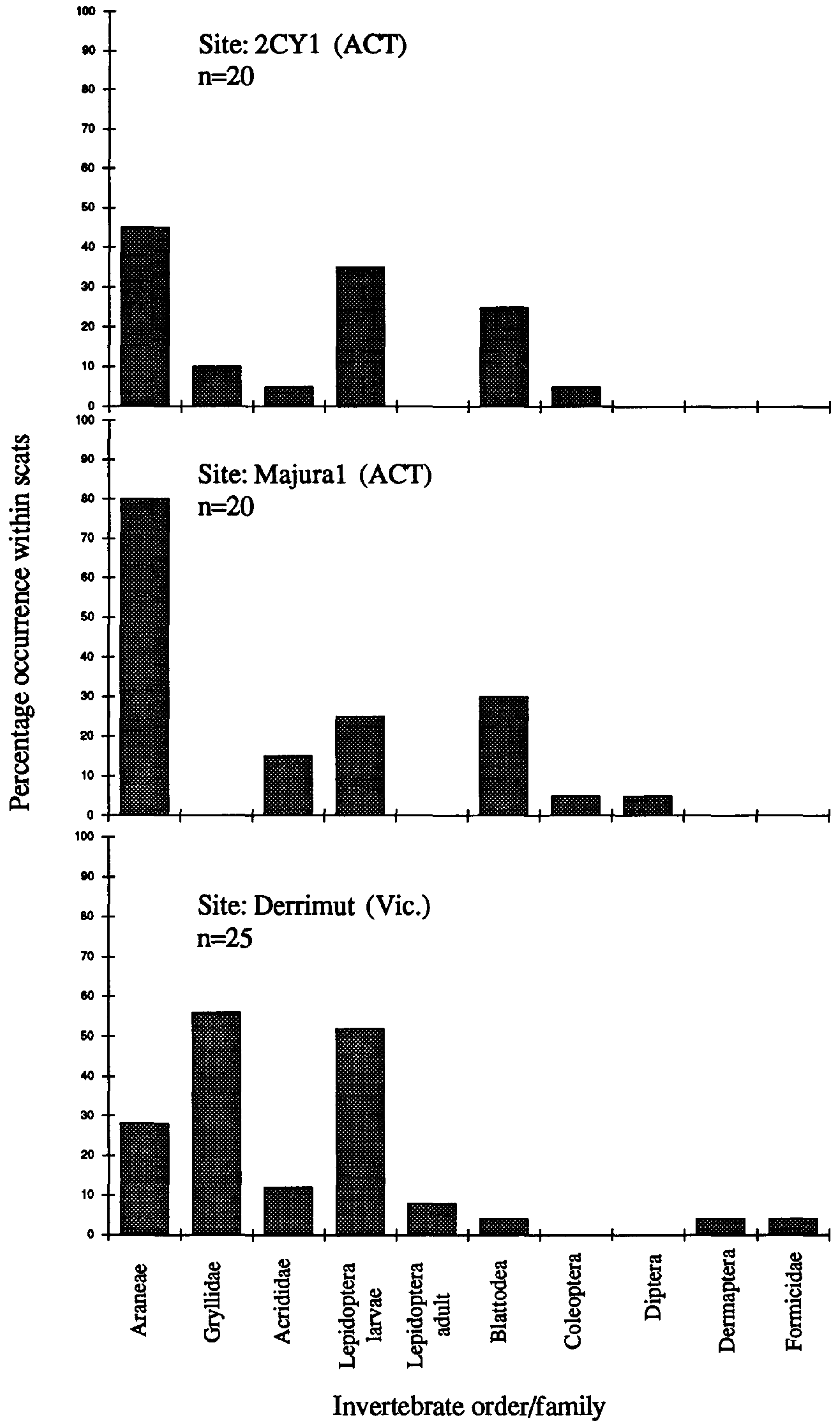

Figure 21. Percentage occurrence of invertebrate orders/families within *Delma impar* scats for late spring/summer of 1991/92 in the ACT and at Derrimut in Victoria. For location of ACT sites, refer to Figure 3.

p=0.001) but also between ACT sites (for Majural and 2CY1: $\chi^2 = 5.23$; df=1; n=40; p=0.022).

The proportion of scats containing Lepidoptera larvae was found not to be significantly different between all three sites (3 ×2 contingency table, $\chi^2 = 3.57$; df=2; n=65; p=0.168) while a significant difference in the proportion of scats containing crickets was found between Victoria and the ACT (Fisher Exact Test, 2×2 contingency table, for 2CY1 and Derrimut: p=0.001; n=45, for Majural and Derrimut: p<0.001; n=45) but not between ACT sites (for 2CY1 and Majural p=0.487; n=40). This was also the case for cockroaches (for 2CY1 and Derrimut: p<0.001; n=45, for Majural and Derrimut: p=0.033; n=45, for 2CY1 and Majural: p=0.723; n=40). No significant difference was found in the proportion of scats containing grasshoppers between all sites (for 2CY1 and Majural: p=0.605; n=40, for 2CY1 and Derrimut: p=0.617; n=45, for Majural and Derrimut: p=1.00; n=45). Lepidoptera adults and ants were absent from 2CY1 and Majural scats, although they did occur in scats from ACT sites collected in 1994 (Table 4). Scats collected at the Victorian site contained a wider range of prey types, although these did not include beetles, nor flies (Figure 21).

### Diet of *Delma inornata*

A total of 17 *D. inornata* scats collected within the ACT during November and December 1991 were analysed. Spiders were the most common prey item within the scats while Lepidoptera adults, cockroaches and grasshoppers were also common. Spiders of the families Lycosidae and Salticidae both occurred within scats, with the former being the most common. The average number of prey per scat ranged from 1.5 to 2.5 with spiders and grasshoppers both occurring in multiple numbers within one scat (Table 6).

Due to the non-uniformity of invertebrate fragment size and shape, size differences between individual prey items could not be quantified. However, dimensions of head and leg fragments were noticeably larger within D. *inornata* scats, in comparison to those within *D. impar* scats. Apart from springtails, all prey types known to be taken by *D. impar* within the ACT were also taken by *D. inornata*, with Hemiptera the only *D. inornata* prey type absent from *D. impar* scats (Table 7).

Table 6. Diet of *Delma inornata* during November and December of 1991 at the National Museum, Lake Ginninderra and Jerramalee sites. L=larvae. A=adult. Numbers in parentheses are the percentage of all prey constituted by each prey type and the percentage of scats that contained each prey type. For location of sites, refer to Figure 3.

| Site | National Museum | | Lake Ginninderra | | Jerramalee | |
|---|---|---|---|---|---|---|
| Taxon | No. prey | No. scats | No. prey | No. scats | No. prey | No. scats |
| Araneae | 6(40) | 3(50) | 9(45) | 5(56) | 2(67) | 1(50) |
| Gryllidae | 1(7) | 1(17) | 1(5) | 1(11) | 0 | 0 |
| Acrididae | 6(40) | 2(33) | 1(5) | 1(11) | 0 | 0 |
| Lepidoptera L | 0 | 0 | 1(5) | 1(11) | 1(33) | 1(50) |
| Lepidoptera A | 1(7) | 1(17) | 3(15) | 3(33) | 0 | 0 |
| Blattodea | 1(7) | 1(17) | 2(10) | 2(22) | 0 | 0 |
| Coleoptera | 0 | 0 | 1(5) | 0 | 0 | 0 |
| Diptera | 0 | 0 | 0 | 0 | 0 | 0 |
| Formicidae | 0 | 0 | 1(5) | 0 | 0 | 0 |
| Hemiptera | 0 | 0 | 1(5) | 0 | 0 | 0 |
| Total | 15 | 6 | 20 | 9 | 3 | 2 |
| Average no. prey per scat | | 2.5 | | 2.2 | | 1.5 |

Table 7. Presence of invertebrate types in the diet of *Delma impar* and *D. inornata* within the ACT. L=larvae. A=adult.

| | *D. impar* | *D. inornata* |
|---|---|---|
| Araneae | ● | ● |
| Gryllidae | ● | ● |
| Acrididae | ● | ● |
| Lepidoptera L. | ● | ● |
| Lepidoptera A. | ● | ● |
| Blattodea | ● | ● |
| Coleoptera | ● | ● |
| Diptera | ● | ● |
| Formicidae | ● | ● |
| Collembola | ● | |
| Hemiptera | | ● |

# CHAPTER 4

# DISCUSSION

## Diet of *Delma impar*

*Delma impar* has previously been described as an opportunistic insectivore or generalist arthropod feeder, displaying some dietary selectivity (Wainer 1992). The results of the current study do not support either of these descriptions, for the following reasons. Firstly, as dietary opportunists utilise whatever resources are locally and immediately available (James 1991), the lack of a number of abundant invertebrate types, particularly Isopoda, Hemiptera and Formicidae, within the diet of *D. impar* does not justify its inclusion within this category. Secondly, while values for trophic niche calculated for *D. impar* in 1994 did vary, all were closest to the specialist end of the niche scale (Table 4). Therefore, defining the species as a generalist is considered incorrect. In view of the findings of the current study, *D. impar* may therefore be best defined as a selective arthropod feeder that preys most commonly on spiders, crickets, Lepidoptera larvae and cockroaches. While the species should not be considered as a dietary specialist, it does feed on a range of invertebrates which is narrower than the range that is available.

While the use of dietary descriptives such as "specialist" and "generalist" may be useful for comparative situations, I would like to stress that the use of these terms on an absolute level can be ambiguous as they are often inconsistent in definition (see Fox and Morrow 1981). Although the calculation of dietary niche breadth may reduce this ambiguity, accuracy of its calculation is difficult to achieve, as it relies on the ability to determine what is, and what is not, available to an organism, as well as gauge the organism's level of resource discrimination (Petraitis 1979).

Wainer (1992) suggested that the absence of invertebrates, such as Isopoda, from the diet of *D. impar* may be due to their unpalatability, or the fact that these invertebrates are not diurnally active. Results of the current study confirm that Isopoda are predominantly nocturnal (Figures 14-15), however, as cockroaches were also predominantly nocturnal, but occurred within the diet, the lack of Isopoda within scats does seem puzzling. Isopoda occur within the diet of other lizards (Guerrero and Perez-Mellado 1994, Brown 1991, Fellers and Drost 1991, Duarte Da Rocha 1989, Brown 1988) which suggests that they are indeed palatable, at least to some species.

Isopoda were found to be absent, or relatively low in abundance, at the study sites dominated by native grasslands (Figure 5). As decisions on energy expenditure, such a prey selection, are honed through evolution (Zug 1993) a possible reason for their absence in the diet may therefore be the fact that they were unavailable to *D. impar* in relatively high numbers prior to inhabiting disturbed grassland sites, and may not be recognised as a potential prey item as a result. Alternatively, the hard exoskeleton of Isopoda may be too difficult for *D. impar* to manipulate and handle. This would also offer an explanation as to why Coleoptera were an uncommon prey item (Table 4).

While scats containing noctuid moth larvae in Victoria were also found to contain large amounts of *Themeda* (Coulson 1990, Wainer 1992), both Coulson and Wainer suggested that this was a result of secondary ingestion. The incidence of grass within scats containing Lepidoptera larvae was uncommon in the current study. This may be a reflection of the dry conditions experienced in the region in the months before and during the study, possibly resulting in poor food quality for the larvae. While grass found within scats collected in 1994 was most commonly in the form of single fragments, it was also considered to be ingested unintentionally. As the occurrence of herbivory in lizards increases with body size (Brown 1991, Schoener *et al.* 1982) and is seen predominantly in the diet of those greater than 100g in weight (Pough 1973) it seems unlikely that a lizard the size of *D. impar* would be deliberately ingesting plant matter.

The occurrence of springtails within *D. impar* scats was unexpected, due to their small body size (< 2 mm), but interesting nonetheless. Several interpretations are plausible. Firstly, as springtails were found within scats that also contained soil particles, they may have been accidentally ingested when soil particles were consumed. Secondly, springtails may have been ingested deliberately, with soil accidentally ingested as a result. As springtails were not found to occur within any ACT scats from previous years, nor within scats from Victoria, the irregularity of their presence suggests that deliberate ingestion is unlikely. Alternatively, this absence from scats of previous years may reflect opportunistic behaviour. As a particularly dry period was experienced in 1994 (Figure 2), the possibility that Collembola may be opportunistically utilised as a food resource in times of low prey availability should be considered. Regardless of interpretation, in view of the small body size and infrequent occurrence of springtails within scats, it is unlikely that they are a major contributor to energy intake on a regular basis.

## Seasonal variation in diet

Although there was little evidence of seasonal variation in diet within the activity period of *D. impar*, results were based on low sample sizes and therefore cannot be considered conclusive. One might expect availability of prey types, such as Lepidoptera adults and larvae, as well as grasshoppers, to differ throughout the year as a result of their seasonal life stages. Variation in the seasonal availability of these prey types has been linked to compositional changes in diet for other lizard species (Brown 1988, Crome 1981). Considering the fact that *D. impar* appears to select spiders in relation to availability, one might therefore expect the species to also capitalise on changes in the availability of other prey types. The lack of conclusive results on seasonal variation in diet for *D. impar* emphasises the difficulties associated with reliance upon pitfall traps to collect sufficient data, particularly on a species for which trap success is best only in spring and early summer. Further difficulty in collecting sufficient sample sizes is added by the low rate of trap success that is characteristic of this species (Kukolic *et al.* 1994, Kukolic 1994).

## Effects of diet on distribution and abundance

Variation between the diet of *D. impar* within the ACT and Derrimut in Victoria has revealed that diet composition may vary spatially, representing a degree of dietary flexibility. While it cannot be assumed that this is a result of variation in prey availability, the increasing utilisation of spiders with increasing availability shown in the results of the current study (Figure 8) does suggest this.

Flexibility in dietary selectivity between populations has been observed in many reptile studies (Castilla *et al.* 1991, James 1991, Drummond and Marcias Garcia 1989, Losos and Greene 1988, Henderson *et al.* 1987, Shine 1986c, Pianka 1970) and provides a species with the ability to utilise those resources that are most readily available in their environment. Flexibility in the selection of main prey types and degree of specialisation may therefore explain why *D. impar* manages to persist over such a range of native and non-native grassland sites.

While the ability to vary diet may allow individuals to persist over a range of habitats, this does not necessarily constitute the maintenance of a viable population. Individuals must not only obtain energy requirements for survival, but also that required for successful reproduction. Brown (1988) noted that mean food volume per lizard was greatest just before mating for the scincid *Leiolopisma entrecasteauxii*, while for the tree lizard *Urosaurus ornatus*, Ballinger (1977) found maximum body weight was obtained just prior to the onset of reproduction, and linked reduced availability of prey with smaller clutch size and lower clutch frequency. Such examples clearly show that dietary requirements for reproduction may go beyond that of individual survival.

Gravid females and juveniles were caught at all sites except 2CY2 and Kaleen3 (Appendix B). Therefore, regardless of differences in composition, it appears that at these sites, diet is providing *D. impar* with the requirements for successful reproduction. This is further supported by the lack of difference in body condition between sites. It is unfortunate that Kaleen3 could not be included within the body condition comparison (see Body condition and abundance, page 30) as the highly disturbed nature of this site, together with the narrow range of prey taken, would have provided more substantial information on the persistence of *D. impar* populations at highly disturbed sites. However, the presence of gravid females at this site is a positive sign in terms of short term population recruitment and sustainability.

With flexibility in the degree of specialisation and selectivity, the diet of *D. impar* does not appear to be currently limiting the distribution of the species within the ACT, allowing it to persist over a range of native and non-native grassland sites. Results of the current study do suggest however, that the availability of Lepidoptera larvae is a possible limiting factor of lizard abundance (Figure 17). It seems puzzling that at the least disturbed and predominantly *Themeda* site 2CY2, numbers of *D. impar* were relatively low, with an absence of gravid females and juveniles. Numbers of Lepidoptera larvae, however, were also relatively low at this site. As only five lizards were caught at 2CY2, one might expect the chances of catching gravid females or juveniles to be unlikely. However, consideration must be given to the fact that within the same time frame, three gravid females and two juveniles were caught at the other *Themeda* site, 2CY1. In view of the predominance of Lepidoptera larvae in the diet of the species in Victoria (Figure 21), and at ACT sites in previous years (Figure 18 and 19), it is possible that this prey type is of particular importance.

If Lepidoptera larvae were a prey type of particular importance, one might expect the occurrence of this prey type within scats to vary between sites in relation to availability. However, no such relationship was found. Furthermore, a reduction in body condition was not shown at sites where larva numbers were low. There are a number of possible explanations for this. Firstly, sample sizes may have been too low to detect between site differences in body condition or larva utilisation. Secondly, individuals may be spacing themselves in relation to the availability of this prey type and maintaining levels of utilisation, as well as body condition, as result. As no information on intra-specific behaviour is documented for this species, such a suggestion is merely speculation; however, it could easily be tested through the experimental addition of Lepidoptera larva together with the monitoring of *D. impar* abundance. The manipulation of food availability and its effects on the spacing of individuals has previously been examined for a number of lizard species, with varying results (Simon 1975, Dubas and Bull 1992).

No consistent trend was shown between native and non-native grasslands in term of the availability of prey, or the relative abundance of *D. impar*. This suggests that factors affecting habitat quality for *D. impar* are not specifically determined by floristics and go beyond that of the main vegetation type. Furthermore, this reflects the variability in habitat quality which can occur between sites with the same predominant grass species.

## Correlates of movement and dietary attributes

- **Active foraging**

Although the original documentation of foraging mode for *D. impar* is unclear (see Patchell and Shine 1986, Bustard 1970), other species in the genus have previously been classed as active foragers (Patchell and Shine 1986). This is supported by the results of studies on movement for *D. impar* (Kutt 1992). With relatively slow moving prey (Lepidoptera larvae) and diurnally inactive prey (cockroaches) occurring within the diet, it does appear likely that *D. impar* are indeed active foragers, searching for their prey. The behaviour of *D. impar* when disturbed in the field (pers. obs.) is also consistent with that of widely foraging species, which tend to escape predation by fleeing (Perry *et al.* 1990). Research specifically on foraging behaviour is, however, required to substantiate this suggestion.

Different studies have linked widely foraging habits with opportunistic behaviour (Auffenberg 1978), dietary specialisation and also with broad dietary range (Lewis 1989, Pianka 1977, Schoener 1971). Such examples show that widely foraging habits may provide reptiles with the opportunity to change their dietary preference. In comparison to sit-and-wait predation, Lewis (1989) linked widely foraging with a greater chance of encountering rich prey patches. Therefore, as a wide forager, *D. impar* would have the ability to exploit food resources within patchy habitats, a useful trait for inhabiting sub-optimal or highly disturbed grassland sites.

As widely foraging predators generally do not take active prey (Henderson 1982), the predominance of spiders in the diet is interesting. While spiders were found to be active both nocturnally and diurnally in the current study (Figure 14 and 15), a possible explanation lies with the fact that the predominant spider family within the diet, Lycosidae, move in and out of their burrows during the day to maintain body temperature (Humphreys 1974). *Delma impar* may therefore be actively searching for spiders that are inactive within their burrows, for much of the day. An alternative hypothesis is prompted by other studies which have found that species may utilise a range of foraging modes (see Heatwole and Taylor 1987) with patterns of seasonal and diel variation (Pietruska 1986). Such an example is the Kalahari gecko *Ptenopus garrulus*. This species is normally a nocturnal predator, employing the sit-and-wait tactic of foraging from the entrance of its burrow. However, the species has been observed to forage widely, during the day, on occasions when termites swarm (Huey and Pianka 1981). While such a change in movement patterns is clearly a response to variation in prey availability, it does show that some lizards possess the ability to switch foraging strategies. If *D. impar* also has this switching ability it may spend time foraging widely, searching for prey types such as diurnally inactive cockroaches and relatively sedentary Lepidoptera larvae, as well as engaging in periods of little movement, when predation upon more active prey types such as spiders, crickets and grasshoppers would occur. The occurrence of such flexibility in foraging movements would support the alternative view that foraging behaviour is a continuum of tactics, rather than two polarised strategies. Observations of captive specimens suggest that *D. impar* does utilise both sit-and-wait and widely foraging strategies (Osmond 1994), however captive conditions and behaviour can be far removed from that of the natural environment.

- **Fossorial behaviour**

Bustard (1970) described the Pygopodidae as a fossorial family. However, whilst Osmond (1994) found that *D. impar* exhibited low temperature preferences similar to those of sedentary, fossorial lizards, she suggested that this may be more of an adaptation to a cool thermal regime, rather than the soil environment *per se*. The body form of *D. impar* is consistent with that of fossorial lizards, with reduced limbs and head width, as well as a smooth elongated body (Greer 1989). However, my results show that the species does not feed on those prey types that are characteristic of fossorial lizards, such as Annelida, Formicidae, Gastropoda and Isoptera (Brown 1991, Huey *et al.* 1974) supporting the view that the species is at least partly surface-active. Jones (1992) found a component of inorganic material within the majority of forty six scats of the pygopodid *Aprasia parapulchella*, a species known to exhibit fossorial behaviour (Osborne *et al.* 1991, Kluge 1974) and described as an adept burrower (Jenkins and Bartell 1980). The extremely low occurrence of such inorganic material within *D. impar* scats supports the view that *D. impar* is predominantly a surface-active predator that forages above the ground.

- **Difficulties in inferring movement patterns**

The physiological, behavioural, morphological and ecological traits of species have been associated with particular foraging strategies (see Perry *et al.* 1990), however species that utilise a range of foraging modes may possess morphological and ecological characteristics of both sit-and-wait and widely foraging groups (Heatwole and Taylor 1987). This stresses the fact that inferring movement patterns from such traits can be misleading and somewhat contradictive. In using physiological and genetic attributes to infer the activity patterns of *D. impar*, Osmond (1994) found contradictions between the two, with standard rates of metabolism suggesting that *D. impar* is largely surface-dwelling with moderate levels of activity, while displaying temperature preferences more similar to those of a fossorial lizard.

Inferences made on foraging behaviour in the current study are based on general trends observed over a range of reptile studies. However, exceptions to these trends are not uncommon. For example, the iguanid *Cortophanes cristatus* is classed as a highly sedentary, sit-and-wait predator, however it specialises on slow moving arthropods which are relatively uncommon (Andrews 1979). This is an exception to the trend of sit-and-wait predators taking active or highly abundant prey types (Pianka 1977). Such examples highlight the fact that the examination of prey types does not allow infallible predictions and is only constructive in developing hypothesises concerning movement patterns for the species.

## Difficulties in measuring prey availability and determining selectivity

To determine the degree to which predators are selecting food resources, knowledge is required on the behaviour of both predator and prey. As a result of their lack of movement, determining the availability of plants as food items for herbivores is relatively straight forward. However, as invertebrates vary in their range, mode and time of locomotion, determining their availability as prey items may be considered somewhat more complicated. This is reflected in the paucity of reptile studies which examine prey selection in lizards. Brown (1988) noted the dearth of Australian studies examining prey availability for lizards, as well as the resulting lack of knowledge on factors influencing prey selection.

When studies do examine prey availability, it is generally for comparative purposes, often utilising invertebrate pitfalling and sticky traps to compare lizard diet between years (Ballinger and Congdon 1980), seasons (James 1991), individuals (Simon 1975) and populations (Brown and Perez-Mellado 1994). Comparative use of these techniques overcomes the problem of between prey type bias which is inherent to both. While Luff (1975) showed that the efficiency of capturing Coleoptera in pitfalls is affected by size, shape and construction material, the use of preserving agents within the traps can attract different invertebrate types to varying degrees (Greenslade and Greenslade 1971). Sticky traps, on the other hand, are considered to show a bias against slow moving prey (Brown 1988), with evidence that they are avoided by invertebrates such as ants (Dunham 1978, Ballinger 1977).

Regardless of the possibility of these effects, pitfall and sticky traps are measures of invertebrate activity which may provide some information on prey selection for sit-and wait-predators. Due to the more extensive movements of active foragers, collecting invertebrates that move over a stationary point is unlikely to be an accurate measure of availability. A more appropriate method is the use of area sampling techniques, such as vacuum or litter sampling. These techniques measure actual abundance and allow dietary selection to be analysed for active foraging species (e.g. Lewis 1989). However, the use of area sampling can result in samples which are low in invertebrate numbers (Brown and Perez-Mellado 1994) and may be inhibited by the nature of the environment, as was the case in the current study, with dense grass tussocks too difficult to affectively sample. Furthermore, area sampling may be considered more labour intensive and time consuming than pitfall and sticky trap methods. Considering the problems associated with obtaining accurate measures of availability over a range of prey types, it is not surprising that few studies have addressed the determination of dietary selection in lizards.

## Diet of *Delma inornata*

The diet of *D. inornata* has previously been examined by Patchell and Shine (1986), based on the stomach analysis of eight specimens. Prey types identified by Patchell and Shine were consistent with those found within scats during the current study, although the former found grasshoppers to be the predominant prey item within stomachs, with spiders predominant within scats in the current study. As with Patchell and Shine (1986), I found no evidence to support Jenkins and Bartell's (1980) statement that the bulk of the diet of this species consists of lygosomine skinks.

While the extent of overlap in diet between *D. inornata* and *D. impar* is not clear, the presence of a number of prey types and the predominance of spiders (particularly Lycosidae) within the diet of both species suggests that there is potential for trophic resource competition. *Delma inornata* is considered to be the larger bodied of the two species (Cogger 1992, Jenkins and Bartell 1980). Since it is well known that larger predators have access to larger prey (Webb and Shine 1993, Heatwole and Taylor 1987, Vezina 1985, Robson and Lambert 1980) it is therefore not surprising that prey items taken by *D. inornata* were generally noted as being larger than those taken by *D. impar*. The absence of Collembola from *D. inornata* scats may reflect the lower size limit of prey selection for this species, however consideration must be given to the fact that the number of scats examined for this species was relatively low. Furthermore, the ability to access larger prey items does not necessitate preference. Optimal foraging theory in its simplest form (Schoener 1971) predicts that small prey will be the major component of lizards diet, provided that they are sufficiently abundant (Pough and Andrews 1985). Regardless of whether *D. inornata* selects prey above or within the size range taken by *D. impar*, the potential for trophic resource competition may still exist between juveniles of the former, and adults of the latter species.

The magnitude of dietary overlap between *D. inornata* and *D. impar* could not be quantified in the current study owing to limitations in sample size and origin. Therefore no inferences can be made on the extent to which inter-specific competition for trophic resources limits the distribution of *D. impar*. It may be constructive, however, to further examine the distribution of these two *Delma* species within the ACT, and determine if possibilities for resource competition go beyond that of dietary requirements.

## Implications for possible translocations

Very few known populations of *D. impar* occur within conservation reserves, with many in close proximity to areas heavily populated by humans in Victoria and the ACT. The loss of habitat through urbanisation and development is therefore a threat requiring serious consideration. In view of this situation , the use of tools such as translocation and reintroduction may be required to allow individuals and populations to be saved, at least in the short term.

While the concept may appear straightforward, the value of translocation in aiding to conserve species has received considerable criticism with many associated problems (Gorden 1994, Smith and Clark 1994, Karesh 1993, Dodd and Seigal 1991, Reinert 1991, Griffith *et al.* 1989, Boyer and Brown 1988, Conant 1988, Neilson 1988, Friend 1987, Caldecott and Kavanagh 1983). Often translocations are attempted with reliance only upon a scant or insubstantial knowledge base (Conant 1988). In order to provide the greatest chances of translocation success, one needs to know why a species is living in one area before it can be moved to another. Such information should include a knowledge of diet and food availability in the proposed translocation site. While the current study provides further information on the habitat requirements of *D. impar*, knowledge of the species is not yet at a level where we can confidently predict the species distribution. As a result, the ability to pinpoint areas which satisfy the habitat and dietary requirements of *D. impar* is still limited.

Although in its infancy, translocation is a conservation tool that provides some hope for those species, such as *D. impar*, which are threatened by loss of habitat. However, as there are many associated difficulties, with limited benefits, the implementation of translocation as a conservation strategy should not be considered lightly. The possibility of other options, such as habitat protection, should be thoroughly explored. In cases where the movement of *D. impar* individuals is deemed necessary, a carefully designed research program should be incorporated into the translocation program, which would include examining the diet of the lizard before and after the translocation, at control and release sites.

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Appendix A. Plant species list for all 1994 study sites. * denotes introduced species. For location of sites, refer to Figure 3.

| | | | | | Site | | | |
|---|---|---|---|---|---|---|---|---|
| Family | Species name | Common name | 2CY1 | 2CY2 | 2CY3 | CSIRO1 | Stockpound | Kaleen3 |
| **MONOCOTYLEDON** | | | | | | | | |
| ANTHERICACEAE | *Tricoryne elatior* | Yellow Rush-lily | | • | | | | |
| ASPHODELACEAE | *Bulbine bulbosa* | Bulbine Lily | | • | | | | |
| CYPERACEAE | *Carex breviculmis* | Sedge | • | | | | | |
| | *Carex inversa* | Knob Sedge | | • | | | | |
| JUNCACEAE | *Juncus australis* | | | • | • | | | |
| | *Juncus filicaulis* | | • | • | • | | • | |
| | *Juncus homalocaulis* | | • | • | | | | |
| | *Juncus subsecundus* | Finger Rush | • | • | • | | | |
| LOMANDRACEAE | *Lomandra bracteata* | Matrush | • | | | | | |
| | *Lomandra multifida* | Matrush | | • | | | | |
| POACEAE | *Agrostis avenacea var. avenacea* | Blown Grass | | • | | | | |
| | * *Avena barbata* | Bearded Oats | | • | | | | • |
| | * *Briza minor* | Shivery Grass | • | • | | | | |
| | * *Bromus hordeaceus* | Soft Brome | • | • | | • | | • |
| | *Danthonia auriculata* | Lobed Wallaby Grass | | | | | • | |
| | *Danthonia carphoides* | Short Wallaby Grass | • | • | | | • | |
| | *Danthonia monticola* | Wallaby Grass | | | | | • | |
| | *Danthonia racemosa ssp. racemosa* | Wallaby Grass | | | | | • | |
| | * *Festuca elatior* | Tall Fescue | • | | | | | • |
| | * *Holcus lanatus* | Yorkshire Fog Grass | • | | | • | • | |
| | * *Lolium perenne* | Perennial Ryegrass | | | • | | • | • |
| | * *Nassella trichotoma* | Serrated Tussock | | | | • | | • |
| | *Panicum effusum* | Hairy Panic Grass | | | | • | | |

## Appendix A continued.

| Family | | Species name | Common name | Site | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2CY1 | 2CY2 | 2CY3 | CSIRO1 | Stockpound | Kaleen3 |
| POACEAE | * | *Paspalum dilatatum* | Paspalum | | | | ● | ● | ● |
| | * | *Phalaris aquatica* | Phalaris | ● | ● | ● | ● | ● | ● |
| | | *Poa sieberiana* *var. sieberiana* | Tussock Grass | ● | ● | | | | |
| | | *Stipa bigeniculata* | Tall Speargrass | | | | ● | ● | |
| | | *Themeda australis* | Kangaroo Grass | ● | ● | | | ● | |
| **DICOTYLEDONS** | | | | | | | | | |
| APIACEAE | | *Eryngium rostratum* | Blue Devil | | ● | | | | |
| ASTERACEAE | * | *Chondrilla juncea* | Skeleton Weed | | | | ● | | |
| | | *Chrysocephalum apiculatum* | Yellow buttons | | | | | ● | |
| | * | *Cirsium vulgare* | Spear Thistle | ● | ● | | | ● | |
| | | *Cymbonotus sp.* | | ● | | | | | |
| | * | *Hypochoeris radicata* | Cat's Ear Flatweed | ● | ● | ● | ● | ● | ● |
| | | *Leptorhynchos squamatus* | Scaly Buttons | ● | ● | | | | |
| | | *Senecio quadridentatus* | Cotton Fireweed | | ● | | | | |
| | * | *Sonchus asper* | Prickly Sowthistle | | ● | | | | |
| | * | *Sonchus oleraceus* | Common Sowthistle | ● | | | | | |
| | * | *Tragopogon porrifolius* | Salsify | | ● | ● | | | |
| BORAGINACEAE | | *Cynoglossum suaveolens* | Sweet Hound's Tongue | | ● | | ● | | |
| | * | *Echium plantagineum* | Patterson's Curse | | | | | ● | ● |
| CAMPANULACEAE | | *Wahlenbergia communis* | Tufted Bluebell | | ● | | | | |
| CLUSIACEAE | | *Hypericum gramineum* | Small St John's Wort | | ● | | | | |
| | * | *Hypericum perforatum* | St John's Wort | | ● | | | ● | ● |
| CONVOLVULACEAE | | *Convolvulus erubescens* | Austral Bindweed | ● | ● | | ● | ● | |

Appendix A continued.

| Family | | Species name | Common name | | | Site | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2CY1 | 2CY2 | 2CY3 | CSIRO1 | Stockpound | Kaleen3 |
| FABACEAE | * | *Medicago lupulina* | Black Medic | • | | | | | |
| | * | *Trifolium arvense* | Hare's Foot Clover | | • | | | | |
| | * | *Trifolium campestre* | Hop Clover | | • | | | | |
| | * | *Trifolium striatum* | Knotted Clover | | • | | | | |
| | * | *Trifolium subterraneum* | Subterranean Clover | | • | | | | |
| GENTIANACEAE | * | *Centaurium erythraea* | Pink Stars | • | • | | | • | |
| GOODENIACEAE | | *Goodenia pinnatifida* | Scrambled Eggs | • | • | | | • | |
| HALORAGACEAE | | *Haloragis heterophylla* | Perenial Raspweed | • | • | • | | | |
| LAMIACEAE | * | *Salvia verbenaca* | Wild Sage | • | | | | | |
| MYRTACEAE | | *Eucalyptus blakelyi* | Blakety's Redgum | | • | | | | |
| ONOGRACEAE | | *Epilobium billardierianum ssp. cinereum* | Willowherb | • | | | | | |
| OXALIDACEAE | * | *Oxalis corniculata* | Yellow Wood Sorrel | • | • | | | • | |
| PLANTAGINACEAE | * | *Plantago lanceolata* | Ribwort | • | • | • | • | • | • |
| | | *Plantago varia* | Variable Plantain | | • | | | | |
| POLYGONACEAE | * | *Acetosella vulgaris* | Sheep Sorrel | | • | | • | | |
| | | *Rumex brownii* | Swamp Dock | | | | • | | |
| | * | *Rumex crispus* | Curled Dock | | • | • | | | • |
| | | *Rumex dumosus* | Wiry Dock | | • | | | | |
| | *? | *Rumex sp.* | | • | | | | | |
| ROSACEAE | | *Acaena sp.* | | • | • | | | • | |
| | * | *Crataegus sp.* | Hawthorn | | | | | • | |
| | * | *Poterium polyganum* | Sheep's Burnet | | | | | | • |
| | * | *Rosa rubiginosa* | Briar Rose | | • | | | | |
| RUBIACEAE | | *Asperula conferta* | Common Woodruff | | • | • | | • | |

Appendix B. *Delma impar* trapping data for 1994. SVL=snout to vent length. All length measurements (mm). All weight measurements (g). Stripe visibility: well striped=3 through to stripes barely visible=1. For location of sites, refer to Figure 3.

**2CY 1**

| Capture Date | Days open | Date opened | Trap number | SVL | Original Tail | Regen. tail | Total tail | Total length | Weight | Gravid | Sex | Stripes | No. Recapt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/10/94 | 31 | 10/10/94 | 7 | **75** | 166 | | 166 | **241** | 4.33 | | | 1 | 1 |
| 11/11/94 | 32 | 10/10/94 | 12 | **91** | 116 | 30 | 146 | **237** | 4.64 | | | 1 | |
| 11/11/94 | 32 | 10/10/94 | 13 | **84** | 140 | | 140 | **224** | 4.20 | | | 2 | |
| 18/11/94 | 39 | 10/10/94 | 20 | **96** | 92 | | 92 | **188** | 4.27 | | | 2 | |
| 21/11/94 | 42 | 10/10/94 | 8 | **91** | 30 | 55 | 85 | **176** | 4.13 | y | f | 3 | 3 |
| 21/11/94 | 42 | 10/10/94 | 13 | **95** | 168 | | 168 | **263** | 7.33 | y | f | 2 | |
| 23/11/94 | 44 | 10/10/94 | 20 | **78** | 170 | | 170 | **248** | 3.61 | | | 2 | |
| 12/12/94 | 63 | 10/10/94 | | **92** | 40 | 15 | 55 | **147** | 3.54 | | | 3 | |
| 14/12/94 | 65 | 10/10/94 | 12 | **91** | 145 | | 145 | **236** | 4.39 | | | 3 | |
| 19/12/94 | 70 | 10/10/94 | 5 | **54** | 105 | | 105 | **159** | 1.16 | | | 3 | |
| 19/12/94 | 70 | 10/10/94 | 9 | **80** | 150 | | 150 | **230** | 3.18 | | | 3 | |
| 26/12/94 | 77 | 10/10/94 | 5 | **62** | 119 | | 119 | **181** | 1.88 | | | 4 | |
| 28/12/94 | 79 | 10/10/94 | 2 | **83** | 167 | | 167 | **250** | 3.39 | | | 2 | |
| 2/1/95 | 84 | 10/10/94 | 20 | **99** | 200 | | 200 | **299** | 7.10 | y | f | 1 | |

**2CY 2**

| Capture Date | Days open | Date opened | Trap number | SVL | Original Tail | Regen tail | Total tail | Total length | Weight | Gravid | Sex | Stripes | No. Recapt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18/11/94 | 39 | 10/10/94 | 2 | **87** | 190 | | 190 | **277** | 4.94 | | | 3 | |
| 14/12/94 | 65 | 10/10/94 | 17 | **100** | 0 | 115 | 115 | **215** | 4.77 | | | 3 | |
| 14/12/94 | 65 | 10/10/94 | 5 | **67** | 113 | | 113 | **180** | 1.57 | | | 4 | |
| 21/12/94 | 72 | 10/10/94 | 19 | **82** | 165 | | 165 | **247** | 3.74 | | | 3 | |
| 28/12/94 | 79 | 10/10/94 | 14 | **90** | 166 | | 166 | **256** | 4.47 | | | 2 | |

Appendix B continued.

**CSIRO 1**

| Capture Date | Days open | Date opened | Trap number | SVL | Original Tail | Regen tail | Total tail | Total length | Weight | Gravid | Sex | Stripes | No. Recapt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/11/94 | 30 | 10/10/94 | 20 | **75** | 176 | | 176 | **251** | 4.03 | | | 2 | |
| 21/11/94 | 42 | 10/10/94 | 16 | **78** | 55 | | 55 | **133** | 2.36 | | | 3 | |
| 21/11/94 | 42 | 10/10/94 | 15 | **76** | 131 | | 131 | **207** | 3.57 | y | f | 1 | |
| 25/11/94 | 46 | 10/10/94 | 20 | **92** | 223 | | 223 | **315** | 4.85 | | | 2 | |
| 28/11/94 | 49 | 10/10/94 | 6 | **87** | 168 | | 168 | **255** | 4.69 | | | 1 | |
| 2/12/94 | 53 | 10/10/94 | 3 | **93** | 122 | 35 | 157 | **250** | 6.35 | y | f | 1 | |
| 12/12/94 | 63 | 10/10/94 | 19 | **77** | 165 | | 165 | **242** | 3.31 | | | 1 | 1 |
| 16/12/94 | 67 | 10/10/94 | 9 | **51** | 94 | | 94 | **145** | 1.11 | | | 3 | |
| 4/1/95 | 86 | 10/10/94 | 19 | **53** | 121 | | 121 | **174** | 1.41 | | | 2 | |

**2CY 3**

| Capture Date | Days open | Date opened | Trap number | SVL | Original Tail | Regen tail | Total tail | Total length | Weight | Gravid | Sex | Stripes | No. Recapt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/10/94* | ### | 10/10/94 | 5 | **73** | 142 | | 142 | **215** | 3.61 | | | 3 | 1 |
| 11/11/94 | 32 | 10/10/94 | 12 | **80** | 163 | | 163 | **243** | 3.60 | | | 3 | |
| 16/11/94 | 37 | 10/10/94 | 15 | **92** | 136 | | 136 | **228** | 4.92 | | | 4 | |
| 16/11/94 | 37 | 10/10/94 | 18 | **86** | 183 | | 183 | **269** | 4.48 | | | 2 | |
| 5/12/94 | 56 | 10/10/94 | 15 | **61** | 53 | | 53 | **114** | 1.44 | | | 4 | |
| 9/12/94 | 60 | 10/10/94 | 14 | **102** | 24 | 40 | 64 | **166** | 5.35 | y | f | 2 | |
| 12/12/94 | 63 | 10/10/94 | 10 | **76** | 144 | | 144 | **220** | 2.64 | | | 4 | |
| 14/12/94 | 65 | 10/10/94 | 10 | **90** | 179 | | 179 | **269** | 5.48 | | | 3 | 2 |
| 19/12/94 | 70 | 10/10/94 | 8 | **68** | 120 | | 120 | **188** | 1.92 | | | 3 | |
| 23/12/94 | 74 | 10/10/94 | 15 | **99** | 63 | 10 | 73 | **172** | 4.41 | | | 4 | |

*lizard caught prior to opening traps.

## Appendix B continued.

**Stockpound**

| Capture Date | Days open | Date opened | Trap number | SVL | Original Tail | Regen tail | Total tail | **Total length** | Weight | Gravid | Sex | Stripes | No. Recapt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24/10/94 | 14 | 10/10/94 | 11 | **87** | 198 | | 198 | **285** | 5.75 | | | 1 | 1 |
| 9/11/94 | 30 | 10/10/94 | 2 | **81** | 83 | 10 | 93 | **174** | 3.39 | | | 3 | 1 |
| 9/11/94 | 30 | 10/10/94 | 2 | **83** | 205 | | 205 | **288** | 4.69 | | | 3 | 1 |
| 9/11/94 | 30 | 10/10/94 | 11 | **111** | 65 | 40 | 105 | **216** | 7.69 | y | f | 2 | 1 |
| 11/11/94 | 32 | 10/10/94 | 11 | **85** | 186 | | 186 | **271** | 4.45 | | | 1 | 3 |
| 2/12/94 | 53 | 10/10/94 | 3 | **109** | 214 | | 214 | **323** | 9.96 | y | f | 1 | 1 |
| 14/12/94 | 65 | 10/10/94 | 11 | **89** | 196 | | 196 | **285** | 4.78 | | | 3 | |
| 28/12/94 | 79 | 10/10/94 | 10 | **59** | 108 | | 108 | **167** | 1.42 | | | 3 | |

**Kaleen 3**

| Capture Date | Days open | Date opened | Trap number | SVL | Original Tail | Regen tail | Total tail | **Total length** | Weight | Gravid | Sex | Stripes | No. Recapt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/11/94 | 23 | 10/10/94 | | **83** | 178 | | 178 | **261** | 5.94 | y | f | 1 | 1 |
| 11/11/94 | 32 | 10/10/94 | | **82** | 123 | 27 | 150 | **232** | 5.07 | | | 3 | 1 |
| 25/11//94 | 46 | 10/10/94 | | **89** | 150 | 15 | 165 | **254** | 4.58 | | | 2 | |
| 21/12//94 | 72 | 10/10/94 | | **96** | 75 | | 75 | **171** | 3.25 | | | 3 | |

Appendix C. All herpetofauna species found to occur at study sites during October, November and December of 1994. For location of sites, refer to Figure 3.

| | Site | | | | | |
|---|---|---|---|---|---|---|
| Species | 2CY1 | 2CY2 | 2CY3 | CSIRO1 | Stockpound | Kaleen3 |
| **Frogs** | | | | | | |
| *Crinia signifera* | ● | ● | ● | | ● | |
| *Crinia parinsignifera* | ● | | ● | | ● | |
| *Limnodynastes tasmaniensis* | ● | ● | ● | ● | ● | ● |
| *Limnodynastes peronii* | | | ● | | | |
| *Litoria verreauxii* | | ● | ● | ● | | |
| *Neobatrachus sudelli* | | | | ● | | |
| **Lizards** | | | | | | |
| *Delma impar* | ● | ● | ● | ● | ● | ● |
| *Lampropholis delicata* | | | | | ● | ● |
| *Morethia boulengeri* | | | | | ● | |
| *Tiliqua scincoides* | | | | ● | | |
| **Snakes** | | | | | | |
| *Pseudonaja textilis textilis* | | | | | ● | |
| **Tortoises** | | | | | | |
| *Chelodina longicollis* | | | | ● | | |

Appendix D. Total number of invertebrates > or = 3 mm in length caught in pitfall traps for weeks ending 24-Nov-94 and 16-Dec-94. A=adult. L=larvae. For location of sites, refer to Figure 3.

Week ending 24-Nov-94

| Site<br>Taxon | 2CY1 | 2CY2 | 2CY3 | Stockp. | CSIRO1 | Kaleen3 |
|---|---|---|---|---|---|---|
| Araneae | 11 | 41 | 25 | 28 | 60 | 52 |
| Acrididae | 2 | 1 | 0 | 9 | 1 | 21 |
| Gryllidae | 10 | 35 | 5 | 13 | 6 | 7 |
| Lepidoptera L. | 0 | 2 | 5 | 3 | 1 | 1 |
| Lepidoptera A. | 0 | 0 | 0 | 0 | 4 | 0 |
| Blattodea | 0 | 1 | 0 | 0 | 3 | 2 |
| Isopoda | 0 | 3 | 3 | 121 | 1 | 130 |
| Formicidae | 32 | 105 | 13 | 117 | 37 | 35 |
| Coleoptera A. | 13 | 11 | 30 | 27 | 9 | 16 |
| Coleoptera L. | 0 | 4 | 0 | 6 | 0 | 0 |
| Diptera | 4 | 6 | 3 | 5 | 7 | 8 |
| Hemiptera | 13 | 11 | 20 | 12 | 3 | 21 |
| Hymenoptera | 8 | 46 | 23 | 21 | 98 | 4 |
| Chilopoda | 0 | 0 | 0 | 0 | 1 | 0 |
| Isoptera | 0 | 2 | 0 | 0 | 0 | 0 |
| Thysanura | 0 | 0 | 0 | 0 | 0 | 0 |
| Dermaptera | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 93 | 268 | 127 | 362 | 231 | 297 |

Week ending 16-Dec-94

| Site<br>Taxon | 2CY1 | 2CY2 | 2CY3 | Stockp. | CSIRO1 | Kaleen3 |
|---|---|---|---|---|---|---|
| Araneae | 22 | 34 | 30 | 36 | 66 | 72 |
| Acrididae | 1 | 3 | 0 | 0 | 4 | 6 |
| Gryllidae | 24 | 44 | 17 | 286 | 26 | 132 |
| Lepidoptera L. | 13 | 0 | 6 | 1 | 2 | 0 |
| Lepidoptera A. | 2 | 2 | 2 | 0 | 0 | 6 |
| Blattodea | 0 | 1 | 1 | 0 | 1 | 0 |
| Isopoda | 0 | 6 | 8 | 235 | 9 | 318 |
| Formicidae | 241 | 280 | 21 | 486 | 85 | 161 |
| Coleoptera | 35 | 28 | 45 | 92 | 22 | 62 |
| Coleoptera L. | 0 | 3 | 0 | 0 | 2 | 0 |
| Diptera | 22 | 4 | 5 | 2 | 9 | 5 |
| Hemiptera | 15 | 17 | 23 | 4 | 7 | 26 |
| Hymenoptera | 31 | 25 | 10 | 6 | 75 | 13 |
| Chilopoda | 0 | 0 | 0 | 0 | 0 | 0 |
| Isoptera | 0 | 0 | 0 | 0 | 0 | 0 |
| Thysanura | 0 | 1 | 0 | 0 | 0 | 0 |
| Dermaptera | 0 | 0 | 0 | 16 | 0 | 0 |
| Total | 406 | 448 | 168 | 1164 | 308 | 801 |

Appendix E. Table showing invertebrate orders found to occur at all study sites. Indented taxa are families. For location of sites, refer to Figure 3.

| | Site | | | | | |
|---|---|---|---|---|---|---|
| Taxon | 2CY1 | 2CY2 | 2CY3 | CSIRO1 | Stockpound | Kaleen |
| Acarina | ● | ● | ● | ● | ● | ● |
| Araneae | | | | | | |
| Lycosidae | ● | ● | ● | ● | ● | ● |
| Salticidae | ● | ● | ● | ● | ● | ● |
| Other | ● | ● | ● | ● | ● | ● |
| Blattodea | ● | ● | ● | ● | ● | ● |
| Chilopoda | ● | | | | | |
| Coleoptera adult | ● | ● | ● | ● | ● | ● |
| Coleoptera larvae | | ● | ● | ● | ● | ● |
| Dermaptera | | | | | ● | |
| Diptera | ● | ● | ● | ● | ● | ● |
| Hemiptera | ● | ● | ● | ● | ● | ● |
| Hymenoptera | | | | | | |
| Formicidae | ● | ● | ● | ● | ● | ● |
| Other | ● | ● | ● | ● | ● | ● |
| Isopoda | | ● | ● | ● | ● | ● |
| Isoptera | ● | ● | ● | | ● | |
| Lepidoptera A. | ● | ● | ● | ● | ● | ● |
| Lepidoptera L. | ● | ● | ● | ● | ● | ● |
| Neuroptera | | | | | | ● |
| Opiliones | | | | | ● | ● |
| Orthoptera | | | | | | |
| Acrididea | ● | ● | ● | ● | ● | ● |
| Gryllidea | ● | ● | ● | ● | ● | ● |
| Mantodea | | | | ● | ● | |
| Thysanura | | ● | | | | |