The effect of different vineyard management systems on the epigaeic arthropod assemblages in the Cape Floristic Region, South Africa

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DECLARATION

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ABSTRACT

In the Cape Floristic Region of South Africa, where wine grape production and biodiversity conservation are of major importance, innovative management of the landscape is necessary to integrate the two activities. Alternative farming, such as organic and biodynamic farming, focuses on the preservation of biological processes in agroecosystems with the aim of increasing the sustainability of these sytems. It has been demonstrated in other regions that alternative farming can enhance biodiversity. This study assessed the potential of alternative vineyard management to conserve biodiversity, in particular epigaeic arthropod diversity, relative to the more widespread integrated vineyard management in the CFR. A hierarchical design was used, consisting of three localities, with three land-uses nested within each locality. The land-uses were alternative vineyards, integrated vineyards and natural vegetation sites as reference habitats. Sampling was done in June and October 2006 using pitfall traps. Nested ANOVAs were used to test for differences in abundance and species richness of the total assemblages, functional feeding guilds and selected generalized predatory taxa. Assemblage patterns were assessed using hierarchical agglomerative clustering and non-metric multidimensional scaling. Canonical correspondence analyses were used to evaluate the effects of environmental variables, management practices and landscape variables on community composition. Alternative vineyards supported a significantly higher overall arthropod abundance and species richness, more diverse predatory, saprophagous, phytophagous and omnivorous guilds, as well as more abundant and speciose spider and rove beetle assemblages than the integrated vineyards. Integrated vineyards harboured a greater abundance of predators, whereas results for nectarivores, wood borers, parasitoids and carabid beetles were variable. The differences could be explained in part by higher non-crop vegetation complexity and reduced management intensity of the alternative vineyards. Community composition was influenced by a combination of management practices, the surrounding landscape and geographic locality, which highlighted the interdependence of the cultivated land and its surroundings. This study supports the prediction of increased arthropod diversity in alternative vineyards and highlights its potential for biodiversity conservation in the CFR. Because of the complex nature of these agroecosystems, it is recommended that multi-scale and site-specific studies should precede any efforts to integrate it into conservation strategies.

OPSOMMING

In die Kaapse Floristiese Ryk van Suid Afrika, waar wingerdbou en bewaring van biodiversitieit van uiterste belang is, is vindingryke bestuur van die landskap nodig om die twee aktiwiteite te integreer. Alternatiewe boerdery, soos organiese en biodinamiese boerdery, fokus op die biologiese prosesse in boerderysisteme, met die doel om volhoubaarheid van hierdie sisteme te verbeter. Studies in ander streke het aangedui dat alternatiewe boerdery biodiversiteit kan bevoordeel. Hierdie studie het alternatiewe wingerdbou geëvalueer ten opsigte van die vermoë om biodiversiteit te onderhou, relatief tot die meer algemene geïntegreerde wingerbou in die KFR. Daar is spesifiek gekyk na grondoppervlak-aktiewe gelidpotiges. `n Hiërargiese ontwerp is gebruik, wat bestaan het uit drie areas, wat elk een alternatiewe wingerd, een geïntegreerde wingerd en een natuurlike habitat bevat het. Monsters is geneem in Junie en Oktober 2006 deur middel van pitval strikke. Daar is statisties getoets vir verskille tussen die talrykheid en spesierykheid van die algehele versameling, funksionele voedingsgroepe en gesekteerde algemene predatoriese taxa. Gemeenskapsamestelling is geëvalueer, asook die invloed van omgewingsveranderlikes, bestuurspraktyke en landskapveranderlikes op die samestelling. In vergelyking met die geïntegreerde wingerde, het die alternatiewe wingerde beduidend hoër algemene talrykheid en spesierykheid vertoon, meer diverse versamelings van predatore, saprofage, omnivore en planteters, asook meer talryke en spesieryke araneae en staphylinidae groepe. Daar is `n hoër talrykheid van predatore in die geïntegreerde wingerde gevind, terwyl die resultate vir nektarivore, houtboorders, parasiete en carabidae onbestendig was. Die verskille is toegeskryf aan die hoër plantkompleksiteit en verlaagde bestuursintensiteit van die alternatiewe wingerde. Gemeenskapsamestelling is beïvloed deur `n kombinasie van bestuurspraktyke, die omliggende omgewing en geografiese ligging, wat aangedui het hoe `n noue verband daar bestaan tussen die bewerkte land en die omgewing. Hierdie studie het aangedui dat alternatiewe wingerbou die diversiteit van gelidpotiges kan bevoordeel en het die potensiaal vir algemene biodiversiteit bewaring beklemtoon. As gevolg van die komplekse aard van hierdie sisteme, word daar aanbeveel dat studies op verskillende skale, asook area- spesifieke studies moet gedoen word voordat enige pogings aangewend word om alternatiewe wingerdbou met bewaringstrategieë te vereenselwig.

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1. INTRODUCTION

1.1. Biodiversity in agriculture

The global human population is forecast to increase by 50% during the next 50 years, increasing the pressure on agricultural systems to meet the demand for fuel, food and fibre (Tilman *et al*. 2001). It is predicted that this increase in demand, in conjunction with the globalization of agricultural markets and climate change, will cause unparalleled transformation of the agricultural landscape (Jackson *et al.* 2007). Modern, intensive agriculture has greatly increased global food supply, but is also associated with high chemical input, a great deal of mechanical disturbance, and simplification of the landscape, all of which are highly detrimental to the natural environment (Gurr *et al.* 2003). The ability of these systems to be productive and support biodiversity in the long term has been questioned (Hole *et al*. 2005, Krebs *et al*. 1999).

The need for a balance between agricultural production and ecological stability has been realized and much research has been dedicated to the interface between agriculture and the environment (Carter 2001). In particular, the interaction of biological diversity and agricultural systems is a field of research that has received a great deal of interest, and the value of biodiversity in agriculture has long been recognised (Altieri 1999).

In addition to supplying the organisms that are used in agricultural production, biodiversity performs vital ecosystem services such as nutrient cycling, pest and disease control, soil protection and pollination (Diaz *et al*. 2006; Altieri 1999, Perrings *et al.* 2006). Research suggests that a high level of biodiversity in agroecosystems is essential to maintain stability and long-term productivity of the system. When considering natural ecosystems, communities possess self-regulating abilities that depend on interactions between ranges of different organisms. A large number of these internal links enables the system and its processes to renew itself and adapt to environmental change. This ability is lost in intensive agricultural systems, resulting in simplified, artificial systems that require constant human intervention and external inputs (Altieri 1999).

1.2. Alternative agriculture

The adoption of alternative farming practices has been proposed as an approach that can potentially improve the sustainability of agricultural production (Jackson 2007). A range of alternative farming systems has been developed to deal with the sustainability issue, including among others, organic farming, low input farming, agroecology, biodynamic farming and permaculture (Madge 2007, Rigby & Cáceres 2001).

In alternative farming, a holistic approach is taken in the management of the farm, and it is seen not merely as a production system, but as an ecosystem. The focus is on the interrelatedness of the farm production, farm biota and the surrounding environment. There is greater reliance upon biological processes and interactions, as well as on farm-derived renewable resources. The aim is to enhance the resilience and stability of the system and reduce the need for human interference (Madge 2007, Rigby & Cáceres 2001).

To implement this approach, a range of alternative management practices are applied on these farms, of which many are believed to be more environmentally benign than their conventional counterparts (Biao *et al.* 2003). Biodiversity in particular, seems to benefit to a great extent from these farming practices (Hansen *et al*. 2001, Hole *et al*. 2005, Mäder *et al.* 2002). Positive effects on non-crop flora (Petersen *et al.* 2006), soil organisms (Doles *et al.* 2001, Reganold *et al*. 1993), arthropods (Berry 1996, Clark 1999, Feber *et al*. 1998), birds (Beecher *et al*. 2002, Chamberlain *et al*. 1999) and mammals (Wickramasinghe *et al.* 2004) have been demonstrated. The resulting increase in biodiversity on these farms has also been shown to translate into indirect benefits to production, such as improved pest control by natural enemies of pest species (Letourneau & Goldstein 2001) and increased nutrient uptake by crops (Gosling *et al*. 2006).

The following alternative practices, that help create more favourable conditions for biodiversity, are highlighted[1]:

One of the most prominent features of alternative farming is the prohibition of pesticides, herbicides and fungicides. It is evident that these chemicals have direct and indirect negative effects on species diversity (Taylor *et al.* 2006, Teodorescu & Cogălniceanu 2005, Witt & Samways 2004) and its reduction is usually associated with increased diversity of many different organisms (Hole *et al*. 2005). Instead, emphasis is placed on cultural and mechanical control and habitat manipulation to improve natural biological control (Madge 2007).

Water soluble, artificial fertilizers are replaced by organic fertilizers, including farmyard manure, compost and slow release mineral fertilizers such as rock phosphate (Madge 2007). These organic additions support a greater abundance of organisms that rely on high soil organic matter, such as earthworms, nematodes and soil microbes (Hole *et al.* 2005). Additionally, green manure crops and cover crops are used to improve soil nutrients. These also provide a greater variety of food sources for many organisms, greater structural complexity and a more suitable microclimate within crop fields.

Another factor that is intrinsic to these systems is the preservation and sensitive management of non-crop habitats such as field edges, windbreaks and hedgerows. Landscape features such as these act as structurally stable habitats in the disturbed landscape and provide valuable refuge, food sources and dispersal corridors (Samways 2005).

Many organisms also benefit from the reduction of tillage in alternative systems. Discs or tines are used to disturb soil instead of inversion ploughing, the latter being much more detrimental to organisms that are associated with the soil, such as Collembola (Alvarez *et al*. 2001) and mycorrhizal fungi (Gosling *et al*. 2006).

[1] Only features that are relevant to this specific study are discussed, however, other traits such as small field size, mixed farming and diverse crop rotations are important in many alternative farming systems.

These measures are not exclusive to alternative systems and are also used occasionally in conventional and integrated farming. However, it should be noted that the emphasis in the alternative farming philosophy is on the system as a whole. It is not simply a substitution of individual conventional practices for alternative ones, but a change in management approach and it is likely that a combination of alternative farming practices interact to promote biodiversity (Soil Association 2000).

1.3. Wine grape production in the Cape Floristic Region

In the Cape Floristic Region (CFR) of South Africa, cultivation for agriculture has transformed approximately a quarter of the landscape and this growth is predicted to continue over the next 20 years (Rouget *et al*. 2003). The wine industry in particular has experienced much growth in South Africa, with 110 000 ha under vine, of which more than 90% occurs in the CFR (Rogers 2006). It is considered the most lucrative agriculture business in the Western Cape (Cape Wine Academy 2002).

This increased pressure on the natural landscape is particularly concerning because the CFR is such a high priority conservation area, being classified as a global biodiversity hotspot and a world heritage site (Myers *et al.* 2000). The climatic and edaphic conditions that give rise to high levels of biodiversity are also optimal for growing high quality wine grapes. Consequently, a conflict of interest exists over the use of the land. On the one hand, the growth of the industry is desired but at the same time conservation of the land is very important (Fairbanks *et al*. 2004).

Fortunately, there is a well-established ethos of sustainability in the South African wine industry. South Africa is one of the leaders in terms of international best practice with regards to sustainable wine production. Systems such as the Integrated Production of Wine scheme (IPW) and the Biodiversity and Wine Initiative (BWI) work towards promoting sustainable vini- and viticulture, aiming to reduce the impact of the industry on the natural environment (Tromp 2006). In addition, they seek to prevent further habitat loss due to vineyard

expansion, and to increase the amount of protected natural habitat in vineyard landscapes (BWI 2007).

There is widespread support of these systems by wine producers, with more than 95% of wine production being registered with the IPW and approximately 63 000 ha of natural habitat protected in these farming landscapes. This gives a good indication of the level of environmental responsibility exhibited by the industry as a whole (Rosenthal Duminy 2004). Clearly, there is a great deal of interest to protect the biodiversity in the winelands of the CFR and there is a need for increased research into how this can be achieved.

In South Africa, local consumer demand for ecologically produced wine is still marginal. The alternative wine sector is fragmented and operates on a small scale. A small number of pioneering producers in the CFR have converted their vineyards to organic and biodynamic management, being motivated primarily by environmental concerns (Rosenthal Duminy 2004). To date, no research has been done on how these management systems in their entirety affect the biodiversity in the CFR. Although there is much anecdotal evidence of increased biodiversity, it has not yet been formally demonstrated.

1.4. Arthropods in agriculture in relation to the aims of this study

The intention of this study is to test the assumption that alternative vineyard management and the more widespread integrated vineyard management systems differ in their effect on biodiversity in the CFR. To this end, the surface-dwelling arthropod communities of paired alternative and integrated vineyards in the CFR were compared. In addition, these assemblages were compared to those of the natural vegetation in the area to assess how they relate to the naturally occurring fauna.

Arthropods were chosen as study taxa because they are the most diverse group of organisms in terrestrial ecosystems and they tend to reach large population sizes, which makes them ideal candidates for quantitative biodiversity assessments (Duelli *et al.* 1999, Kremen *et al.* 1993). Insects in particular play key roles in a vast variety of terrestrial ecosystem processes.

Certain species have such a massive influence on ecosystem structure and function, that they have been termed ecosystem engineers (Samways 2005). In agricultural systems, arthropods are highly functional ecologically, but are also of economic importance, since they include both beneficial and pest species (Olfert *et al.* 2002) and as a result have been commonly used in comparisons of farming systems (Hole *et al.* 2005). Specifically, epigaeic arthropods were chosen as study organisms because they are easily sampled, they include a range of different functional groups and their mobility is suitable for the scale of the study.

Many previous studies have highlighted the positive effects of alternative farming on arthropod diversity (Hole *et al*. 2005). However, responses across taxa have been varied, with different organisms responding in different ways to the management practices and environmental conditions on the farms (Fuller *et al*. 2005). In a comparison between organic and conventional winter wheat, Heteroptera densities were higher in organic fields, being favoured mainly by the organic management practices such as reduced pesticide use (Moreby 1996). Other taxa, for example non-pest butterflies, have been shown to respond positively to the increased vegetational complexity in organic fields and field margins (Feber *et al.* 1997), whereas in a study by Purtauf *et al*. (2005) carabids were favoured by a combination of the landscape context and management practices on organic farms.

A common theme in many of these studies is the effect of alternative farming on different functional guilds. In particular, beneficial groups such as parasitoids and predators have been studied widely because of their role in pest control. In tomato fields in California, natural enemy abundance and the species richness of all functional groups was higher in organic fields than in conventional fields (Letourneau & Goldstein 2001). Berry *et al.* (1996) found a more diverse predatory and parasitoid community in organic carrot fields than in conventional fields, as well as a higher abundance of selected parasitoid and predatory taxa.

Carabids, staphylinids and spiders are common generalized predators in farming systems and have been the focal taxa in the majority of these studies. They are mostly favoured by alternative management practices (Clark 1999, Feber *et al*. 1998, Krooss & Schaefer 1998), although the interactions are not always easily predicted (Andersen & Eltun 2000). Their

increased diversity is often attributed to the higher plant diversity and cover on alternative farms, which makes fields more habitable for these predators and supports a more diverse prey community (Feber *et al*. 1998).

Although one would expect alternative farming to promote diversity of arthropods and especially beneficial species, it is clear that the effects are not always uniform or predictable. Because of the large number of interacting variables in agricultural systems, it is likely that the effects will be site specific. To assess how these factors interact in the CFR, this study addresses the following questions:

- Do the alternative vineyards, integrated vineyards and natural habitat differ in terms of their:
    - Environmental conditions
    - Arthropod abundance and species richness
    - Arthropod community composition
    - Functional feeding guilds
    - Abundance and species richness of carabids, staphylinids and spiders

- What is the relationship between community parameters and environmental variables, management practices and landscape features?

Differences between the assemblage structures, functional guilds and selected predators in the different sites are identified. The most important factors responsible for these differences are discussed. The issues of scale and the landscape context are addressed. This leads into an evaluation of the potential of the two vineyard systems to conserve arthropod diversity in the CFR. This study will provide baseline community data on a range of different arthropod taxa in these habitats and a better understanding of their responses to the associated conditions and disturbances.

2. METHODS

2.1. Study area

The Cape Winelands are situated in the Cape Floristic Region (CFR), a Mediterranean climate ecoregion, which comprises a land area of 90 000km^2 at the southwestern tip of South Africa (Goldblatt & Manning 2002). The CFR is of high conservation priority and is classified as a global biodiversity hotspot and a world heritage site (Myers *et al.* 2000). It is the smallest of the world's six floral kingdoms, but is an area of exceptional floristic biodiversity (Cowling *et al.* 1996). An estimated 9 000 vascular plant species occur in the CFR, of which 70% are endemic (Goldblatt & Manning 2002).

The high species richness in the area and high species turnover across the landscape is a reflection of the structural and climatic diversity of the landscape. Sharp differences in local soil, climate and topography combine to produce a highly varied mosaic of different habitats (Goldblatt & Manning 2002).

80% of the vegetation in the CFR is known as fynbos, a shrubland vegetation type that grows in areas of winter rainfall, low soil fertility and regular fire. It consists mainly of restioids, ericoids, geophytes and sclerophyllous proteoids (Cowling & Richardson 1995). The other major vegetation type is renosterveld, which consists of low growing, sclerophyllous shrubs dominated by *Elytropappus rhinocerotis* (renosterbos), as well as grasses and a great variety of geophytes (Donaldson *et al.* 2002).

Although many data are available on the plant diversity in the CFR, the arthropod fauna is less well known (Procheş & Cowling 2006). Because Mediterranean systems exhibit extremely high spatial variability of insect species (Caterino 2007), comprehensive inventory is unlikely. In a recent comparison between fynbos insects and those in neighbouring biomes, it was shown that the fynbos diversity was similar to that in the other biomes. Additionally, a strong positive relationship was found between insect and plant diversity (Procheş & Cowling 2006). Also, high levels of invertebrate endemism have been demonstrated for certain areas in the CFR, as well as congruence between areas

of high plant and invertebrate species richness (Picker & Samways 1996). It is therefore likely that insect diversity mirrors the high plant diversity in the CFR.

2.2. Study sites

The study was done around Stellenbosch in the Western Cape Province (33°55’12”S, 18°51’36”E). A hierarchical design was used in the selection of study sites, which allowed for testing of differences between localities, as well as variability of sites within localities. Three localities were selected, here referred to as Polkadraai, Blaauwklippen and Kanonkop. Each locality contained three land-uses, or habitat types, nested within locality.

The three habitat types were alternative vineyards, integrated vineyards and native fynbos or renosterveld sites (Fig. 1). One additional integrated vineyard was added in the Polkadraai locality, as it provided highly contrasting environmental conditions of two neighboring integrated vineyards in the area. All alternative vineyards have been operating as either organic or biodynamic vineyards for at least four years, and all integrated vineyards were registered with the Integrated Production of Wine Scheme (IPW). Within these two categories, vineyards represented a range of different management practices. All sites were chosen to be within 5 km of each other.

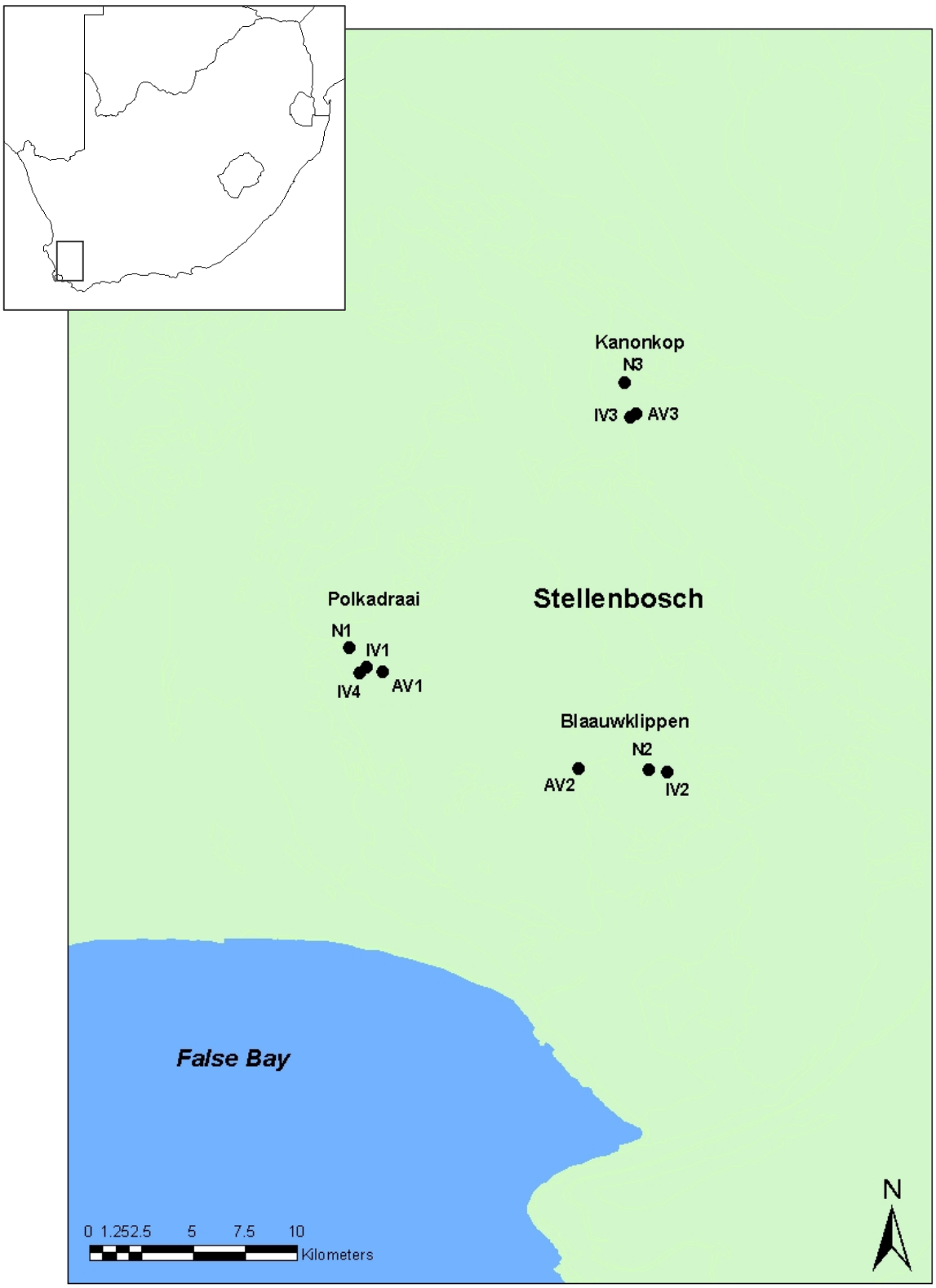


Figure 1. Map of the study sites around Stellenbosch, Western Cape Province, South Africa. (N=natural vegetation, AV=alternative vineyard, IV=integrated vineyard)

2.3. Site descriptions

2.3.1. Locality 1: Polkadraai

2.3.1.1. Alternative vineyard 1 (AV1)

AV1 (Fig. 2a) is part of a certified biodynamic wine farm. It has been managed organically since the mid-1990s, and then became fully biodynamic in 2000. Farm management is committed to maintaining soil and plant health, and interference is minimized. In the vineyards, there is a high degree of non-crop vegetation. Diverse cover crops include *Hypochoeris radicata, Raphanus raphanistrum, Avena fatula* and leguminous species such *Vicia* spp. Vineyard blocks are interspersed with semi-natural vegetation. The farm is surrounded by other vineyards, all operating under integrated production standards.

2.3.1.2. Integrated vineyard 1 (IV1)

IV1 (Fig. 2b) is part of a wine farm that is registered under the IPW scheme. Oats are sown annually as cover crops in alternate vine rows and a moderate level of broadleaf weeds are present in the vineyards. The site is bordered by other integrated vineyards on two sides, by a biodynamic vineyard on one other side and by a large expanse of semi-natural habitat on the fourth side.

2.3.1.3. Integrated vineyard 4 (IV4)

IV4 (Fig. 2c) is part of a wine farm that operates under integrated production guidelines. Careful monitoring and an understanding of pests and diseases allows farm management to reduce the amount of biocides used in the vineyards. Wherever possible, domesticated ducks are used to control snail pests. Oats (*A. fatula*) are sown in alternate vine rows as a cover crop, but the vineyards are mostly free of other non-crop vegetation. The study site is surrounded by other integrated vineyards.

2.3.1.4. Natural vegetation 1 (N1)

N1 (Fig. 2d) is a remnant of Swartland Granite renosterveld that is situated in a mosaic of agricultural land. It is bordered by vineyards on three sides, and on the remaining side it is bordered by a mixed stand of natural vegetation and some invasive tree species, including pine and eucalyptus. It is dominated by *Elytropappus rhinocerotis, Seriphium plumosum, Helichrysum* sp. and indigenous grasses. It also has a low occurrence of agricultural weeds, such as *Plantago lanceolata* and *Pennisetum clandistinum* that have presumably spread from the surrounding farmland.

2.3.2. Locality 2: Blaauwklippen

2.3.2.1. Alternative vineyard 2 (AV2)

AV2 (Fig. 2e) is part of a biodynamic wine farm. The vineyards were formerly managed conventionally, and were converted to biodynamic management in 2002. Great emphasis is placed on the reduction of off-farm inputs and maintenance of soil fertility. Diverse cover crops include *H. radicata, Erodium moschatum, Bidens pilosa* and leguminous species including *Vicia* spp. Hay mulches are used to improve soil moisture and fertility. The vineyards are distally surrounded by other wine farms, but are directly bordered by a stream, a remnant of natural vegetation and semi-natural vegetation.

2.3.2.2. Integrated vineyard 2 (IV2)

IV2 (Fig. 2f) is part of a wine farm that has been managed according to the IPW principles since 1998. Cover crops of oats (*A. fatula*) and rye grass (*Lolium* sp.) are sown between vine rows and a low level of other non-crop plants such as *E. moschatum* is tolerated. The vineyards are adjacent to a large stretch of pristine fynbos and are also in close proximity to a great deal of semi-natural habitat.

2.3.2.3. Natural vegetation 2 (N2)

N2 (Fig. 2g) is situated on the lower slopes of a 364 ha remnant of undisturbed Boland Granite fynbos, most of which extends into the mountain slopes. On the lowland side it is

bordered by vineyards. The vegetation is dominated by *Protea* spp., *Ischyrolepis* sp., *Restio* sp., *Metalasia* sp. and *Brunia* sp. It was last burnt in February 1998.

2.3.3. Locality 3: Kanonkop

2.3.3.1. Alternative vineyard 3 (AV3)

AV3 (Fig. 2h) is a certified organic vineyard. Soil fertility building is central to the management of the vineyard and this is achieved through composting and the use of cover crops. A variety of cover crop plants are maintained in the vineyard, such as *R. raphanistrum, H. radicata* and *A. fatula.* In addition, yarrow and fennel are sown around the vineyard to attract and provide habitat for natural enemies of vineyard pests. The study site is bordered by integrated vineyards on three sides and on one side by a highway.

2.3.3.2. Integrated vineyard 3 (IV3)

IV3 (Fig. 2i) is directly adjacent to AV3. This site operates under integrated production guidelines and permitted chemicals are used judiciously in the vineyard. In contrast to AV3, the percentage of ground cover was very low during the study period. Chipped vine wood is used as mulch to retain soil moisture and decrease soil temperature. The vineyard is bordered by integrated vineyards, one organic vineyard and a highway.

2.3.3.3. Natural vegetation 3 (N3)

N3 (Fig. 2j) is located within the Kanonkop fynbos conservancy. It is a Boland Granite fynbos remnant that is surrounded by vineyards on all sides. A few scattered pine trees used to occur in certain areas within the conservancy, but they were removed before the start of the study. The vegetation is dominated by *Ischyrolepis* sp., *Platycaulos* sp., *Cliffortia ruscifolia, E. rhinocerotis,* and *S. plumosum.*

Polkadraai locality

Figure 2a. Alternative vineyard 1, Polkadraai locality (AV1)

Figure 2b. Integrated vineyard 1, Polkadraai locality (IV1)

Figure 2c. Integrated vineyard 4, Polkadraai locality (IV4)

Figure 2d. Natural vegetation 1, Polkadraai locality (N1)

Blaauwklippen locality

Figure 2e. Alternative vineyard 2, Blaauwklippen locality (AV2)

Figure 2f. Integrated vineyard 2, Blaauwklippen locality (IV2)

Figure 2g. Natural vegetation 2, Blaauwklippen locality (N2)

Kanonkop locality

Figure 2h. Alternative vineyard 3, Kanonkop locality (AV3)

Figure 2i. Integrated vineyard 3, Kanonkop locality (IV3)

Figure 2j. Natural vegetation 3, Kanonkop locality (N3)

2.4. Arthropod sampling

Sampling was done in June 2006, just before the start of the cool, rainy season and in October 2006, at the start of the warm, dry summer. Each study site was approximately 5 ha. Random samples, consisting of ten replicates per site, were taken at least 20 m away from field edges to avoid edge effects and to represent the arthropod community associated with the centre of the sites. Sampling points were placed 40- 50 m apart to ensure statistical independence of samples. Each sampling point consisted of two traps, placed 3 m apart. Sampling in vineyards was done under vine rows to minimize disturbance by vehicles and farm workers.

Pitfall trapping was done, as it is one of the most widely-used trapping methods for capturing surface-active invertebrates (Woodcock 1997). Each trap consisted of an outer 500 ml PCV jar with a depth of 10 cm and diameter of 8 cm, and an inner 250 ml paper cup with a depth of 9 cm and a diameter of 8 cm. The outer jar was dug into the soil and was left in position for the duration of the study. The jar was opened and the cup inserted and replaced only during sampling times. This reduced disturbance of the substrate and simplified field work. To avoid digging-in effects[1], no sampling was done during the first 7 days after the jars were inserted.

During sampling times, traps were opened for 5 days and 70% ethanediol solution was used as preservative. Trap content was then collected, taken to the laboratory and washed in a fine meshed sieve to remove loose soil and ethanediol. Specimens were preserved in 75% ethanol solution until they could be sorted and identified.

Sorting to morphospecies and counting of individuals was done using a Leica MZ75 stereomicroscope (Oliver & Beattie 1995). Because the Collembola were so numerous it was not possible to count individuals, and therefore estimates of the Collembola were made by counting groups of approximately ten at a time. Reference collection specimens of species in the orders Coleoptera, Araneae, Orthoptera, Diplopoda, Chilopoda,

[1] Digging-in effects refer to changes in capture rates of pitfall traps that can occur directly after trap installation due to physical disturbance (Woodcock, 1997).

Hymenoptera, Diptera, Hemiptera and Acari were then identified to family level, and to species where possible, by specialists. Specimens from the orders Blattodea, Amphipoda, Thysanura, Archeognatha, Pseudoscorpiones, Psocoptera, Solpugidae, Phasmatodea, Mantodea, Scorpiones, Dermaptera, Isopoda and Isoptera were identified to family level using Borror *et al*. (1989) and Scholtz & Holm (1985). The reference collection of arthropod specimens has been deposited at the entomology museum at the University of Stellenbosch, and spider specimens were deposited at the National Collection of Arachnida in the National Museum in Pretoria.

2.5. Environmental variables

2.5.1. Vegetation sampling

A vegetation survey of each site was done during both sampling times. A 0.5 X 0.5 m quadrat was placed 4 m from each trap. Within each quadrat, plants were identified and a visual estimate made of the percentage cover of each species. Average non-crop plant height per quadrat was measured with a measuring rule. Agricultural weeds were identified to genus using Botha (2001) and Fourie (1996) and indigenous vegetation was identified to family level using Haaksma & Linder (2000), Heywood (1993) and Manning (2007). The different plant species were subsequently broadly categorized as vines, grass weeds, broadleaf weeds, indigenous grasses, indigenous restios and sedges, indigenous forbs and indigenous woody plants.

2.5.2. Leaf litter sampling

During vegetation sampling, the relative amount of leaf litter per site was also measured. Leaf litter depth per quadrat was measured with a measuring rule and all the loose organic material within each quadrat was collected, dried and weighed to obtain a relative measure of the amount of litter for each site.

2.5.3. Proximity to potential source habitat

Although this study was done at the field scale, arthropod assemblages are also likely to be influenced by the surrounding landscape. Therefore, an assessment was made of the

natural and semi-natural habitat in proximity to the sites. The distance to potential source habitat, as well as the amount of source habitat in close proximity to each site was determined using ArcMap 9.2. GPS point locality data for each site were overlain on orthophotos provided by the Department of Water Affairs and Forestry. All maps were projected in Transverse Mercator. 500 m buffers were created around each site, and within buffers, percentage natural and semi-natural habitat were calculated as well as distance to nearest source habitat.

2.6. Vineyard management variables

For the vineyard sites, the following information was obtained from the viticulturalists for the period January 2006 to January 2007:

- Pesticide application
- Herbicide application
- Fungicide application (and other disease control agents)
- Fertilizer application
- Tillage methods

2.6.1. Biocide application index

To quantify pesticide, herbicide and fungicide applications during the study period, each product used per site was assigned a risk level and associated code according to the biocide coding system of the IPW (IPW 2007):

- Low risk=1
- Medium risk=2
- Medium-high risk=3
- High risk=4

The codes for all the products per site were added up to obtain a relative measure of the magnitude of pesticide, herbicide and fungicide application[2]. All biocides were applied at quantities within the limits of the IPW system.

2.6.2. Fertilizer intervention index

A fertilizer intervention index was assigned to each site. For each site, this was the total of codes assigned to each type of fertilizer applied during the study period, where codes were assigned as follows:

- No fertilizer=0
- Foliar fertilizer and biodynamic preparations=1
- Organic fertilizer=2
- Inorganic fertilizer=3

2.6.3. Tillage index

A similar method was used to categorize tillage methods for each site, ranging from low disturbance to high disturbance and/or soil compaction:

- No tillage=0
- Light tillage using tine=1
- Disc cultivation=2
- Heavy cultivation using bulldozer=3

[2] It is acknowledged that frequency and intensity of application, as well as timing, will affect biocide impact. However, because the management of the different vineyard types was not easily comparable, this method was adopted for simplicity.

2.7. Data analysis

2.7.1. Environmental variables

Environmental data were averaged over the two sampling periods. To examine the differences in plant cover between the different sites, the mean percentage plant cover, as well as the mean percentage cover of each plant category, was calculated for each site. Nested analysis of variance (ANOVA) was done to test for differences in total percentage plant cover between localities and habitat types nested within locality using SPSS 13.0. Data were arcsine transformed (Quinn & Keogh 2002). Post-hoc Tamhane T2 tests were used to test for the significance of pairwise differences between habitat types within localities.

Means for number of plant species, non-crop plant height, leaf litter depth and leaf litter dry weight were calculated. Nested ANOVAs were also used to test for effects of locality and habitat type on the means of the variables and Tamhane T2 were used to test the significance of pairwise differences. These four variables were square-root transformed to improve homogeneity of variance (Quinn & Keogh 2002).

To determine how the sites were related in terms of environmental data, cluster analysis was done on the averaged environmental data set. This multivariate method groups sites into clusters with distinct environmental variables. Hierarchical agglomerative clustering was done using Primer v.5.0 (Clarke & Warwick 2002). The similarity matrix was based on normalized Euclidean distance and group-average linking was used to produce a dendrogram of the sites. This method has been shown to be appropriate for ecological data (Clarke & Warwick 2002).

Multi-dimensional scaling (MDS) is an ordination method that can be used to cross-check for adequacy and consistency of cluster analysis. It has the advantage of being flexible, easily interpretable and making few assumptions about the data (Clarke & Warwick 2002). Non-metric MDS was performed on the same data set, but using unaveraged environmental data, to represent the grouping of sampling units from the different sites in low dimensional space.

2.7.2. Arthropod data

Arthropod data for the two sampling periods were combined. Mean abundance and species richness was calculated for the ten sites. A separate calculation was made for the estimated abundances of collembola, but data on species richness were included with the other arthropod data. To determine whether locality and habitat type significantly influenced arthropod abundance and species richness, nested ANOVAs were performed on these two variables using SPSS 13.0. Post-hoc Tamhane T2 tests were used to test for the significance of pairwise differences between habitat types within localities.

To identify which of the sites were similar in terms of species assemblage patterns, cluster analysis was done on the averaged data set using the Primer v.5.0 software package. Data were fourth-root transformed before analysis to improve homogeneity of variance and to reduce the influence of very abundant species (Clarke & Warwick 2001). Hierarchical agglomerative clustering was based on a Bray-Curtis similarity matrix, and group-average linking was used to produce the dendrogram of the sites. Non-metric, multi-dimensional scaling (nMDS) was performed on the unaveraged data set as a complementary technique and to visualize the clustering of groups in low dimensional space.

To determine how the three site types related to each other in terms of numbers of species shared, the numbers and percentages of unique species and shared species were calculated, as well as the Jaccard index of similarity which is defined as:

$C_j = j/(a+ b–j)$

where j = number of species found at both sites,

a = number of species at site A and

b = number of species at site B (Magguran 1988).

To prevent overestimation of species numbers in integrated vineyards because of the additional site, the calculations were made twice, using the species for either IV1 or IV4.

2.7.3. Functional feeding guilds

To assess the functional composition of the arthropod communities in the different sites, families were assigned to the following broad functional guilds based on their general feeding habits:

1. Predators
2. Parasitoids
3. Phytophages feeding on living plant tissues
4. Nectarivores and pollen feeders
5. Saprophages/fungivores feeding on decaying organic matter, excrement, fungi and mosses
6. Omnivores/unspecialized feeders
7. Wood borers

The differences between sites in terms of absolute numbers of individuals and species within each functional guild were examined. Means of these parameters were calculated and differences within localities tested using one-way ANOVAs and Tamhane's T2 post-hoc tests in SPSS 13.0. The relative proportion of each guild per site was also calculated for abundance and species richness and proportions per site were displayed as pie charts. Collembola morphospecies were included in species richness calculations, but their abundances were excluded from arthropod abundance calculations.

2.7.4. Araneae, Carabidae and Staphylinidae

Mean abundance and species richness of spiders, ground beetles and rove beetles were calculated for each site. To test for effects of locality and habitat type nested within locality, nested ANOVAs were performed on these parameters using SPSS 13.0. ANOVAs were based on square-root transformed data for spiders and log (x+1) transformed data for ground and rove beetles (Quinn & Keogh 2002). Tamhane's T2 tests were used to assess the significance of differences between habitat types.

2.7.5. Ecological correlates

Regression analysis was used to determine the significance of correlations between individual environmental variables and community parameters, functional guilds and selected taxa. The majority of the data sets were shown to be nonparametric, which is typical for ecological community data sets with a high prevalence of zero values. Therefore, nonparametric Spearman's rank correlation coefficient was used in the regression analysis (Lepš & Šmilauer 2003). Statistica 7 was used for these analyses. Initial regression analysis revealed that correlations with certain environmental variables were confounded when the combined data for all habitat types were used in the analysis. Presumably, this was because not all environmental variables were present or applicable to both vineyard and natural habitats. Also, from the other univariate analyses, it was clear that the responses of arthropods in these two habitat types were very different. Therefore, separate regression analyses were done for vineyards and natural vegetation.

2.7.6. Relationship between assemblage structure and environmental variables

Canonical community ordination, using CANOCO v4.5 software, was used to visualize the relationship between assemblage structure and the environmental variables (ter Braak & Šmilauer 2002). Canonical correspondence analysis was performed on abundance data (Lepš & Šmilauer 2003). The analysis was first done for the assemblages in all habitat types and then separately for those in vineyards and natural vegetation. Separate analyses were also done for each locality to detemine how assemblages and variables were related within each locality.

A forward selection procedure was used to identify the environmental variables that significantly contributed to arthropod assemblage structure. Correlations of these variables with the assemblage composition were tested using Monte Carlo permutation tests. The model was then rerun including only the significant variables to determine the amount of variation in assemblage structure explained by these variables. CCA results were displayed as biplots, where samples were represented by symbols, environmental variables were represented by arrows and nominal variables represented by triangles.

3. RESULTS

3.1. Environmental variables

3.1.1. Vegetation cover and composition

Nested ANOVA indicated that there were no significant differences in total percentage plant cover between localities, but that the habitat types differed significantly ($F=6.36$, $n=7$, $p \leq 0.001$). Natural sites and alternative vineyards did not differ notably in terms of cover, but in all three localities, the integrated vineyards had the lowest percentage plant cover (Fig. 3) Plant category composition was similar for alternative and integrated vineyards, both types comprising mostly broadleaf weeds and grass weeds in varying amounts, together with vine cover. IV3 had a negligible amount of non-crop vegetation cover. The vineyards contrasted sharply with the composition of the natural vegetation sites, which consisted of mostly indigenous plant categories. N1 differed from the other two natural sites in having a higher degree of weed cover and in lacking the indigenous restio component that is prevalent in the other two sites.

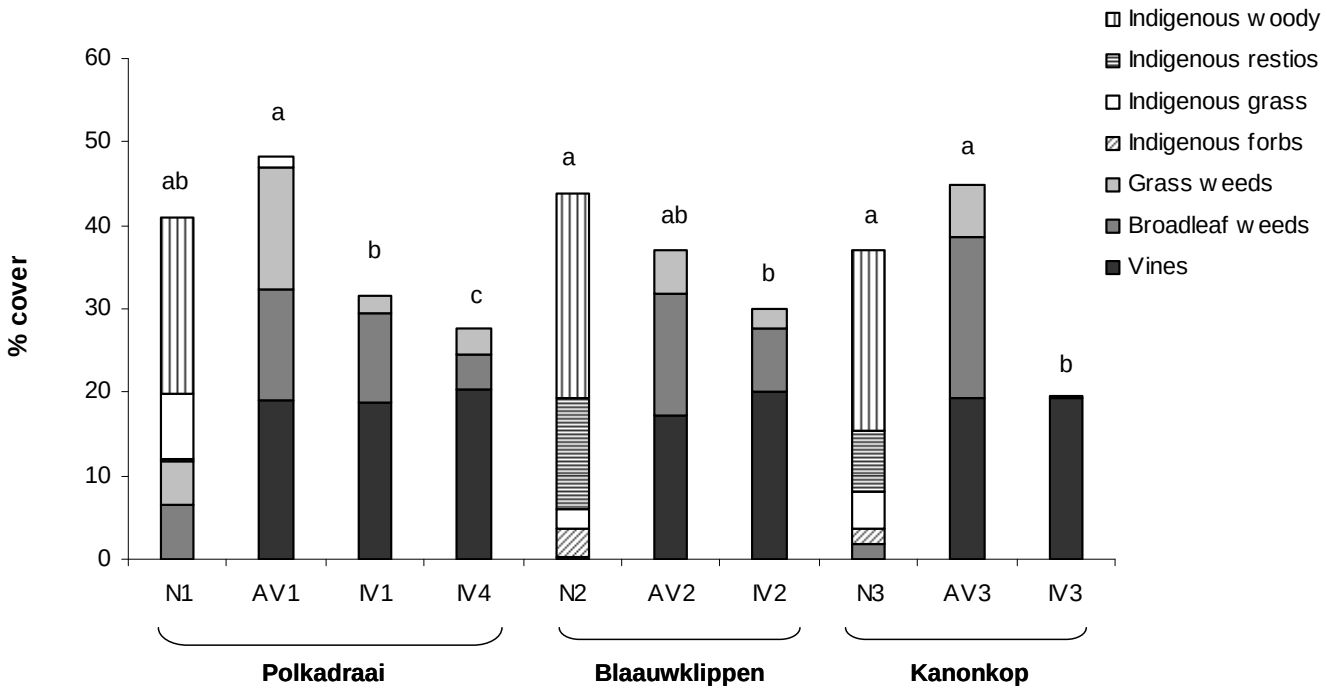


Figure 3. Type and percentage plant cover in natural vegetation, alternative vineyards and integrated vineyards at the three sampling localities. Bars with letters in common are not significantly different in terms of total plant cover at the 5% level. (N=natural vegetation, AV=alternative vineyard, IV=integrated vineyard)

Nested ANOVA's revealed that there were significant differences in number of plant species and non-crop plant height between sites. Locality had a significant effect on number of plant species ($F=9.69$, $n=2$, $p\leq0.001$) and plant height ($F=9.69$, $n=2$, $p\leq0.001$). Habitat type also had an effect on number of plant species ($F=52.54$, $n=7$, $p\leq0.001$) and plant height ($F=113.28$, $n=7$, $p\leq0.001$). Natural sites generally had the highest number of plant species and non-crop plant height across all localities, followed by the alternative vineyards (Table 1).

Leaf litter depth and dry weight also differed between sites. Again, both locality and habitat type had significant effects on leaf litter depth (locality: $F=15.47$, $n=2$, $p\leq0.001$) (habitat type: $F=14.73$, $n=7$, $p\leq0.001$) and leaf litter dry weight (locality: $F=27.74$, $n=2$, $p\leq0.001$) (habitat type: $F=20.70$, $n=7$, $p\leq0.001$). The alternative vineyards had the highest amount of leaf litter in all three areas, and especially the one in Blaauwklippen, which had disproportionately high amounts of leaf litter (Table 1).

Table 1: Mean number of plant species (NrPl), non-crop plant height (H), leaf litter depth (LLD) and leaf litter dry weight (LLW) (±S.E.) for the study sites. Subscripts indicate means that are significantly higher than natural vegetation (n), alternative vineyards (a) and integrated vineyards (i) within each locality ($p<0.05$). The subscript i4 indicates a significantly higher mean than IV4.

Locality	**Polkadraai**				**Blaauwklippen**			**Kanonkop**		
Site	**N1**	**AV1**	**IV1**	**IV4**	**N2**	**AV2**	**IV2**	**N3**	**AV3**	**IV3**
NrPl	$7.7 \pm 0.58_{a\,i4}$	$5.5 \pm 0.40_{i4}$	$4.8 \pm 0.44_{i}$	3.1 ± 0.18	$9.2 \pm 0.47_{a\,i}$	$5.5 \pm 0.48_{i}$	3.8 ± 0.33	$7.7 \pm 0.54_{i}$	$6.5 \pm 0.40_{i}$	1.2 ± 0.13
H (cm)	$61.0 \pm 5.85_{a\,i}$	$20.0 \pm 2.10_{i\,i4}$	7.65 ± 1.21	7.85 ± 1.55	$74.0 \pm 3.62_{a\,i}$	$14.05 \pm 1.12_{i}$	5.30 ± 0.52	$54.0 \pm 7.92_{a\,i}$	$14.25 \pm 0.89_{i}$	0.60 ± 0.31
LLD (cm)	0.63 ± 0.16	$1.38 \pm 0.27_{i\,i4}$	0.45 ± 0.19	0.38 ± 0.15	0.43 ± 0.13	$3.51 \pm 0.33_{n\,i}$	0.73 ± 0.11	0.35 ± 0.08	0.75 ± 0.25	0.60 ± 0.16
LLW (g)	1.11 ± 0.29	$5.65 \pm 1.69_{i\,i4}$	1.65 ± 0.71	1.30 ± 0.43	1.70 ± 0.72	$9.76 \pm 1.46_{n\,i}$	2.46 ± 0.43	0.61 ± 0.24	1.89 ± 0.81	1.90 ± 0.55

3.1.2. Management activities

Table 2 lists the calculated indices for biocide applications, fertilizer intervention and tillage intensity. A complete breakdown of products and methods used is in Appendix A. Management activities varied greatly between all vineyards. However, a consistent trend is evident in the applications, with integrated vineyards generally having higher intensity scores than alternative vineyards for pesticides, fungicides and herbicides, and higher fertilizer intervention indices. Tillage intensity was variable, and no pattern was discernable.

Table 2. Indices for biocide application, fertilizer intervention and tillage intensity for vineyards. A lower score indicates lower management intensity. A complete breakdown of products and methods used is in Appendix A (AV=alternative vineyards, IV=integrated vineyards)

Locality	Site	Pesticide application index	Fungicide application index	Herbicide application index	Fertilizer intervention index	Tillage intensity index
Polkadraai	AV1	0	4	0	5	1
	IV1	5	14	4	6	0
	IV4	6	14	2	6	1
Blaauwklippen	AV2	0	4	0	1	3
	IV2	4	14	7	10	3.5
Kanonkop	AV3	0	4	0	2	2
	IV3	2	7	4	3	2

3.1.3. Landscape variables

Table 3 lists the landscape variables for the different sites. All natural sites were located at a higher elevation than the vineyards, which is typical for agricultural landscapes where cultivation is usually confined to lower slopes. On average Blaauwklippen locality had the most potential source vegetation in the vicinity and was also the closest to natural and semi-natural vegetation.

Table 3. Landscape variables for the ten different sites (AV=alternative vineyards, IV=integrated vineyards, N=natural vegetation).

Locality	Site	Elevation	% Source vegetation	Distance to source vegetation (m)
Polkadraai	AV1	187	9.65	208.23
	IV1	205	8.62	92.56
	N1	262.3	44.3	0
	IV4	182	18.72	159.57
Blaauwklippen	AV2	140	24.36	0
	IV2	221	57.85	0
	N2	246.7	69.48	0
Kanonkop	AV3	253.7	9.58	157.58
	IV3	262.7	15.45	182.47
	N3	357.7	67.68	0

3.1.4. Site association

Cluster analysis revealed clear groupings according to habitat type (Fig. 4). All the vineyards were more similar to each other in terms of environmental conditions than to the natural sites. Within the vineyard cluster, alternative vineyards and integrated vineyards grouped into separate clusters. IV1 and IV4 were the sites that were most closely related despite their apparent differences.

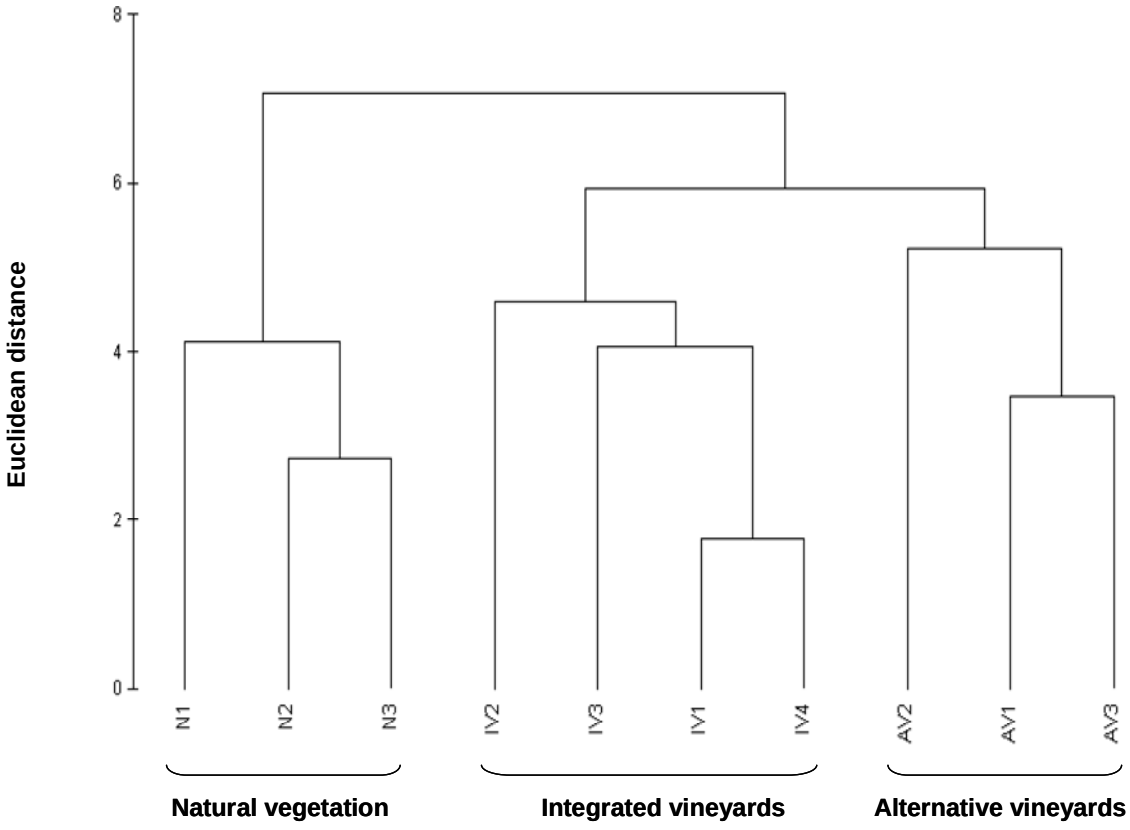


Figure 4. Cluster dendrogram of sites (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4) based on the averaged, fourth root transformed environmental data set.

A similar result was obtained from nMDS (Fig. 5). Except for some variation in the natural sites, sampling units showed a distinct tendency to group together according to habitat type, which confirms the cluster analysis result that sites of the same landuse were most similar to each other in terms of their environmental conditions.

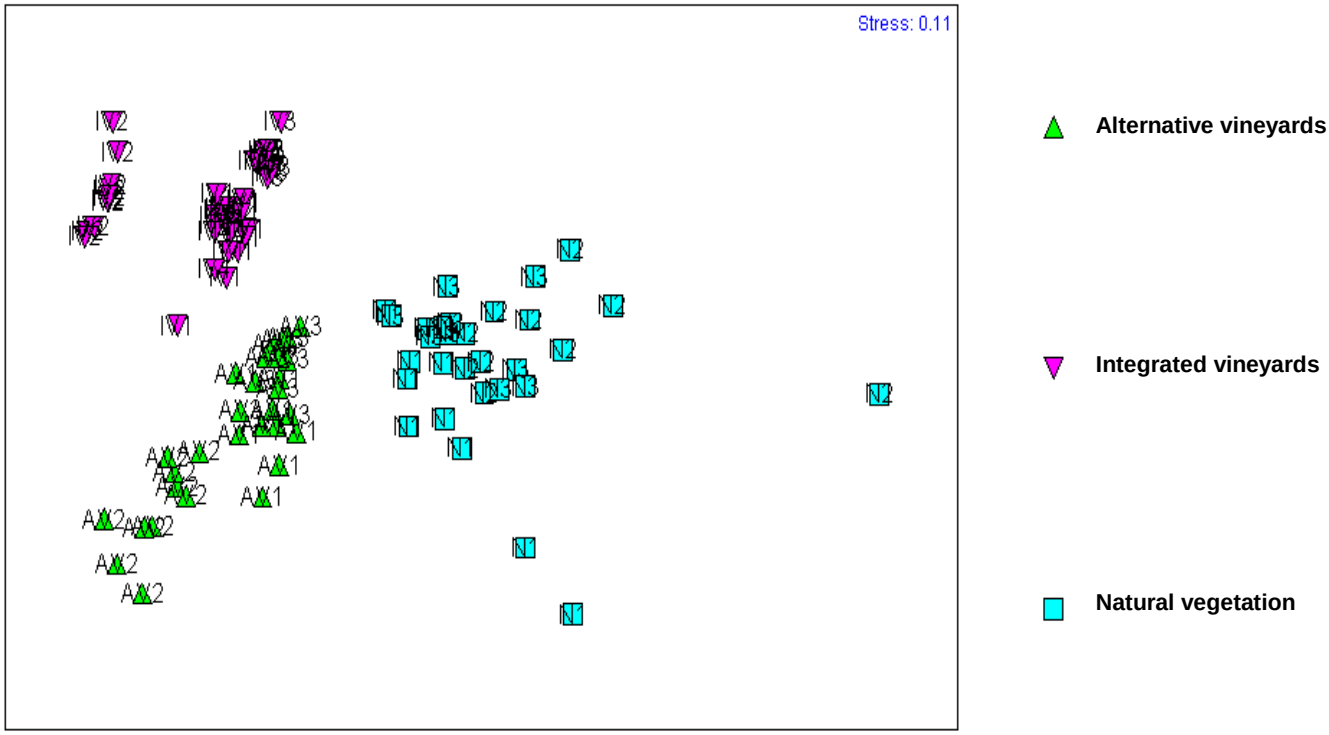


Figure 5. nMDS ordination of unaveraged, fourth-root transformed environmental data from alternative vineyards (AV), integrated vineyards (IV) and natural vegetation (N), showing grouping of sites and habitat types.

3.2. Arthropods

3.2.1. Abundance and species richness

A total of 25 242 macro-arthropods were sampled, consisting of 389 morphospecies from 130 families (Appendix B). The most abundant orders were Acari (6310), Coleoptera (5020) and Hymenoptera (4735). The most species rich orders were Coleoptera (98), Hemiptera (66) and Hymenoptera (58). The most abundant families were Formicidae (4448), Oribatei (3324) and Julomorphidae (2081) and the most species rich families were Formicidae (31), Curculionidae (17) and Cicadelidae (17). The separate estimate for Collembola was 46 089 individuals, represented by 12 morphospecies from 2 suborders (Appendix C).

The nested ANOVA indicated that there was a significant difference between the three localities ($F=26.54$, $n=2$, $p\leq0.001$) and between habitat types nested within locality ($F=9.48$, $n=7$, $p\leq0.001$). Within the three sampling localities, mean abundance was consistently higher in the alternative vineyards compared to the integrated vineyards, but significantly so only in Blaauwklippen and Kanonkop ($p\leq0.01$) (Fig. 6, Table 4). The mean abundance of the alternative vineyard at Blaauwklippen was also significantly higher than that of the natural site ($p\leq0.01$) and the same result was obtained at Kanonkop ($p\leq0.01$). At Polkadraai, the highest mean abundance was found in the natural vegetation, which was considerably higher than IV1 ($p<0.05$).

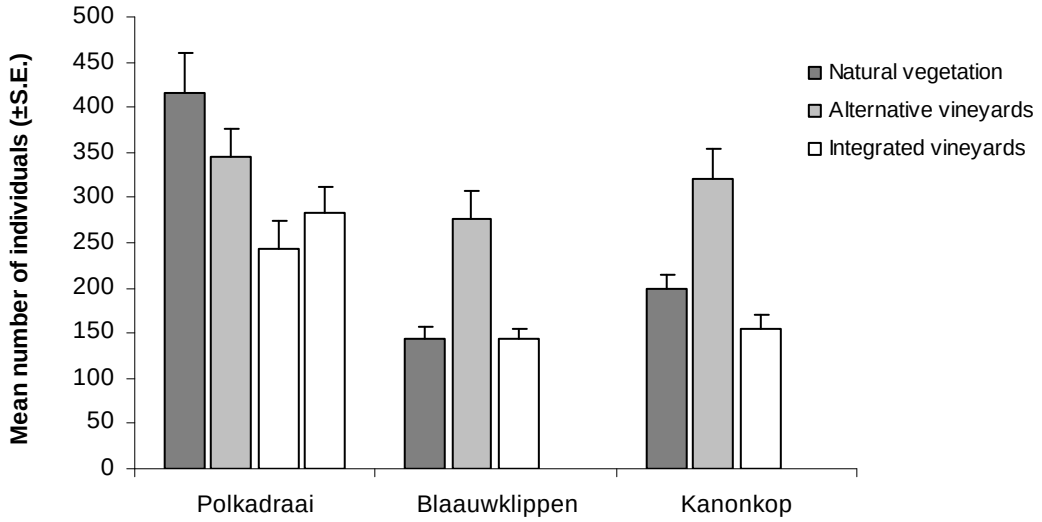


Figure 6. Mean arthropod abundance (±S.E.) for natural vegetation, alternative vineyards and integrated vineyards in the three sampling localities.

Table 4. Mean arthropod abundance (±S.E.) for natural vegetation, alternative vineyards and integrated vineyards in the three sampling localities. Subscripts indicate means that are significantly higher than natural vegetation (n), alternative vineyards (a) and integrated vineyards (i) within locality ($p \leq 0.05$). The subscript i4 indicates a significantly higher mean than IV4.

	Natural vegetation	**Alternative vineyards**	**Integrated vineyards**
Polkadraai	$415.5 \pm 45.18_{\ i\ i4}$	345.1 ± 31.58	243.7 ± 30.43 (IV1)
Polkadraai			282.7 ± 28.88 (IV4)
Blaauwklippen	144.5 ± 12.26	$275.5 \pm 31.13_{\ n\ i}$	143.8 ± 10.13
Kanonkop	199 ± 15.02	$320.5 \pm 34.57_{\ n\ i}$	153.9 ± 16.33

For species richness, there was a significant difference between the three localities ($F=28.88$, $n=2$, $p \leq 0.001$) and between habitat type nested within locality ($F=24.43$, $n=7$, $p \leq 0.001$). Within all three areas, mean species richness in the alternative vineyards were significantly higher than the integrated sites ($p \leq 0.05$) (Fig. 7, Table 5). Mean species richness of natural sites was also higher than in all the integrated vineyards and significantly so at Polkadraai and Kanonkop ($p \leq 0.01$). At Polkadraai and Kanonkop, the highest species richness was in the natural sites, whereas at Blaauwklippen, the alternative vineyard contained the most species.

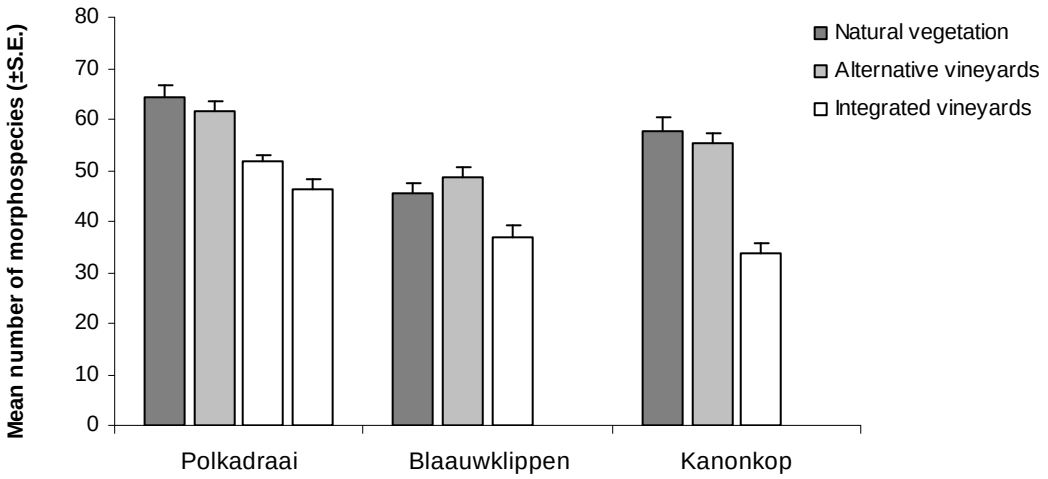


Figure 7. Mean species richness (±S.E.) for natural vegetation, alternative vineyards and integrated vineyards in the three sampling localities.

Table 5. Mean species richness (±S.E.) for natural vegetation, alternative vineyards and integrated vineyards in the three sampling localities. Subscripts indicate means that are significantly higher than natural vegetation (n), alternative vineyards (a) and integrated vineyards (i) within locality ($p \leq 0.05$). The subscript i4 indicates a significantly higher mean than IV4.

	Natural vegetation	**Alternative vineyards**	**Integrated vineyards**
Polkadraai	$64.4 \pm 2.46_{i}$	$61.6 \pm 2.05_{i}$	51.6 ± 1.44 (IV1)
Polkadraai			46.4 ± 1.86 (IV4)
Blaauwklippen	45.4 ± 2.12	$48.7 \pm 2.04_{i}$	36.7 ± 2.51
Kanonkop	$57.7 \pm 2.57_{i}$	$55.1 \pm 1.97_{i}$	33.8 ± 1.69

3.2.2. Site association

The cluster analysis based on species assemblage data did not yield clear groupings according to habitat type (Fig. 8). However, the species assemblages of all the vineyards were more similar to each other, at 49.79% similarity, than to the natural sites. Within the vineyards cluster, alternative and integrated vineyards within the same locality were grouped together, indicating that for the vineyards, the effect of locality on species composition was greater than the effect of habitat type.

The vineyards in the Polkadraai locality were 55.83% similar. Here, IV1, the integrated vineyard with the higher plant and leaf litter cover, was more closely associated (60.52% similarity) with the alternative vineyard than IV4, which was more cleanly cultivated. The vineyards in the Blaauwklippen locality were 57.83% similar and vineyards in the Kanonkop locality were 58.45% similar. The natural sites at Polkadraai and Kanonkop, which were both slightly disturbed sights, were grouped together at 54.66% similarity. The natural site at Blaauwklippen was the most undisturbed site, and was least similar to all other sites in terms of species assemblage at 39.45% similarity.

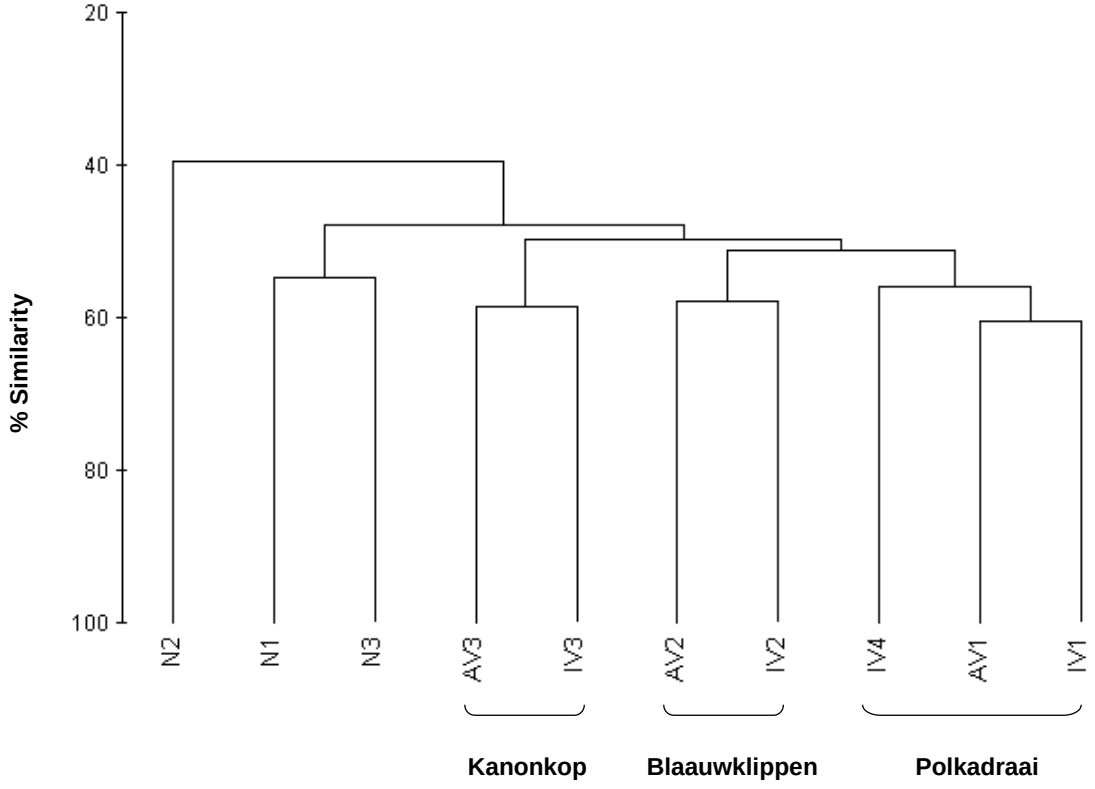


Figure 8. Cluster dendrogram of arthropod species abundance. Dendrogram was derived from averaged, fourth root transformed data. (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4.)

nMDS ordination of species assemblages in sampling units revealed a similar pattern as the cluster analysis. From the ordination diagram (Fig. 9) it is evident that the vineyard sampling units are more closely associated to each other than to the natural sites. Again, different vineyard types grouped together within localities, suggesting that the effect of geographic locality had a greater influence on the species assemblage patterns than the vineyard management regime. There was greater variability between the natural vegetation sampling units, yet the sampling units from Polkadraai and Kanonkop were clearly more closely associated than those from Blaauwklippen.

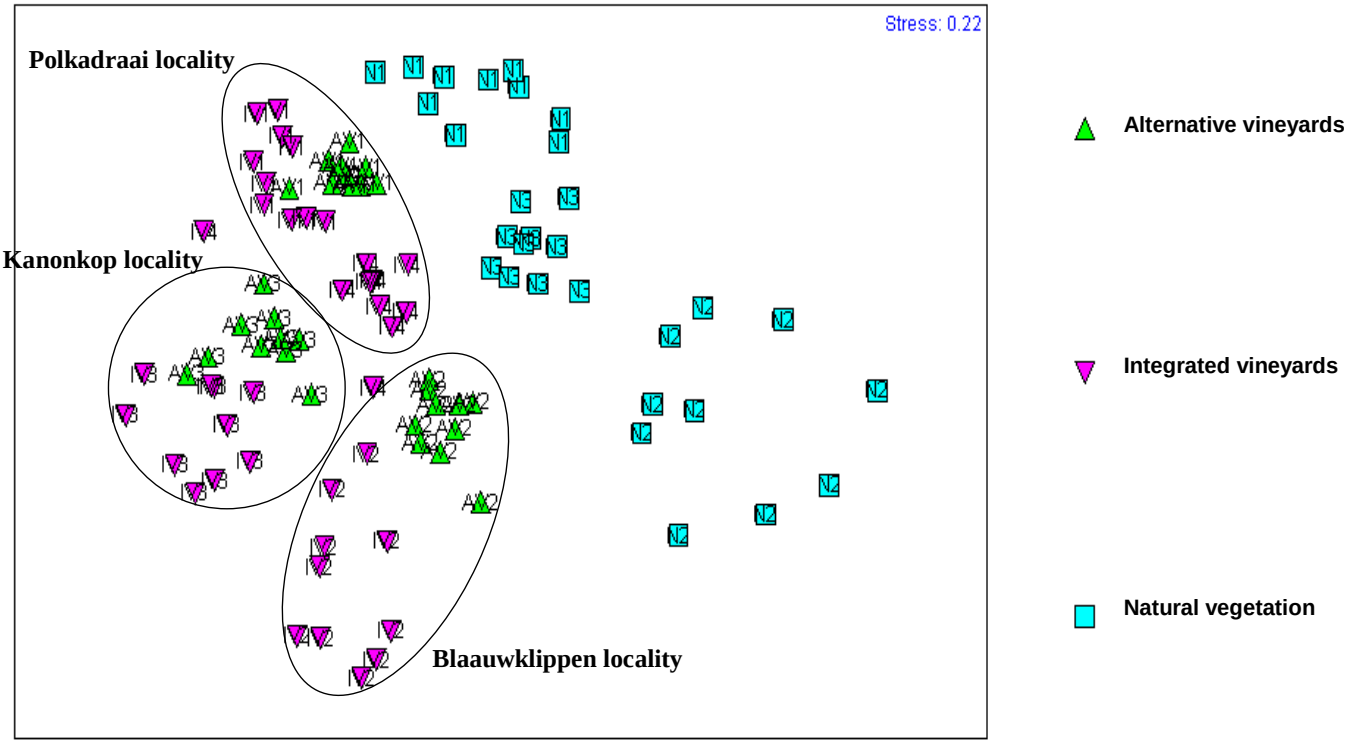


Figure 9. nMDS ordination of unaveraged, fourth-root transformed species abundance data in alternative vineyards (AV), integrated vineyards (IV) and natural vegetation (N), showing groupings according to habitat type and locality.

The two sets of calculations for the Jaccard indices of similarity yielded comparable results. In both cases, the highest similarity based on species shared, was between the two vineyard types (C_j = 0.54) (Fig. 10a & b). The same index was also obtained in the two calculations for the relationship between alternative vineyards and natural habitat (C_j = 0.47), which was higher than the indices for the similarity between integrated vineyards and natural habitat (C_j = 0.43 when IV4 was excluded and C_j = 0.42 when IV1 was excluded). This indicates that alternative vineyards were more similar to natural sites, than integrated vineyards were to natural sites in terms of species shared. In both cases, the greatest number of unique species was found in the natural sites, followed by the alternative vineyards.

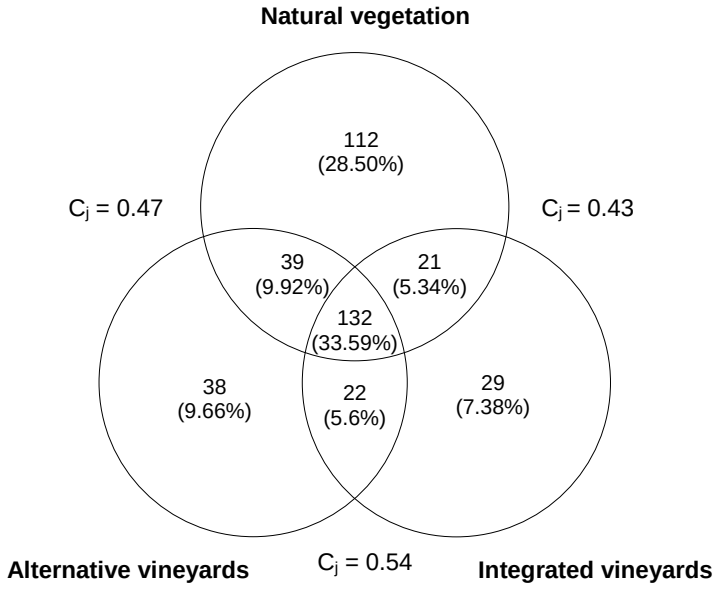


Figure 10a. Venn diagram indicating numbers and percentages of unique species per site type, species shared between site types and Jaccard index of similarity (C_j). This graph excludes IV4.

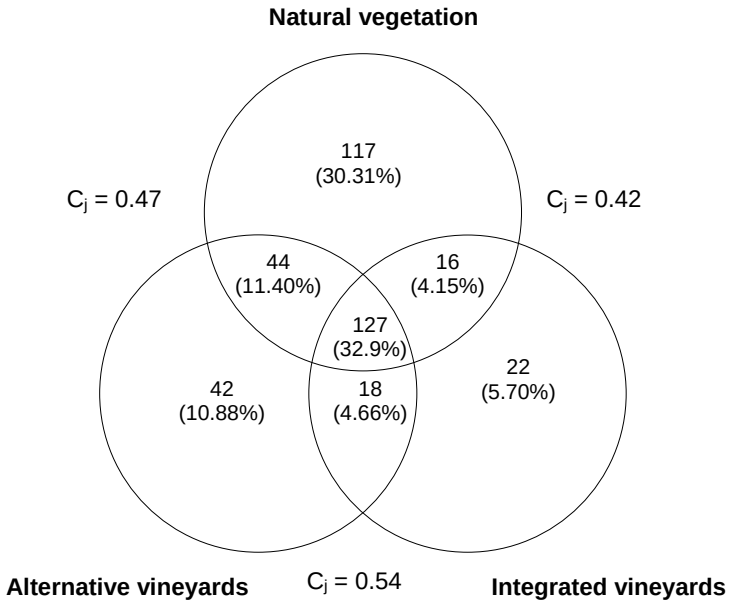


Figure 10b. Venn diagram indicating numbers and percentages of unique species per site type, species shared between site types and Jaccard index of similarity (C_j). This graph excludes IV1.

3.3. Ecological correlates: Vineyards

R-values for significant correlations between total arthropod abundance and species richness and environmental variables are available in Appendix D a & b.

3.3.1. Vegetation

A consistent trend is evident in the correlations of total abundance and species richness with the environmental variables in the vineyards (Appendix D a). Abundance and species richness were positively correlated with total percentage plant cover, broadleaf and grass weed cover, number of plant species and plant height ($p \leq 0.05$). Species richness was also positively correlated with indigenous grass cover in vineyards ($p \leq 0.05$).

3.3.2. Management activities

Abundance and species richness showed very similar correlations with management activities in the vineyards (Appendix D a). Pesticide, fungicide and herbicide application were all negatively correlated with abundance and species richness ($p \leq 0.05$). Fertilizer intervention and tillage intensity also showed negative relationships with these two parameters ($p \leq 0.05$).

3.3.3. Landscape variables

Total abundance and species richness were both negatively correlated with elevation and percentage potential source habitat in the area ($p \leq 0.05$). Abundance was positively correlated with distance from potential source habitat ($p \leq 0.05$) (Appendix D a).

3.4. Ecological correlates: Natural vegetation

3.4.1. Vegetation

In the natural vegetation, both abundance and species richness were positively correlated with broadleaf and grass weed cover, but negatively correlated with indigenous forb and

restio cover ($p \leq 0.05$). Abundance also showed a negative correlation with number of plant species ($p \leq 0.05$) (Appendix D b).

3.4.2. Landscape variables

Species richness and elevation were positively correlated ($p \leq 0.05$). There was a negative relationship between both abundance and species richness and percentage potential source habitat in the surrounding area ($p \leq 0.05$) (Appendix D b).

3.5. CCA Ordination

3.5.1. CCA of all sites

Fig. 11a. shows the CCA ordination of all sites and displays the samples and the environmental variables that were significant in determining species composition of these samples. Monte Carlo tests confirmed the significance of the two axes (p=0.002), which together explained 43.2% of the variation in the species-environment relationship (Table 6a). Species composition was influenced by both habitat type and locality, and the vineyards, especially, were clearly associated with locality. It is also evident that species assemblage was significantly influenced by both field scale variables (tillage, fertilizer and pesticide) and landscape scale variables (elevation and distance to source vegetation). Vineyards were most clearly associated with distance to source vegetation, whereas differences in natural assemblages seemed to be associated with indigenous woody plant cover.

Table 6a. Summary of eigenvalues and Monte Carlo testing for CCA ordination of all sites.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.444	0.309	0.222	0.191	4.446
Species-environment correlations	0.959	0.958	0.926	0.896	
Cumulative % variance of species data	10	16.9	21.9	26.2	
Cumulative % variance of species-environment relation	25.5	43.2	56	67	
Monte Carlo test of significance	**F-ratio**	**p-value**			
First canonical axis:eigenvalue 0.444	9.872	0.002			
All canonical axes: trace 1.742	5.733	0.002			

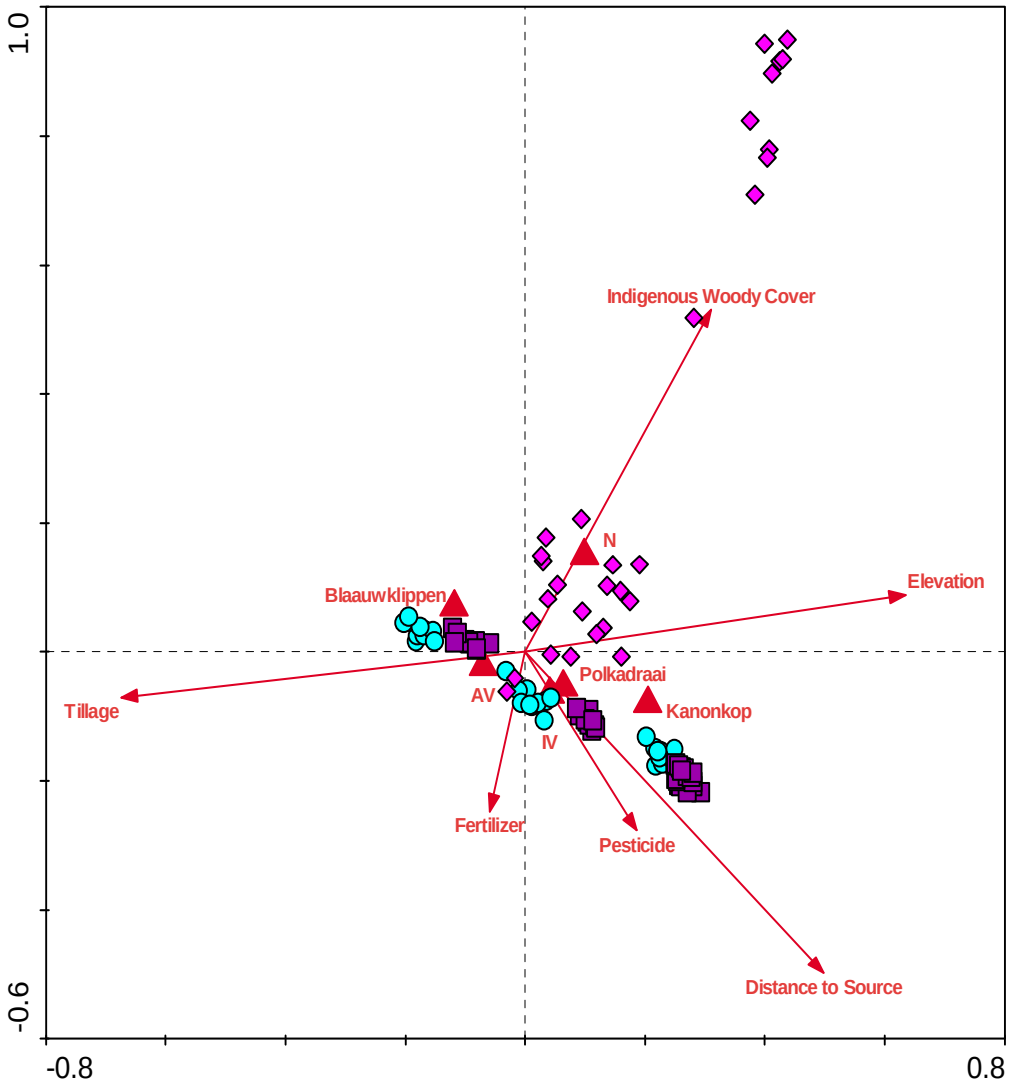


Figure 11a. CCA ordination diagram of samples (alternative vineyards ● , integrated vineyards ■ and natural vegetation ◆), and environmental variables (quantitative variables → and nominal variables ▲) that significantly influenced species distribution patterns across all sites. (AV=alternative vineyards, IV=integrated vineyards, N=natural vegetation)

3.5.2. CCA of vineyards

The CCA ordination for vineyards is shown in Fig. 11b. Both ordination axes were shown to be significant (p=0.002) and they explained 57.5% of the variation in the relationship between species assemblage and environmental variables (Table 6b). Again, both habitat type and locality significantly influenced species composition, but the effect of locality seemed to be greater. The other significant variables were pesticide and tillage intensity and percentage source vegetation in the vicinity.

Table 6b. Summary of eigenvalues and Monte Carlo testing for CCA ordination of vineyards.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.494	0.221	0.214	0.13	3.036
Species-environment correlations	0.965	0.903	0.939	0.908	
Cumulative % variance of species data	16.3	23.6	30.6	34.9	
Cumulative % variance of species-environment relation	39.7	57.5	74.7	85.2	
Monte Carlo test of significance	**F-ratio**	**p-value**			
First canonical axis:eigenvalue 0.494	12.256	0.002			
All canonical axes: trace 1.244	7.29	0.002			

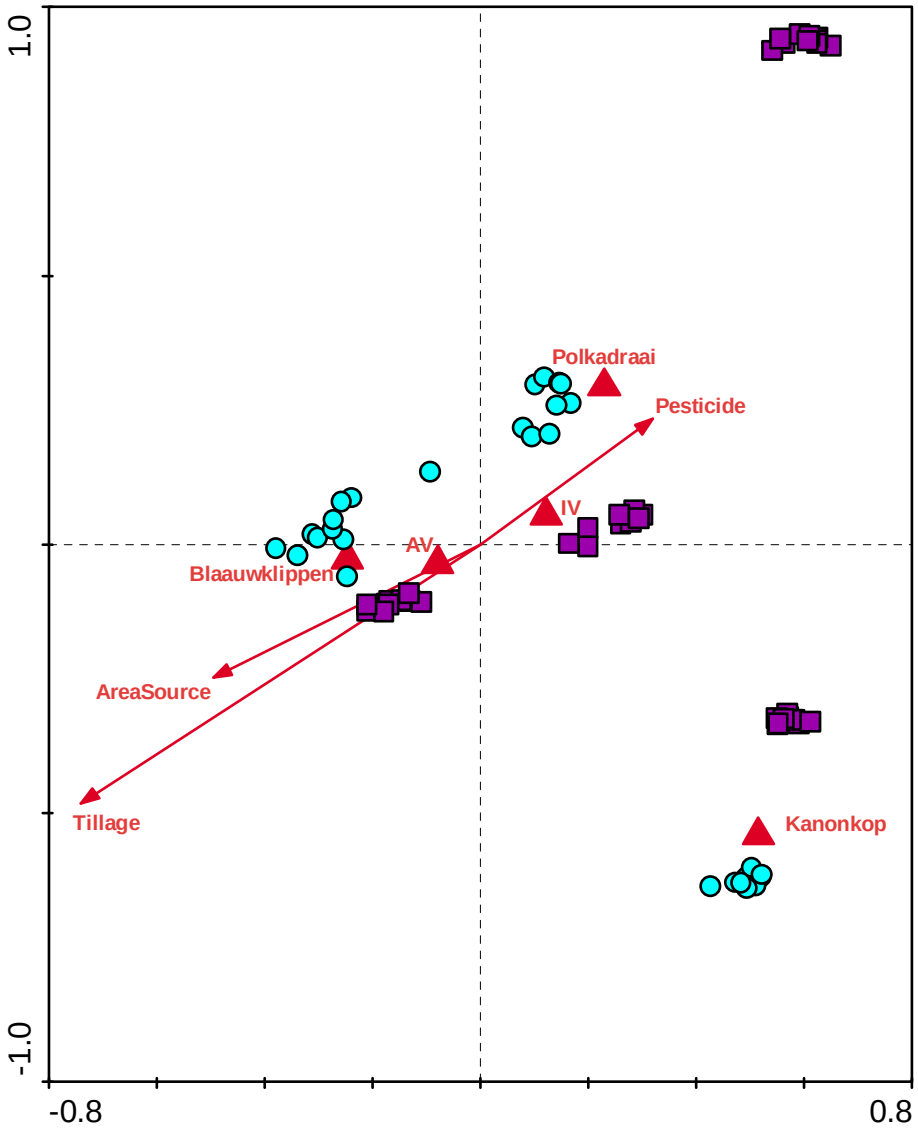


Figure 11b. CCA ordination diagram of samples (alternative vineyards ● and integrated vineyards ■**)**, and environmental variables (quantitative variables → and nominal variables ▲) that significantly influenced species distribution patterns in vineyards. (AV=alternative vineyards, IV=integrated vineyards)

3.5.3. CCA of natural vegetation

Fig. 11c. shows the CCA ordination of the natural sites. The first two ordination axes were significant and accounted for 84.2 % of the species-environment relation (p=0.002) (Table 6c). By excluding the vineyards, it is evident that locality is also highly significant in determining the species assemblages of the natural sites, even though variability was greater within natural sites. The only other significant variable was indigenous grass cover, and Polkadraai natural site was associated with increasing indigenous grass cover, as this was the renosterveld site which generally contains more grass than fynbos.

Table 6c. Summary of eigenvalues and Monte Carlo testing for CCA ordination of natural vegetation

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.497	0.197	0.13	0.211	2.831
Species-environment correlations	0.977	0.961	0.912	0	
Cumulative % variance of species data	17.5	24.5	29.1	36.5	
Cumulative % variance of species-environment relation	60.4	84.2	100	0	
Monte Carlo test of significance	**F-ratio**	**p-value**			
First canonical axis:eigenvalue 0.497	5.534	0.002			
All canonical axes: trace 0.823	3.552	0.002			

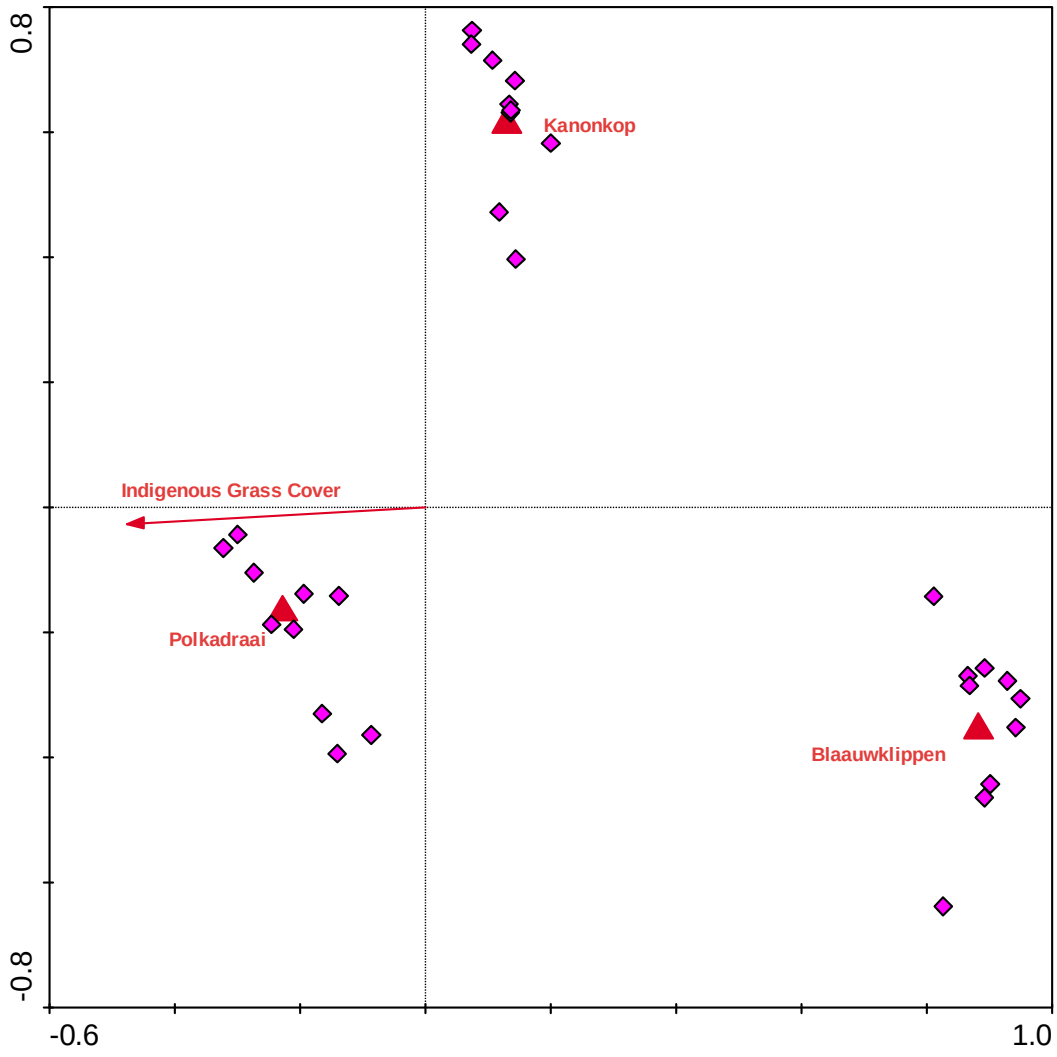


Figure 11c. CCA ordination diagram of samples (natural vegetation ◆), and environmental variables (quantitative variables → and nominal variables ▲) that significantly influenced species distribution patterns in natural vegetation.

3.5.4. CCA of Polkadraai locality

The CCA ordination for Polkadraai locality is shown in Fig. 11d. Both ordination axes were shown to be significant (p=0.002) and they explained 67.5% of the variation in the relationship between species assemblage and environmental variables (Table 6d). Habitat type had a significant influence on species composition. Percentage source vegetation in the vicinity and indigenous woody plant cover significantly influenced composition, and samples in the natural site were associated with these two variables. The other significant variables were pesticide and tillage intensity, with two of the vineyards associating with these management practices. The alternative vineyard samples were associated with lower levels of intensity and IV4 were associated with higher intensities, whereas IV1 did not show clear associations with any of the variables.

Table 6d. Summary of eigenvalues and Monte Carlo testing for CCA ordination of the three habitat types within Polkadraai locality.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.353	0.272	0.196	0.105	2.739
Species-environment correlations	0.971	0.962	0.936	0.773	
Cumulative % variance of species data	12.9	22.8	30	33.8	
Cumulative % variance of species-environment relation	38.1	67.5	88.7	100	
Monte Carlo test of significance	**F-ratio**	**p-value**			
First canonical axis:eigenvalue 0.353	5.173	0.002			
All canonical axes: trace 0.926	4.472	0.002			

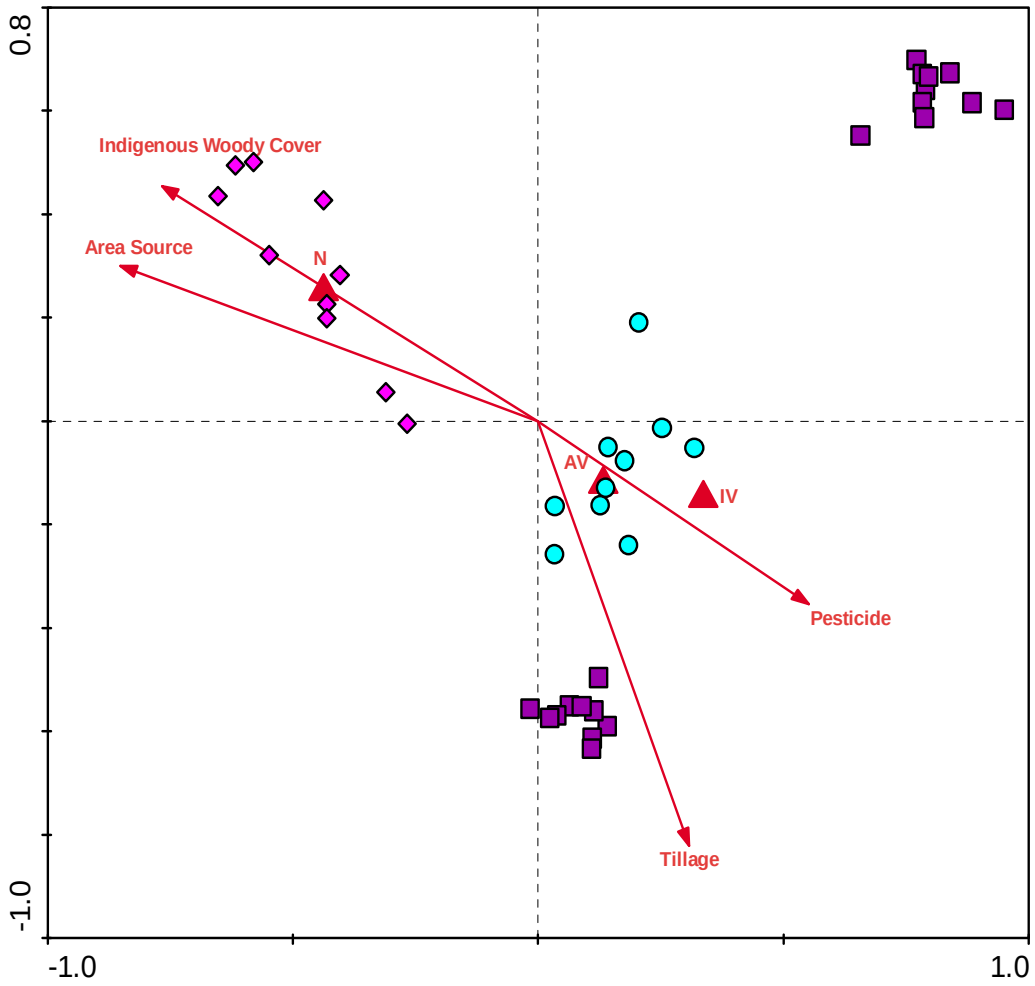


Figure 11d. CCA ordination diagram of samples (alternative vineyards ○ , integrated vineyards ■ and natural vegetation ◆), and environmental variables (quantitative variables → and nominal variables ▲) that significantly influenced species distribution patterns at Polkadraai locality. (AV=alternative vineyards, IV=integrated vineyards, N=natural vegetation)

3.5.5. CCA of Blaauwklippen locality

The CCA ordination graph for Blaauwklippen locality can be seen in Fig. 11e. 85.8% of the variance in the species-environment relationship is explained by the first two ordination axes (p=0.002)(Table 6e). Again, habitat type had a significant influence on species composition, and at this locality it can be seen even more clearly. Significant effects of landscape (percentage source vegetation), vegetation (indigenous woody cover) and management (herbicide) were evident.

Table 6e. Summary of eigenvalues and Monte Carlo testing for CCA ordination of the three habitat types within Blaauwklippen locality.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.565	0.207	0.128	0.202	2.289
Species-environment correlations	0.99	0.97	0.903	0	
Cumulative % variance of species data	24.7	33.8	39.3	48.2	
Cumulative % variance of species-environment relation	62.8	85.8	100	0	
Monte Carlo test of significance	**F-ratio**	**p-value**			
First canonical axis:eigenvalue 0.573	5.346	0.002			
All canonical axes: trace 1.521	2.439	0.002			

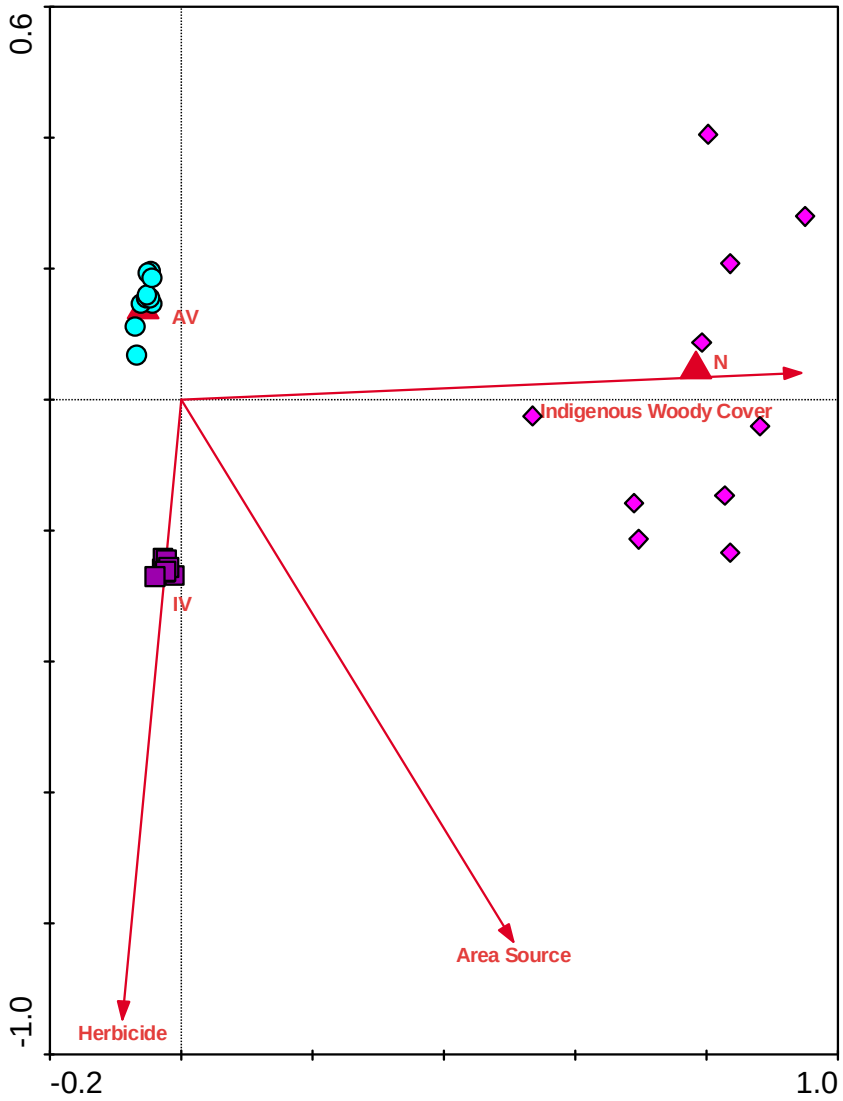


Figure 11e. CCA ordination diagram of samples (alternative vineyards ○ , integrated vineyards ■ and natural vegetation ◆), and environmental variables (quantitative variables → and nominal variables ▲) that significantly influenced species distribution patterns in the three habitat types at Blaauwklippen locality. (AV=alternative vineyards, IV=integrated vineyards, N=natural vegetation)

3.5.6. CCA of Kanonkop locality

The CCA ordination diagram of Kanonkop locality (Fig11f.) displays the samples in the three habitat types and variables that significantly influenced species composition. The first two axes were significant and accounted for 86.1% of the variation in the species-environment relationship (p=0.002)(Table 6f). There was a clear effect of habitat type on species assemblage structure. The first axis represented an increase in elevation, with the natural samples closely associated with higher elevations. Pesticide was also significant in explaining differences in the assemblages and the integrated samples were mostly associated with high pesticide use. In Kanonkop, grass weed cover was also a significant variable, with the alternative vineyard samples being associated with higher grass weed cover.

Table 6f. Summary of eigenvalues and Monte Carlo testing for CCA ordination of the three habitat types within Kanonkop locality.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.416	0.212	0.101	0.273	2.463
Species-environment correlations	0.971	0.894	0.787	0	
Cumulative % variance of species data	16.9	25.5	29.6	40.7	
Cumulative % variance of species-environment relation	57	86.1	100	0	
Monte Carlo test of significance	**F-ratio**	**p-value**			
First canonical axis:eigenvalue 0.416	5.278	0.002			
All canonical axes: trace 0.729	3.642	0.002			

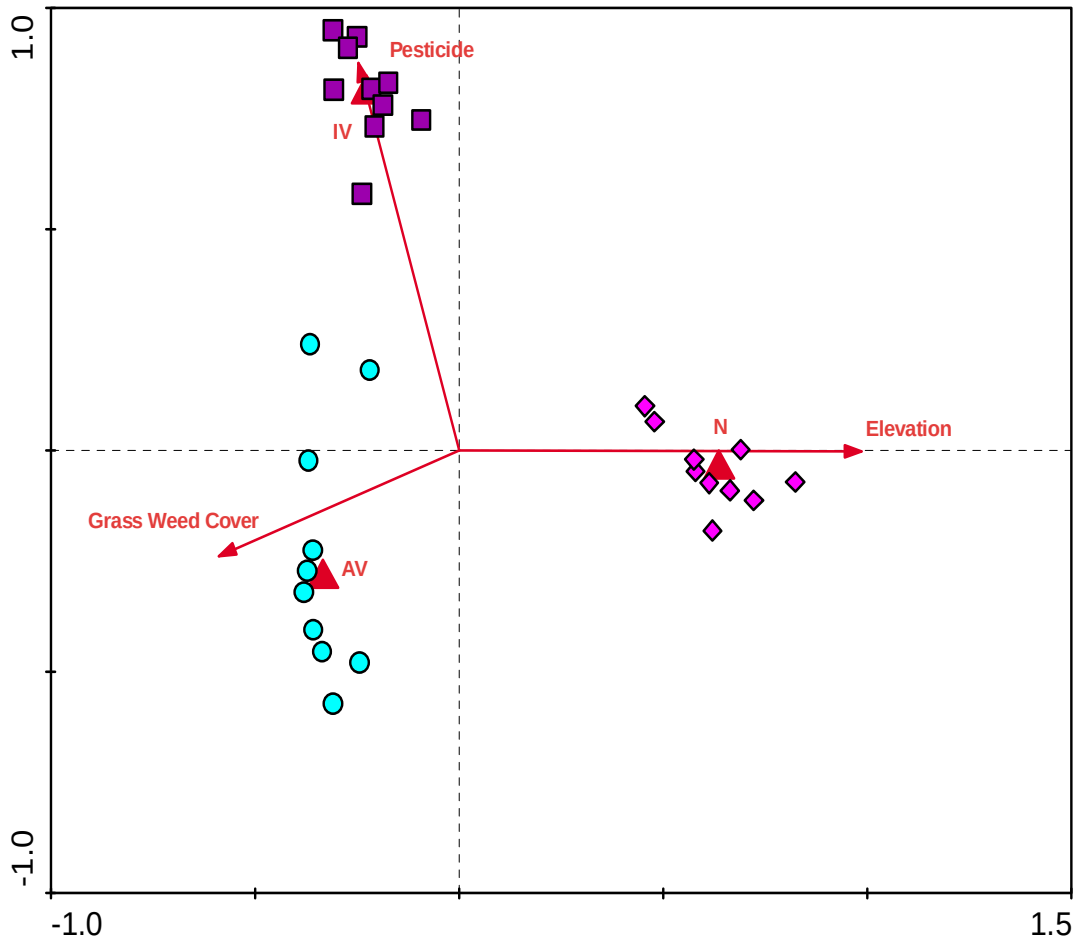


Figure 11f. CCA ordination diagram of samples (alternative vineyards ● , integrated vineyards ■ and natural vegetation ◆), and environmental variables (quantitative variables → and nominal variables ▲) that significantly influenced species distribution patterns in the three habitat types at Kanonkop locality. (AV=alternative vineyards, IV=integrated vineyards, N=natural vegetation)

3.6. Functional feeding guilds

Across all sites, phytophages contributed 22 families (102 morphospecies), nectarivores 3 families (7 morphospecies), omnivores 9 families (67 morphospecies), parasitoids 12 families (17 morphospecies), predators 53 families (123 morphospecies), saprophages 31 families (79 morphospecies) and wood borers 2 families (6 morphospecies). A complete record of how families were assigned to functional guilds is available in Appendix B.

Table 7a. & b list the means and significant differences between abundances and species richness of functional guilds in the ten study sites.

3.6.1. Phytophages

In terms of abundance and species richness, integrated vineyards generally had the least amount of phytophages in all study localities (Table 7a & b). In all three cases, the highest abundance and most species of phytophages were found in either the natural sites or the alternative vineyards.

3.6.2. Nectarivores

Differences in nectarivores between sites were less pronounced (Table 7a & b). Both abundance and species richness was significantly higher in the integrated vineyard than the other two habitats in Kanonkop, and in Polkadraai, the natural site had the most species.

3.6.3. Omnivores

Omnivore abundances were the lowest in the integrated sites in all three sampling localities (Table 7a & b). Omnivore abundances were highest in the alternative vineyards in Kanonkop and Blaauwklippen, and in Polkadraai, the highest abundance was in the natural site. Species richness of omnivores was similar in the three habitats in Polkadraai, but in Kanonkop and Blaauwklippen, integrated vineyards had the lowest species richness.

3.6.4. Parasitoids

A low number of parasitoids were sampled across all sites and differences in their abundance and species richness between sites were minor (Table 7a & b).

3.6.5. Predators

The effect of habitat type on predator abundance and species richness varied across the different localities (Table 7a & b). In Polkadraai, the highest abundance was in the natural site, followed by the two integrated vineyards. Species richness was also highest in the natural site, but here the integrated sites had lower richnesses than the alternative vineyard. In Blaauwklippen, the abundance of predators was highest in the integrated vineyards, but differences in species richness were not definite. At Kanonkop, abundance was highest in the integrated site and the highest species richness was in the natural site.

3.6.6. Saprophages

A clear trend could be seen in the saprophage abundances and species richness (Table 7a & b). In all three localities, alternative vineyards had the highest saprophage abundance and species richness, followed by the natural sites.

3.6.7. Wood borers

Wood borers were also sampled in low numbers and differences between sites were not clear (Table 7a & b). At Kanonkop, the alternative vineyard had more individuals and species than the other sites, and the integrated vineyard at Blaauwklippen had a significantly higher abundance than the other sites.

Table 7a. Mean abundance (±S.E.) per functional guild for the ten study sites. Subscripts indicate means that are significantly higher than natural vegetation (n), alternative vineyards (a) and integrated vineyards (i) within each locality ($p<0.05$).The subscript i4 indicates a significantly higher mean than IV4. (Phy=phytophages, Nec=nectarivores, Omn=omnivores, Par=parasitoids, Pre=predators, Sap=saprophages, Wo=wood borers).

	Polkadraai				Blaauwklippen			Kanonkop		
	N1	**AV1**	**IV1**	**IV4**	**N2**	**AV2**	**IV2**	**N3**	**AV3**	**IV3**
Phy	$124.80 \pm 28.11_{i\ i4}$	$49.00 \pm 4.28_{i4}$	$37.80 \pm 5.87_{i4}$	11.60 ± 1.58	5.90 ± 1.35	14.70 ± 5.68	5.20 ± 0.99	$30.60 \pm 6.31_{i}$	$16.50 \pm 1.75_{i}$	5.40 ± 0.92
Nec	0.90 ± 0.23	0.40 ± 0.22	3.20 ± 1.41	$4.30 \pm 1.21_{a}$	0.20 ± 0.20	0.40 ± 0.27	0.40 ± 0.31	$3.10 \pm 1.44_{a\ i}$	0.10 ± 0.10	0.20 ± 0.20
Omn	75.20 ± 11.20	$73.30 \pm 5.66_{i4}$	57.40 ± 5.70	40.50 ± 4.95	$56.20 \pm 7.28_{i}$	$65.10 \pm 10.08_{i}$	32.70 ± 5.63	56.40 ± 8.20	$179.30 \pm 33.26_{i\ n}$	53.60 ± 8.51
Par	0.60 ± 0.22	1.50 ± 0.82	1.20 ± 0.39	0.80 ± 0.25	3.80 ± 0.95	1.60 ± 0.65	2.70 ± 1.13	$1.50 \pm 0.4_{i}$	$1.10 \pm 0.31_{i}$	0.20 ± 0.13
Pre	$116.40 \pm 11.93_{a\ i4}$	44.20 ± 4.59	71.10 ± 12.20	$73.40 \pm 4.78_{a}$	25.00 ± 1.67	$47.10 \pm 6.13_{n}$	$61.70 \pm 6.76_{n}$	44.80 ± 4.51	48.80 ± 3.71	57.30 ± 5.96
Sap	97.00 ± 12.19	$176.80 \pm 21.96_{i\ n}$	72.20 ± 16.09	151.00 ± 26.45	$52.00 \pm 6.34_{i}$	$141.60 \pm 23.36_{i\ n}$	26.90 ± 4.39	$62.30 \pm 5.31_{i}$	$71.40 \pm 6.15_{i}$	35.50 ± 4.12
Wo	0.60 ± 0.22	0.30 ± 0.21	0.80 ± 0.36	1.10 ± 0.48	1.40 ± 0.34	5.00 ± 1.37	$14.20 \pm 1.78_{a\ n}$	0.30 ± 0.15	$3.30 \pm 0.67_{n}$	1.70 ± 0.56

Table 7b. Mean species richness (±S.E.) per functional guild for the ten study sites. Subscripts indicate means that are significantly higher than natural vegetation (n), alternative vineyards (a) and integrated vineyards (i) within each locality ($p<0.05$). The subscript i4 indicates a significantly higher mean than IV4. (Phy=phytophages, Nec=nectarivores, Omn=omnivores, Par=parasitoids, Pre=predators, Sap=saprophages, Wo=wood borers).

	Polkadraai				Blaauwklippen			Kanonkop		
	N1	**AV1**	**IV1**	**IV4**	**N2**	**AV2**	**IV2**	**N3**	**AV3**	**IV3**
Phy	$9.50 \pm 0.76_{i4}$	$10.30 \pm 0.78_{i4}$	$8.80 \pm 0.84_{i4}$	4.50 ± 0.56	4.80 ± 0.98	5.20 ± 0.93	3.50 ± 0.58	$8.20 \pm 0.7_{i}$	$7.50 \pm 0.54_{i}$	2.70 ± 0.40
Nec	0.80 ± 0.20	0.40 ± 0.22	1.30 ± 0.30	$1.50 \pm 0.22_{a}$	0.10 ± 0.10	0.30 ± 0.21	0.30 ± 0.21	$1.40 \pm 0.37_{a\,i}$	0.10 ± 0.10	0.10 ± 0.10
Omn	11.10 ± 0.80	11.10 ± 0.60	11.50 ± 0.79	9.50 ± 0.52	$9.90 \pm 0.67_{i}$	$10.30 \pm 0.72_{i}$	5.90 ± 0.81	$11.00 \pm 0.8_{i}$	$10.30 \pm 0.76_{i}$	4.80 ± 0.57
Par	0.60 ± 0.22	0.80 ± 0.33	0.90 ± 0.28	0.70 ± 0.21	1.40 ± 0.27	0.80 ± 0.25	1.00 ± 0.21	$1.30 \pm 0.3_{i}$	1.00 ± 0.30	0.20 ± 0.13
Pre	$22.90 \pm 1.05_{a\,i\,i4}$	$17.50 \pm 0.82_{i\,i4}$	13.80 ± 0.61	12.60 ± 1.10	13.80 ± 0.76	14.40 ± 0.88	12.50 ± 0.86	$17.80 \pm 1.09_{i}$	$15.90 \pm 0.5_{i}$	12.90 ± 0.74
Sap	$19.00 \pm 1.23_{i}$	$21.50 \pm 0.55_{i\,i4}$	14.80 ± 0.53	16.90 ± 0.86	14.60 ± 0.58	$16.80 \pm 0.76_{i}$	12.50 ± 0.91	$17.70 \pm 0.8_{i}$	$19.30 \pm 0.7_{i}$	12.40 ± 0.56
Wo	0.50 ± 0.17	0.30 ± 0.21	0.50 ± 0.22	0.70 ± 0.21	0.80 ± 0.13	0.90 ± 0.18	1.00 ± 0.00	0.30 ± 0.15	$1.00 \pm 0.15_{n}$	0.70 ± 0.15

3.7. Relative proportions of functional feeding guilds

For functional guild composition, the calculations based on species numbers yielded similar results across all sites, with functional groups never differing by more than 11% between sites (Fig. 12a.). Predators and saprophages contributed the most in all sites, together accounting for 53-72% of the total number of species per site. IV3 had the highest percentage of both these groups.

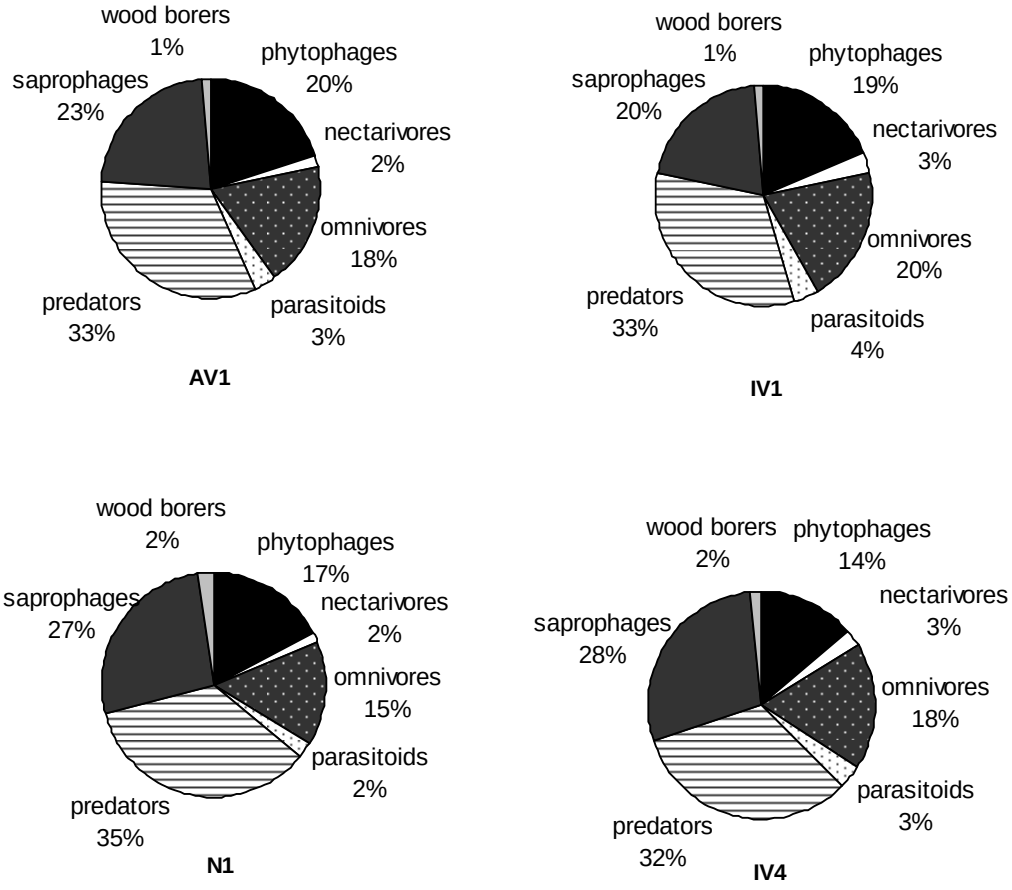


Figure 12a. Functional arthropod guild composition of the ten sites based on species richness. (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4)

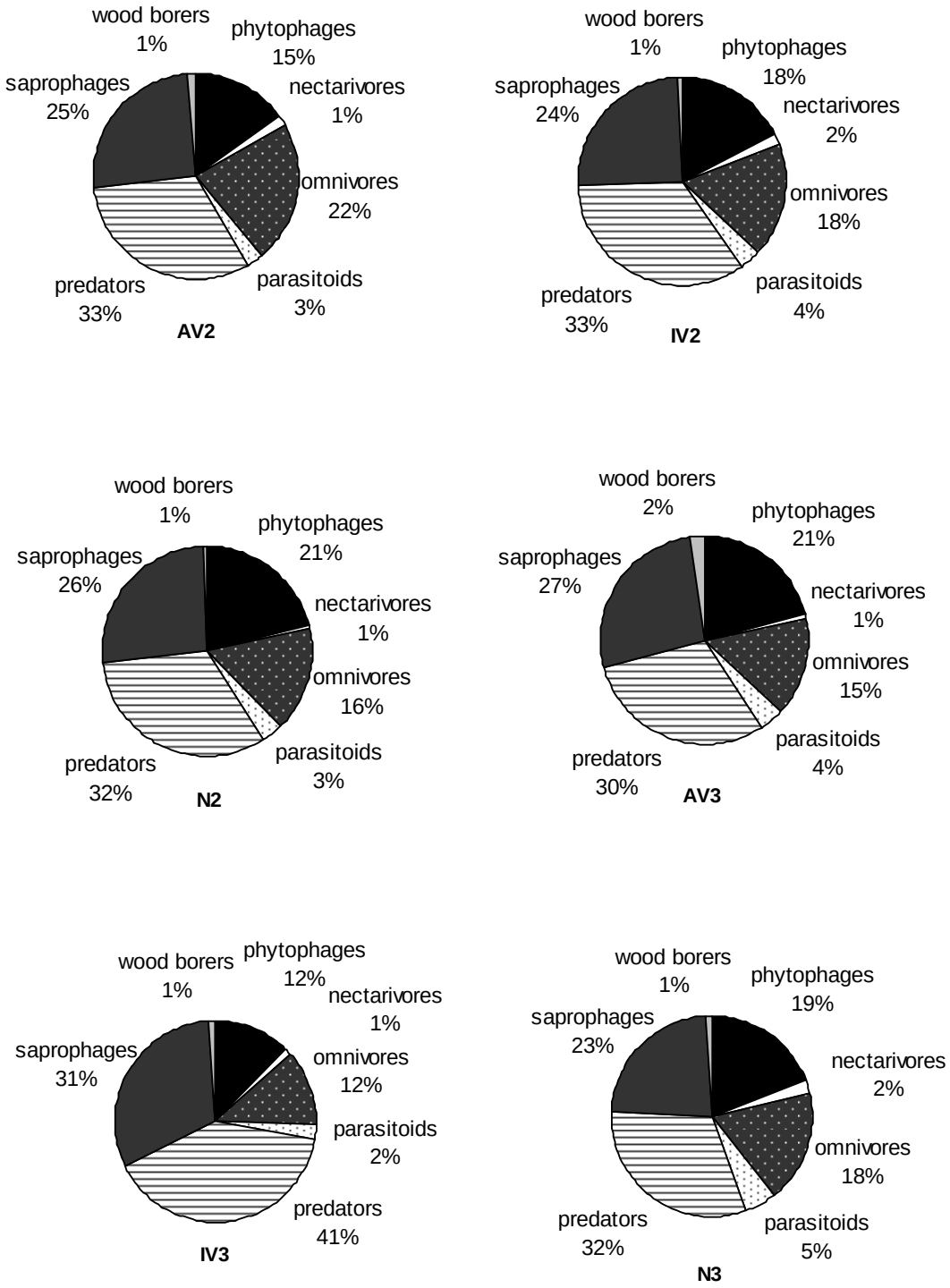


Figure 12a. continued. Functional arthropod guild composition of the ten sites based on species richness. (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4)

In contrast, the functional guild compositions based on abundance differed greatly between sites (Fig.12b). Predators, omnivores and saprophages contributed most in all sites, accounting for 70-95% of the total arthropod abundance per site, with the exception of N1, where phytophages were relatively more abundant, contributing 30%. Wood borers, nectarivores and parasitoids were present in very low percentages. In the natural sites N1 and N3, predators, omnivores, saprophages and herbivores were present in similar proportions. In N2, the most undisturbed natural site, saprophages and omnivores dominated. The two biodynamic sites, AV1 and AV2 seemed to favour saprophages, whereas AV3, the organic site, had a prevalence of omnivores. Predators and omnivores occurred in the greatest proportions in two of the integrated sites, IV2 and IV3. In IV1 and IV4, the integrated sites that were both located in Polkadraai, predators and saprophages were most common

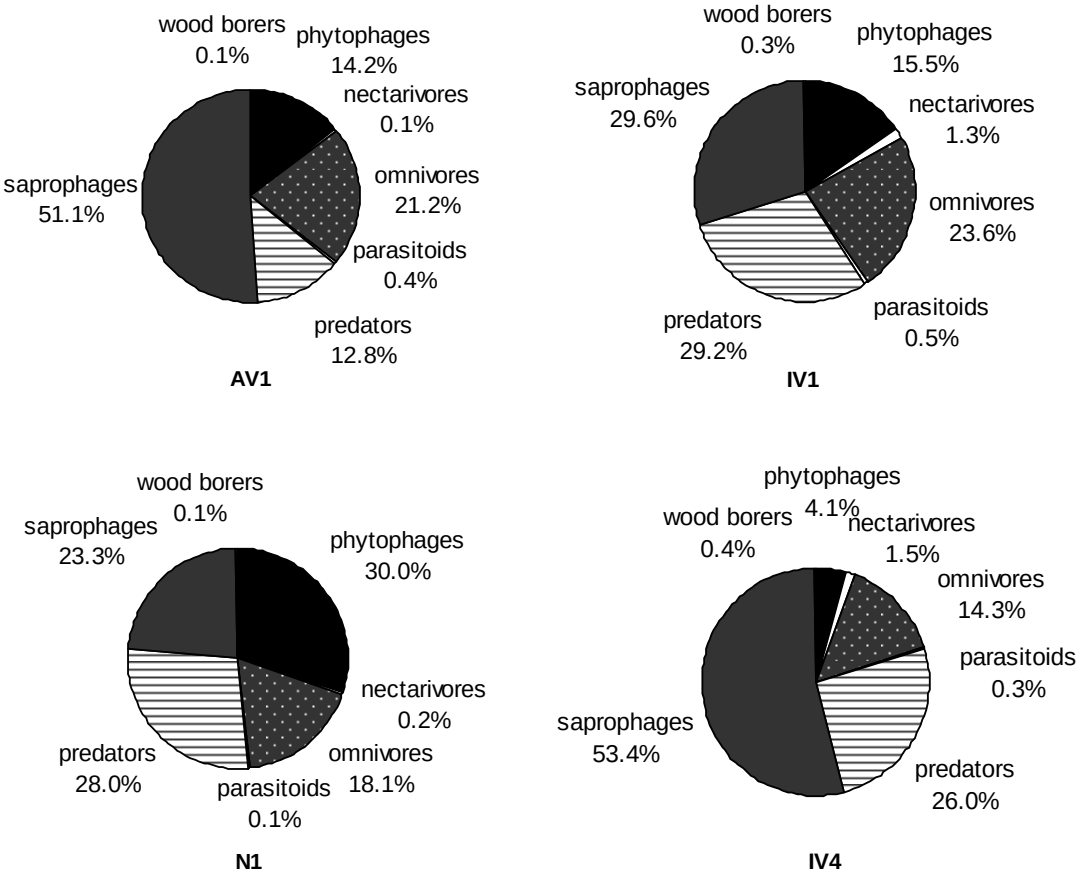
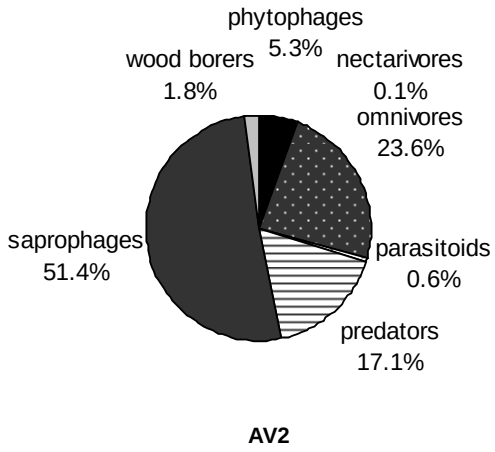
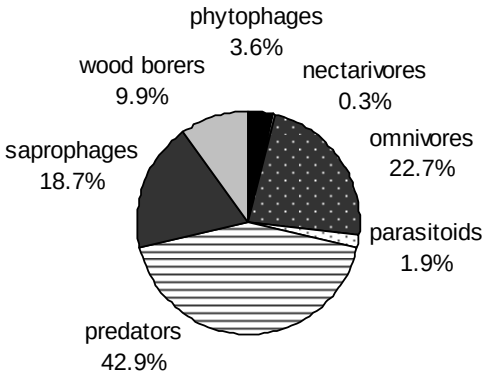


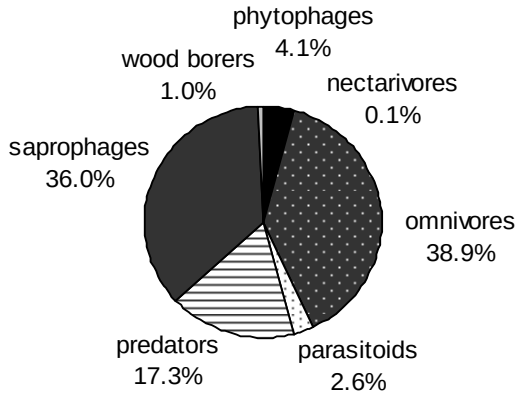
Figure 12b. Functional arthropod guild composition of the ten sites based on abundance. (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4)



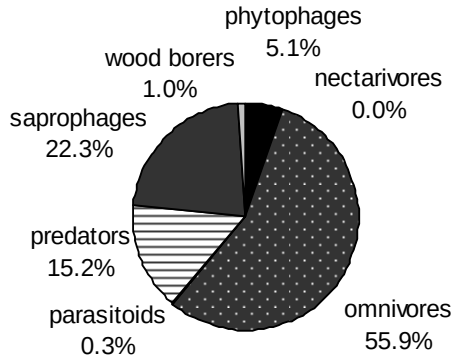
AV2



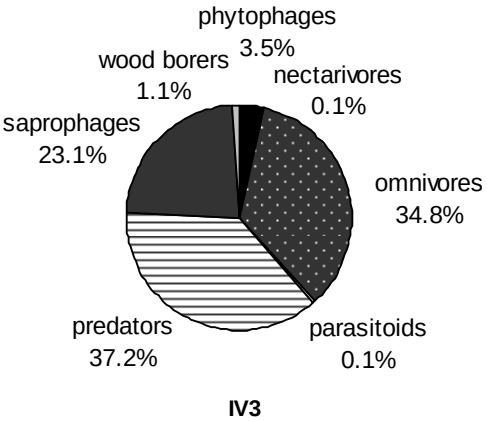
IV2



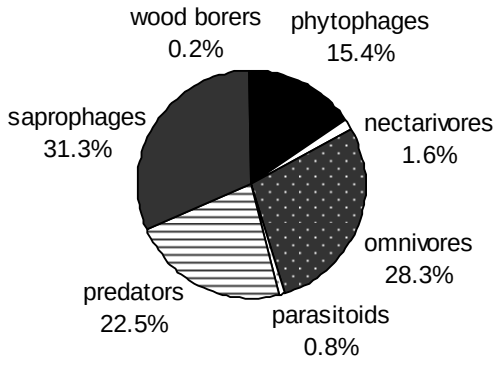
N2



AV3



IV3



N3

Figure 12b. continued. Functional arthropod guild composition of the ten sites based on abundance. (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4)

3.8. Ecological correlates: Vineyards

Detailed R-values for significant correlations between functional guild abundance and species richness and the environmental variables are available in Appendix D a. & b.

3.8.1. Vegetation

The majority of functional guilds (except for nectarivores and wood borers) showed positive significant correlations with the vegetation parameters of weed cover, indigenous grass cover, number of plant species and non-crop plant height ($p \leq 0.05$). Predator abundance showed negative correlations with these variables, but the opposite tendency was seen in predator species richness ($p \leq 0.05$). Wood borer abundance and species richness showed a negative relationship with indigenous grass cover ($p \leq 0.05$) (Appendix D a).

3.8.2. Leaf litter

Few groups correlated significantly with leaf litter (Appendix D a). The only significant correlations, which were negative, were with nectarivore abundance and predator abundance and species richness ($p \leq 0.05$).

3.8.3. Management activities

Significant negative correlations with biocides, fertilizer and tillage intensity could be seen for most functional guilds ($p \leq 0.05$). Only nectarivores, wood borers and predator abundance showed positive correlations with some of these parameters ($p \leq 0.05$) (Appendix D a).

3.8.4. Landscape variables

The significant correlations with elevation and percentage source vegetation were mostly negative for the majority of groups ($p \leq 0.05$). Saprophages were positively correlated with distance to source vegetation and wood borers and parasitoid abundance were negatively correlated with it ($p \leq 0.05$) (Appendix D a).

3.9. Ecological correlates: Natural vegetation

3.9.1. Vegetation

Correlations in the natural vegetation were less uniform than in the vineyards (Appendix D b). Phytophages, predators and saprophages showed positive correlations with weed cover ($p \leq 0.05$). However, parasitoids correlated negatively with increasing weed cover ($p \leq 0.05$). Few groups were significantly correlated with indigenous grass and woody plant cover. Phytophages, predators and saprophages correlated negatively with indigenous restio and forb cover and parasitoids correlated positively with it ($p \leq 0.05$). Predators were negatively correlated with number of plant species and wood borers were positively correlated with plant height ($p \leq 0.05$).

3.9.2. Leaf litter

The only group that showed a significant correlation with leaf litter was phytophage abundance ($p \leq 0.05$) (Appendix D b).

3.9.3. Landscape variables

Phytophages, nectarivores, predator abundance and saprophage species richness showed positive correlations with elevation and wood borer correlated negatively with it ($p \leq 0.05$). Percentage source vegetation correlated positively with parasitoids, but negatively with phytophages, predators, saprophages and nectarivore species richness ($p \leq 0.05$) (Appendix D b).

3.10. Araneae, Carabidae and Staphylinidae

3.10.1. Abundance and species richness

Spiders

There was a significant effect of locality ($F=4.89$, $n=2$, $p\leq0.01$) and habitat type nested within locality ($F=8.66$, $n=7$, $p\leq0.001$) on spider abundance. Similarly, there were significant differences in spider species richness between localities ($F=6.13$, $n=2$, $p\leq0.01$) and habitat types ($F=6.13$, $n=7$, $p\leq0.001$). At the Polkadraai locality, the natural site had the highest spider abundance and species richness ($p\leq0.01$), whereas at Blaauwklippen, the highest abundance and species richness was found in the alternative vineyard ($p\leq0.01$)(Figs 13 &14)(Table 7a & b). In Kanonkop locality, the natural and alternative sites had similar spider abundances and species richness, both significantly higher than in the integrated site ($p\leq0.05$).

Carabids

Carabid abundance was significantly affected by locality ($F=14.83$, $n=2$, $p\leq0.001$) and habitat type ($F=17.27$, $n=7$, $p\leq0.001$). Locality ($F=18.16$, $n=2$, $p\leq0.001$) and habitat type ($F=17.15$, $n=7$, $p\leq0.001$) also had significant effects on carabid species richness. Overall, carabid abundance and species richness was greater in the vineyards than in the natural sites (Figs 13 & 14)(Table 7a & b). Excluding IV4, at Polkadraai and Blaauwklippen, the abundance was highest in the integrated vineyards, whereas at Kanonkop, the highest abundance was found in the alternative vineyard. Species richness was highest in the alternative vineyards at Polkadraai and Kanonkop, and in the integrated vineyard at Blaauwklippen.

Staphylinids

Locality ($F=9.97$, $n=2$, $p\leq0.001$) and habitat type ($F=6.15$, $n=7$, $p\leq0.001$) had significant effects on staphylinid abundance, however, only habitat type had an effect on species richness ($F=5.15$, $n=7$, $p\leq0.001$). At Polkadraai, the natural site had the highest rove beetle abundance and species richness, which was significantly higher than either of the two

integrated vineyards ($p \leq 0.05$)(Figs 13 &14)(Table 7.a & b). At Blaauwklippen locality, the abundances were higher in the natural and alternative sites than in the integrated site ($p \leq 0.05$), but the differences in species richness were less clear. The natural site had the highest staphylinid species richness at Kanonkop.

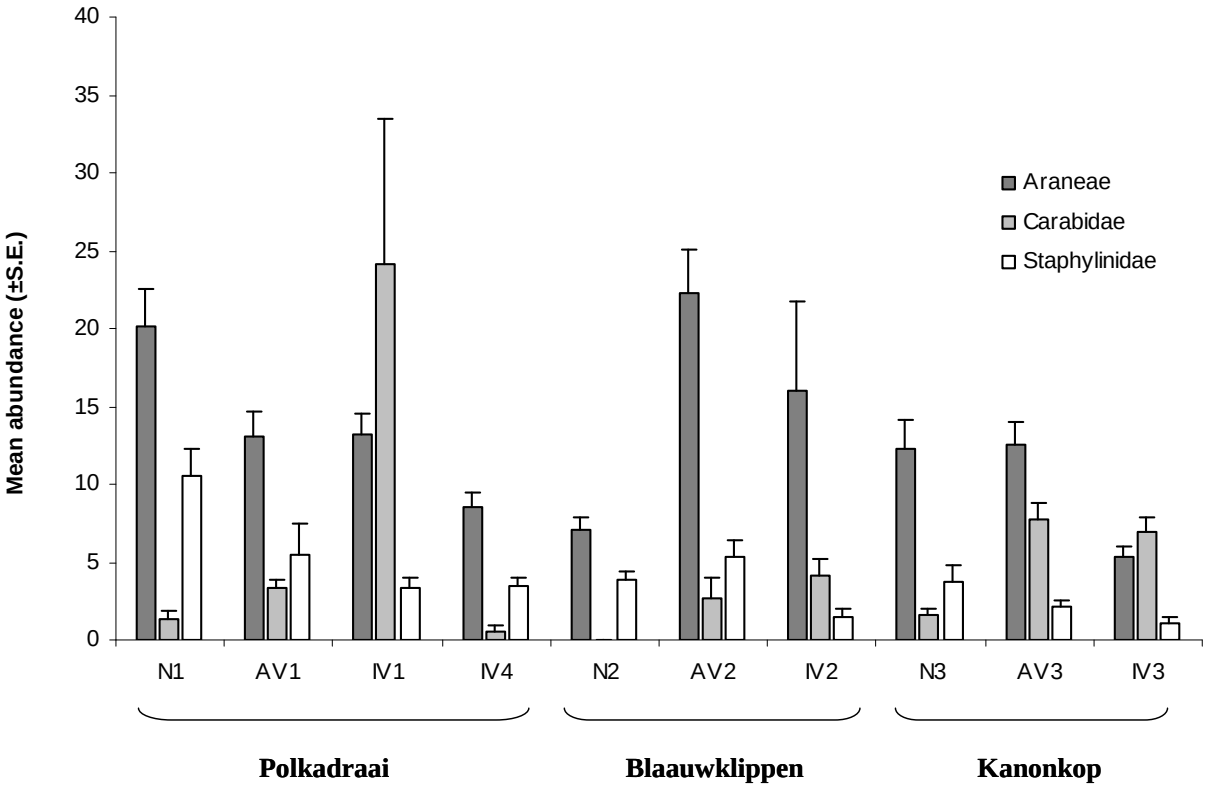


Figure 13. Mean abundance (±S.E.) of Araneae, Carabidae and Staphylinidae at the ten study sites. (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4)

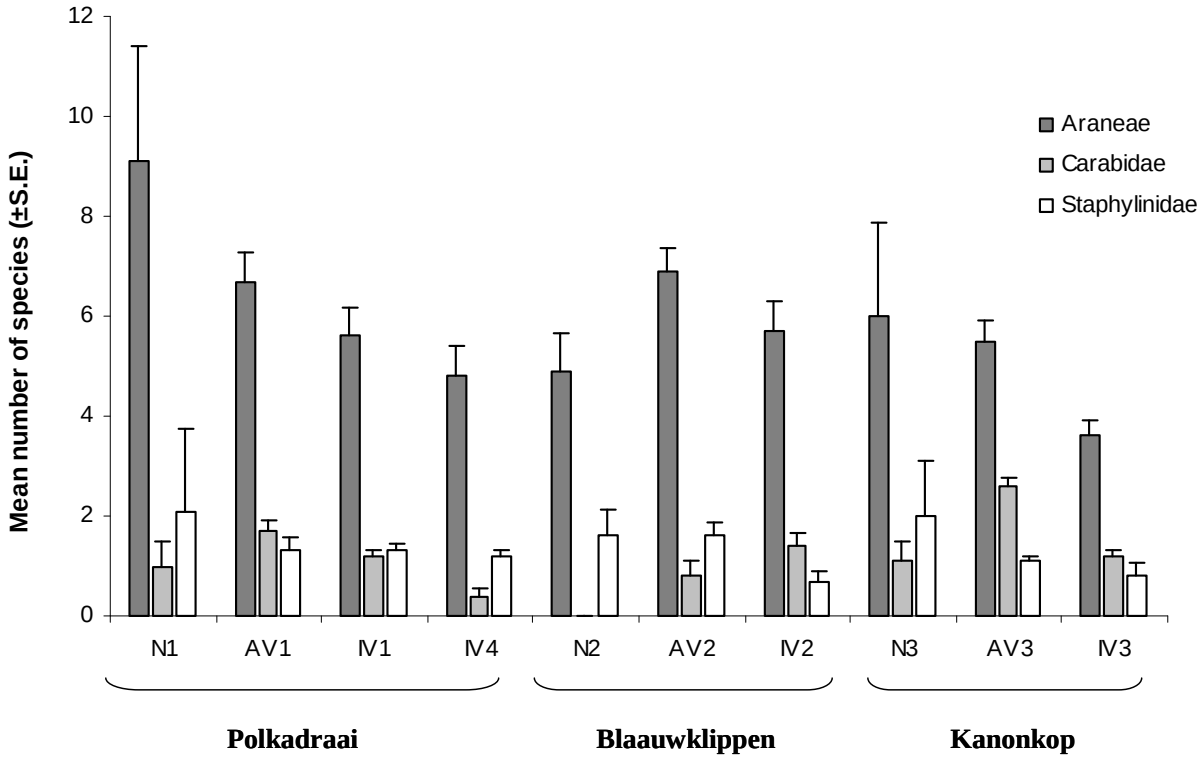


Figure 14. Mean species richness (±S.E.) of Araneae, Carabidae and Staphylinidae at the ten study sites. (AV1=alternative vineyard 1, IV1=integrated vineyard 1, N1=natural vegetation 1, AV2=alternative vineyard 2, IV2=integrated vineyard 2, N2=natural vegetation 2, AV3=alternative vineyard 3, IV3=integrated vineyard 3, N3=natural vegetation 3, IV4=integrated vineyard 4)

Table 8a. Mean abundances (±S.E.) of spiders, carabids and staphylinids in the ten study sites. Subscripts indicate means that are significantly higher than natural vegetation (n), alternative vineyards (a) and integrated vineyards (i) within locality ($p \leq 0.05$). The subscript i4 indicates a significantly higher mean than IV4.

Locality	Polkadraai				Blaauwklippen			Kanonkop		
Site	**N1**	**AV1**	**IV1**	**IV4**	**N2**	**AV2**	**IV2**	**N3**	**AV3**	**IV3**
Araneae	$20.20 \pm 2.30_{i}$	13.10 ± 1.53	13.20 ± 1.32	8.50 ± 0.98	7.10 ± 0.77	$22.30 \pm 2.73_{n}$	16.00 ± 5.78	$12.30 \pm 1.86_{i}$	$12.60 \pm 1.45_{i}$	5.40 ± 0.58
Carabidae	1.40 ± 0.48	$3.40 \pm 0.52_{i\,n}$	$24.20 \pm 9.24_{a\,i\,n}$	0.60 ± 0.31	0.00 ± 0.00	2.70 ± 1.28	$4.20 \pm 1.06_{n}$	1.60 ± 0.37	$7.80 \pm 0.98_{n}$	$7.00 \pm 0.86_{n}$
Staphylinidae	$10.6 \pm 1.63_{i}$	5.5 ± 2.01	3.40 ± 0.62	3.50 ± 0.54	$3.90 \pm 0.55_{i}$	$5.40 \pm 1.01_{i}$	1.50 ± 0.52	3.70 ± 1.12	2.20 ± 0.39	1.10 ± 0.38

Table 8b. Mean species richness (±S.E.) of spiders, carabids and staphylinids in the ten study sites. Subscripts indicate means that are significantly higher than natural vegetation (n), alternative vineyards (a) and integrated vineyards (i) within locality ($p \leq 0.05$). The subscript i4 indicates a significantly higher mean than IV4.

Locality	Polkadraai				Blaauwklippen			Kanonkop		
Site	**N1**	**AV1**	**IV1**	**IV4**	**N2**	**AV2**	**IV2**	**N3**	**AV3**	**IV3**
Araneae	$9.10 \pm 2.30_{i}$	6.70 ± 0.60	5.60 ± 0.56	4.80 ± 0.61	4.90 ± 0.77	$6.90 \pm 0.46_{n}$	5.70 ± 0.60	$6.00 \pm 1.86_{i}$	$5.50 \pm 0.43_{i}$	3.60 ± 0.31
Carabidae	1.00 ± 0.48	$1.70 \pm 0.21_{n\,i}$	$1.20 \pm 0.13_{n\,i}$	0.40 ± 0.16	0.00 ± 0.00	0.80 ± 0.33	$1.40 \pm 0.27_{n}$	1.10 ± 0.37	$2.60 \pm 0.16_{n}$	$1.20 \pm 0.13_{n}$
Staphylinidae	$2.10 \pm 1.63_{i}$	1.30 ± 0.26	1.30 ± 0.15	1.20 ± 0.13	1.60 ± 0.55	1.60 ± 0.27	0.70 ± 0.21	$2.00 \pm 1.10_{i}$	1.10 ± 0.10	0.80 ± 0.25

3.11. Ecological correlates: Vineyards

A detailed matrix of the R-values for significant correlations between the abundance and species richness of the three taxa and environmental variables can be seen in Appendix D c. & d.

3.11.1. Vegetation

Generally, the three taxa were positively correlated with plant cover, number of plant species and plant height (Appendix D c). Total percentage plant cover, broadleaf weed cover and number of plant species were positively correlated with spider species richness and abundance, as well as with carabid species richness ($p \leq 0.05$). Grass weed cover correlated positively with spider species richness and abundance and with staphylinid abundance, but showed a negative correlation with carabid abundance ($p \leq 0.05$). Average plant height correlated positively with spider species richness, spider abundance, carabid species richness and staphylinid abundance ($p \leq 0.05$).

3.11.2. Leaf litter

Out of the three groups, only spiders were significantly correlated with leaf litter (Appendix D c). Both leaf litter depth and leaf litter dry weight were positively correlated with spider species richness and abundance ($p \leq 0.05$).

3.11.3. Biocides and fertilizers

A consistent trend can be seen in the correlations of the three groups with the biocides and fertilizer intervention (Appendix D c). All significant correlations were negative. Pesticide and fungicide application was negatively correlated with spider species richness, spider abundance and carabid species richness ($p \leq 0.05$). Herbicide had a negative relationship with spider species richness and abundance, as well as with staphylinid species richness and abundance ($p \leq 0.05$). Fertilizer intensity was correlated negatively with spider abundance ($p \leq 0.05$).

3.11.4. Landscape variables

Elevation was negatively correlated with spider and staphylinid species richness and abundance, whereas carabid species richness and abundance showed a positive relationship to elevation ($p \leq 0.05$). Carabid species richness and abundance also correlated negatively with percentage source vegetation in the area, whereas spider abundance showed a negative correlation with increasing distance from source vegetation ($p \leq 0.05$) (Appendix D c).

3.12. Ecological correlates: Natural vegetation

3.12.1. Vegetation

Interestingly, invasive plants had a significant positive relationship with some of the groups (Appendix D d). Broadleaf weed cover was positively correlated with spider species richness and abundance, and so was grass weed cover, which, in addition, was also positively correlated with staphylinid abundance ($p \leq 0.05$). In contrast, significant correlations with indigenous plant cover were all negative. Restio cover and spider species richness, abundance and staphylinid abundance were negatively correlated ($p \leq 0.05$). Staphylinid abundance was also negatively correlated with indigenous forb cover ($p \leq 0.05$). Spider abundance and carabid species richness were both negatively correlated with number of plant species ($p \leq 0.05$).

3.12.2. Landscape variables

As in the vineyards, carabid species richness and abundance were positively correlated with elevation ($p \leq 0.05$). Percentage source vegetation showed significant negative correlations with all groups, except for staphylinid species richness ($p \leq 0.05$) (Appendix D d).

3.13. CCA Ordination

Fig. 15 shows the CCA ordination graph of spider, carabid and staphylinid species and the environmental variables that significantly influenced their distribution. Monte Carlo tests indicated that the first two axes were significant ($p<0.002$) (Table 8). Together they explained 47.4% of the species distribution in relation to the environmental variables. From the diagram it is evident that locality had an influence on the distribution of these groups. Habitat type was also important in their distribution and more species tended to associate with natural vegetation and alternative vineyards, than with integrated vineyards. The first axis represents a gradient of increasing pesticide use, with maximum use clearly not favouring these groups, except for two species of carabids that were associated with pesticide use. There was also a loose, but definite, association of species with percentage source area and distance from source habitat, which together represented a gradient of increasing influence from source habitat. Most species seemed to be favoured by being closer to the source and having a greater amount of source habitat in the vicinity. Elevation and tillage were also significant in the species assemblage distribution, but associations were less clear.

Table 9: Summary of eigenvalues and Monte Carlo testing for CCA ordination of spiders, carabids and staphylinids across all sites.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.399	0.342	0.268	0.152	5.052
Species-environment correlations	0.903	0.944	0.928	0.823	
Cumulative % variance of species data	7.9	14.7	20	23	
Cumulative % variance of species-environment relation	25.5	47.4	64.6	74.3	
Monte Carlo test of significance	**F-ratio**	**p-value**			
First canonical axis:eigenvalue 0.399	7.72	0.002			
All canonical axes: trace 1.563	4.477	0.002			

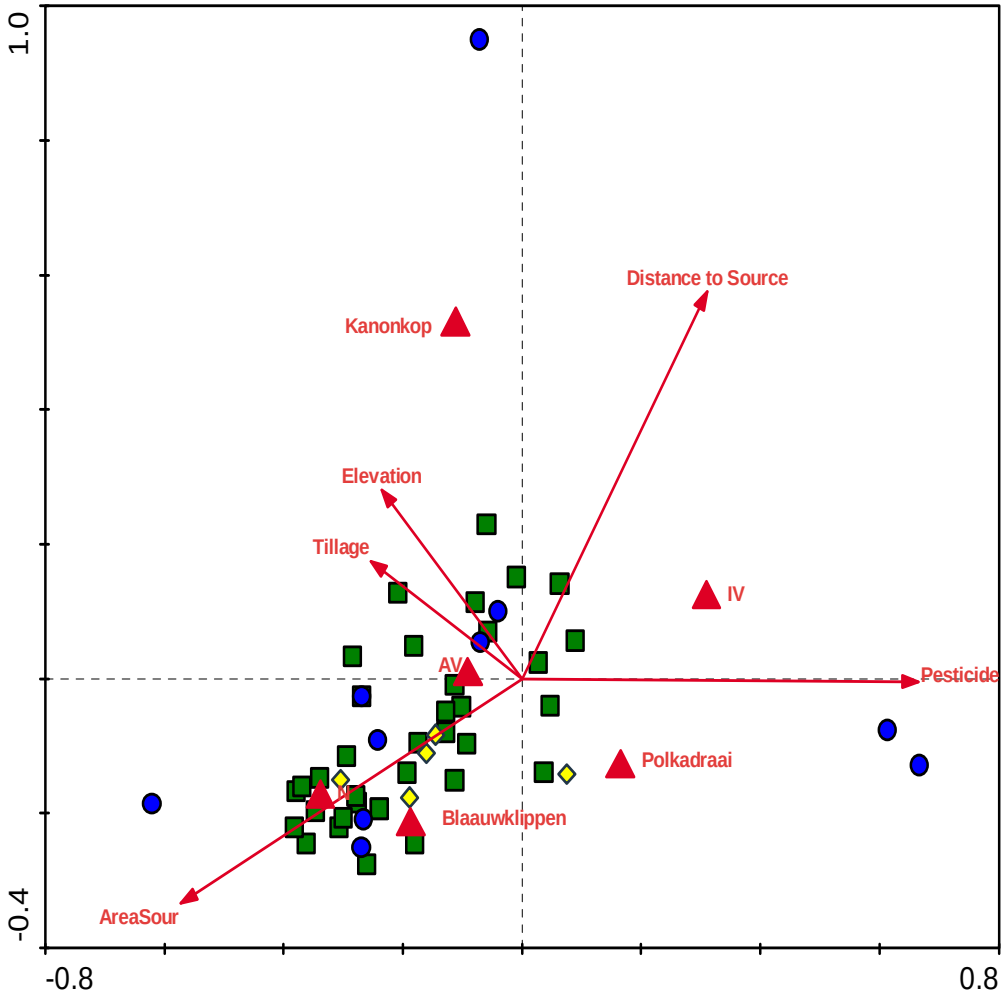


Figure 15. CCA ordination graph of species (spiders ■ , carabids ● and staphylinids ◆), and environmental variables (quantitative variables → and nominal variables ▲) that significantly influenced their distribution across all sites. (AV=alternative vineyards, IV=integrated vineyards, N=natural vegetation)

4. DISCUSSION

4.1. Abundance, species richness and community composition

4.1.1. Vineyards

Many studies have investigated the effects of alternative farming on biodiversity. Although some reported no effect, or negative effects on certain taxa, the vast majority indicated that alternative farms support higher levels of biodiversity than non-alternative farms (Bengtsson *et al*. 2005, Hole *et al*. 2005). The two main land-uses that were compared in this study, integrated and alternative vineyards, differed considerably in terms of management intensity and environmental conditions. Given that the conditions on alternative farms are commonly more favourable for various organisms (Fuller *et al*. 2005), it was not surprising to discover that the arthropod abundance and species richness in alternative vineyards exceeded that of the integrated vineyards. What makes the result convincing is that, despite the substantial background variation in terms of landscape context, management practices and other influences, the positive effects were consistent for all sites.

This increased ability of alternative vineyards to support a greater diversity of species bodes well for biodiversity conservation, as well as for functioning of biotic processes in the vineyards. A more diverse community may lead to a more constant delivery of ecosystem services, increasing the self-sufficiency of the system (Altieri 1999, Tscharntke *et al*. 2005a). Even if certain species are redundant at a specific time i.e. not fulfilling any unique and additional function in the ecosystem, such species may become increasingly important when others are lost due to environmental change (Tscharntke *et al.* 2005a). Hence, more diverse ecosystems have a greater ability to recover after disturbance, which will become progressively more important for species conservation and sustainability of agriculture in the face of climate change. In addition, it has been suggested that the cost of agricultural inputs could increase considerably in the future because of increased oil prices (Tscharntke *et al*. 2005b). The improvement and maintenance of biodiversity in agriculture could reduce the reliance on external inputs, thereby providing a measure of insurance against such a scenario.

The effect of land-use also influenced community composition, but was less marked than its effect on abundance and species richness. Natural sites and vineyards comprised very different communities. This was expected, as all arable systems, including low-input systems, represent highly disturbed environments compared to natural ecosystems (Feber *et al.* 1998). However, within the natural site and vineyard groups, geographic locality was the most important factor influencing composition. Other studies have also identified locality as being a major influencing factor for arthropod communities (e.g. Alvarez *et al*. 2001). This can be expected, particularly in Mediterranean-type ecosystems, where the spatial variability is very high (Caterino 2007). This implies that in the Cape Winelands, but probably also in many other types of landscapes, vineyard management activities will have varying effects on species composition, depending on the particular species assemblages present in the landscape. Measures to improve or manage arthropod diversity in these vineyards will have to be site specific and be preceded by careful monitoring and an understanding of how the specific assemblages interact with the agricultural systems and surroundings.

Related to the influence of geographic locality, is the effect of spatial scale on the results of these types of studies. In their analysis of studies at a variety of spatial scales, Bengtsson *et al.* (2005) found that effects of farming practice on biodiversity were more pronounced at the small scale, indicating that farming regime was not solely responsible for patterns of biodiversity in the farming landscape. They suggested that processes at different scales were involved in shaping communities at the habitat level. This was also evident in this study, where virtually all ordinations indicated that communities were influenced by landscape variables, e.g. locality and distance to non-agricultural habitat, as well as farm and field-scale variables, e.g. pesticide intensity and plant cover. This emphasizes the importance of understanding the responses of organisms at different spatial scales and to integrate multi-scale approaches to optimize the management of biodiversity in farmland (Tscharntke *et al.* 2005b).

4.1.2. Natural vegetation

The natural sites represented reference habitats that were relatively free of human interference and were expected to support a greater diversity of arthropods than the cultivated systems. Another comparative study on the arthropods in natural and cultivated systems in the CFR, found that species richness in fynbos was higher than in orchards, but abundance was highest in low-input orchards (Witt & Samways 2004). A similar trend was seen in this study. Species richness was within similar ranges for the natural sites and alternative vineyards, whereas abundance was highest in the alternative vineyards in two of the localities. Thus, in terms of species numbers, alternative vineyards could sustain levels approaching that of the natural vegetation. In addition, the fact that the alternative vineyards shared more species with the natural sites compared to the integrated vineyards, suggests that the alternative vineyards may be more habitable for naturally occurring species.

In terms of community composition, the large differences between the communities in the natural sites add merit to preserving scattered patches of native habitat throughout the agricultural landscape. It has been demonstrated that even small patches of natural habitat in the CFR are valuable for the conservation of many endemic species (Kemper *et al.* 1999). In the agricultural landscape, where large natural areas are scarce and natural habitat is often highly fragmented, conserving these small patches may be the best strategy to maximize overall species diversity. This is particularly relevant for plants and insects that require smaller habitats (Tscharntke *et al.* 2001) and for narrow-range endemics that are adapted to surviving in small patches (Samways 2006). The risk, of course, with such small fragments is that they are very susceptible to adverse outside conditions due to the large edge-interior ratio. In addition to being vulnerable to climate change (Kuchlein & Ellis 1997), they are susceptible to ecological relaxation over time (Tilman *et al*. 1994). Fortunately, compared to many other wine-producing regions, the CFR still has relatively large amounts of natural habitat fragments (BWI 2007). By maintaining these habitats and by increasing their connectivity throughout the landscape, they could be highly instrumental in sustaining overall diversity.

4.2. Effects of environmental variables on overall abundance and species richness

4.2.1. Vegetation and leaf litter

An increase in non-crop vegetation has often been cited as one of the principle factors that can increase arthropod diversity in agricultural fields (Hole *et al*. 2005). The increased structural complexity, food resources and microhabitat diversity increases the suitability of crop fields for many species (Clark 1999, Feber *et al*. 1998, Pfiffner & Luka 2003). The majority of vineyards in this study had weeds and cover crops, but the alternative vineyards generally had higher non-crop vegetation cover, more diverse cover crops and the vegetation was usually of greater height than in the integrated vineyards. All of these factors seemed to contribute towards the higher abundance and species richness in the alternative vineyards.

Even in the natural sites, increased weed cover benefited arthropod diversity, whereas indigenous plant cover showed a negative relationship with arthropod diversity. It is plausible that, especially for surface-active fauna, the increased herbaceous and grass cover provided refuge and food for a greater variety of organisms in the natural vegetation, where palatability of the vegetation is naturally relatively low (Giliomee 2003). Leaf litter was expected to increase arthropod diversity. Settle *et al*. (1996) indicated that increased organic matter in rice production systems increased levels of detritivores, plankton-feeders and predators. In contrast, in this study there was no detectable effect of leaf litter on arthropod diversity.

4.2.2. Management activities

The detrimental effect of biocides on farmland biodiversity has been well documented (Krebs *et al*. 1999). Pesticides directly reduce the diversity of many non-target organisms such as butterflies (Feber *et al*. 1997) and earthworms (Reganold *et al*. 1993). Their influence is not limited to crop fields, with pesticide drift threatening semi-cultivated areas and small biotopes in the farming landscape (Hansen *et al*. 2005). Herbicides have been shown to indirectly reduce beneficial arthropod populations and prey insects of farmland birds by reducing non-

crop flora (Krooss & Schaefer 1998, Taylor *et al.* 2006). The effects of fungicides on arthropods is less clear, but it can disrupt beneficial associations of fungi and plants (Gosling *et al*. 2005), which could potentially influence organisms on higher trophic levels. In accordance with other studies, this study also indicated that the reduction of pesticide, herbicide and fungicide in vineyards contributed to a higher diversity of epigaeic arthropods.

The increased arthropod diversity in alternative vineyards could not be attributed directly to tillage method, as the tillage intensity varied between all vineyards. However, tillage intensity correlated negatively with overall abundance and species richness, suggesting that minimum tillage may reduce some of the detrimental effects associated with deep ploughing, such as physical destruction and desiccation (Alvarez *et al*. 2001).

Lastly, higher fertilizer intervention, i.e. the use of higher levels of inorganic fertilizers, reduced arthropod abundance and species richness. The alternative vineyards received only organic fertilizers, which most likely helped support a greater abundance of arthropods and arthropod prey that depend on undegraded organic matter as food.

4.2.3. Landscape variables

The aim of measuring the percentage potential source habitat in the vicinity was to obtain a general indication of the effect of the surroundings on arthropods in the vineyards. The result was unexpected, with increasing source habitat actually having a negative effect on overall abundance and species richness. Considering that the natural habitats generally comprised the highest species richness of the three habitat types, and assuming that some arthropods disperse up to 500 m, one would expect source vegetation to increase arthropod species richness in the vineyards.

A possible reason for this discrepancy is that the measurement of the source habitat was not detailed enough. As it was intended to be a rough variable, size and distance to the sites were the only factors considered. Conceivably, aspects such as habitat quality and amount of edge habitat would have influenced the results. Additionally, the mosaic concept proposes that, in

contrast to island biogeography theory, habitat variability, heterogeneity and proportions of different habitats might be more important than habitat size for biodiversity in arable landscapes (Duelli 1997).

Alternatively, the spatial scale at which biodiversity was measured might not be the same scale at which source vegetation would have influenced biodiversity. Biodiversity patterns change with different spatial scales considered (Tscharntke *et al.* 2005b). Whereas farming practice might influence farm-scale biodiversity, uncultivated habitat in the landscape most probably causes an increase in biodiversity that can only be measured at the regional scale (Bengtsson *et al.* 2005). Perhaps measurements of heterogeneity at the farm scale would have been more suitable, as this has also been shown to be an important determinant of species richness for certain taxa (Weibull *et al.* 2003).

4.3. Functional guilds

In the absence of detailed taxonomic information for each species, the use of broad functional feeding guilds is a potentially useful way to describe arthropod communities. It includes a large amount of information and can elucidate the functional responses of communities to different environmental conditions and disturbances (Kremen *et al.* 1993). Understanding the functional responses of biodiversity is particularly relevant in agriculture. Here, the goal is not necessarily to increase biodiversity for the sake of conservation, but increasing functional biodiversity that will improve production and sustainability.

4.3.1. Absolute abundance and species richness

Differences in functional groups under different management regimes have been demonstrated, particularly for herbivore pests and beneficial groups such as predators and parasitoids (Letourneau & Goldstein 2001), as these groups are of major concern in crop protection. A common concern over alternative farming is that pests will increase in the absence of pesticides. However, it has been proposed that the increased biotic processes on the alternative farms may compensate for the reduced conventional pest management

(Lampkin 1992). In fact, recent studies have demonstrated that natural enemies of crop pests are significantly higher under organic and biodynamic management (Mäder *et al*. 2002), increasing the potential for natural pest control. Other functional groups that have been demonstrated to be favoured by alternative farming include parasitoids (Berry *et al.* 1996) and nectarivores (Feber *et al*. 1997).

The three habitat types represented in this study, differed greatly in terms of disturbance regime, structure and resources. The different functional feeding guilds have diverse habitat requirements and were, therefore, expected to vary between habitat types. This was the case, with species richness and abundance within most functional groups differing between the habitat types in all three localities.

Predator abundance, species richness and activity density have been shown to be higher on organic and biodynamic farms compared to non-organic farms (Pfiffner & Luka 2003, Mäder *et al*. 2002). In this study the same was found for predator species richness, which, in alternative vineyards, was consistently higher than in integrated vineyards. It was also higher than in the natural site in one of the localities. In contrast to other studies, predator abundance was higher in the integrated vineyards than in alternative vineyards, as well as being higher than the natural sites in two localities. The reason for the high predator abundances could not be ascertained. The higher abundance may be beneficial in terms of short term protection against pest outbreaks. However, to ensure long term management of pest levels, high diversity of species and genotypes may be of greater importance.

In a meta-analysis of recent publications, Bengtsson *et al.* (2005) found that in the majority of studies, the selected non-predatory functional groups did not respond positively to organic farming. Other studies highlighted that non-predatory groups were, in fact, favoured by alternative farming (Feber *et al* 1997, Letourneau & Goldstein 2001). In this study, phytophages, saprophages and omnivores were more abundant and species rich in the alternative vineyards. The differences between wood borers, nectarivores and parasitoids were less pronounced, as these groups were trapped in low numbers. This could be due to the fact

that pitfall traps target mostly epigaeic arthropods and are not as suitable for flying and vegetation-dwelling organisms (Woodcock 1997).

The higher phytophage abundance and species richness in alternative vineyards could be explained by the increased plant diversity and the absence of pesticides. The diversity of phytophages could potentially contribute towards pest control, as a more varied phytophage community implies that it will be less dominated by severe vineyard pests, such as mites, leafhoppers and snout beetles. It also provides a more diverse prey assemblage for natural enemies (Letourneau & Goldstein 2001).

Alternative vineyards had the most abundant and species rich saprophage assemblages of all sites in all three areas. Other studies did not indicate large differences between saprophages under different management regimes. Doles *et al.* (2001) found no difference in densities of Collembola, Cryptostigmatid mites or fungivorous prostigmatid mites in organic and conventional apple orchards across all sampling dates, but found higher densities in organic orchards only on selected dates. In a comparison of Collembola under organic, integrated and conventional management, populations were not significantly different (Alvarez *et al.* 2001). In addition to reduced pesticides, saprophages in this study were most probably favoured by the enhanced detritus-based food webs in the alternative vineyards resulting from increased organic amendments and reduced fungicides (Scow *et al.* 1994). A diverse saprophage community could be very beneficial as they promote increased decomposition and nutrient cycling (Alvarez *et al*. 2001).

Omnivore species richness and abundance of alternative vineyards and natural sites were within similar ranges, being higher than in integrated vineyards in all areas. This suggests that biocides and lower plant complexity in the integrated vineyards were responsible for a reduction in omnivores. In terms of abundance, the organic site at Kanonkop had disproportionately high numbers of omnivores, dominated mostly by ants, and represented to a lesser degree by cockroaches, crickets and earwigs. High ant abundances are generally not desired in vineyards because of their mutualistic relationship with the vine mealybug, which is a common vineyard pest (IPW 2006). However, in this vineyard, mealybug levels were

controlled by augmentative release of natural enemies of the pest. It is therefore likely that some underlying enviromental factor in the specific vineyard favoured high ant abundances.

In summary, the greater diversity of species within most functional groups in the alternative vineyards has implications for the resilience of these systems. A high diversity of species in the same functional group ensures a variety of responses to environmental change (Tscharntke *et al.* 2005a), which is important for sustained ecological interactions in a disturbed environment.

4.3.2. Relative abundance and species richness

Examining the relative proportions of functional guilds within sites was intended to clarify whether certain functional groups were favoured more, relative to others, under different conditions. Interestingly, even though total species richness of the different guilds varied between study sites, the relative proportions remained highly similar for all sites. This suggests that, even though species assemblages of different sites comprised totally different species and different numbers of species, trophic functioning remained constant throughout all sites. This implies that there is a basic structure to the community interactions that remained fixed even under highly varied conditions.

In contrast, no clear trend was observed for proportional abundance within guilds. Proportions varied much between all sites, reflecting how the large variation in conditions and management activities in the different sites influenced abundance. Incidentally, one could argue that abundance is not the most suitable measure for examining functional response in a community. Differences in the relative abundances of different sites were often a result of a few highly numerous and small-bodied species. This does not adequately reflect the relative effect of those guilds within the communities. It would, however, be interesting to examine how biomass within functional guilds differ between the sites. As this would be a more accurate indicator of how energy is distributed throughout the community, perhaps a result similar to the one obtained from the species richness data would be found.

4.4. Spiders, carabids and staphylinids

In alternative farming systems, where pesticides are not permitted, arthropod pest management is of major importance (Zehnder *et al.* 2007). One of the key strategies is to create conditions that are suitable for natural enemies of pest species (Landis *et al*. 2000). This can be done effectively in alternative systems that typically include a greater diversity of microhabitats, adult food sources and alternative prey species. This study implicitly evaluated potential pest control in alternative vineyards by assessing the spider, carabid and rove beetle communities in the different habitat types, as these polyphagous predators are known to be highly instrumental in controlling various pests (Duelli *et al.* 1999). Certain taxa within these groups are voracious feeders and can consume up to their own body mass in food daily (Kromp 1999). All three groups are sensitive to chemical and cultural management and so, in theory, alternative farming should benefit these groups relative to more intensive farming (Bohac 1999, Kromp 1999, Marc *et al.* 1999).

4.4.1. Spiders

Spiders were the most abundant and species rich of the three groups and also seemed to be most closely correlated with the environmental variables in the vineyards. As in other studies (Feber *et al*. 2002), abundance and species richness was higher under organic and biodynamic management than under non-organic management. Schmidt *et al*. (2005) indicated that spider density in winter wheat increased due to organic management, but attributed an increase in species richness on organic farms to higher landscape heterogeneity. Similarly, Pfiffner and Luka (2003) found that a combination of organic management, higher weed cover and semi-natural habitat increased spider species richness and abundance in organic cereals compared to low-input integrated cereal crops. Spiders in this study benefited from decreased biocides and inorganic fertilizer. Furthermore, the increased understorey weed cover and complexity improved microclimatic conditions for the spiders in vineyards and in natural sites, as they were positively correlated with these variables. Leaf litter also seemed to benefit them, possibly by providing greater structural complexity and improved temperature at the soil surface.

In agricultural landscapes, spiders generally are most diverse in semi-natural habitat (Duelli *et al*. 1999). In this study, spider abundance and species richness was also highest in the natural sites in two of the three localities and, in the ordination, associated most closely with natural habitat. As many species of spiders are highly mobile (Marc *et al*. 1999), movement of spiders into vineyards from natural and semi-natural habitat in the vicinity would be likely. This is supported by spider abundance in the vineyards increasing with decreasing distance from source vegetation.

4.4.2. Carabids

Carabids are common inhabitants of arable land (Kromp 1999). In this study, they were found more frequently in the vineyards than in natural areas and seemed to decrease with increasing amount of source vegetation in the landscape. Responses of the carabids were not as uniform as those of the spiders and their abundance and species richness were independently affected by management regime. This was supported by the ordination, where it is clear that carabids did not associate with any of the variables included. Responses also varied between localities. A number of studies have indicated the positive effects of alternative farming on carabid diversity (e.g. Andersen & Eltun 2000, Pfiffner & Luka 2003). However, this study is consistent with that of Fuller *et al.* (2005), where the effects of farming system on carabids were not as definite as for certain other taxa. Species richness seemed to be negatively influenced by pesticide and herbicide use. However, effects of other variables were unclear. It is probable that the carabids were influenced by a combination of interacting factors instead of specific differences in management (Clark 1999). In addition, Purtauf *et al*. (2005) demonstrated that landscape heterogeneity was more important than management type in determining carabid diversity, suggesting that they are influenced by factors on a larger scale than can be measured at the field or farm scale.

In addition to the complexity of the influencing factors, species within the family Carabidae also exhibit a range of different responses to environmental conditions. Different species can be bound more or less strictly to their habitats, and react in different ways to environmental

fluctuation (Kromp 1999), making it difficult to predict which factors will maximize the diversity of the group as a whole.

4.4.3. Staphylinids

Staphylinids are generally negatively affected by agricultural intensification (Krooss & Schaefer 1998). Their abundance and activity density have been shown to be favoured by organic and biodynamic practices (Berry *et al.* 1996, Mäder *et al.* 2002). However, it cannot always be predicted how they will respond to different practices because the family Staphylinidae also comprise species with different life history strategies, like the carabids. For example, in a long term study on the effects of conversion to organic management, staphylinid diversity and activity density decreased in response to conversion, because of competition with carabids (Andersen & Eltun 2000). In the vineyards in this study, there was a tendency for staphylinids to be favoured by alternative management relative to integrated management, but the most diverse populations were found in the natural habitat. Conditions of lowest disturbance therefore seemed to be most suitable to them.

Weed cover has been identified as being one of the major influencing factors of rove beetle populations (Krooss & Schaefer 1998) as they prefer dark and shaded micro biotopes (Bohac 1999). Here, it also seemed to be of importance, as they were favoured by increased grass weed cover in vineyards, as well as in natural sites. Herbicide was also the biocide that seemed to have the greatest negative effect on their abundance and species richness, probably influencing them indirectly by reducing plant cover. Effects of other practices were indistinct, but it is likely that a combination of the practices in the alternative vineyards sustained them, as they frequently also respond positively to other factors such as organic fertilizer, reduced pesticides and conservation tillage (Krooss & Schaefer 1998). Rove beetles are usually influenced by the surrounding landscape (Bohac 1999). Although no correlation was evident between overall diversity and surrounding vegetation, most species were associated with increasing non-agricultural vegetation in the vicinity.

To conclude, the fact that the alternative vineyards were able to sustain higher levels of some natural enemies suggests that this could contribute towards pest control, compensating for the lack of pesticides. However, to assess the true efficiency of the natural pest management, the effects of natural enemies on pest species levels and pest damage would also have to be tested.

4.5. The relative effectiveness of the two systems to conserve biodiversity

A central issue regarding the implementation of alternative farming practices, is whether the holistic approach is necessarily more beneficial for biodiversity than focusing on a few key practices in non-alternative systems. Proponents of alternative farming claim that the synergy of positive effects in the whole-system approach results in benefits that are greater than the additive effects of the individual practices (Soil Association 2000). However, this has not yet been tested (Hole *et al.* 2005) and was not considered in this study. The aim here was to make overall comparisons of the two management systems on arthropods; differences in specific practices were intrinsic to the two systems. As far as epigaeic arthropods are concerned, the alternative vineyards exhibited a greater potential for biodiversity conservation. Whether this was a result of synergies or just because the farms in their entirety were subjected to stricter environmental standards, is unclear.

It has to be highlighted that, although the diversity was lower in the integrated vineyards, they still supported a reasonable number of species. The fact that non-alternative farms can also maintain high levels of species diversity is frequently disregarded (Biao *et al*. 2003). In some cases, changes in specific practices on non-alternative farms can make significant contributions to the overall diversity of the farmland (Thomas & Goulson 2000). Gurr *et al.* (2003) reviewed how agrobiodiversity can be enhanced by diversification at various spatial scales. They emphasized that even simple, small-scale diversification can benefit biodiversity to a great extent.

The relative effectiveness of the different vineyard management systems to increase arthropod diversity will depend to a large extent on the landscape context. Alternative vineyards certainly represented a less hostile environment to arthropods. However, in highly heterogeneous landscapes, it might not make a considerable difference to the overall diversity of the area (Bengtsson *et al.* 2005). Tscharntke *et al.* (2005b) propose that alternative farming practices may be most effective in landscapes of intermediate heterogeneity with some degree of colonization from the surroundings.

Because agricultural systems are so dynamic and intimately linked to the particular conditions of an area, it is perhaps not realistic to prescribe a specific regime that will improve diversity in all situations (Rigby & Caceres 2001). The focus should be on developing and refining our management systems as our understanding improves of how the different farming systems function under different circumstances. Alternative vineyard management seems to be a promising approach for biodiversity conservation and further research on these systems would definitely contribute to our existing knowledge. Ideally, we need a range of different management systems that aim to improve sustainability and that is flexible enough to be adapted to suit the area, the specific conditions and the objectives of the producers.

4.6. Biodiversity as a tangible concept in the wine industry

Biodiversity conservation in agricultural landscapes depends to a large extent on the perceptions and attitudes of individual landowners, as decisions regarding the use of the land are still made at the individual farm level. In the wine industry of the CFR, biodiversity protection has received much attention recently and there is a reasonably high level of awareness of the concept. The industry is currently working on marketing strategies that will endorse and promote the sales of biodiversity-friendly wines. However, direct economic benefits from biodiversity protection have not yet been demonstrated and it remains a rather abstract concept. Increased research on biodiversity functioning in farmland in the CFR, particularly highlighting benefits from biodiversity and valuation of ecosystem services, would increase receptivity of decision-makers to the concept.

4.7. Conclusion

In an era where conservation in human-influenced landscapes is becoming increasingly important, protection of biodiversity in agricultural systems certainly presents many challenges and opportunities. From the wealth of research on the subject it is clear that conservation and farming are not irreconcilable. Through innovative management, farmland can contribute significantly to overall biodiversity conservation. This is achievable in the CFR, where environmental standards for vineyard management are already well established, natural habitat in farmland still exists and the motivation to conserve biodiversity is very high. Owing to the complex nature of agroecosystems, collaboration between conservationists, ecologists and farmers will be crucial in gaining a better understanding of the functioning of these systems. Ultimately, we should aim to manage these agricultural landscapes in a way that is environmentally and socio-economically sustainable, while conserving as much of the CFR's precious biodiversity as possible.

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Appendix Aa. Active ingredients of pesticides, fungicides and herbicides applied to the vineyards during Jan 2006-Jan 2007 with their associated risk coding and calculated application index. Letters in brackets indicate risk level of biocides according to the IPW coding system (L=low risk, M=medium risk, MH=medium to high risk, H=high risk).

Pesticides

Site	Active ingredients of applications	Risk coding	Application index
AV1	none	0	0
IV1	methiocarb + metaldehyde (M)	2	
	prothiofos (MH)	3	5
AV2	none	0	0
IV2	chlorpyrifos (MH)	3	
	metaldehyde (L)	1	4
AV3	none	0	0
IV3	methiocarb + metaldehyde (M)	2	2
IV4	endosulfan (MH)	3	
	chlorpyrifos (MH)	3	6

Fungicides

Site	Active ingredients of applications	Risk coding	Application index
AV1	copper (M)	2	
	sulphur (M)	2	4
IV1	cymoxanil + mancozeb (M)	2	
	cymoxanil + propineb (M)	2	
	folpet (L)	1	
	mancozeb (L)	1	
	penconazole (L)	1	
	potassium phosphite (M)	2	
	spiroxamine (M)	2	
	sulphur (M)	2	
	trifloxystrobin (L)	1	14
AV2	copperoxychloride (M)	2	
	sulphur (M)	2	4
IV2	dimethomorph + mancozeb (M)	2	
	flusilazole (M)	2	
	folpet (L)	1	
	mancozeb (L)	1	
	phosphorous acid (M)	2	
	pyraclostrobin + mancozeb (M)	2	
	quinoxyfen (M)	2	
	sulphur (M)	2	14

Appendix Aa. continued

Fungicides

Site	Active ingredients of applications	Risk coding	Application index
AV3	copperhydroxide (M)	2	
	sulphur (M)	2	4
IV3	copperhydroxide (M)	2	
	mancozeb (L)	1	
	phophorous acid (M)	2	
	sulphur (M)	2	7
IV4	copperoxychloride (M)	2	
	dimethomorph + mancozeb (M)	2	
	famoxadone + cymoxanil (M)	2	
	krexoxim methyl (L)	1	
	mancozeb (L)	1	
	phosphorous acid (M)	2	
	quinoxyfen (M)	2	
	sulphur (M)	2	14

Herbicides

Site	Active ingredients of applications	Risk coding	Application index
AV1	none	0	0
IV1	glyphosate iso-propyl ammonium (M)	2	
	simazine (L)	1	
	terbuthylazine (L)	1	4
AV2	none	0	0
IV2	glyphosate iso-propyl ammonium (M)	2	
	paraquat + diquat (MH)	3	
	simazine (L)	1	
	terbuthylazine (L)	1	7
AV3	none	0	0
IV3	glyphosate iso-propyl ammonium (M)	2	
	simazine (L)	1	
	terbuthylazine (L)	1	4
IV4	glyphosate iso-propyl ammonium (M)	2	2

Appendix Ab. Fertilizer applied to the vineyards during Jan 2006 – Jan 2007 with their associated coding and fertilizer index.

Site	Fertilizer type	Coding	Fertilizer intervention index
AV1	organic compost	2	
	rock phosphate	2	
	biodynamic preparations (cattle manure, quartz/silica, yarrow, stinging nettle, dandelion, valerian, chamomile, oak bark)	1	5
IV1	K.A.N. fertilizer	3	
	Inorganic fertilizer	3	6
AV2	foliar application (algae and herb extracts, cytokines, phytohormones, organic and amino acids, trace elements)	1	1
IV2	nitrogen	3	
	phosphate	3	
	urea	3	
	foliar application (seaweed extract and plant growth regulators)	1	10
AV3	organic bat guano fertilizer	2	2
IV3	K.A.N. fertilizer	3	3
IV4	chicken manure	2	
	double superphosphate	3	
	foliar application (zinc, boron, magnesium, potasium)	1	6

Appendix Ac. Tillage methods used in vineyards during Jan 2006- Jan 2007 with their associated coding and tillage index.

Site	Tillage method	Coding	Tillage index
AV1	Ghrop (tine tillage)	1	1
IV1	None	0	0
AV2	Disc	2	
	Ghrop (tine tillage)	1	3
IV2	Bulldoze ½ site	1.5	
	Disc ½ site	1	
	Ghrop (tine tillage)	1	3.5
AV3	Disc	2	2
IV3	Disc	2	2
IV4	Ghrop (tine tillage)	1	1

Appendix B: Arthropods recorded during the study period, their functional feeding guild and their mean abundance (± S.E.) for each site type.

ORDER	Family & species nr	Genus & species	Functional guild *	Natural vegetation		Alternative vineyards		Integrated vineyards	
				Mean	Std errror	Mean	Std error	Mean	Std errror
ACARI	Anystidae sp. 1	(Genus & species undetermined)	Pred	1.13	0.28	2.73	0.99	6.85	1.32
	Anystidae sp. 2	(Genus & species undetermined)	Pred	-	-	-	-	0.25	0.25
	Anystidae sp. 3	*(Chausseria capensis)*	Pred	2.77	1.24	0.40	0.22	15.78	3.19
	Anystidae sp. 4	*(Anystis baccarum)*	Pred	0.67	0.67	0.33	0.33	-	-
	Anystidae sp. 5	(Genus & species undetermined)	Pred	0.20	0.11	0.67	0.67	-	-
	Bdellidae sp. 1	(Genus & species undetermined)	Pred	-	-	0.33	0.33	0.10	0.70
	Bdellidae sp. 2	*(Bdellodes* sp.*)*	Pred	0.97	0.29	0.63	0.25	0.93	0.44
	Caeculidae sp. 1	(Genus & species undetermined)	Pred	0.37	0.16	-	-	0.15	0.67
	Erythraeidae sp. 1	*(Erythrites* sp.*)*	Pred	0.17	0.97	2.23	1.53	4.50	1.62
	Erythraeidae sp. 2	*(Leptus* sp.*)*	Pred	0.67	0.67	0.33	0.33	-	-
	Erythraeidae sp. 3	*(Erythraeus* sp.*)*	Pred	0.13	0.13	-	-	-	-
	Halotydeidae sp. 1	*(Halotydeus destructor)*	Phy	29.77	9.36	2.87	1.76	0.10	0.10
	Macrochelidae sp. 1	*(Macrocheles* sp.*)*	Pred	0.67	0.67	0.87	0.44	0.13	0.90
	Ologamasidae sp. 1	(Genus & species undetermined)	Pred	0.27	0.13	1.40	0.72	0.98	0.37
	Oribatei sp. 1	(Genus & species undetermined)	Sap	12.67	2.85	32.20	6.55	27.20	8.52
	Oribatei sp. 2	(Genus & species undetermined)	Sap	3.33	1.28	26.63	7.76	-	-
	Penthalodidae sp. 1	(Genus & species undetermined)	Pred	9.93	3.83	0.33	0.33	-	-
	Trombidiidae sp. 1	(Genus & species undetermined)	Pred	4.47	1.62	0.70	0.25	0.50	0.35
AMPHIPODA	Talitridae sp. 1	(Genus & species undetermined)	Sap	9.00	1.92	0.33	0.33	-	-
ARANEAE	Amaurobiidae sp. 1	*(Chresiona* sp.*)*	Pred	4.37	0.57	2.17	0.58	2.50	0.59
	Ammoxenidae sp. 1	*(Ammoxenus* sp.*)*	Pred	1.10	0.78	-	-	-	-
	Clubionidae sp. 1	*(Clubiona* sp.*)*	Pred	0.33	0.33	0.33	0.33	-	-
	Clubionidae sp. 2	(Genus & species undetermined)	Pred	0.67	0.46	-	-	-	-
	Clubionidae sp. 3	*(Clubiona umbilensis)*	Pred	-	-	0.33	0.33	-	-
	Cyrtaucheniidae sp. 1	*(Ancylotrypa* sp. *1)*	Pred	-	-	-	-	0.75	0.42
	Cyrtaucheniidae sp. 2	*(Ancylotrypa* sp. *2)*	Pred	0.33	0.33	-	-	-	-
	Gnaphosidae sp. 1	*(Camillina* sp.*)*	Pred	0.27	0.96	0.30	0.98	0.13	0.53
	Gnaphosidae sp. 2	(Genus & species undetermined)	Pred	0.43	0.11	0.60	0.18	0.33	0.13

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
ARANEAE	Gnaphosidae sp. 3	*(Zelotes* sp. 3)	Pred	0.20	0.12	-	-	0.50	0.35
	Gnaphosidae sp. 4	(Genus & species undetermined)	Pred	0.67	0.46	0.50	0.14	-	-
	Gnaphosidae sp. 5	*(Trachyzelotes jaxartensis)*	Pred	2.97	0.45	2.63	0.44	1.55	0.21
	Gnaphosidae sp. 6	*(Drassodes solitarius)*	Pred	1.70	0.28	3.10	0.42	3.00	0.39
	Gnaphosidae sp. 7	*(Zelotes fuligineus)*	Pred	0.30	0.18	0.27	0.12	0.13	0.53
	Gnaphosidae sp. 8	*(Setaphis subtilis)*	Pred	0.13	0.79	-	-	0.75	0.75
	Gnaphosidae sp. 9	*(Zelotes oneili)*	Pred	0.13	0.63	0.87	0.21	0.50	0.13
	Gnaphosidae sp. 10	*(Pterotrichia varia)*	Pred	0.23	0.12	0.67	0.46	0.25	0.86
	Gnaphosidae sp. 11	*(Upognampa parvipalpa)*	Pred	0.33	0.33	0.13	0.14	-	-
	Idiopidae sp. 1	*(Ctenolophus sp.)*	Pred	0.33	0.33	-	-	-	-
	Linyphiidae sp. 1	(Genus & species undetermined)	Pred	0.60	0.18	0.77	0.22	0.73	0.19
	Linyphiidae sp. 2	(Genus & species undetermined)	Pred	0.70	0.33	0.17	0.84	0.75	0.55
	Linyphiidae sp. 3	(Genus & species undetermined)	Pred	0.77	0.38	0.33	0.33	0.50	0.35
	Linyphiidae sp. 4	(Genus & species undetermined)	Pred	0.33	0.33	0.67	0.67	0.13	0.53
	Liocranidae sp. 1	*(Rhaeboctesis* sp.*)*	Pred	0.33	0.33	-	-	0.25	0.25
	Lycosidae sp. 1	*(Geolycosa* sp.)	Pred	0.37	0.14	0.17	0.84	0.15	0.67
	Lycosidae sp. 2	*(Hogna* sp.)	Pred	0.77	0.20	2.00	0.33	1.50	0.24
	Lycosidae sp. 3	*(Trabea* sp.)	Pred	0.30	0.19	0.33	0.33	-	-
	Lycosidae sp. 4	*(Pardosa crassipalpis)*	Pred	0.67	0.46	2.20	0.78	0.18	0.87
	Lycosidae sp. 5	*(Pardosa* sp. 2)	Pred	0.97	0.23	1.63	0.48	1.70	1.25
	Palpimanidae sp. 1	*(Diaphorocellus biplagiatus)*	Pred	0.97	0.26	-	-	-	-
	Philodromidae sp. 1	*(Thanatus* sp.)	Pred	0.33	0.33	0.13	0.79	0.50	0.35
	Pisauridae sp. 1	*(Rothus* sp.)	Pred	0.33	0.33	-	-	-	-
	Salticidae sp. 1	*(Pellenes* sp. 2)	Pred	0.33	0.12	0.47	0.14	0.63	0.16
	Salticidae sp. 2	*(Langelurillus* sp.)	Pred	0.10	0.56	0.40	0.15	0.25	0.78
	Salticidae sp. 3	*(Euophrys* sp.)	Pred	0.23	0.14	-	-	0.50	0.35
	Salticidae sp. 4	*(Pellenes* sp. 3)	Pred	0.27	0.16	0.67	0.46	-	-
	Salticidae sp. 5	*(Stenaelurillus* sp.)	Pred	0.33	0.33	0.33	0.33	-	-
	Salticidae sp. 6	*(Pellenes* sp. 1)	Pred	0.33	0.33	-	-	0.25	0.25
	Salticidae sp. 7	*(Massagris* sp.)	Pred	0.23	0.92	0.13	0.79	0.25	0.25
	Salticidae sp. 8	*(Evarcha* sp.)	Pred	0.33	0.33	-	-	-	-
	Scytodidae sp. 1	*(Scytodes testudo)*	Pred	0.10	0.56	0.67	0.46	0.50	0.35

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
ARANEAE	Theridiidae sp. 1	*(Steatoda capensis)*	Pred	0.33	0.33	-	-	0.50	0.35
	Theridiidae sp. 2	(*Theridion* sp.)	Pred	0.33	0.33	-	-	-	-
	Theridiidae sp. 3	(*Steatoda* sp. 2)	Pred	0.67	0.46	-	-	-	-
	Thomisidae sp. 1	*(Xysticus subjugalis)*	Pred	0.27	0.96	0.67	0.46	0.25	0.25
ARCHEOGNATHA	Meinertellidae sp. 1	(Genus & species undetermined)	Sap	1.77	0.66	-	-	-	-
BLATTODEA	Blaberidae sp. 1	(Genus & species undetermined)	Omn	0.80	0.25	1.80	0.47	1.23	0.27
	Blaberidae sp. 2	(Genus & species undetermined)	Omn	0.33	0.33	-	-	-	-
	Blaberidae sp. 3	(Genus & species undetermined)	Omn	0.10	0.56	-	-	-	-
	Blattellidae sp. 1	(Genus & species undetermined)	Omn	-	-	0.33	0.33	-	-
	Blattellidae sp. 2	(Genus & species undetermined)	Omn	0.33	0.33	-	-	-	-
	Blattellidae sp. 3	(Genus & species undetermined)	Omn	0.13	0.63	-	-	0.15	0.57
	Blattellidae sp. 4	(Genus & species undetermined)	Omn	-	-	0.33	0.33	-	-
	Blattellidae sp. 5	(Genus & species undetermined)	Omn	-	-	0.67	0.46	-	-
	Blattidae sp. 1	(Genus & species undetermined)	Omn	0.37	0.14	0.30	0.98	0.93	0.22
	Blattidae sp. 2	(Genus & species undetermined)	Omn	-	-	-	-	0.50	0.35
	Blattidae sp. 3	(Genus & species undetermined)	Omn	0.67	0.46	0.17	0.18	-	-
	Blattidae sp. 4	(Genus & species undetermined)	Omn	-	-	0.13	0.79	-	-
CHILOPODA	Cryptopidae sp. 1	(*Crytops audax*)	Pred	0.33	0.33	-	-	-	-
	Geophilomorpha sp. 1	(Genus & species undetermined)	Pred	0.67	0.46	-	-	-	-
	Henicopidae sp. 1	(Genus & species undetermined)	Pred	2.57	0.52	3.87	0.70	8.73	1.34
	Lithobiidae sp. 1	(Genus & species undetermined)	Pred	0.10	0.74	1.37	0.52	0.85	0.26
	Scolopendridae sp. 1	(Cormocephalus anceps anceps)	Pred	0.33	0.33	-	-	-	-
	Scutigeridae sp. 1	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
COLEOPTERA	Alticinae sp. 1	(Genus & species undetermined)	Phy	12.67	4.25	2.57	0.91	0.75	0.42
	Alticinae sp. 2	(Genus & species undetermined)	Phy	-	-	-	-	0.25	0.25
	Alticinae sp. 3	(Genus & species undetermined)	Phy	0.20	0.88	1.70	0.60	0.58	0.22
	Alticinae sp. 4	(Genus & species undetermined)	Phy	0.23	0.12	0.67	0.46	0.75	0.55
	Alticinae sp. 5	(Genus & species undetermined)	Phy	0.23	0.12	-	-	0.18	0.18

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
COLEOPTERA	Alticinae sp. 6	(Genus & species undetermined)	Phy	-	-	-	-	0.25	0.25
	Alticinae sp. 7	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Alticinae sp. 8	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Alticinae sp. 9	(Genus & species undetermined)	Phy	0.13	0.79	0.33	0.33	0.25	0.25
	Alticinae sp. 10	(Genus & species undetermined)	Phy	0.17	0.17	-	-	-	-
	Anthicidae sp. 1	(Genus & species undetermined)	Omn	1.83	3.12	25.33	4.52	9.13	1.55
	Anthicidae sp. 2	(Genus & species undetermined)	Omn	-	-	0.23	0.92	0.10	0.60
	Anthicidae sp. 3	(Genus & species undetermined)	Omn	0.13	0.14	-	-	0.13	0.53
	Anthicidae sp. 4	(Genus & species undetermined)	Omn	0.10	0.56	0.10	0.56	0.25	0.25
	Anthicidae sp. 5	(Genus & species undetermined)	Omn	-	-	-	-	0.25	0.25
	Bostrychidae sp. 1	(Genus & species undetermined)	Wo	0.10	0.56	0.13	0.63	0.30	0.12
	Bostrychidae sp. 2	(Genus & species undetermined)	Wo	0.47	0.16	2.67	0.63	4.15	1.39
	Buprestidae sp. 1	(Genus & species undetermined)	Wo	-	-	0.33	0.33	-	-
	Buprestidae sp. 2	(Genus & species undetermined)	Wo	0.10	0.74	-	-	-	-
	Buprestidae sp. 3	(Genus & species undetermined)	Wo	0.67	0.46	0.33	0.33	-	-
	Buprestidae sp. 4	(Genus & species undetermined)	Wo	0.33	0.33	-	-	-	-
	Byrrhidae sp. 1	(Genus & species undetermined)	Sap	0.67	0.67	0.33	0.33	0.25	0.25
	Cantharidae sp. 1	(Genus & species undetermined)	Pred	-	-	0.33	0.16	-	-
	Carabidae sp. 1	(Genus & species undetermined)	Pred	0.20	0.11	1.93	0.35	6.48	2.77
	Carabidae sp. 2	(Genus & species undetermined)	Pred	-	-	-	-	0.25	0.25
	Carabidae sp. 3	(Genus & species undetermined)	Pred	0.13	0.63	1.37	0.40	1.80	0.59
	Carabidae sp. 4	(Genus & species undetermined)	Pred	0.67	0.46	-	-	-	-
	Carabidae sp. 5	(Genus & species undetermined)	Pred	0.20	0.16	0.50	0.27	-	-
	Carabidae sp. 6	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
	Carabidae sp. 7	(Genus & species undetermined)	Pred	0.30	0.15	-	-	-	-
	Carabidae sp. 8	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
	Carabidae sp. 9	(Genus & species undetermined)	Pred	-	-	0.73	0.26	0.70	0.22
	Carabidae sp. 10	(Genus & species undetermined)	Pred	0.33	0.33	0.10	0.56	-	-
	Chrysomelidae sp. 1	(Genus & species undetermined)	Phy	0.20	0.74	0.30	0.19	0.55	0.14
	Chrysomelidae sp. 2	(Genus & species undetermined)	Phy	0.37	0.14	0.33	0.33	0.40	0.16
	Chrysomelidae sp. 3	(Genus & species undetermined)	Phy	-	-	0.10	0.74	-	-
	Chrysomelidae sp. 4	(Genus & species undetermined)	Phy	-	-	0.67	0.46	0.75	0.42

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation		Alternative vineyards		Integrated vineyards	
				Mean	Std errror	Mean	Std error	Mean	Std errror
COLEOPTERA	Chrysomelidae sp. 5	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Chrysomelidae sp. 6	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Chrysomelidae sp. 7	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Chrysomelidae sp. 8	(Genus & species undetermined)	Phy	-	-	0.17	0.17	-	-
	Chrysomelidae sp. 9	(Genus & species undetermined)	Phy	0.67	0.67	-	-	-	-
	Cleridae sp. 1	(Genus & species undetermined)	Pred	-	-	0.33	0.33	0.13	0.53
	Cleridae sp. 2	(Genus & species undetermined)	Pred	1.00	0.41	0.13	0.79	0.50	0.35
	Coccinellidae sp. 1	(Genus & species undetermined)	Pred	0.33	0.33	0.20	0.74	0.23	0.76
	Colydiidae sp. 1	(Genus & species undetermined)	Pred	-	-	0.33	0.33	-	-
	Cryptophagidae sp. 1	(Genus & species undetermined)	Sap	0.67	0.67	0.27	0.96	0.75	0.42
	Cryptophagidae sp. 2	(Genus & species undetermined)	Sap	0.67	0.46	0.23	0.14	0.38	0.14
	Cryptophagidae sp. 3	(Genus & species undetermined)	Sap	0.20	0.88	1.57	0.37	0.20	0.19
	Curculionidae sp. 1	(Genus & species undetermined)	Phy	0.50	0.25	0.43	0.12	0.43	0.34
	Curculionidae sp. 2	(Genus & species undetermined)	Phy	0.67	0.46	0.67	0.46	0.25	0.25
	Curculionidae sp. 3	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Curculionidae sp. 4	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Curculionidae sp. 5	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-
	Curculionidae sp. 6	(Genus & species undetermined)	Phy	-	-	0.10	0.56	-	-
	Curculionidae sp. 7	(Genus & species undetermined)	Phy	0.33	0.33	0.33	0.33	0.18	0.15
	Curculionidae sp. 8	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Curculionidae sp. 9	(Genus & species undetermined)	Phy	0.10	0.10	-	-	-	-
	Curculionidae sp. 10	(Genus & species undetermined)	Phy	-	-	0.40	0.15	0.93	0.29
	Curculionidae sp. 11	(Genus & species undetermined)	Phy	0.17	0.84	0.33	0.33	-	-
	Curculionidae sp. 12	(Genus & species undetermined)	Phy	0.10	0.56	0.10	0.74	-	-
	Curculionidae sp. 13	(Genus & species undetermined)	Phy	0.37	0.16	0.77	0.28	0.28	0.17
	Curculionidae sp. 14	(Genus & species undetermined)	Phy	0.20	0.16	-	-	-	-
	Curculionidae sp. 15	(Genus & species undetermined)	Phy	0.23	0.18	-	-	-	-
	Curculionidae sp. 16	(Genus & species undetermined)	Phy	0.10	0.74	-	-	-	-
	Curculionidae sp. 17	(Genus & species undetermined)	Phy	-	-	0.10	0.56	0.10	0.60
	Histeridae sp. 1	(Genus & species undetermined)	Pred	-	-	0.33	0.33	-	-
	Histeridae sp. 2	(Genus & species undetermined)	Pred	0.67	0.46	-	-	-	-
	Lagriidae sp. 1	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
COLEOPTERA	Meloideae sp. 1	(Genus & species undetermined)	Pred	0.67	0.46	-	-	0.25	0.25
	Melyridae sp. 1	(Genus & species undetermined)	Pred	0.33	0.33	0.67	0.46	0.13	0.64
	Mordellidae sp. 1	(Genus & species undetermined)	Sap	2.87	0.52	0.10	0.74	0.25	0.25
	Nitidulidae sp. 1	(Genus & species undetermined)	Sap	0.67	0.46	3.23	0.48	1.63	0.31
	Nitidulidae sp. 2	(Genus & species undetermined)	Sap	0.17	0.69	-	-	-	-
	Ptiliidae sp. 1	(Genus & species undetermined)	Sap	0.67	0.46	0.13	0.79	-	-
	Scarabaeidae sp. 1	(Genus & species undetermined)	Sap	0.27	0.13	1.87	0.42	0.43	0.16
	Scarabaeidae sp. 2	(Genus & species undetermined)	Sap	0.47	0.18	-	-	-	-
	Scarabaeidae sp. 3	(Genus & species undetermined)	Sap	0.70	0.26	-	-	-	-
	Scarabaeidae sp. 4	(Genus & species undetermined)	Sap	-	-	-	-	0.25	0.25
	Scarabaeidae sp. 5	(Genus & species undetermined)	Sap	0.67	0.46	-	-	-	-
	Scarabaeidae sp. 6	(Genus & species undetermined)	Sap	-	-	0.33	0.33	-	-
	Scarabaeidae sp. 7	(Genus & species undetermined)	Sap	0.67	0.46	-	-	0.50	0.35
	Scarabaeidae sp. 8	(Genus & species undetermined)	Sap	-	-	-	-	0.25	0.25
	Scarabaeidae sp. 9	(Genus & species undetermined)	Sap	0.67	0.46	-	-	-	-
	Staphylinidae sp. 1	(Genus & species undetermined)	Pred	4.37	0.74	3.27	0.47	2.10	0.29
	Staphylinidae sp. 2	(Genus & species undetermined)	Pred	0.27	0.14	0.10	0.74	0.15	0.67
	Staphylinidae sp. 3	(Genus & species undetermined)	Pred	0.67	0.46	-	-	0.25	0.25
	Staphylinidae sp. 4	(Genus & species undetermined)	Pred	0.80	0.21	-	-	-	-
	Staphylinidae sp. 5	(Genus & species undetermined)	Pred	0.57	0.27	1.00	0.37	0.10	0.48
	Tenebrionidae sp. 1	(Genus & species undetermined)	Sap	0.93	0.31	5.33	1.96	1.58	0.74
	Tenebrionidae sp. 2	(Genus & species undetermined)	Sap	0.13	0.79	-	-	0.25	0.25
	Tenebrionidae sp. 3	(Genus & species undetermined)	Sap	0.67	0.46	-	-	-	-
	Tenebrionidae sp. 4	(Genus & species undetermined)	Sap	3.33	0.79	2.47	0.59	3.45	1.19
	Tenebrionidae sp. 5	(Genus & species undetermined)	Sap	0.57	0.40	0.13	0.79	0.25	0.25
	Tenebrionidae sp. 6	(Genus & species undetermined)	Sap	0.37	0.13	6.17	1.27	1.65	0.32
	Tenebrionidae sp. 7	(Genus & species undetermined)	Sap	-	-	-	-	0.75	0.55
	Tenebrionidae sp. 8	(Genus & species undetermined)	Sap	0.37	0.13	0.67	0.46	0.50	0.50
	Tenebrionidae sp. 9	(Genus & species undetermined)	Sap	0.17	0.69	0.20	0.16	0.25	0.25
				-	-	-	-	-	-
DERMAPTERA	Labiduridae sp. 1	(Genus & species undetermined)	Omn	0.13	0.63	0.87	0.27	0.65	0.24
	Labiduridae sp. 2	(Genus & species undetermined)	Omn	0.10	0.56	0.77	0.29	0.13	0.73

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation		Alternative vineyards		Integrated vineyards	
				Mean	Std errror	Mean	Std error	Mean	Std errror
DERMAPTERA	Labiduridae sp. 3	(Genus & species undetermined)	Omn	0.10	0.56	1.13	0.43	0.23	0.14
DIPTERA	Anthomyiidae sp. 1	(Genus & species undetermined)	Sap	0.40	0.15	0.17	0.84	0.50	0.35
	Anthomyiidae sp. 2	(Genus & species undetermined)	Sap	0.33	0.33	-	-	-	-
	Anthomyiidae sp. 3	(Genus & species undetermined)	Sap	0.67	0.67	-	-	-	-
	Asilidae sp. 1	(Genus & species undetermined)	Pred	-	-	-	-	0.25	0.25
	Asilidae sp. 2	(Genus & species undetermined)	Pred	0.70	0.24	-	-	0.50	0.35
	Calliphoridae sp. 1	(Genus & species undetermined)	Sap	-	-	0.67	0.67		
	Chironomidae sp. 1	(Genus & species undetermined)	Omn	6.90	1.75	2.93	0.56	3.35	0.84
	Chloropidae sp. 1	(Genus & species undetermined)	Sap	0.80	0.23	1.10	0.25	1.63	0.36
	Cryptochetidae sp. 1	(Genus & species undetermined)	Par	0.67	0.46	-	-	-	-
	Dolichopodidae sp. 1	(Genus & species undetermined)	Pred	4.97	2.34	0.10	0.74	0.10	0.60
	Dolichopodidae sp. 2	(Genus & species undetermined)	Pred	0.20	0.20	0.13	0.79	0.50	0.35
	Drosophilidae sp. 1	(Genus & species undetermined)	Sap	0.23	0.22	0.33	0.33	-	-
	Drosophilidae sp. 2	(Genus & species undetermined)	Sap	0.33	0.33	-	-	-	-
	Drosophilidae sp. 3	(Genus & species undetermined)	Sap	0.17	0.17	0.67	0.46	0.25	0.25
	Drosophilidae sp. 4	(Genus & species undetermined)	Sap	-	-	-	-	1.73	0.57
	Empididae sp. 1	(Genus & species undetermined)	Pred	-	-	-	-	0.25	0.25
	Empididae sp. 2	(Genus & species undetermined)	Pred	0.20	0.14	0.47	0.23	0.35	0.17
	Empididae sp. 3	(Genus & species undetermined)	Pred	-	-	-	-	0.10	0.48
	Empididae sp. 4	(Genus & species undetermined)	Pred	0.17	0.84	-	-	-	-
	Empididae sp. 5	(Genus & species undetermined)	Pred	0.60	0.25	0.40	0.18	0.25	0.25
	Fanniidae sp. 1	(Genus & species undetermined)	Sap	0.27	0.82	0.43	0.11	0.35	0.84
	Muscidae sp. 1	(Genus & species undetermined)	Sap	0.33	0.33	0.10	0.56	0.25	0.25
	Muscidae sp. 2	(Genus & species undetermined)	Sap	-	-	-	-	0.10	0.48
	Muscidae sp. 3	(Genus & species undetermined)	Sap	-	-	0.10	0.56	-	-
	Muscidae sp. 4	(Genus & species undetermined)	Sap	0.30	0.27	-	-	-	-
	Muscidae sp. 5	(Genus & species undetermined)	Sap	1.33	0.42	-	-	-	-
	Mydidae sp. 1	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
	Platypezidae sp. 1	(Genus & species undetermined)	Sap	0.67	0.46	0.67	0.67	0.25	0.25
	Sarcophagidae sp. 1	(Genus & species undetermined)	Sap	-	-	-	-	0.25	0.25
	Sarcophagidae sp. 2	(Genus & species undetermined)	Sap	0.20	0.74	0.40	0.16	0.30	0.15

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
DIPTERA	Sphaeroceridae sp. 1	(Genus & species undetermined)	Sap			0.43	0.18		
	Syrphidae sp. 1	(Genus & species undetermined)	Pred	0.43	0.15	0.10	0.74	0.10	0.60
	Tephritidae sp. 1	(Genus & species undetermined)	Phy	0.10	0.56	0.33	0.33	0.28	0.17
	Therevidae sp. 1	(Genus & species undetermined)	Pred	-	-			-	-
	Therevidae sp. 2	(Genus & species undetermined)	Pred	-	-	0.33	0.33	-	-
	Tipulidae sp. 1	(Genus & species undetermined)	Sap	0.33	0.33	-	-	-	-
						-	-	-	-
DIPLOPODA	Dalodesmidae sp. 1	(*Gonokollesis* sp.)	Sap	0.70	0.36	0.67	0.27	0.48	0.17
	Julomorphidae sp. 1	(*Julomorpha* sp. 1)	Sap	15.23	3.38	13.83	1.43	21.85	2.68
	Julomorphidae sp. 2	(*Julomorpha* sp. 2)	Sap	0.40	0.18	9.47	1.96	0.98	0.35
HEMIPTERA	Alydidae sp. 1	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-
	Anthocorridae sp. 1	(Genus & species undetermined)	Pred	0.33	0.33	0.33	0.33	-	-
	Aphididae sp. 1	(Genus & species undetermined)	Phy	-	-	2.80	0.86	3.40	1.25
	Aphididae sp. 2	(Genus & species undetermined)	Phy	0.70	0.27	4.33	1.22	2.73	0.72
	Aphididae sp. 3	(Genus & species undetermined)	Phy	-	-	1.90	0.74	0.25	0.25
	Aphididae sp. 4	(Genus & species undetermined)	Phy	-	-	1.20	0.49	0.18	0.79
	Aphididae sp. 5	(Genus & species undetermined)	Phy	1.53	0.59	0.93	0.32	0.58	0.24
	Aphididae sp. 6	(Genus & species undetermined)	Phy	1.40	0.47	0.93	0.45	2.30	0.57
	Cercopidae sp. 1	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Cercopidae sp. 2	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Cercopidae sp. 3	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-
	Cercopidae sp. 4	(Genus & species undetermined)	Phy	-	-	-	-	0.50	0.35
	Cercopidae sp. 5	(Genus & species undetermined)	Phy	0.10	0.56	-	-	-	-
	Cicadellidae sp. 1	(Genus & species undetermined)	Phy	0.37	0.16	0.67	0.67	0.75	0.42
	Cicadellidae sp. 2	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Cicadellidae sp. 3	(Genus & species undetermined)	Phy	0.10	0.56	-	-	-	-
	Cicadellidae sp. 4	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Cicadellidae sp. 5	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Cicadellidae sp. 6	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Cicadellidae sp. 7	(Genus & species undetermined)	Phy	0.63	0.19	-	-	-	-
	Cicadellidae sp. 8	(Genus & species undetermined)	Phy	0.13	0.63	0.33	0.33	-	-

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
HEMIPTERA	Cicadellidae sp. 9	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Cicadellidae sp. 10	(Genus & species undetermined)	Phy	-	-	0.33	0.33	0.10	0.60
	Cicadellidae sp. 11	(Genus & species undetermined)	Phy	0.37	0.12	0.37	0.14	0.15	0.67
	Cicadellidae sp. 12	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Cicadellidae sp. 13	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Cicadellidae sp. 14	(Genus & species undetermined)	Phy	0.10	0.56	-	-	-	-
	Cicadellidae sp. 15	(Genus & species undetermined)	Phy	0.33	0.33	0.10	0.56	0.10	0.60
	Cicadellidae sp. 16	(Genus & species undetermined)	Phy	0.33	0.33	0.13	0.79	0.50	0.35
	Cicadellidae sp. 17	(Genus & species undetermined)	Phy	-	-	0.67	0.67	0.25	0.25
	Cixiidae sp. 1	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
	Cydnidae sp. 1	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-
	Cydnidae sp. 2	(Genus & species undetermined)	Phy	0.10	0.56	-	-	-	-
	Cydnidae sp. 3	(Genus & species undetermined)	Phy	-	-	-	-	0.25	0.25
	Issidae sp. 1	(*Gameromorphus* sp.)	Phy	-	-	0.67	0.46	-	-
	Issidae sp. 2	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Issidae sp. 3	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Issidae sp. 4	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Lygaeidae sp. 1	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-
	Lygaeidae sp. 2	(Genus & species undetermined)	Phy	0.30	0.98	0.23	0.14	-	-
	Lygaeidae sp. 3	(Genus & species undetermined)	Phy	0.33	0.33	0.67	0.67	-	-
	Lygaeidae sp. 4	(Genus & species undetermined)	Phy	-	-	0.37	0.22	0.25	0.25
	Lygaeidae sp. 5	(*Scantius* sp.)	Phy	-	-	0.10	0.56	0.25	0.25
	Lygaeidae sp. 6	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Lygaeidae sp. 7	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
	Lygaeidae sp. 8	(Genus & species undetermined)	Phy	-	-	0.10	0.74	-	-
	Lygaeidae sp. 9	(Genus & species undetermined)	Phy	-	-	-	-	0.25	0.25
	Miridae sp. 1	(Genus & species undetermined)	Phy	-	-	0.30	0.19	0.50	0.35
	Miridae sp. 2	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-
	Pentatomidae sp. 1	(Genus & species undetermined)	Phy	-	-	0.20	0.16	0.75	0.75
	Pyrrhocoridae sp. 1	(Genus & species undetermined)	Phy	-	-	-	-	0.50	0.50
	Pyrrhocoridae sp. 2	(Genus & species undetermined)	Phy	-	-	0.70	0.42	0.50	0.50
	Pyrrhocoridae sp. 3	(Genus & species undetermined)	Phy	-	-	0.10	0.74	-	-

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
HEMIPTERA	Pyrrhocoridae sp. 4	(Genus & species undetermined)	Phy	0.10	0.56	0.40	0.11	-	-
	Reduviidae sp. 1	(Genus & species undetermined)	Pred	0.23	0.14	-	-	-	-
	Reduviidae sp. 2	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
	Reduviidae sp. 3	(*Cleptria* sp.)	Pred	0.33	0.33	-	-	-	-
	Reduviidae sp. 4	(Genus & species undetermined)	Pred	0.67	0.46	0.27	0.16	-	-
	Reduviidae sp. 5	(Genus & species undetermined)	Pred	-	-	-	-	0.25	0.25
	Reduviidae sp. 6	(Genus & species undetermined)	Pred	0.67	0.67	-	-	0.25	0.25
	Reduviidae sp. 7	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
	Reduviidae sp. 8	(Genus & species undetermined)	Pred	0.67	0.46	-	-	-	-
	Reduviidae sp. 9	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
	Rhopalidae sp. 1	(Genus & species undetermined)	Phy	-	-	-	-	0.50	0.50
	Rhopalidae sp. 2	(Genus & species undetermined)	Phy	0.33	0.33	0.13	0.14	-	-
	Tingidae sp. 1	(Genus & species undetermined)	Phy	0.67	0.46	-	-	-	-
HYMENOPTERA	Apidae sp. 1	(Genus & species undetermined)	Nec	-	-	0.33	0.33	-	-
	Apidae sp. 2	(Genus & species undetermined)	Nec	0.33	0.33	-	-	0.50	0.35
	Apidae sp. 3	(Genus & species undetermined)	Nec	0.67	0.46	0.10	0.56	0.18	0.79
	Braconidae sp. 1	(Genus & species undetermined)	Par	0.33	0.33	0.50	0.25	0.20	0.82
	Ceraphronidae sp. 1	(Genus & species undetermined)	Par	0.67	0.46	0.33	0.33	0.10	0.60
	Chalcididae sp. 1	(Genus & species undetermined)	Par	-	-	-	-	0.25	0.25
	Chrysididae sp. 1	(Genus & species undetermined)	Par	0.10	0.74	0.33	0.33	-	-
	Cynipidae sp. 1	(Genus & species undetermined)	Par	0.33	0.33	-	-	-	-
	Embolemidae sp. 1	(Genus & species undetermined)	Par	0.33	0.33	-	-	-	-
	Eupelmidae sp. 1	(Genus & species undetermined)	Par	0.17	0.69	0.40	0.15	0.58	0.34
	Eupelmidae sp. 2	(Genus & species undetermined)	Par	-	-	0.10	0.74	0.50	0.35
	Formicidae sp. 1	(*Pheidole* sp.)	Omn	8.73	3.95	21.90	3.88	13.73	2.29
	Formicidae sp. 2	(*Linepithema humile)*	Omn	1.17	0.54	0.97	0.36	0.58	0.22
	Formicidae sp. 3	(*Tetramorium* sp. 1)	Omn	-	-	-	-	0.75	0.75
	Formicidae sp. 4	(*Monomorium* spp. 1 + 2)	Omn	0.30	0.19	0.33	0.33	-	-
	Formicidae sp. 5	(*Tetramorium* sp. 2)	Omn	5.40	1.76	-	-	-	-
	Formicidae sp. 6	(*Tetramorium* sp. 3)	Omn	5.40	0.96	0.30	0.24	0.50	0.35
	Formicidae sp. 7	(*Crematogaster* sp. 2)	Omn	-	-	0.33	0.33	-	-

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation		Alternative vineyards		Integrated vineyards	
				Mean	Std errror	Mean	Std error	Mean	Std errror
HYMENOPTERA	Formicidae sp. 8	(*Tapinoma* sp.)	Omn	0.83	0.58	24.63	12.83	0.43	0.28
	Formicidae sp. 9	(*Lepisiota* sp. 2)	Omn	-	-	0.13	0.79	0.25	0.25
	Formicidae sp. 10	(*Tetramorium* sp. 4)	Omn	-	-	0.33	0.33	0.50	0.35
	Formicidae sp. 11	(*Anaporepus* sp.)	Omn	-	-	-	-	0.25	0.25
	Formicidae sp. 12	(*Solenopsis* sp.)	Omn	5.57	1.42	6.67	2.64	5.10	1.75
	Formicidae sp. 13	(*Meranoplus* sp.)	Omn	0.67	0.67	-	-	-	-
	Formicidae sp. 14	(*Ocemyrmex* sp.)	Omn	0.67	0.46	-	-	-	-
	Formicidae sp. 15	(*Monomorium* sp. 3)	Omn	0.33	0.33	-	-	-	-
	Formicidae sp. 16	(*Technomyrmex* sp. 1)	Omn	0.13	0.63	-	-	-	-
	Formicidae sp. 17	(*Tecnomyrmex* sp. 2)	Omn	0.33	0.33	-	-	-	-
	Formicidae sp. 18	(*Monomorium* sp. 4)	Omn	-	-	-	-	0.25	0.25
	Formicidae sp. 19	(*Monorium* sp. 1)	Omn	-	-	0.33	0.33	-	-
	Formicidae sp. 20	(*Camponotus* sp. 1)	Omn	-	-	-	-	0.50	0.50
	Formicidae sp. 21	(*Camponotus* sp. 2)	Omn	-	-	-	-	0.75	0.55
	Formicidae sp. 22	(*Monorium* sp. 2)	Omn	0.40	0.37	-	-	-	-
	Formicidae sp. 23	(*Camponotus* sp. 3)	Omn	6.80	1.40	5.73	0.93	2.43	0.64
	Formicidae sp. 24	(*Technomyrmex* sp. 3)	Omn	0.13	0.14	-	-	-	-
	Formicidae sp. 25	(*Cerapachys* sp. 1)	Omn	0.10	0.56	-	-	-	-
	Formicidae sp. 26	*(Crematogaster* sp. 3)	Omn	0.27	0.14	2.43	0.63	0.63	0.24
	Formicidae sp. 27	*(Crematogaster peringyii)*	Omn	2.53	0.84	5.93	1.50	2.43	0.59
	Formicidae sp. 28	(*Lepisiota capensis)*	Omn	1.57	0.30	1.67	0.40	0.40	0.16
	Formicidae sp. 29	*(Genus & species undetermined)*	Omn	0.23	0.12	0.37	0.18	1.13	0.55
	Formicidae sp. 30	(*Tetramorium* sp. 4)	Omn	-	-	0.33	0.33	-	-
	Formicidae sp. 31	(*Camponotus* sp. 4)	Omn	0.37	0.12	0.33	0.33	0.48	0.19
	Halictidae sp. 1	(Genus & species undetermined)	Nec	0.73	0.34	0.17	0.84	0.88	0.35
	Halictidae sp. 2	(Genus & species undetermined)	Nec	0.13	0.13	-	-	0.50	0.50
	Halictidae sp. 3	(Genus & species undetermined)	Nec	0.27	0.16	-	-	0.88	0.33
	Ichneumonidae sp. 1	(Genus & species undetermined)	Par	0.33	0.33	0.33	0.33	0.25	0.25
	Masaridae sp. 1	(Genus & species undetermined)	Nec	0.17	0.18	-	-	-	-
	Pompilidae sp. 1	(Genus & species undetermined)	Par	-	-	-	-	0.25	0.25
	Pompilidae sp. 2	(Genus & species undetermined)	Par	-	-	0.33	0.33	0.75	0.55
	Pompilidae sp. 3	(Genus & species undetermined)	Par	-	-	0.33	0.33	-	-

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation Mean	Natural vegetation Std errror	Alternative vineyards Mean	Alternative vineyards Std error	Integrated vineyards Mean	Integrated vineyards Std errror
HYMENOPTERA	Pompilidae sp. 4	(Genus & species undetermined)	Par	0.33	0.33	-	-	0.25	0.25
	Pteromalidae sp. 1	(Genus & species undetermined)	Par	0.63	0.21	0.33	0.33	0.10	0.60
	Pteromalidae sp. 2	(Genus & species undetermined)	Par	0.33	0.33			-	-
	Scoliidae sp. 1	(Genus & species undetermined)	Par	0.73	0.36	0.20	0.14	0.25	0.25
	Sphecidae sp. 1	(Genus & species undetermined)	Pred	-	-	-	-	0.75	0.75
	Sphecidae sp. 2	(Genus & species undetermined)	Pred	-	-	-	-	0.25	0.25
	Sphecidae sp. 3	(Genus & species undetermined)	Pred	0.33	0.33	-	-	-	-
	Sphecidae sp. 4	(Genus & species undetermined)	Pred	0.67	0.46	-	-	-	-
ISOPODA	Armadillidiidae sp. 1	(Genus & species undetermined)	Sap	-	-	0.13	0.63	0.25	0.25
	Armadillidiidae sp. 2	(Genus & species undetermined)	Sap	-	-	0.33	0.33	-	-
	Armadillidiidae sp. 3	(Genus & species undetermined)	Sap	2.33	0.89	9.67	2.51	4.35	1.85
	Porcellionidae sp. 1	(Genus & species undetermined)	Sap	0.93	0.34	6.83	1.75	1.30	0.47
	Porcellionidae sp. 2	(Genus & species undetermined)	Sap	-	-	-	-	0.25	0.25
	Trichoniscidae sp. 1	(Genus & species undetermined)	Sap	2.80	0.62	0.17	0.17	-	-
	Trichoniscidae sp. 2	(Genus & species undetermined)	Sap	0.63	0.26	3.97	0.68	1.13	0.31
	Trichoniscidae sp. 3	(Genus & species undetermined)	Sap	0.53	0.17	-	-	0.25	0.25
ISOPTERA	Termitidae sp. 1	(Genus & species undetermined)	Sap	3.70	2.22	-	-	-	-
MANTODEA	Mantidae sp. 1	(Genus & species undetermined)	Pred	0.10	0.56	-	-	-	-
ORTHOPTERA	Acrididae sp. 1	(Genus & species undetermined)	Phy	0.30	0.15	0.20	0.17	0.10	0.48
	Acrididae sp. 2	(*Aiolopus* sp.)	Phy	0.10	0.56	0.47	0.16	0.15	0.84
	Acrididae sp. 3	(*Acrotylus* sp.)	Phy	0.33	0.33	0.40	0.19	0.75	0.55
	Acrididae sp. 4	(Genus & species undetermined)	Phy	-	-	0.33	0.33	-	-
	Acrididae sp. 5	(Genus & species undetermined)	Phy	0.13	0.63	0.67	0.46	0.23	0.98
	Gryllacrididae sp. 1	(Genus & species undetermined)	Omn	0.33	0.33	-	-	-	-
	Gryllidae sp. 1	(Genus & species undetermined)	Omn	0.67	0.46	0.33	1.00	0.48	0.14
	Gryllidae sp. 2	(*Cophogryllus* sp.)	Omn	-	-	-	-	0.25	0.12
	Gryllidae sp. 3	(*Oecanthus* sp.)	Omn	0.80	0.23	0.13	0.14	-	-
	Gryllidae sp. 4	(Genus & species undetermined)	Omn	-	-	0.10	0.56	0.20	0.19

Appendix B continued

ORDER	Family & species nr	Genus & species	Functional guild	Natural vegetation		Alternative vineyards		Integrated vineyards	
				Mean	Std errror	Mean	Std error	Mean	Std errror
ORTHOPTERA	Gryllidae sp. 5	(Genus & species undetermined)	Omn	0.13	0.79	-	-	-	-
	Gryllidae sp. 6	(Genus & species undetermined)	Omn	-	-	-	-	0.50	0.35
	Gryllidae sp. 7	(Genus & species undetermined)	Omn	0.10	0.74	0.40	0.13	0.23	0.98
	Gryllidae sp. 8	(Genus & species undetermined)	Omn	-	-	0.33	0.33	-	-
	Gryllidae sp. 9	(Genus & species undetermined)	Omn	0.80	0.34	0.70	0.20	0.33	0.13
	Gryllidae sp. 10	(Genus & species undetermined)	Omn	0.50	0.18	0.17	0.84	0.75	0.75
	Gryllidae sp. 11	(Genus & species undetermined)	Omn	-	-	0.33	0.33	-	-
	Gryllidae sp. 12	(Genus & species undetermined)	Omn	-	-	0.67	0.46	-	-
	Gryllidae sp. 13	(Genus & species undetermined)	Omn	0.33	0.33	-	-	-	-
	Gryllidae sp. 14	(Genus & species undetermined)	Omn	0.17	0.18	-	-	-	-
	Gryllotalpidae sp. 1	(Genus & species undetermined)	Phy			-	-	0.25	0.25
	Tetrigidae sp. 1	(*Tetiella* sp.)	Sap	0.33	0.33	-	-	-	-
	Tetrigidae sp. 2	(Genus & species undetermined)	Sap	0.17	0.69	-	-	-	-
	Tetrigidae sp. 3	(Genus & species undetermined)	Sap	0.33	0.33	-	-	-	-
PHASMATODEA	Phasmidae sp. 1	(Genus & species undetermined)	Phy	0.33	0.33	-	-	-	-
PSOCOPTERA	Liposcelidae sp. 1	(Genus & species undetermined)	Sap	0.17	0.14	1.57	0.64	0.50	0.50
PSEUDO-SCORPIONS	Cheliferidae sp. 1	(Genus & species undetermined)	Pred	1.27	0.46	1.40	0.36	-	-
	Chernetidae sp. 1	(Genus & species undetermined)	Pred	0.67	0.46	-	-	-	-
SCORPIONS	Scorpionidae sp. 1	(Genus & species undetermined)	Pred	0.10	0.74	-	-	-	-
SOLPUGIDAE	Solpugidae sp. 1	(Genus & species undetermined)	Pred	0.87	0.52	-	-	0.30	0.12
	Solpugidae sp. 2	(Genus & species undetermined)	Pred	0.47	0.15	0.10	0.56	0.28	0.11
THYSANURA	Lepismatidae sp. 1	(Genus & species undetermined)	Sap	1.80	0.47	0.40	0.15	0.25	0.25

***** Phy=phytophage, Omn=omnivore, Nec=nectarivore, Par=parasitoid, Pred=predator, Sap=saprophage, Wo=wood borer

Appendix C: Collembola taxa recorded during the study period, their functional guild and mean abundance (± S.E.) for each site type.

ORDER	Suborder & species nr	Genus & species	Functional guild	Natural vegetation		Alternative vineyards		Integrated vineyards	
				Mean	Std errror	Mean	Std error	Mean	Std errror
COLLEMBOLA	Arthropleona sp. 1	(Genus & species undetermined)	Sap	98.13	2.52	197.43	45.73	118.23	27.47
	Arthropleona sp. 2	(Genus & species undetermined)	Sap	62.87	17.32	332.37	99.89	111.50	27.16
	Arthropleona sp. 3	(Genus & species undetermined)	Sap	0.40	0.29	179.57	43.36	5.90	3.22
	Arthropleona sp. 4	(Genus & species undetermined)	Sap	9.67	1.55	37.30	7.83	42.53	8.78
	Arthropleona sp. 5	(Genus & species undetermined)	Sap	1.00	1.61	1.50	2.78	8.85	1.64
	Arthropleona sp. 6	(Genus & species undetermined)	Sap	0.20	0.15	1.53	0.73	1.35	0.44
	Arthropleona sp. 7	(Genus & species undetermined)	Sap	2.77	1.17	2.20	0.92	6.13	1.72
	Arthropleona sp. 8	(Genus & species undetermined)	Sap	1.20	0.58	-	-	-	-
	Arthropleona sp. 9	(Genus & species undetermined)	Sap	1.67	0.54	-	-	0.30	0.18
	Symphypleona sp. 1	(Genus & species undetermined)	Sap	14.43	4.94	22.77	5.77	2.18	5.82
	Symphypleona sp. 2	(Genus & species undetermined)	Sap	42.23	16.27	4.20	6.61	31.80	5.83
	Symphypleona sp. 3	(Genus & species undetermined)	Sap	-	-	-	-	6.25	3.94

Appendix Da. Spearman's rank order correlations for vineyards relating total and functional guild abundance and species richness to environmental variables. Marked correlations are significant at $p<0.05$.

	Total abundance	Total spp richness	Phytophage abundance	Phytophage spp richness	Nectarivore abundance	Nectarivore spp richness	Omnivore abundance	Omnivore spp richness	Parasitoid abundance	Parasitoid spp richness	Predator abundance	Predator spp richness	Saprophage abundance	Saprophage spp richness	Wood borer abundance	Wood borer spp richness
Total vegetation cover	**0.469**	**0.663**	**0.503**	**0.542**	-0.096	-0.071	**0.377**	**0.394**	0.202	**0.243**	**-0.254**	**0.453**	**0.375**	**0.652**	-0.053	-0.045
Vine cover	-0.1	-0.072	-0.043	-0.023	0.057	0.053	-0.116	-0.085	0.073	0.067	0.168	-0.128	-0.167	-0.042	0.018	-0.006
Broadleaf weed cover	**0.459**	**0.638**	**0.436**	**0.472**	-0.041	-0.023	**0.4**	**0.473**	**0.304**	**0.333**	-0.171	**0.415**	**0.335**	**0.526**	0.053	0.018
Grass weed cover	**0.406**	**0.492**	**0.31**	**0.328**	-0.097	-0.09	**0.261**	0.222	-0.022	-0.006	**-0.295**	**0.451**	**0.458**	**0.641**	-0.074	-0.047
Indigenous grass cover	0.196	**0.271**	**0.366**	**0.278**	-0.018	0.011	0.086	0.14	-0.073	-0.052	**-0.27**	0.199	**0.269**	**0.367**	**-0.273**	**-0.258**
Number of plant species	**0.484**	**0.65**	**0.527**	**0.508**	-0.106	-0.082	**0.461**	**0.511**	**0.277**	**0.304**	-0.222	**0.434**	**0.328**	**0.558**	-0.01	-0.034
Plant height	**0.515**	**0.699**	**0.487**	**0.458**	0.002	0.035	**0.317**	**0.499**	0.116	0.163	**-0.282**	**0.508**	**0.562**	**0.701**	-0.119	-0.041
Leaf litter depth	0.029	0.106	-0.071	0.029	**-0.236**	-0.217	0.065	-0.019	-0.005	-0.037	**-0.379**	0.086	0.182	0.113	0.157	0.087
Leaf litter weight	-0.014	0.073	-0.09	-0.003	-0.218	-0.197	-0.005	-0.022	-0.016	-0.029	**-0.325**	0.033	0.164	0.039	0.219	0.18
Pesticide	**-0.277**	**-0.394**	-0.142	**-0.251**	**0.555**	**0.529**	**-0.518**	-0.146	0.021	0.006	**0.488**	**-0.431**	-0.218	**-0.427**	-0.066	-0.037
Fungicide	**-0.406**	**-0.467**	-0.212	**-0.288**	**0.453**	**0.434**	**-0.559**	-0.229	0.068	0.039	**0.457**	**-0.456**	**-0.382**	**-0.538**	0.081	0.008
Herbicide	**-0.644**	**-0.65**	**-0.409**	**-0.425**	0.131	0.123	**-0.528**	**-0.47**	0.02	-0.021	**0.318**	**-0.462**	**-0.685**	**-0.734**	**0.259**	0.073
Fertilizer	**-0.239**	**-0.244**	-0.049	-0.11	**0.322**	**0.319**	**-0.484**	-0.185	0.109	0.088	**0.324**	**-0.238**	-0.211	-0.225	0.066	-0.072
Tillage	**-0.361**	**-0.399**	**-0.644**	**-0.492**	**-0.474**	**-0.469**	-0.132	**-0.446**	0.088	0.054	-0.129	-0.124	**-0.354**	**-0.274**	**0.681**	**0.37**
Elevation	**-0.371**	**-0.341**	**-0.249**	-0.18	**-0.313**	**-0.311**	0.133	**-0.434**	-0.117	-0.108	0.01	-0.084	**-0.66**	**-0.334**	0.163	0.108
Source vegetation	**-0.336**	**-0.476**	**-0.628**	**-0.578**	-0.127	-0.135	**-0.467**	**-0.411**	0.067	0.026	0.065	**-0.264**	-0.129	**-0.297**	**0.491**	**0.236**
Distance to source	**0.251**	0.177	**0.289**	0.191	0.026	0.021	0.205	0.021	**-0.273**	-0.224	-0.048	0.21	**0.243**	**0.324**	**-0.559**	**-0.301**

Appendix Db. Spearman's rank order correlations for natural vegetation relating total and functional guild abundance and species richness to environmental variables. Marked correlations are significant at p<0.05.

	Total abundance	Total spp richness	Phytophage abundance	Phytophage spp richness	Nectarivore abundance	Nectarivore spp richness	Omnivore abundance	Omnivore spp richness	Parasitoid abundance	Parasitoid spp richness	Predator abundance	Predator spp richness	Saprophage abundance	Saprophage spp richness	Wood borer abundance	Wood borer spp richness
Total % cover	-0.018	0.062	-0.050	0.128	**-0.398**	**-0.375**	0.094	0.010	0.121	0.001	-0.164	0.019	0.171	-0.041	**0.489**	**0.452**
Broadleaf weed cover	**0.640**	**0.582**	**0.725**	**0.500**	0.303	0.328	0.231	0.315	**-0.532**	**-0.469**	**0.656**	**0.582**	**0.384**	**0.423**	-0.261	-0.176
Grass weed cover	**0.679**	**0.530**	**0.679**	**0.562**	-0.006	0.015	0.237	0.045	**-0.515**	**-0.455**	**0.726**	**0.581**	**0.414**	0.294	-0.059	-0.040
Indigenous forb cover	**-0.477**	**-0.388**	-0.335	-0.063	-0.272	-0.244	-0.121	-0.180	**0.422**	0.327	**-0.428**	**-0.377**	-0.291	**-0.470**	0.126	0.151
Indigenous restio cover	**-0.703**	**-0.605**	**-0.704**	**-0.601**	-0.322	-0.313	-0.179	-0.224	**0.604**	**0.468**	**-0.754**	**-0.563**	**-0.452**	**-0.485**	0.230	0.216
Indigenous grass cover	0.313	0.222	0.256	0.286	0.166	0.190	0.051	-0.058	-0.337	-0.238	0.214	0.115	0.315	**0.396**	-0.027	-0.146
Indigenous woody cover	-0.167	0.021	-0.184	0.096	-0.009	-0.026	0.004	0.079	0.210	0.247	-0.209	-0.107	-0.118	-0.125	**0.433**	0.344
Number of plant species	**-0.395**	-0.283	-0.303	-0.058	-0.229	-0.216	-0.112	-0.167	0.186	0.055	**-0.462**	**-0.426**	-0.300	-0.320	0.268	0.173
Plant height	-0.114	-0.205	-0.341	-0.166	-0.160	-0.172	0.197	0.081	0.330	0.276	-0.253	-0.314	-0.116	-0.311	**0.387**	**0.367**
Leaf litter depth	0.304	0.342	0.315	**0.489**	-0.082	-0.091	0.258	0.205	-0.134	-0.249	0.260	0.225	0.345	0.136	-0.004	-0.037
Leaf litter weight	0.145	0.272	0.195	**0.451**	-0.098	-0.148	0.059	0.133	-0.100	-0.265	0.099	0.118	0.239	0.140	-0.008	-0.063
Elevation	0.297	**0.392**	**0.482**	**0.424**	**0.542**	**0.567**	0.002	0.172	-0.353	-0.053	**0.453**	0.346	0.167	**0.450**	**-0.489**	**-0.409**
% Source vegetation	**-0.849**	**-0.692**	**-0.885**	**-0.583**	-0.351	**-0.402**	-0.260	-0.186	**0.619**	**0.383**	**-0.935**	**-0.791**	**-0.519**	**-0.545**	0.325	0.245

Appendix Dc. Spearman's rank order correlations for vineyards relating Araneae, Carabid and Staphylinid species richness and abundance to environmental variables. Marked correlations are significant at $p<0.05$.

	Araneae spp richness	Araneae abundance	Carabid spp richness	Carabid abundance	Staphylinid spp richness	Staphylinid abundance
Total % cover	**0.429**	**0.473**	**0.375**	-0.031	0.116	0.222
Vine cover	-0.196	-0.176	0.022	0.000	0.015	-0.015
Broadleaf weed cover	**0.486**	**0.583**	**0.384**	0.112	0.014	0.152
Grass weed cover	**0.450**	**0.408**	0.163	**-0.330**	0.175	**0.252**
Indigenous grass cover	0.135	0.048	0.110	-0.089	0.034	0.104
Number of plant species	**0.465**	**0.526**	**0.378**	0.107	0.105	0.226
Plant height	**0.531**	**0.550**	**0.251**	-0.152	0.132	**0.303**
Leaf litter depth	**0.361**	**0.343**	0.065	-0.170	0.052	0.205
Leaf litter weight	**0.362**	**0.329**	-0.003	-0.225	0.031	0.201
Pesticide	**-0.289**	**-0.334**	**-0.421**	-0.098	-0.118	-0.064
Fungicide	**-0.262**	**-0.301**	**-0.349**	-0.020	-0.178	-0.142
Herbicide	**-0.310**	**-0.356**	-0.180	0.178	**-0.294**	**-0.342**
Fertilizer	-0.119	**-0.255**	-0.168	-0.170	-0.199	-0.150
Tillage	0.068	0.087	0.064	-0.131	-0.157	-0.195
Elevation	**-0.371**	**-0.430**	**0.425**	**0.539**	**-0.326**	**-0.508**
% Source vegetation	0.044	-0.002	**-0.344**	**-0.490**	-0.099	-0.047
Distance to source	-0.223	**-0.393**	0.112	0.018	-0.019	-0.080

Appendix Dd. Spearman's rank order correlations for natural vegetation relating Araneae, Carabid and Staphylinid species richness and abundance to environmental variables. Marked correlations are significant at $p<0.05$.

	Araneae spp richness	Araneae abundance	Carabid spp richness	Carabid abundance	Staphylinid spp richness	Staphylinid abundance
Total % cover	0.160	-0.007	-0.305	-0.316	-0.064	0.250
Broadleaf weed cover	**0.567**	**0.688**	0.135	0.176	0.164	0.253
Grass weed cover	**0.566**	**0.581**	0.135	0.116	0.137	**0.632**
Indigenous forb cover	-0.310	-0.322	-0.097	-0.142	-0.200	**-0.507**
Indigenous restio cover	**-0.514**	**-0.712**	-0.296	-0.281	-0.246	**-0.448**
Indigenous grass cover	0.082	0.194	0.189	0.167	-0.048	0.190
Indigenous woody cover	-0.126	-0.133	-0.145	-0.073	0.109	0.022
Number of plant species	-0.289	**-0.449**	**-0.434**	-0.355	-0.251	-0.187
Height	-0.160	-0.307	-0.175	-0.130	-0.234	0.074
Leaf litter depth	0.215	0.288	-0.033	-0.059	0.118	0.296
Leaf litter weight	0.151	0.205	-0.208	-0.214	0.122	0.185
Elevation	0.181	0.357	**0.609**	**0.627**	0.179	-0.116
% Source vegetation	**-0.685**	**-0.799**	**-0.548**	**-0.516**	-0.289	**-0.551**