ASPECTS OF THE TAXONOMY AND ECOLOGY OF THE GROUND BEETLE (COLEOPTERA: CARABIDAE) ASSEMBLAGE OF THE SWAN COASTAL PLAIN

(WITH PARTICULAR REFERENCE TO HABITAT FRAGMENTATION AND THE QUINDALUP DUNE SYSTEM)

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ABSTRACT

Long term studies encompassing seasonal variation in abundance and species present, forming base-line phenological data, are required to understand the responses of the carabid (Ground Beetle) fauna to major habitat changes. In addition, few habitats unaffected by human disturbance remain in Australia, and evaluation of these fauna in these areas is required before further habitat loss occurs.

Generally an unknown group of terrestrial predatory invertebrates in Australia, carabids have been the subjects of few ecological studies in this country. This restricts the utility of the Carabidae in environmental or conservation assessment programs in Australia.

A study was initiated to assess the effects of habitat fragmentation and to provide base-line phenological data on the carabid fauna occurring in remnant bushland areas within part of the Perth Metropolitan Area, encompassing the Quindalup, Spearwood and Bassendean Dunes Systems, and Ridge Hill Shelf geological landforms of the Swan Coastal Plain. An intensive study, documenting and comparing seasonal occurrence of carabids was also carried out in bushland remnants within the Quindalup Dune System.

Pitfall traps from a Western Australian Museum survey and from the author's fieldwork, accessed 39 sites in 14 remnant areas across the four geological landforms of the Swan Coastal Plain concurrently in 1993 through to 1997. A total of 3049 specimens of 37 species representing 26 genera and 11 subfamilies were collected. The richest geological landform was found to be the Bassendean Dune System with 17 species, followed closely by the Quindalup Dune System (12) and the Ridge Hill Shelf (14 species).

Relationships were found between the carabid fauna and the size of the remnant areas. The r values of the regressions between the total number of carabid species ($r = 0.3782$, $p < 0.05$), and the number of volant species ($r = 0.3776$, $p < 0.05$) and the log of remnant area were statistically significant. However, these r values are very low and indicate that only about 14 % of the variation in total and volant species richness is accounted for by remnant area. The non-volant species richness and log of remnant area correlation was not significant ($r = 0.1912$, $p > 0.05$). In this case, the variable remnant area accounted for less than 4 % of the variation in the non-volant species richness.

The distribution of volant to non-volant species across the Plain was highly irregular, with volant species represented usually by few individuals in either the Quindalup or Bassendean Dune Systems whereas the non-volant species were generally more common and widespread. This is probably attributable to the collection method rather than a reflection of real distributional patterns.

A series of environmental parameters were generated by the climate program *Bioclim*. Most of the carabid species present on the Plain are at the extremity of their ranges and the physical and environmental parameters were found to have limited influence on species richness, individual species' abundances or distributions spatially across the Plain. Environmental parameters were also scored for each sampling period for the Quindalup Dune System sites between 1996 and 1997 to determine their influence on the species distribution temporally and spatially in that dune system. As previously, these parameters had little apparent influence on either the non-volant assemblage species richness or individual species abundances.

Evidence of seasonality of several species was observed, along with possible spatial and temporal partitioning between two species, *Scaraphites lucidus* and *S. silenus*. The former was only found on Quindalup and associated soils, and the latter found in most other remnants across the Plain. Similarity classifications revealed that it is possible to discriminate the broader geological features of the Swan Coastal Plain on the basis of the entire carabid assemblage. However, finer-grained discrimination is possible if only the non-volant assemblage is used. Within the Quindalup Dune System discrimination between the remnants is not as clear, with sites tending to cluster in three main groups, beach associated, heath associated and older areas. Distinct seasonal activity levels (within a six week window) were documented for the first time for several common species, with only two species active at some level through all seasons. Most species were found to be active in the adult form during spring and summer months, activity tapering off in autumn. Slight variations between remnants were observed.

Redescriptions of eight non-volant species and *Gnathoxys pannuceus* sp. nov. (with details of gross male genitalia) are presented. An identification key to the carabid species encountered on the Quindalup Dune System is also presented.

While this study does not provide conclusive evidence of habitat fragmentation directly affecting the carabid assemblage structure it indicates that the species are not uniformly distributed across the Swan Coastal Plain either temporarily or spatially. Also, the presence of both rare and undescribed forms within the remnants underline the desirability of further surveys of these localities. Research into the relationships between the various taxa in these localities is required before fully informed conservation decisions for either the carabid fauna or the remnants themselves can be made.

Dedicated to the loving memory of
Judy M. Guthrie (1942-1999).

I certify that this thesis does not, to the best of my knowledge and belief:

- *(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;*
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Nadine A. Guthrie **Date: Thursday, 14 June 2001**

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CHAPTER 1:

GENERAL INTRODUCTION

1.1 INTRODUCTION

Few habitats unaffected by human disturbance remain in Australia. Many of these are reduced in size to remnants of their former distributions and are surrounded by highly modified environments such as urban landscapes. It is these urban remnants and their biota, accessible to the general public, which can be used to highlight the need for habitat conservation. Examples of these are the native bushland remnants of the Swan Coastal Plain in Western Australia. Evaluation of the persisting fauna is required before further degradation and habitat loss occurs to assist the persistence and management of these remnants.

World wide, the use of invertebrates in evaluating habitat fragmentation and landscape change to assist management of habitat remnants has increased over the last decade (Thiele 1977; Czechowski 1982; Burel 1989; Erye and Rushton 1989; Webb 1989; Neumann 1991; Kremen *et al.* 1993; Spence and Niemala 1994; Didham *et al.* 1996; Yen and Butcher 1997; Burke and Goulet 1998; Fisher 1998; New 1998). Invertebrates occupy many ecological niches, reflecting both large scale geographic changes and fine grained microhabitats within a community. Compared to vertebrates, invertebrate assemblages also exhibit greater seasonal and successional turnovers (Kremen *et al.* 1993). It is for these reasons that epigaeic invertebrates, such as Collembola, arachnids, ants and ground beetles, have been used individually and in combination to assist in reserve selection, delineation of biogeographic zones and community types, and to provide early warnings of ecological change (Czechowski 1982; Burel 1989; Erye and Rushton 1989; Webb 1989; Neumann 1991; Margules 1992; Kremen *et al.* 1993; Spence and Niemala 1994; Abensperg-Traun *et al.* 1996; How *et al.* 1996; Harvey *et al.* 1997; Major and Brown 1997; Yen and Butcher 1997; Burke and Goulet 1998; Didham *et al.* 1998a, 1998b; Fisher 1998; New 1998).

In Australia, invertebrate assemblages are increasingly the focus of habitat studies. However, their use in such studies is hampered by a lack of detailed biological knowledge about most groups (New 1998). This can be offset by using a suite of complimentary groups which can be sampled using straightforward and standardized techniques (Kremen *et al.* 1993; New 1998). But difficulties with species-level identifications has affected analyses of some of these Australian studies (New 1998). Australian ground beetles (Carabidae) are one group where a lack of biological and taxonomic knowledge is impeding their evaluation and use in many habitat studies. A number of studies (Friend 1995; Michaels and McQuillan 1995; Abensperg-Traun *et al.* 1996; Davies and Margules 1998; Horne and Edwards 1998; Michaels and Mendel 1998; Michaels 1999) indicate that, once appropriate biological information is assigned to individual ground beetle species, the family may prove to be an important member of the suite of invertebrates routinely surveyed in environmental assessment studies.

This study was initiated to assess the effects of habitat fragmentation on the carabid fauna on the Swan Coastal Plain in the context of the urban environment, and to provide base-line phenological data to assist management of these populations.

1.2 HISTORICAL PERSPECTIVE

Since European colonisation of the Swan Coastal Plain 170 years ago there has been a loss of native fauna and flora as native vegetation has been cleared for urbanisation. Initially, clearing occurred along the Swan River, but it now extends across the Plain and along the coast. The remaining vegetation has become highly degraded and fragmented, surviving in only small scattered areas.

Faunal surveys conducted on the Northern Swan Coastal Plain by the Western Australian Museum in 1978 indicated that native mammal and bird species diversity had been significantly reduced since colonisation (How 1978). The herpetological fauna appeared to be more robust, with no known extinctions at that point in time (How 1978). Aquatic invertebrates were documented from various water bodies, but terrestrial invertebrates were omitted due to the vast taxonomic complexities involved. However, it was assumed that the distribution of terrestrial invertebrates was probably similar to that of the vegetation (How 1978).

Fifteen years later (in 1993) the Western Australian Museum began a comprehensive survey of persisting ground fauna in urban bushland fragments (How *et al.* 1996). Terrestrial invertebrates were included as a major component of the survey.

Initial results from the Urban Bushland Survey showed that native mammals and small, insectivorous birds that are habitat specialists were seriously affected by habitat fragmentation. The persistence of most other birds and non-skink lizards was strongly influenced by remnant area. Smaller remnants were most important for maintaining skink diversity and populations of various bird species (How *et al.* 1996).

Invertebrate taxa representing three major feeding guilds were also examined (predacious: arachnids and centipedes; detrivorous: millipedes and cockroaches; parasitic: baeine wasps) and found to be very diverse. Several groups were collected for the first time at various spatial scales: first records for the Swan Coastal Plain (various rare spider families found elsewhere), for south west Western Australia (wasp family Rhopalosomatidae, and two spider subfamilies), and for Australia (pseudoscorpion subfamily Pycnocheiridiinae and genus *Aldabrinus*; How *et al.* 1996). Among the various groups differing patterns of distribution related to vegetation and landform were observed, indicating varying levels of spatial partitioning (Harvey *et al.* 1996; How *et al.* 1996).

Many other invertebrate taxa collected during this survey still need to be examined. Once examined, the effects of habitat fragmentation between and within feeding guilds in these native communities can be better understood. This study examines the carabid fauna collected from two invertebrate surveys, the first survey was of the Swan Coastal Plain as a whole, by How *et al.* (1996) between 1993-1996, and the second, of the Quindalup Dune System exclusively, between 1996-1997 by the author.

1.3 CARABID BEETLES

First appearing in the Jurassic Period (210- 145 mybp) ground beetles, or carabids, have diversified to occupy almost every land mass except Antarctica (Lawrence and Britton 1994). Currently between 40 000 and 60 000 identified carabid species are recognized

(Gaston 1991; Lovei and Sunderland 1996; Noonan 1995 in Niemela 1996), with recent studies in under-surveyed areas indicating the actual number could be much higher (Baehr 1995).

Primarily generalist predators, some carabid groups have modified dietary requirements including partial phytophagy (Matthews 1980), feeding on seeds (Harpalines; Maddison 1996), fungi, millipedes, snails or particular insect groups (such as Paussinae and Pseudomorphinae which feed exclusively on ants; Matthews 1980; Lawrence and Britton 1994; Maddison 1996). A few carabid groups have developed ectoparasitic lifestyles, including on other carabids (Maddison 1996). Specific dietary requirements of Australian carabids however, are unknown (Matthews 1980) but generalisations are usually drawn based on generic trends (Moore *et al.* 1987).

Usually cursorial, Australian carabids also occur in foliage (e.g. Lebiini), within caves (e.g. various Harpalini, Lebiini, Psydrini, Trechini and Zolini; Matthews 1980; Lawrence and Britton 1994) or under bark (Baehr 1990; Lawrence and Britton 1994). Darlington (1961) defined three main ecological groups among the Carabidae: *geophiles/mesophiles* (ground dwellers not associated with water); *hydrophiles* (associated at the edge of water bodies) and *arboricoles* (living above ground in vegetation). The distribution of Australian carabid species across these groups are roughly 2:1:1 (Matthews 1980; Baehr 1990; Lawrence and Britton 1994). However, geophilic carabid species appear to be scarce in terms of individuals per species (Baehr 1990) in contrast to arboricoles which have higher numbers of individuals per species, and therefore, according to Lawrence and Britton (1994), are considered to be an ecologically dominant group. New (1998) notes that this scenario appears to be only prevalent in the mesic areas of Australia.

The Australian carabid genera have high levels of endemism (New 1998), often associated with the diversification of *Acacia* and *Eucalyptus* communities during the Tertiary (Baehr 1990; Lawrence and Britton 1994; Roig-Junent 2000). In general, the Australian carabid fauna is comprised of three main elements. The oldest element is the Archaic group with transcontinental distributions (for example, the genus *Calosoma*; Moore *et al.* 1987; or the Broscinae which have a Pangaean origin and amphipolar distribution; Crowson 1980; Roig-Junent 2000). The Gondwanan or South Temperate element has southern, widespread distributions, or are restricted to mountain ranges (Matthews 1980; Lawrence and Britton 1994; New 1998). The younger Oriental elements, representing recent invasions, are usually confined to tropical regions but are sometimes found further south (Lawrence and Britton 1994; New 1998).

Affinity to particular habitats (New 1998; Boscaini *et al.* 2000) and responsiveness to abiotic factors (Thiele 1977; Lovei and Sunderland 1996; Boscaini *et al.* 2000) have allowed carabids to be used extensively in habitat disturbance and land management assessment studies (Czechowski 1982; Burel 1989; Luff *et al* 1992; Niemela *et al* 1993; Desender *et al* 1994; de Vries 1994; Loreau 1994; Lovei and Sunderland 1994; Butterfield *et al.* 1995; Friend 1995; Michaels and McQuillan 1995; Abensperg-Traun *et al.* 1996; Davies and Margules 1998; Garcia-Villanueva *et al.* 1998; Horne and Edwards 1998; Michaels and Mendel 1998; Ings and Hartley 1999; Koivula, *et al.* 1999; Michaels 1999 and others). Stages of forest regeneration (Niemela *et al* 1993; Butterfield *et al.* 1995; Michaels and McQuillan 1995; Garcia-Villanueva *et al.* 1998; Ings and Hartley 1999; Koivula, *et al.* 1999), size of, and degree and time of isolation of habitat remnant (de Vries 1994) have been correlated with changes in the carabid assemblage structure. However, responses to disturbances are usually quantified in terms of species richness which may prove less informative than assemblage composition and individual species responses. Niemela (1993) suggests that species history (phylogeny) should be incorporated into studies of community organisation, thereby improving interpretation of assemblage structure and individual species responses to disturbance.

Warren *et al.* (1987), Friend and Williams (1993), and Van Heurck *et al.* (1997, unpublished) found that fire had little effect on carabid species richness. In contrast, Holliday (1992) and Garcia-Villanueva *et al.* (1998) found that post-fire carabid species richness was lower than pre-fire levels, and the assemblage was dominated by opportunistic species. Habitat fragmentation, size of fragment and edge effects did not affect overall carabid species richness (Davis and Margules 1998), however these authors did report changes in abundance and presence of individual species.

Physical changes to a habitat have similar effects, with some species declining or disappearing completely and others increasing or colonizing the habitat (ground water levels; Desender *et al.* 1991; erosion and deposition patterns and vegetation structure; Niemela *et al.* 1988; Rushton *et al.* 1991; Niemela *et al.*1992). One or few carabid species were found to dominate assemblages after changes in bramble and hedgerow management practices were initiated (Burel 1991; Burel and Baudry 1991). Bromham *et al.* (1999) reported that beetle diversity in grazed areas of Victorian woodland remnants was lower than in ungrazed areas. Likewise, Eyre *et al.* (1989) and Petit and Usher (1998) found few carabid species dominate in heavily farmed areas of Europe. The level of disturbance was found to adversely affect carabid body size, and smaller, invasive species were more common in highly disturbed habitats in both agricultural and urban areas (Sustek 1987; Blake *et al.* 1994).

Composition of the carabid species assemblage of a habitat reflects the habitat disturbance history. Disturbed environments appear to have reduced numbers of carabid species with opportunistic smaller species dominating larger specialized species. The endemic carabid fauna of Australia, while being less speciose than their northern hemisphere counterparts (New 1998) reflect both human induced environmental disturbances and historical environmental changes. Because of the level of endemicity, responsiveness to abiotic factors (Thiele 1977; Lovei and Sunderland 1996; Boscaini *et al.* 2000) and the ease of which carabids can be collected, biogeographic relationships and the effects of environmental disturbances on the Australian carabid fauna can be studied.

1.4 THE QUINDALUP DUNE SYSTEM

Several major dune systems form the Swan Coastal Plain, and associated with them are various ecosystems reflecting the differing structures and ages of the dunes. The oldest dunes are many hundreds of thousands of years old, while the youngest, forming the current coastline, date from the late Holocene (Semeniuk, Cresswell and Wurm 1989). As a general, rule the fauna and flora of these regions show increasing diversity in a west-east direction, reflecting the increasing soil depositional complexity and geological age of the terrestrial environment (Marchant, Wheeler, Rye, Bennett, Lander and Macfarlane 1987; How and Dell 1994; Environmental Protection Authority 1998).

The Quindalup Dune System is the western-most geological feature on the Swan Coastal Plain. It forms a disjunct series of dune units extending from Dongara in the north to Dunsborough in the south. Formed during and since the Holocene marine transgression, commencing around 6500 years ago (Semeniuk *et al.* 1989), it is the youngest of a complex of dune units that make up the Swan Coastal Plain. The Quindalup Dune System abuts and partially overlies the Spearwood Dune System of Pleistocene age (see Chapter 2).

Since European settlement in 1829, the native bushland on the Swan Coastal Plain has been progressively cleared and has become increasingly fragmented. Bushland remnants are subjected to intense ongoing degradation as a result of illegal dumping, arson, and invasion by feral species (both plant and animal) and other disturbances. The Quindalup Dunes are no exception, and in addition are under increasing demand as prime beach-front real estate.

Despite the fact that Semeniuk *et al.* (1989) have shown that a variety of geomorphic, habitat and vegetation systems are present in the Quindalup Dune System, few areas are currently protected under the reserve system within the Perth Metropolitan Area. Conservation reserves which do contain Quindalup Dunes (Yalgorup National Park south of Perth; Yanchep National Park north of Perth; Wanagarran Nature Reserve; Nambung and Beekeeper-Mt Leseur National Parks near Cervantes) are not within the Perth Metropolitan Area.

The only conservation reserve within the metropolitan area that includes Quindalup Dunes is Trigg Island Reserve, which is an example of a perched dune system (Semeniuk *et al.*1989). Various other undeveloped areas of Quindalup Dune habitat within the Metropolitan area are reserved as recreation, camping, government and explosives reserves. Although some protection is provided under these non-conservation orientated classifications, the biota of these areas are not specifically protected, and flora and fauna are therefore still exposed to the effects of further fragmentation and degradation.

1.5 HABITAT FRAGMENTATION

Fragmentation and degradation of natural habitats have become critical issues within the wider initiative to maintain biodiversity and ecological stability. Ironically, in the absence of human activity these phenomena are important factors in maintaining species diversity and promoting speciation (Morell 1996). However, it is the elevated rate and extent to which they are occurring in all habitats due to human activity, which is the cause of alarm for conservation biologists.

Major ecological problems associated with habitat fragmentation are reduction of total habitat area (Davies and Margules 1998) and the alteration of physical parameters and ecological processes (Saunders *et al.* 1991; Brokaw 1998). The latter impacts can result in changes in microclimate and resources (e.g. food, living space), thereby inhibiting the viability and dispersal capacity of native organisms (Saunders *et al.* 1991; Yen and Butcher 1997).

Spatial and temporal distribution of remnants in the landscape also has an effect on species persistence in any of the individual remnant fragments (Saunders *et al.* 1991; Fahrig and Merriam 1994), especially if the population dynamics change in relation to the distance from the fragment edge (Fahrig and Merriam 1994). As the process of fragmentation occurs through time, a reduction in resources, increased competition for those resources, and decreased population size, coupled with stochastic events, will lead to species extinctions in the remnants (Diamond 1972, cited in Shafer 1990; Brokaw 1998). The rate at which extinction occurs is dependant on physical attributes of the fragment and the species involved, but the evidence suggests that species most at risk are those with large body and home range sizes or those at high trophic levels and with low dispersal rates, e.g. larger vertebrates or occupiers of specialist niches (Shafer 1990).

Island biogeography theory, while providing an initial basis for debate, has proven of limited utility in understanding the dynamics of populations isolated in habitat fragments (Margules *et al.* 1982; Saunders *et al.* 1991; Soberon 1992). Metapopulation dynamics theory and landscape ecology have developed out of island biogeography theory. These schools of thought attempt to understand the nature of fragmentation and how the biota of fragmented remnants interact with each other and with the surrounding matrix (Nee and May 1992; Samways 1994; Hanski 1998; Harrison and Bruna 1999).

Invertebrates tend to be 'fugitive species', maintaining sub-populations, which are effectively isolated from each other within a habitat (Simberloff 1978). However, these localised populations maintain the potential for inter-dispersal, thereby forming the effective metapopulations in a habitat (Nee and May 1992; New 1995; Hanski 1998).

Species survival in local sub-populations represents a balance between local extinction and colonisation (Hanski 1998). While extinction may be occurring in some local populations, other neighbouring populations may be increasing, following colonisation from other surrounding populations. By forming a network of sub-populations effectively isolated in various stages of development (intial colonisation, increasing population, satuation level, and finally reduction/extinction) from eachother the effects of habitat wide catastrophies (such as fire, flood, disease etc) can be minimised (Simberloff 1978; New 1995; Hanski 1998). However, as pointed out by Nee and May (1992), species within patchily distributed metapopulations are prone to local extinction in fragmented habitats. This is because at any one time only a few habitat fragments or patches may be occupied (New 1995), thereby limiting opportunities for re-colonisation from elsewhere.

Three interrelated factors affect re-colonisation of vacant fragments by sub-populations. Firstly, the number and spatial scale of fragments in the landscape affects an organism's ability to disperse between fragments (Burel 1989; Fahrig and Merriam 1994). Discussion in the literature on this topic centres around reserve design and the much debated "single large or several small" or SLOSS theory. Various authors (e.g. Higgs, Hobbs, Margules, Nicholls, Pressey, Saunders, Simberloff and Usher, among others) have contributed to this subject but as the majority of fragments are formed without consideration of these factors during the development of natural areas, reserve design theories have limited relevance (Saunders *et al.* 1991).

Secondly, dispersal ability within the landscape also influences an organism's ability to colonise. Fahrig and Merriam (1994) suggested that if the surrounding matrix is conducive to movement then only a few fragments are required to maintain the metapopulation. Burel (1989) however, observed that high dispersal rates generally equate to high extinction rates in a habitat, and low dispersal rates to low extinction rates; implying that highly mobile metapopulations have a higher probability of overall extinction by stochastic events than more sedentary ones.

Finally, an organism's ability to negotiate fragment edges influences the rate of re-colonisation. Stamps *et al.* (1987) and Samways (1994) discussed the permeability of different habitat edge types and the differing abilities of species to cross them. These authors suggested that some edges might be psychological barriers as well as physical ones to the individual species. The effectiveness of edges for promoting species diversity and their detrimental effects for dispersal have been extensively debated (Yahner 1988; Samways 1994; New 1995; Yen and Butcher 1997 and references therein). However much remains to be done in clarifying the concepts of "edge species" and edge dimensions in addition to understanding how individual species perceive and respond to them.

Arthropods, especially insects, perform vital functions within ecosystems as pollinators, predators, herbivores and decomposers, and also represent the major protein source for vertebrates (Majer 1983; Didham *et al.* 1996; Burke and Goulet 1998). Habitat fragmentation can disrupt these multi-trophic level interactions (by modifying herbivore communities, predator numbers etc.) and therefore can adversely effect ecosystem functioning (Didham *et al.* 1996; Yen and Butcher 1997; Harrison and Bruna 1999). However, little has been done to rationalise the attributes of arthropods in habitat fragmentation (Didham *et al.* 1998). At present it is not possible to make any generalisations concerning the impact of fragmentation, because responses vary greatly, being dependant on complex interactions of biotic and abiotic factors (e.g. size of fragment, position in the landscape etc; Margules *et al.* 1994; Bennett 1990, cited in Yen and Butcher 1997; Didham *et al.* 1998).

Several major experiments using artificially fragmented ecosystems are currently underway with a view to attempt to bridge this gap in the theoretical literature with empirical information about the effects on invertebrates (Margules 1992; Didham *et al.* 1998; Lovejoy 1986, cited in Piman 1998; Didham *et al.* 1998; Davies and Margules 1998). Initial results from these experiments suggest that poorly-dispersing but competitively dominant species will become extinct before rarer species. However, these results also show wide ranging responses between individual species and area, and thus are difficult to interpret (Didham *et al.* 1998). In addition, Davies and Margules (1998) suggest that populations do not have to be isolated by fragmentation to show declines.

The Quindalup Dune System can be considered an example of a naturally fragmentary environment placed under stress from added human-induced fragmentation. The bushland remnants are isolated from each other and under threat from further fragmentation and disturbance. The shape and position in the landscape of these remnants are linear in both respects. As a consequence of their shape and position in the landscape there are impacts on ecological processes and physical parameters, resulting in inhibition of population viability.

It is conceivable that the surrounding urban environment is not conducive to movement of all but the most mobile fauna between these fragments, which are effectively islands in a sea of urbanisation. Maintaining long-term population viability of the majority of the native fauna in these fragments may be impossible,. Especially those of species at high trophic levels or specialist niche occupiers (Shafer 1990). While this applies to most vertebrates, many long-lived invertebrates (for example predators such as carabids and various spiders) would also qualify.

1.6 AIMS AND THESIS STRUCTURE

This project was initiated to determine the effects of fragmentation on the diversity of ground beetle (Carabidae) fauna on the Quindalup Dune System within the Perth Metropolitan Area. To achieve this aim four objectives were identified:

1. To document the carabid taxa present.
2. To determine whether there is seasonal succession in carabid assemblages.
3. To determine whether carabids exhibit spatial partitioning within the Quindalup Dune System.
4. To investigate the importance of the Quindalup Dune System and its remnants in maintaining populations of these carabids, by comparing the carabid assemblages of the Quindalup Dune System with those present on the other geological formations that form the Swan Coastal Plain.

This thesis was designed to utilise, and extend the carabid fauna collected during the Urban Bushland Survey (How *et al.* 1996).

The remainder of this thesis comprises five chapters.

Chapter 2 places the study sites into context within the Swan Coastal Plain. The characteristics and components of the Swan Coastal Plain are briefly discussed, with detail given to the Quindalup Dune System. The recent history and general characteristics of each remnant bushland area under study are reviewed and specific site descriptions within the remnants are given.

Chapter 3 details the collecting methods, sources of environmental data and species distributional data, and analysis techniques.

Chapter 4 contains redescriptions of several carabid species, along with a description of a new species of broscine, *Gnathoxys pannuceus* sp. nov. These descriptions include gross genital morphology for both sexes for all flightless species except for *G. pannuceus* (male only). Wider distribution maps are presented for several species. A diagnostic key is presented for all Carabidae encountered in the Quindalup study sites.

In Chapter 5, the spatial and seasonal distributions of carabids collected between May 1993 and August 1997 are presented. These include species lists and abundances for fourteen remnant bushland areas surveyed both sequentially between 1993-1996, and concurrently over 1996-1997. The influence on carabid ecology of various environmental parameters is considered.

Chapter 6 contains a general discussion of the major findings of this work, with special consideration given to the conservation and management issues raised here.

CHAPTER 2:

HISTORY AND CHARACTERISTICS OF THE STUDY SITES

2.1 INTRODUCTION – THE SWAN COASTAL PLAIN

Established in 1829 along the Swan River, Perth is the largest urban development in the western half of Australia. The climate combines hot dry summers and wet winters, with mean summer and winter temperatures of 24°C and 13°C respectively (Environmental Protection Authority 1998). Annual rainfall varies from 800-1000 mm across the Plain with more than half of this falling between June and August (Environmental Protection Authority 1998). The mild climate has encouraged rapid urbanisation over the last 170 years. This expansion across the Swan Coastal Plain has resulted in extensive clearing and modification of much of the native vegetation, leaving only small bushland remnants irregularly placed within the landscape.

The Swan Coastal Plain is the western-most component of the environmental management area known as the *Darling System* in southwestern Australia. It consists of several distinct sedimentary units arranged parallel to the present coastline, each of which differs in geomorphic origin, topography, soil structure and drainage (Churchward and McArthur 1980; Environmental Protection Authority 1998). Distinct vegetation assemblages are associated with these units, forming a complex mosaic of habitats across the Plain (How *et al.* 1996; Environmental Protection Authority 1998).

Alluvial and colluvial deposits characterise the eastern geological units, with aeolian deposits dominating the western units (Searle and Semeniuk 1985; Environmental Protection Authority 1998). The oldest geomorphic features (positioned against the Darling Scarp) are the Ridge Hill Shelf and the Pinjarra Plain (Searle and Semeniuk 1985). These units consist of old beach sands of late Pliocene age, in addition to colluvial and alluvial deposits, dating from the Pleistocene to the Holocene (Searle and Semeniuk 1985; Environmental Protection Authority 1998).

On the Plain proper there are three major Dune Systems approximating various Quaternary coastlines (Figure 2.1). The most easterly is the Bassendean System formed from leached aeolian sand (Biggs *et al.* 1980; Searle and Semeniuk 1985). Bastian (1996) dated its age as being between the Pliocene and early Pleistocene. Lying west of this System is the Spearwood Dune System, generally considered to be from the Middle to Late Pleistocene in age (Biggs *et al.* 1980). It has a composite structure of multiple dune systems (Kendrick *et al.* 1991; Bastian 1996) and comprises a core of Tamala Limestone with an overlying unit of residual reworked aeolian sand (Kendrick *et al.* 1991; Bastian 1996; Environmental Protection Authority 1998).

The Quindalup Dune System, the main focus of this study, is the youngest and most westerly of the Dune Systems. Generally consisting of Holocene calcareous sands (Churchward and McArthur 1980; Semeniuk, Cresswell and Wurm 1989), the dunes form a relatively narrow and discontinuous band extending from Dongara to Busselton along the present coastline (Figure 2.2). The formation of these dunes commenced during the Early Holocene and continues in some areas today (Semeniuk *et al.* 1989).

This Chapter contains descriptions of all remnants from all landforms on the Swan Coastal Plain surveyed for their carabid fauna between 1993-1997. As the Quindalup Dune remnants are the principle focus of the study, their vegetative and physical features are discussed at length, and histories of individual remnants are provided. Descriptions of the remnants on the other landforms surveyed are restricted to brief vegetative and soil summaries adapted from How *et al.* (1996).

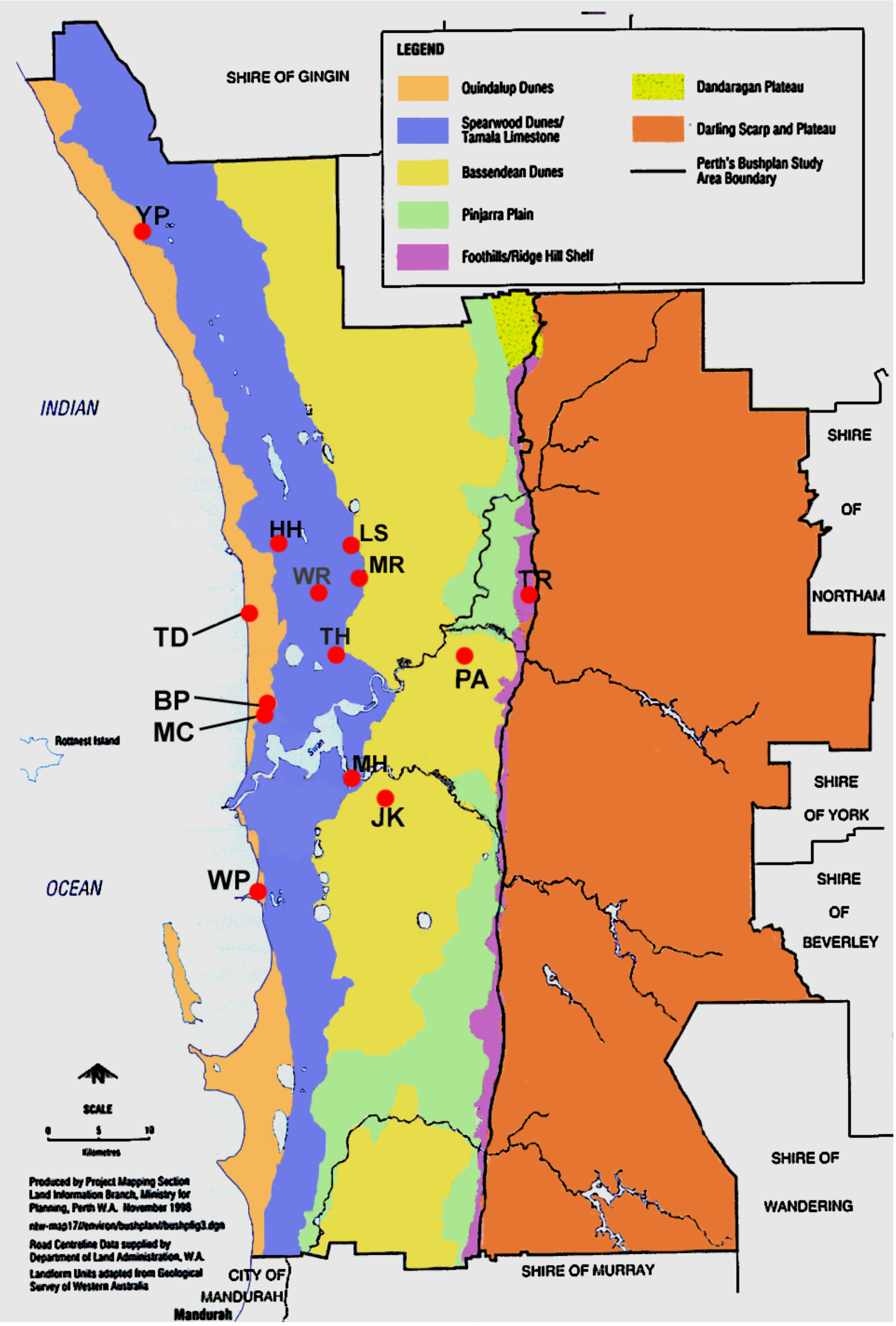

Figure 2.1: **The geomorphology of the Swan Coastal Plain**

The various geological units and the bushland remnants surveyed between 1993-1997, in relation to the Perth Metropolitan Area are illustrated. (Reproduced and adapted with permission, Figure 3, pp 8, *Perth's Bushplan*, Ministry of Planning). Alpha labels identify the positions of reserves investigated in the study. See text for explanation.

2.2 THE QUINDALUP DUNE SYSTEM

2.2.1 GEOMORPHOLOGY

Four distinct phases of accumulation are identified in the Quindalup Dune System (Churchward and McArthur 1980; Bettenay 1984). Steep-sided parabolic dunes extending up to six kilometres inland with lime cementation at one metre depth comprise the oldest phase (Bettenay 1984). The youngest phase of activity is ongoing, most notable along the southern end of the dune system (Churchward and McArthur 1980), and is characterised by coastal dunes with steep leeward slopes and gentle windward slopes (Bettenay 1984).

Searle and Semeniuk (1985) and Semeniuk *et al.* (1989) divided the Quindalup Dunes into five naturally occurring sectors, each exhibiting particular ancestral geomorphology, processes of sedimentation, erosion, transport, stratigraphic evolution and modern geomorphology. From south to north the sectors 1-5 are identified as (1) Geographe Bay-Leschenault; (2)Leschenault-Preston; (3) Cape Bouvard-Trigg Island; (4) Whitfords-Lancelin; and (5) Wedge Island-Dongara (Figure 2.2). Common to all sectors are a number of stratigraphic units. Safety Bay sand was identified as a discrete unit (Semeniuk and Searle 1985; Semeniuk *et al.* 1989) and is made of shell fragments (typically foraminifer and mollusc) and various amounts of quartz and feldspar (Churchward and McArthur 1980). In addition there is a Holocene seagrass sedimentary unit (Becher sand) and an estuarine sedimentary unit (Leschenault Formation; Searle and Semeniuk 1985). These three units were found to have up to five different relationships with the underlying Tamala Limestone in various combinations in each of the Sectors (Semeniuk *et al.* 1989).

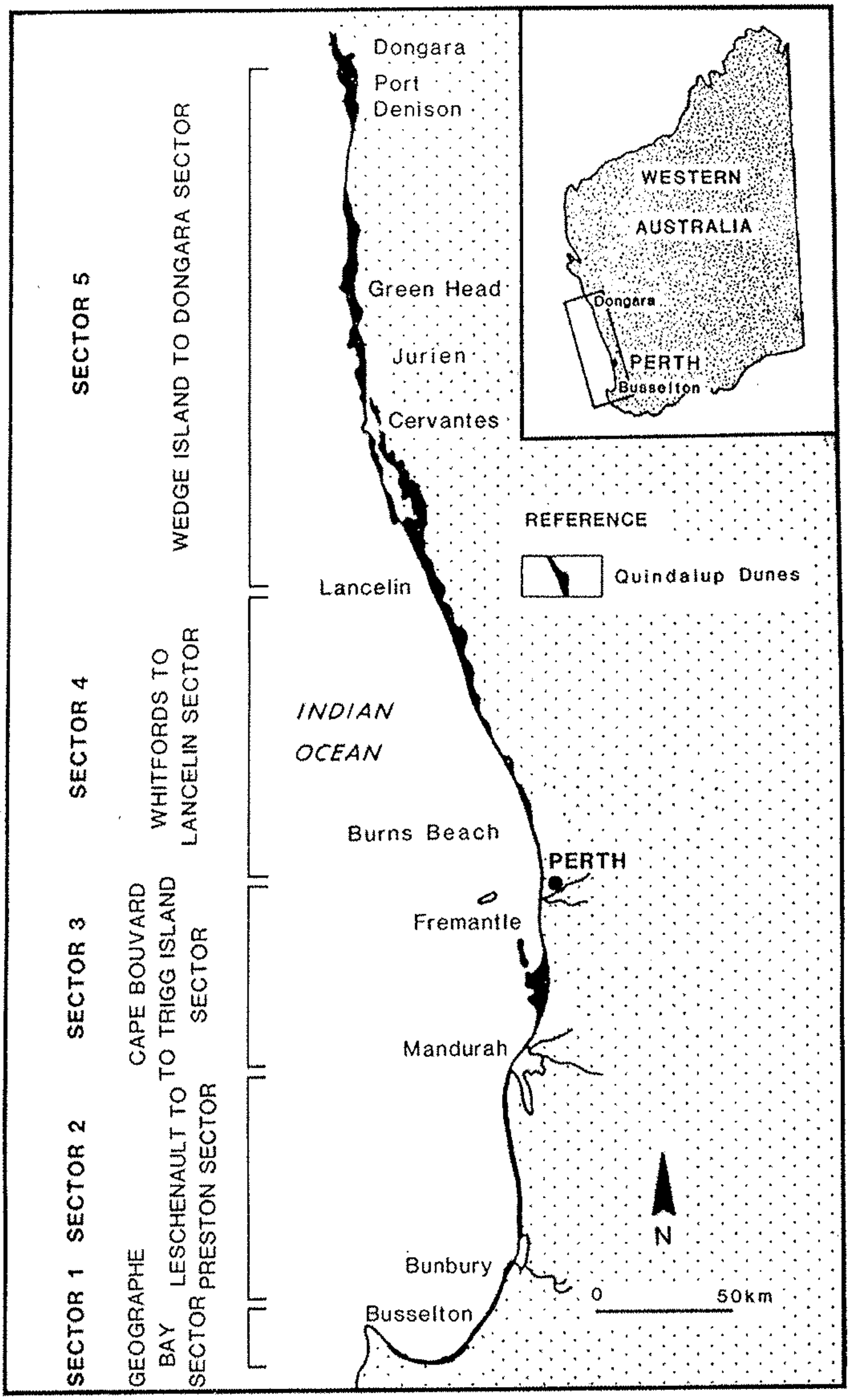

Figure 2-2: **The Quindalup Dune System**
The distribution of the Sectors and the positions of remnant bushland areas within them is shown (Adapted from Searle and Semeniuk 1985; Semeniuk *et al.* 1989).

The two sectors relevant to this study are the Cape Bouvard-Trigg Island and Whitfords-Lancelin Sectors within which the following reserves were studied (see Figure 2.1):

- Woodman Point (WP)
- Mount Claremont (MC)
- Bold Park (BP)
- Trigg Dune Reserve (TD)
- Yanchep National Park (Whitfords-Lancelin Sector) (YP)

The geomorphology of the Cape Bouvard-Trigg Island Sector is characterised by complex nearshore bathymetry and discrete cells of Holocene sediment accretion, reflecting nett, long-term coastal progradation (Searle 1984; Searle and Semeniuk 1985). Semeniuk *et al.* (1989) reported that beachridge accretion lines indicate successive shorelines, with intermittent erosion forming localised blowouts and parabolic dunes extending landwards. On a localised scale, parallel sand ridges up to 3 m high and 50 m wide with associated depressions commonly occur, along with localised blowouts, parabolic dunes up to 20-30 m high, bowls, wetlands and other residual features. Low to steep beachridges and a variety of other dune types are found on the seaward zone (Semeniuk *et al.* 1989). Linear crests, slopes and depressions are the dominant landscape components and are found within 3-5 m of the water table (Semeniuk *et al.* 1989).

In contrast, in the Whitfords-Lancelin Sector, the Quindalup Dunes are restricted to a thin strip along a diffuse rocky coast, with pocket beaches interspersed with straight, beached coast backed by high dunes. In addition, local promontories extend nearly a kilometre seawards and support cuspate dune-fields (Searle and Semeniuk 1985). On a smaller scale this Sector is characterised by complex systems of overlapping and detached dunes with beachridges, swales, parabolic dunes, conical residual hills and wetlands (Semeniuk *et al.* 1989). Unlike the Cape Bouvard-Trigg Island Sector, the Whitfords-Lancelin Sector is dominated by parabolic dunes, chaots, and blowouts with their associated crests and slopes situated high above the water table. They usually overlie limestone with calcrete capstone. Even the flatter areas are elevated above the water table (Semeniuk *et al.* 1989).

2.2.2 *SIGNIFICANCE OF THE QUINDALUP REMNANTS*

A number of vegetation complexes or associations were identified by the Bushplan Report (Environmental Protection Authority 1998) as occurring on the Quindalup Dunes. Of these, one is confined to this dune system and two are threatened ecological communities. As stated in that report, only 48% of the native vegetation on the Quindalup Dunes still exists. This remnant vegetation is highly fragmented, occurring in seventeen separate areas within the Perth Metropolitan Area (Environmental Protection Authority 1998).

The seventeen areas are currently classified for various public and government purposes (including urban, roads, public use and recreation), as crown reserves, nature reserves or as rural (Environmental Protection Authority 1998), and therefore do not necessarily have conservation as their main aim. While these areas equate to 14% of the original 24,381 ha of dunes with some protection, most of these areas are less than 500 m wide, emphasising the seaward instead of landward communities (Semeniuk *et al.* 1989; Environmental Protection Authority 1998).

Significant structural and floristic changes can occur within and between similar habitats, within and between Quindalup Dune sectors (Semeniuk *et al.* 1989). The authors go further to state that, as a result, the vegetation complexes may be restricted to localised habitats. Semeniuk *et al.* (1989) stated that the conservation reserves on the Swan Coastal Plain which contain Quindalup Dunes do not adequately represent the regional diversity in either landform or vegetation associations, and only Woodman Point and Trigg Dune Reserves (Sector 3, Cape Bouvard-Trigg Island) are within the Perth Metropolitan Area. The main features of the Cape Bouvard-Trigg Island Sector, are cuspate beachridge plains composed of low relief shore-parallel sand ridges and intervening swales (Semeniuk *et al.* 1989) and these are not represented in any reserve.

Sectors 3 and 4 (as described by Searle and Semeniuk 1985, and Semeniuk *et al.* 1989) are located within the greater Perth Metropolitan Area, and therefore are under the greatest public pressure to be rezoned for housing. Currently regions of undeveloped Sector 4 dunes exist in the northern reaches of the Metropolitan Area. Therefore there is the potential to form conservation regions, which encompass both seaward and landward areas of the Quindalup Dune System in this Sector. Until this is accomplished however, the current conservation areas will only partially represent the extent of the variability of geomorphology, vegetation and (potentially) fauna assemblages extant on the Quindalup Dune System.

2.3 REMNANTS SURVEYED

The remnant bushlands surveyed on the Swan Coastal Plain within the Perth Metropolitan Area differ substantially in fragment age, size and disturbance history. Locations of the surveyed remnants are presented in Figure 2.1.

All the bushland areas surveyed have significant conservation value (Department of Conservation and Environment 1983; Environmental Protection Authority 1998). The Trigg/Karrinyup Reserves are on the Register of the National Estate while Bold Park and the adjacent bush land areas (including Mount Claremont) are awaiting evaluation, on the Interim List. Initial evaluation is required for Woodman Point, which also is on the Interim List of the Register of the National Estate.

This study has two complimentary components. The first, and the focus of this study is the seasonality of the carabid assemblages of the Quindalup Dune System. This was determined by obtaining seasonal and multiple year data in several remnants (two sites each in Bold Park and Trigg Dune Reserve approximating areas originally surveyed by How *et al.* 1996) in addition to the Yanchep National Park sites, which were concurrently surveyed during 1996-1997. The second component is a general assessment of the assemblages on the wider Swan Coastal Plain.

The study site descriptions with their identifying codes (used for this research) are presented in two sections. In the first section a brief history and description of the Quindalup Dune System remnants surveyed are presented. The second section consists of brief descriptions adapted from How *et al.* (1996) of the remnants surveyed on the Spearwood and Bassendean Dune Systems, and the Ridge Hill Shelf. Of these remnants, the Perth and Jandakot Airport Bushlands and Talbot Road Reserve are also on the Interim List of the Register of the National Estate (How *et al.* 1996).

Table 2.1 presents, for each site the vegetation descriptions, soil and leaf litter characteristics, and latitude and longitude to within 20 m (recorded using a hand held Magellan Pathfinder G.P.S.).

2.3.1 QUINDALUP DUNE SYSTEM REMNANTS

2.3.1.1 Woodman Point Reserve (WP)

Woodman Point Conservation Reserve is located just north of the Quarantine Station and Explosives Magazine Reserve on Woodman Point, which is about 40 km and 9 km south of Perth City and the Swan River mouth respectively (Figure 2.1; Powell and Emberson, 1981). Three separate reserves exist on the Point and were identified in the System Six Report and the current Perth's Bushplan Report as: N° 24305 (113.31 ha), N° 24306 (35.56 ha), and N° 24306 (17.81 ha), making a total area of 170 ha (Department of Conservation and Environment 1983; Department of Environmental Protection 1998). The fragments are separated by public access paths rather than bituminised roads, and for the purposes of both reserve management and this study, the fragments are treated as one entity.

The Point itself is typical Quindalup beach sand overlying a limestone shelf with sand ridges and the swales up to 5 m below sea level. The sand ridge formation present suggests that the Point is no more than 5 000 years old (Powell and Emberson 1981).

Four plant communities form a mosaic of vegetation types. Included are unique stands of Rottnest Island Cypress and Tuart. The four communities as described by Powell and Emberson (1981) are –

1. Seaside Community – including *Cakile maritima* and *Spinifex hirsutus*;
2. Cypress Belt – dense thickets of *Callitris preissii* (Rottnest Island Cypress) with *Melaleuca huegelii* and some patches of *Acacia rostellifera;*
3. Tuart Woodland – *Eucalyptus gomphocephala* occurs on the eastern section of the point with an understorey of *A. rostellifera;* and

4. Heath/Scrub – heath (<2 m tall) mainly occurs on the ridges. Dominant heath plants are *Melaleuca acerosa, Diplolaena dampiera, Conostylis candicans* and *Stipa variabilis*. Scrub (>2 m tall) occurs in small patches in the woodland. Dominant species are *A. rostefillera, Santalum acuminatum, Spyridium globulosum, M. acerosa,* and *Leucopogon parviflorus.*

The disturbance history of the reserve is intertwined with its use over the last 125 years. Europeans first began to use Woodman Point in 1876 with the establishment of a Quarantine Station and later in 1903 as an Explosives Reserve (Powell and Emberson 1981, pp.11, 12). Over the ensuing years the Point has become gradually enclosed on the eastern, northern and southern sides by industry and housing. During its use as a Quarantine Station and Explosives Reserve large areas of vegetation were removed for fire control, resulting in areas of open parkland and grassy paddocks. By the early 1980s the Quarantine Station and Explosives Magazine had been moved and the Point had become a botanical Conservation Reserve. As of 1993, the Point is considered to be analogous to a regional park, and has been declared a "C" class reserve managed by the Department of Conservation and Land Management (CALM) (Department of Conservation and Land Management 1993).

Few major fires have occurred on the Point. Powell and Emberson (1981 pp.12) report that only two major fires have occurred in living memory, one in about 1949 along the southern edge, the other in January 1973 along the eastern section of the Tuart woodland. The authors also report evidence (pp.30) suggesting that the last fire prior to 1949 may have occurred around 1810. Fire and other forms of disturbance therefore appear to be an uncommon occurrence in the ecosystem of the Point.

To sample the ground-dwelling carabid fauna four sites were established and operated during 1994-1995 by How *et al.* (1996). Vegetation and soil descriptions are presented in Table 2.1. The vegetation structures of sites WP1, 2 and 3 are presented in Plate 2.1 (a-c).

a)

b)

c)

Plate 2.1: **Vegetation of Woodman Point Reserve sites**

a) WP1

b) WP2

c) WP3 (WP4 is identical to WP3 in species and composition).

Photos reproduced with permission – a, b- R. How; c- J. Dell.

2.3.1.2 Mount Claremont (MC) and Bold Park (BP)

Mount Claremont Reserve and Bold Park (see Figure 2.1) form one unit, lying adjacent to each other. The former covers an area of 45 ha and Bold Park, which is 338 ha in area, lies directly to the north of it. Currently, Mount Claremont Reserve, now known as 'The Sanctuary' (Interim Environmental Management Plan 2000- J. Mansell-Fletcher, pers. comm.) is managed by the Botanic Gardens and Parks Authority as part of Bold Park. For the purposes of clarity in this study, it is referred to as Mount Claremont. Located approximately 8 km west of Perth, these two areas are the central links in a chain of remnant bushland areas including Swanbourne Beach, Swanbourne Rifle Range and Kings Park.

The southern regions of Bold Park and all of Mount Claremont are typical Quindalup Dune soils, while the remaining areas of Bold Park to the north consist of Spearwood soils (Mitchell McCotter 1993). These authors reported that the Quindalup Dunes in the Park are of a parabolic and nested parabolic nature interspersed with interdunal depressions and hollows. In addition, these dunes were found to have slopes of up to 20% in some areas.

Various areas of Bold Park have been studied (Mitchell McCotter 1993 and references therein), but the most comprehensive study of the vegetation of Bold Park was undertaken by Keighery *et al.* (1990). Seven formations and twenty associations were recognised by the authors in the main body of the Park. Dominant tree and shrub species include *Banksia prionotes, Eucalyptus decipiens, E. calophylla, E. marginata, E. gomphocephala, E. foecunda, Acacia rostellifera, A. xanthina, Dryandra sessilis,* and the introduced pines *Pinus pinasta* and *P. radiata.* Mount Claremont is very similar vegetatively but tends to be dominated by *Banksia* shrubland and heath. It also has significant areas of *Acacia rostellifera* and *E. gomphocephala* in low lying areas.

The area that encompasses Bold Park and Mount Claremont Reserve was first developed during the 1920s with the auctioning of land for housing west of West Coast Highway and south of The Boulevard. In the 1960s, the area was further isolated by housing to the north and south, and areas east of Perry Lakes. The original public park was approximately 499 ha in size. Over the ensuing years parts were excised and developed as a golf course, residential area, school, reservoir and sub-station to form its present size of 338 ha (Mitchell McCotter, 1993). Mount Claremont and Bold Park have significant conservation value (Environmental Protection Authority 1998) and it is unlikely that further excising of land from either will occur.

The fire history for Mount Claremont Reserve and Bold Park is uncertain, but few significant fires have occurred since the initial subdivision. The majority have been deliberately lit and confined to small areas of the perimeter. The central areas of these remnants have not been burned for many years (J. Stansfield, pers. comm. 2000).

To survey the carabid fauna, two sites were established in Mount Claremont (MC) encompassing the dune top and swale vegetation types, and were operated in 1994-1995 by How *et al.* (1996). Two sites were established on Quindalup soils in Bold Park (BP1, BP5) and two on Cottesloe sands of the Spearwood Dune System (BP3, BP4); these were operated by How *et al.* (1996) from 1993-1994. Sites BP1 and BP5 were reopened in 1996-1997 for the present study. The site descriptions are presented in Table 2.1. Plate 2.2 (a, b) and Plate 2.3 (a-c) illustrate the differing vegetation of the Quindalup sites MC1, 2; and BP1, 5 and typical Spearwood vegetation (as exemplified by BP2; How *et al.* 1996) respectively.

a)

b)

Plate 2.2: **Vegetation of Mount Claremont Reserve sites**

a) MC1

b) MC2

Photos reproduced with permission- J. Dell.

Plate 2.3: **Vegetation of Bold Park sites**

a) BP1

b) BP5

c) BP2, showing typical Spearwood community structure

Photo a, b- N.A. Guthrie; c- reproduced with permission- R. How.

2.3.1.3 Trigg Dune Reserve (TD)

Bounded and fragmented by major sealed roads and housing, the Trigg Bushland Reserve covers an area of approximately 150 ha in the City of Stirling (Figure 2.1). Consisting of five remnants, the reserve is a mosaic of coastal Quindalup geomorphology and vegetation, and has been classified by the System Six Report[1] (Department of Conservation and Environment 1983) as having significant dune conservation, education and recreation value.

Four sites (TD1, TD2, TD3, TD4) were established during 1994-1995 by How *et al.* (1996). Site TD3 was abandoned during the survey (R. How, pers. comm.). Approximate areas corresponding to sites TD2 and TD4 were operated again during 1996-1997. Site descriptions are presented in Table 2.1.

The northern fragment totals 22.4 ha in area. Site TD1 was placed in this fragment. Site TD2 was situated in the 8 ha central fragment. The final fragment sampled at TD4 covers 16 ha. The two other fragments, situated to the south and east, were not surveyed. Typical vegetation of sites TD2 and TD4 is illustrated in Plate 2.4 (a-c).

As the Trigg Dune Reserve is surrounded by roads and housing the occurrence of fires is kept to a minimum, but a fire was deliberately lit in the western 16 ha fragment on December 31 1996. This extremely hot fire burnt the middle third of the fragment resulting in almost total vegetation loss in the burnt area. The trap line and previous six weeks of sampling were lost.

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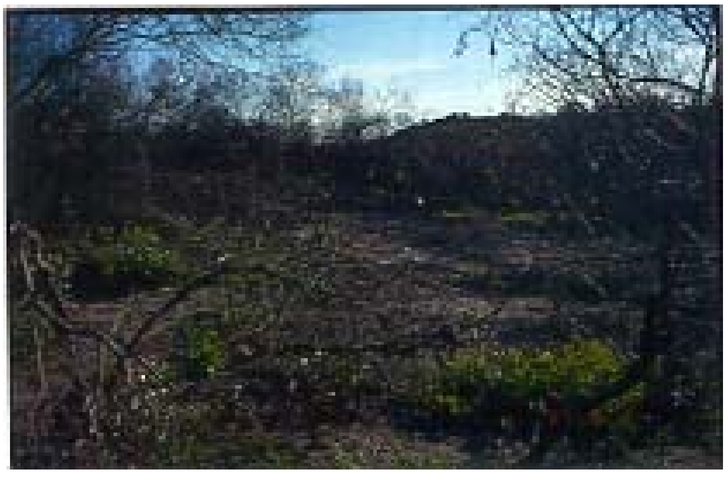
[1] To facilitate the development of a representative reserve system encompassing the major native fauna and flora communities in Western Australia, the state was divided into twelve regions or systems by the Conservation Through Reserves Committee (CTRC; Department of Conservation and Environment 1983). The Darling System, or System 6, consists of the Swan Coastal Plain extending from Moore River in the north, to the Blackwood River in the south (including the Perth Metropolitan Area), plus the Darling Scarp east to the towns of Toodyay, Boddington and Boyup Brook. The System 6 Report was produced to document the conservation values of the remaining intact native bushland fragments (including heaths, woodlands and wetlands) in the region. The recommendations provided took into consideration commercial and productive uses, local government, urban and recreational planning and tourism as well as conservation aspects.

a)

b)



c)

Plate 2.4: **Vegetation of Trigg Dune Reserve sites**

a) TD2

b) TD4, unburnt

c) TD4, burnt, showing initial signs of regrowth.

Photos- N.A. Guthrie.

2.3.1.4 Yanchep National Park (YP)

Yanchep National Park is located 48 km north of Perth on either side of the Wanneroo-Lancelin Road and covers an area of 2799 ha (see Figure 2.1 for the Park's position on the Swan Coastal Plain). First explored by Europeans around the 1830's, the area encompassing the Park was used as a stock route. The area was gazetted as a reserve in 1905, and had various uses as a recreational Park before becoming a National Park in 1969 (Department of Conservation and Land Management 1987). Currently it is a component of the proposed Gnangara Metropolitan Park, encompassing Yanchep and Neerabup National Parks, Lake Joondalup and State Forest No. 65 (Department of Conservation and Land Management 1987). The surrounding land to the north, east and south-east are pine plantations, and to the west and south-west is private farmland.

The Park is situated on a landform known as the Dandaragan Trough (Playford *et al.* 1975), and straddles the Spearwood and Quindalup Dune Systems (Department of Conservation and Land Management 1989). The younger system is restricted to two sections of the park, the watershed in the north-west corner, and a small section north of Pipidinny Swamp and east of Wilgarup Lake. Both northern and southern areas show the parabolic dune formation characteristic of the Whitfords-Lancelin Sector (Semeniuk *et al.* 1989).

Due to its large size and relatively unfragmented nature, Yanchep National Park is considered a good example of native bushland with high conservation value close to the Perth Metropolitan Area. Two sites were established in the areas of Quindalup heath to survey the terrestrial carabid fauna, one in the north (YP1) and the other in the south (YP2). The sites were operated from August 1996-August 1997. The site information is presented in Table 2.1. Plate 2.5 (a, b) illustrates the vegetation of each trap site.

a)

b)

Plate 2.5: **Vegetation of Yanchep National Park sites**

a) YP1

b) YP2.

Photos- N.A. Guthrie.

2.3.2 *SPEARWOOD DUNE SYSTEM REMNANTS*

The Spearwood Dune System forms the main portion of the Swan Coastal Plain (Figure 2.1), producing rocky shores at the coast and nearshore island systems which are a result of incomplete inundation of the dune ridges by the last post glacial transgression (Searle and Semeniuk 1985). Formed during the middle to late Pleistocene (Biggs *et al.* 1980; Bastian 1996), two main soil types are recognised: the older Karrakatta Sands, and the more coastal Cottesloe Sands (Biggs *et al.* 1980; Environmental Protection Authority 1998). Two main elements characterise both these Sands, Tamala Limestone and overlying residual sand (Bastian 1996).

Closed heaths on limestone outcrops typify the vegetation on the Cottesloe sands. On the deeper sands low open forests and woodlands of various species of *Banksia* species and Jarrah/Tuart are found, with the latter dominating in southern regions (Heddle *et al.* 1980; Environmental Protection Authority 1998). In contrast, vegetation on the Karrakatta Sands is predominantly low open forests dominated by Banksia species. Jarrah is absent and Tuart uncommon in the northern regions, but in the southern areas both species are present along with Marri (Heddle *et al.* 1980; Environmental Protection Authority 1998). Descriptions of each site are given in Table 2.1.

2.3.2.1 Hepburn Heights (HH)

Approximately 110 ha in size, Hepburn Heights is situated on the Cottesloe Sands of the Spearwood Dune System in the northern suburbs of the Perth Metropolitan Area. Four major vegetation types identified by Keighery and Kieghery (1991) occur in this remnant; *Eucalyptus gomphocephala* Woodland, *E. marginata* Low Open Woodland, Heath and *Banksia* Low Woodland. Four sampling sites were operated in 1995-1996.

2.3.2.2 Mount Henry Bushland (MH)

Isolated to the north by suburbs, the 13 ha Mount Henry Bushland is bounded on all other sides by the Canning River. Dominated by *Banksia* Low Woodland, the remnant occurs on Karrakatta Sands of the Spearwood Dune System. Two sites in this remnant were surveyed in 1994-1995.

2.3.2.3 Tuart Hill Bushland (TH)

This remnant is located within the grounds of the National Broadcasting Service Transmission Station in the northern suburbs and is approximately 9 ha in size. Located on the Spearwood Dune Karrakatta Sands, the vegetation is predominantly *Eucalyptus/Banksia* Woodland. Two sampling sites were operated in 1993-1994.

2.3.2.4 Warwick Road Reserve (WR)

Surrounded by Erindale and Wanneroo Roads, Warwick Road Reserve is divided into two fragments of 14.4 ha and 28.8 ha by the minor Lloyd Road and is situated on the Karrakatta Sands of the Spearwood Dune System. Two sites were operated in 1995-1996.

2.3.2.5 Landsdale Farm School (LS)

Situated on the junction of the Spearwood and Bassendean Dune Systems, the vegetation of this 16.2 ha remnant is *Banksia* Low Woodland. One sampling site was operated during 1995-1996.

2.3.2.6 Marangaroo Conservation Reserve (MR)

Also situated on the junction between the Spearwood and Bassendean Dune Systems, this 28.1 ha remnant is dominated by *Eucalyptus/Banksia* Woodland and *Banksia* Low Woodland. Two sites were operated in 1995-1996.

2.3.3 BASSENDEAN DUNE SYSTEM AND RIDGE HILL SHELF REMNANTS

The Bassendean Dune System and the Ridge Hill Shelf form the geological junction between the Swan Coastal Plain and the Darling Plateau. Generally considered to be formed during the Pliocene to Early Pleistocene, the Bassendean Dune System has somewhat flattened topography and forms a broad sand plain at the foot of the Darling Scarp (Bastian 1996). Complex vegetation communities present on the Bassendean Dune System reflect the distributions of sandy areas, low-lying damp lands and upper slopes. In the drier northern regions low open forest and low open woodlands of *Banksia* and *Melaleuca* species dominate. Jarrah, sheoak and marri replace them in the wetter southern regions. Speciose understories occur in both regions, reflecting the gradual increase in moisture levels (Heddle *et al.* 1980; Environmental Protection Authority 1998). Site descriptions are adopted from How *et al.* (1996) and are given in Table 2.1.

2.3.3.1 Jandakot Airport (JK)

This remnant covers approximately 900 ha in the Jandakot Airport grounds. It is dominated by *Banksia* spp., *Eucalyptus todtiana, Melaleuca preissiana, Nuytsia floribunda, Allocasuarina fraseriana* Woodland. The remnant is situated on the Bassendean Dune System. Two sites were operated in 1994-1995.

2.3.3.2 Perth Airport (PA)

Covering approximately 800 ha, the bushland present at the Perth Airport represent Southern River and Guildford Vegetation Complexes on the Bassendean Dune System. The four sites (sites PA5-8) were operated in 1993-1994 and are from a series of sites that were used for monitoring purposes by the Western Australian Museum (R. How-pers. comm.).

2.3.3.3 Talbot Road Reserve (TR)

Located on the Ridge Hill Shelf geological unit, the remnant is approximately 90 ha in size and 30 km northeast of Perth. Four sites were operated in 1993-1994 to reflect the various vegetation complexes and physical characteristics of the remnant.

Table 2-1: Sampling site descriptions of each remnant, illustrating within and between differences in vegetation, soil and leaf litter characteristics.
Remnants are listed south-north within each dune system, i.e. Quindalup Dune System-WP, MC, BP, TD and YP; Spearwood Dune System- HH (Cottesloe Sands), MH, TH and WR (Karrakatta Sands), LS, MR (Spearwood/Bassendean Dune junction soils); Bassendean Dune System-JA, PA; Ridge Hill Shelf- TR. Information is extracted from How *et al.* (1996) except for BP, TD and YP sites, 1996-1997.

SITE	LATITUDE	LONGITUDE	VEGETATION PRESENT	LEAF LITTER	SOIL
WP1	32°07'47"S	115°45'23"E	*Callitris preissii, Scirpus acuminatum, Acacia rostellifera*, exotic grasses (e.g. *Asphodelus fistulosus* onion grass).	Continuous <5 cm deep; terete leaves, branches, dead grass	10YR 7/1 light gray sand
WP2	32°07'50"S	115°45'28"E	*A. rostellifera, Myrisphyllum asparagoides, Lepidospermum gladiatum* and grasses.	Continuous <5 cm deep; terete leaves, branches, dead grass	10YR 7/1 light gray sand
WP3	32°07'58"S	115°45'29"E	*A. rostellifera, Spyridium globulosum, C. preissii, M. asparagoides, Lepidospermum* spp., exotic grasses and creepers.	Continuous >5 cm deep	10YR 6/2 light brownish gray sand
WP4	32°07'58"S	115°46'29"E	*Eucalyptus gomphocephala*, thickets of *A. rostellifera, S. globulosum, C. preissii, M. asparagoides, Lepidospermum* spp., exotic grasses and creepers.	Continuous >5 cm deep	10YR 6/2 light brownish gray sand
MC1	31°57'40"S	115°46'60"E	1.5-2.5 m Unstratified tall heath with *Calothamnus quadrifidus, Olearia axillaris, Melaleuca* spp., *A. rostellifera.*	Continuous >5cm deep	10YR 6/2 light brownish gray sand
MC2	31°57'39"S	115°45'56"E	3-4 m *A. rostellifera*, few *Banksia attenuata*, few 10 m *E. gomphocephala, Melaleuca* spp., *O. axillaris, Lepidospermum* spp. and grasses	Continuous >5 cm deep; terete leaves and dead shrubs	10YR 5/2 grayish brown sand
BP1(93-94)	31°57'11"S	115°45'50"E	*Melaleuca* spp. dominant, *O. axllaris, C. quadrifidus, Pelargonium capitatum*, grasses	75% of area; up to 2 cm deep	10YR 5/2 grayish brown sand
BP1(96-97)	31°57'12"S	115°46'31"E	*Melaleuca* spp. dominant, *O. axllaris, C. quadrifidus, Pelargonium capitatum*, grasses	75% of area; up to 2 cm deep	10YR 5/2 grayish brown sand
BP3	31°56'30"S	115°46'27"E	4-7 m *B. menziesii, B. attenuata, C. quadrifidus, A. humilis, Macrozamia riedleyi, Melaleuca* spp., *P. capitatum* and exotic grasses.	Continuous; 5 cm deep	10YR 5/2 grayish brown sand
BP4 -	31°56'29"S	115°46'16"E	Dominated by 10-20 m *E. gomphocephala*, 2-5 m *B. attenuata, B. menziesii*, <2 m *A. humilis, M. riedleyi* and exotic grasses	<50 % cover	10YR 5/2 grayish brown sand
BP5(93-94)	31°57'14"S	115°46'16"E	*Melaleuca* spp., *O. axillaris, P. capitatum* and exotic grasses	Discontinuous with <50 % cover	10YR 5/2 grayish brown sand
BP5(96-97)	31°57'07"S	115°45'54"E	*Melaleuca* spp., *O. axillaris, P. capitatum* and exotic grasses	Discontinuous with <50 % cover	10YR 5/2 grayish brown sand
TD1(95-96)	31°52'09"S	115°45'38"E	Dominated by 2-5 m *B. attenuata, E. gomphocephala, A. pulchella, C. quadrifidus, M. riedleyi* and *A. humilis*	Continuous <5 cm deep	10YR 7/1 light gray sand
TD2(96-97)	31°52'31"S	115°45'44"E	Unstratified *Melaleuca* spp., *O. axillaris*, *Santalum acuminatum* and *A. humilis*	Continuous <5 cm deep	10YR 7/1 light gray sand
TD2(95-96)	31°52'30"S	115°45'35"E	Unstratified *Melaleuca* spp., *O. axillaris*, *Santalum acuminatum* and *A. humilis*	Continuous <5 cm deep	10YR 7/1 light gray sand
TD4(95-96)	31°52'35"S	115°45'37"E	*A. rostellifera*, *O.axillaris*, *C. quadrifidus* and *Hemiandra pungens*	Continuous <5 cm deep	10YR 7/1 light gray sand
TD4(96-97)	31°52'36"S	115°45'41"E	*A. rostellifera*, *O.axillaris*, *C. quadrifidus* and *Hemiandra pungens*	Continuous <5 cm deep	10YR 7/1 light gray sand
YP1	31°31'00"S	115°39'18"E	Low heaths dominated by *Melaleuca acerosa, A. lasiocarpa*, low herbaceous plants and native grasses	Discontinuous <2 cm deep over <25 % of the area	10YR 7/1 light gray sand

SITE	**LATITUDE**	**LONGITUDE**	**VEGETATION PRESENT**	**LEAF LITTER**	**SOIL**
YP2	31°34'07"S	115°40'05"E	Low heaths dominated by *Melaleuca acerosa, Acacia* spp., *A. lasiocarpa*, few herbaceous plants and native grasses	Discontinuous dead herbaceous plants	10YR 7/1 light gray sand
HH1	31°49'06"S	115°46'02"E	*A. saligna, X. preissii, E. gomphocephala, Melaleuca* spp., *Grevillea* spp., *C. quadrifidus, J. sericea, Trachymene coerulea*, sedges, dead grasses	Discontinuous <50%; narrow leaves	Outcrop Limestone
HH2	31°49'07"S	115°46'11"E	*A. rostellifera, X. preissii, C. quadrifidus, Melaleuca* spp., *H. hypericoides, Hakea trifurcata, Dryandra nivea, Thysanotus triandrus*, sedges, dead grasses	Discontinuous <50%, varies discontinuous <25% to continuous < 5cm deep; narrow leaves, twigs	Outcrop Limestone
HH3	31°49'02"S	115°46'13"E	*B. attenuata*, occasional *B. menziesii, E. gomphocephala, X. preissii, M. riedleyi, H. hypericoides, J. sericea*	Discontinuous <50%; broad and narrow leaves, light dead grass	Outcrop Limestone
HH4	31°48'57"S	115°46'41"E	*B. attenuata, E. marginata, E. gomphocephala, A. fraseriana, H. lissocarpha, X. priessii, H. hypericoides, Daviesia* spp., sedges	Continuous <5 cm deep; broad and terete leaves and logs	Outcrop Limestone
MH1	32°01'53"S	115°51'44"E	*B. attenuata, B. menziesii, Jacksonia sternbergiana, X. preissii, A. humilis, M. riedleyi, H. hypericoides, Bossiaea* spp.	Continuous <5 cm deep, deeper under bark; broad and terete leaves	5YR 5/3 reddish brown sand
MH2	32°01'58"S	115°51'38"E	*B. attenuata*, occasional *B. menziesii, H. prostrata, Dryandra sessilis, N. floribunda, A. cygnorum, Hypocalymna angustifolia, M. riedleyi, X.preissii, H. hypericoides, Bossiaea* spp.	Discontinuous <50%; broad and terete leaves and *Banksia* branches	5YR 6/6 reddish yellow sand
TH1	31°52'49"S	115°51'30"E	*B. attenuata, B. menziesii*, occasional *E. marginata, A. fraseriana, Nuytsia floribunda, X. preissii, H. hypericoides, Melaleuca* spp., *Pattersonia occidentalis, Daviesia* spp.	Discontinuous <50%, patchy broad and terete leaves	10YR 6/3 pale brown sand
TH2	31°52'50"S	115°51'32"E	*E. marginata, B. attenuata*, occasional *B. menziesii, A. fraseriana, Jacksonia* spp., *X. preissii, M. riedleyi*	Continuous <5 cm deep, broad and terete leaves	10YR 5/2 grayish brown sand
WR1	31°50'34"S	115°48'50"E	*E. marginata, B. attenuata*, occasional *B. menziesii, X. preissii, M. riedleyi, Oxylobium* spp.	Discontinuous <50% and logs	Not recorded
WR2	31°50'33"S	115°49'00"E	*E. marginata, B. attenuata, X. preissii*	Discontinuous <50% and logs	Not recorded
LS1	31°49'14"S	115°51'01"E	*B. attenuata*, occasional *B. menziesii, B. ilicifolia, E. marginata, N. floribunda, Allocasuarina humilis, X. preissii*,, mixed heath	Continuous >5 cm deep; broad and terete leaves	Not recorded
MR1	31°49'51"S	115°50'03"E	*B. attenuata*, occasional *B. menziesii, E. marginata, B. ilicifolia, A. fraseriana, X. preissii*	Continuous <5 cm deep; broad and terete leaves	Not recorded
MR2	31°49'38"S	115°50'04"E	*E. marginata, B. attenuata, B: menziesii, A. fraseriana*	Continuous <5 cm deep; broad and terete leaves, old logs	Not recorded
JK1	32°05'36"S	115°52'39"E	*B. attenuata, B. menziesii, N. floribunda, E. todtiana, M. preissiana, B. ilicifolia*, occasional *B. grandis, A. fraseriana, X. preissii, Daviesia* spp. *Melaleuca* spp. *Dasypogon* spp.	Continuous >5 cm; broad and terete leaves	5YR 5/2 reddish gray loamy sand
JK2	32°05'31"S	115°52'28"E	*B. attenuata, B. menziesii, E. todtiana, A. fraseriana, A. humilis, H. hypericoides, Melaleuca* spp.	Discontinuous <50% /continuous >5 cm deep; broad and terete leaves	7.5YR N7 light gray sand
PA5	31°58'03"S	115°58'11"E	*Pericalymma ellipticum*, emergent *E. todtiana*	Continuous >5 cm; terete leaves	Not recorded
PA6	31°58'05"S	115°58'05"E	*A. cygnorum;* emergent *B. grandis*	Discontinuous 25%; terete leaves	Not recorded
PA7	31°58'34"S	115°58'25"E	*M. preissiana;* occasional *B. littoralis*, sedges	Continuous <5 cm; terete leaves	Not recorded
PA8	31°58'36"S	115°58'28"E	*B. attenuata, B. menziesii;* occasional *B. ilicifolia, N. floribunda*	Discontinuous 50%; leaves broad and terete	Not recorded
TR1	31°52'05"S	116°03'04"E	*E. marginata, B. menziesii, D. sessilis, Adenanthos cygnorum, X. preissii, M. riedleyi, Hakea* spp.	Discontinuous <50%	10YR 7/1 light gray sand

SITE	**LATITUDE**	**LONGITUDE**	**VEGETATION PRESENT**	**LEAF LITTER**	**SOIL**
TR2	31°52'25"S	116°03'03"E	*E. calophylla, H. lissocarpha*	Discontinuous <50% + fallen *Hakea* bushes	10YR 4/2 dark grayish brown sandy loam
TR3	31°52'24"S	116°02'52"E	*E. calophylla, N. floribunda, H. lissocarpha*	Continuous <5 cm deep; some twigs and logs	10YR 6/1 light gray sand
TR4	31°52'23"S	116°02'46"E	*B. menziesii, E. marginata, E. calophylla, A. cygnorum*	Discontinuous <25%	10 YR 7/1 light gray sand

2.4 SUMMARY

The Swan Coastal Plain has developed since the Pleistocene by the accumulation of continental sediments in a series of dunes forming successive coastlines. Each landform has developed distinctive drainage, geology, topography and soil structures (Churchward and McArthur 1980; Environmental Protection Authority 1998). The eastern landform units are characterised by alluvial and colluvial deposits. Aeolian deposits are dominant in the younger western deposits, with the youngest unit, the Quindalup Dune System, formed from Holocene calcareous sands. Associated with these landform units are vegetation complexes reflecting the localised physical characteristics of the units (How *et al.* 1996; Environmental Protection Authority 1998).

Since the arrival of European settlers in 1829 the native vegetation has been extensively cleared across the Swan Coastal Plain. Remnant areas of vegetation occur in a variety of locations, representing the original bushland of every landform unit. However, there is increasing public pressure to urbanise these areas (especially coastal localities).

To document how the ground beetle (Carabidae) assemblage alters between remnants and seasonally within a single Dune System (namely the Quindalup Dunes), and between the dune systems, a series of bushland remnants were surveyed between 1993-1997. The initial survey, carried out by the Western Australian Museum, examined remnants from each landform in three east-west bands (north, central and southern Metropolitan Areas) concurrently between 1993-1996. The second surveying program, as the field work component of this study, surveyed remnants on the Quindalup Dune System between 1996-1997. Two remnants (Bold Park and Trigg Dune Reserve) previously examined were resurveyed in addition to a large relatively undisturbed remnant north of the Metropolitan Area (Yanchep National Park).

CHAPTER 3:

MATERIALS & METHODS.

3.1 PITFALL TRAPPING

Critical debate in the literature concerning the efficiency of pitfall traps has occurred since Barber (1931) first used ethylene glycol pitfall traps to capture cave dwelling insects. Despite their popularity as an economical method of documenting species simultaneously over several habitats and locations (Thiele 1977), interpretation of capture rates is problematic due to factors influencing trapping efficiency (such as size, shape, arrangement in the landscape; Spence and Niemelä 1994).

Trap size has been found to influence both abundance and richness of target groups; abundance and species richness increases with trap size for spiders (Brennan *et al.* 1999) and beetles (Luff 1975). Brennan *et al.* (1999) found that there was no significant interaction between trap size and spatial positioning.

Variability in species biology and activity levels can also influence trapping performance and apparent abundance levels (Thiele 1977; Halsall and Wratten 1988). Snider and Snider (1986) suggested that pitfall trapping can be a valid means of comparing relative faunal densities of several populations if the location, habitats and climates are roughly similar and that the activity levels of the species in question does not differ over a distance of 30-40 m. However, both Greenslade (1964), and Halsall and Wratten (1988) caution on such conclusions as changing activity levels within and between target species and microhabitat differences will directly affect trapping performance both spatially and temporarily in a study site.

Baars (1979) suggested that death pitfall data should also be interpreted with caution, and used only if factors such as mortality, activity levels and densities of the target species are known. As there is a dearth of such basic information for Australian native species, interpretation of pitfall catches is generally restricted to documenting species diversity.

If consecutive sampling periods are timed to coincide with activity fluctuations, pitfall traps may be suitable to estimate population sizes in several similar habitats. It is with this in mind that pitfall traps were used to describe both the carabid species assemblages, and to estimate population fluctuations in several Quindalup heath sites.

3.1.1 SAMPLING METHOD

As described in Chapter 2, 39 sampling sites (as 100m transects) were established on remnants on the Quindalup, Spearwood and Bassendean Dune Systems and at one remnant on the Ridge Hill Shelf. Sites were surveyed in two consecutive trapping programs. The first program was initiated by the Western Australian Museum as part of a ground fauna survey (encompassing both vertebrate and invertebrate fauna) of urban bushland remnants in Perth Metropolitan Area (How *et al.* 1996). The remnants were selected to represent areas of differing sizes on the various landforms present on the Swan Coastal Plain, and areas of high conservation value listed on the National Estate (How *et al.* 1996).

The remnants were surveyed in three east-west bands over a three year period. Four sites on Bold Park (BP), three on Tuart Hill Reserve (TH), four on Perth Airport (PA) and four sites on Talbot Road Reserve (TR) formed the first band of 15 sites, and were established during 1993-1994.

Ten sites were surveyed in the second band; four sites on Woodman Point Reserve (WP), two sites each on Mount Claremont Reserve (MC), Mount Henry Bushland (MH) and Jandakot Airport (JK) during 1994-1995.

During 1995-1996, three sites on Trigg Dune Reserve (TD), four on Hepburn Heights Reserve (HH), one on Landsdale Farm School (LS) and two each on Warwick Road Reserve (WR) and Marangaroo Conservation Reserve (MR) were surveyed in a third band. All sites in all three bands, were established in early winter and trapped continuously for twelve months.

The concurrent terrestrial veretebrate trapping surveys are presented in Table 3.1. During this part of the overall ground fauna survey, a number of invertebrates were captured in the vertebrate pitfall traps. Unfortunately researchers carrying out this section of the survey did not consistently keep the carabids captured. This restricts their usefulness to noting the species caught rather than to any statistical analysis. The few carabids that were kept are presented in Appendix H.

Table 3-1: Vertebrate sampling periods undertaken during the *"Ground Fauna of Urban Bushland Remnants in Perth"* survey (Adapted from How *et al.* 1996).

1993-1994	**1994-1995**	**1995-1996**
August 22 - 29	October 10 – 16	October 2 – 8
October 18 – 24	October 17 – 23	October 9 – 15
October 25 – 31	November 14 – 20	November 6 – 12
November 21 – 28	November 21 – 27	November 13 – 19
November 29 – December 5	November 28 – December 4	December 4 – 10
January 24 – 30	December 5 – 11	December 11 – 17
January 31 – Febuary 5	Febuary 28 – March 5	
March 14 – 20	March 6 – 12	
March 20 - 26		

The second program, carried out as the major field work component of this work, compared the carabid assemblages of several bushland remnants on the Quindalup Dune System. To facilitate comparisons of the assemblages over multiple years at two remnants, this program surveyed the approximate areas of previously examined sites BP1, BP5, TD2, TD4, and added two sites on Quindalup Dune Soils in Yanchep National Park (YP) during 1996-1997. BP and YP sites were established in late winter and TD sites six weeks later.

Sampling periods for all remnants are presented in Table 3.2 on the following page.

Table 3-2: Sampling Sites and Dates used in "*The Ground Fauna of Urban Bushland Remnants of Perth*" (How *et al.* 1996); and sampling dates used in the 1996 - 1997 trapping program (present study)

Sites are as follows: BP - Bold Park, TH - Tuart Hill Bushland, PA - Perth Airport, TR - Talbot Road Reserve, MC - Mount Claremont Reserve, WP - Woodman Point Reserve, MH - Mount Henry Bushland, JK - Jandakot Airport, TD - Trigg Dune Reserve, HH - Hepburn Heights Reserve, WR - Warwick Open Space, LS - Landsdale Farm School, MR - Marangaroo Conservation Reserve, YP - Yanchep National Park. Date-code = letter identifying the sampling period in combination with site code, i.e. BP1A is the sampling period 20 May - 20 July 1993 from site BP1. *Trigg Dune Reserve Site- established 10 October 1996

SAMPLING PERIOD	DATE-CODE	BP	TH	PA	TR	MC	WP	MH	JK	TD	HH	WR	LS	MR	YP
20 May-20 July 1993	A	BP1, 3, 4, 5	TH1, 2, 3	PA5, 6, 7, 8	TR1, 2, 3, 4										
20 July-24 September 1993	B	BP1, 3, 4, 5	TH1, 2, 3	PA5, 6, 7, 8	TR1, 2, 3, 4										
24 September-18 November 1993	C	BP1, 3, 4, 5	TH1, 2, 3	PA5, 6, 7, 8	TR1, 2, 3, 4										
18 November-6 January 1994	D	BP1, 3, 4, 5	TH1, 2, 3	PA5, 6, 7, 8	TR1, 2, 3, 4										
6 January-18 March 1994	E	BP1, 3, 4, 5	TH1, 2, 3	PA5, 6, 7, 8	TR1, 2, 3, 4										
18 March-19 May 1994	F	BP1, 3, 4, 5	TH1, 2, 3	PA5, 6, 7, 8	TR1, 2, 3, 4										
24 June-1 September 1994	H					MC1, 2	WP1, 2, 3, 4	MH1, 2	JK1, 2						
1 September-4 November 1994	I					MC1, 2	WP1, 2, 3, 4	MH1, 2	JK1, 2						
4 November-19 January 1995	J					MC1, 2	WP1, 2, 3, 4	MH1, 2	JK1, 2						
19 January-21 March 1995	K					MC1, 2	WP1, 2, 3, 4	MH1, 2	JK1, 2						
21 March-4 May 1995	L					MC1, 2	WP1, 2, 3, 4	MH1, 2	JK1, 2						
4 May-6 July 1995	M					MC1, 2	WP1, 2, 3, 4	MH1, 2	JK1, 2						
13 July-25 September 1995	N									TD1, 2, 4	HH1, 2, 3, 4	WR1, 2	LS1	MR1, 2	
25 September-28 November 1995	O									TD1, 2, 4	HH1, 2, 3, 4	WR1, 2	LS1	MR1, 2	
28 November-29 January 1996	P									TD1, 2, 4	HH1, 2, 3, 4	WR1, 2	LS1	MR1, 2	
29 January-28 March 1996	Q									TD1, 2, 4	HH1, 2, 3, 4	WR1, 2	LS1	MR1, 2	
28 March-30 May 1996	Z									TD1, 2, 4	HH1, 2, 3, 4	WR1, 2	LS1	MR1, 2	
29 August-10 October 1996	R	BP1, 5													YP1, 2
10 October-21 November 1996*	S	BP1, 5								TD2, 4					YP1, 2
21 November-2 January 1997	T	BP1, 5								TD2, 4					YP1, 2
2 January-14 February 1997	U	BP1, 5								TD2, 4					YP1, 2
14 February-1 April 1997	V	BP1, 5								TD2, 4					YP1, 2
1 April-9 May 1997	W	BP1, 5								TD2, 4					YP1, 2
9 May-19 June 1997	X	BP1, 5								TD2, 4					YP1, 2
19 June-1 August 1997	Y	BP1, 5								TD2, 4					YP1, 2

At each site, one pitfall trap was placed every 10 m along a 100 m transect for a total of 10 traps. Each pitfall trap was constructed of a 2 litre plastic container sunk into the ground. Approximately 400 ml of 70% ethylene glycol was added to each trap. To exclude rain and leaves, and to limit interference by larger animals, a linoleum floor tile was set roughly 10 cm above the trap with the aid of tent pegs. All traps were cleared and reset approximately every six weeks for a 12 month period. Samples were stored in 75% ethyl alcohol until sorting. Data were pooled from the 10 traps within a site for each sampling period.

3.1.2 SPECIES SORTING

All carabids were removed and identified to morphospecies, hereafter referred to as species. The majority of larger specimens were pinned out, with a few being stored in alcohol for genital dissection; smaller specimens (< 15 mm) were stored in alcohol. All taxa were identified to generic level using Matthews (1980), and relevant literature was then consulted to assign species names (Bänninger 1940; Sloane 1889, 1890, 1893, 1898, 1900, 1902, 1905, 1920). Nomenclature of subfamilies follows Matthews (1980). Once identified, all individuals were given a unique four digit registration number (NAG####). Each species was examined for the presence of functional wings, and determined to be either volant (capable of flight; flying) or non-volant (flightless, non-flying). The sex of all undamaged individuals was determined by external morphological characters and by genital extraction.

3.1.3 ENVIRONMENTAL VARIABLES

To examine the biogeographic characteristics of the carabid assemblage of the Swan Coastal Plain 16 synthetic climatic parameters were generated using the *Bioclim* data program to produce annual estimates of climatic variables which may influence the various species distributions (Busby 1986a; Busby 1986b). These were used in conjunction with physical characteristics (altitude, latitude, longitude and size of remnant area; see below for sources). Eight estimates of temperature were generated:

- annual average temperature (TANN)
- mean temperature of the coolest month (TMNCM)

- maximum temperature of the wettest month (TMXWM)
- greatest temperature span (TSPAN)
- temperature of the coolest quarter (TCLQ)
- temperature of the warmest quarter (TWMQ)
- temperature of the wettest quarter (TWETQ)
- temperature of the driest quarter (TDRYQ)

Eight estimates based on precipitation were also generated:

- annual precipitation (RANN)
- precipitation of the wettest month (RWETM)
- precipitation of the driest month (RDRYM)
- coefficient of monthly precipitation (RCVAR)
- precipitation of the wettest quarter (RWETQ)
- precipitation of the driest quarter (RDRYQ)
- precipitation of the coolest quarter (RCLQ)
- precipitation of the warmest quarter (RWMQ)

The synthetic environmental variables are presented in Appendices A and B (synthetic temperature and precipitation parameters respectively).

To identify potential relationships between species distributions and environmental variables on the Quindalup Dune System, data for physical, weather and vegetation characteristics were collected for each of the 19 Quindalup dune sites. Physical and weather data are presented in Appendix C, and vegetation data are presented in Appendix D.

3.1.3.1 Physical Variables

Latitude and longitude readings correct to a radius of 20 m were taken using a hand-held Magellan Pathfinder G.P.S (see Table 2.1). Altitude was determined from 1:50,000m topographic maps (accurate to 10m). The Bushplan Report (Environmental Protection Authority 1998) was used to obtain remnant-size values for the 39 remnant bushland areas (Table 3.3). Remnant age and fire or disturbance histories were obtained from CALM Fire records for Yanchep National Park and the literature was consulted for the other remnants (Table 3.3; Powell and Emberson 1981; Mitchell McCotter 1993). However, it was found that this information lacked in detail and reliability, both between years and between localities. For this reason fire and disturbance history and remnant age were not included in any of the analyses.

3.1.3.2 Weather Variables

Daily rainfall data were obtained for the five survey years from the Bureau of Meteorology Stations closest to the remnants. Data from station number 9105- Wanneroo Shire (31°44'07"S 115°47'30"E, altitude 30 m) were used for the Yanchep sites; station number 9151- Subiaco Treatment Plant (32°00'00"S 115°00'00" E, altitude 20 m) was used for the Bold Park, Mount Claremont and Trigg Dune Reserve sites. Readings at the East Fremantle station 9192 (32° 06'00"S 115°48'00"E, altitude 15 m) were used for the Woodman Point sites. Rainfall totals were calculated for each sampling period from the relevant station. Daily cloud cover data (in standard oktas measurements). Length of sunlight periods (in hours) were also obtained from the Perth Airport (courtesy of the Bureau of Meteorology) and mean values calculated.

3.1.3.3 Vegetation Variables

Vegetation at each site was described using Muir's (1977) system for vegetation assessment for faunal surveys. Height in meters and percentage cover were recorded for four vegetation strata: stratum 1: dominant trees forming the upper canopy layer (including emergents); stratum 2: mallee type trees (such as Melaleuca spp.) and large bushes; stratum 3: heaths and small bushes; stratum 4: herbaceous plants and grasses. Leaf litter depth in centimeters and leaf litter percentage cover were also recorded. These measurements were then converted to categories. The categories in each percent cover variable (ie for each stratum % cover and the leaf litter % cover) are:
1 = <10%, 2 = 10 – 30%, 3 = 30 – 50%, 4 = 50 – 70%, 5 = 70- 100%.
Stratum height categories are:
Stratum 1: 1 = <1m , 2 = 1-2m, 3 = 2-5m, 4 = 5-7m, 5 = 7-10m, 6 =10-12m, 7 = 12-20m.
Stratum 2: 1 = 0m (absent), 2 = <0.5m; 3 = 0.5-1m; 4 = 1-1.5m, 5 = 1.5-2m, 6 = 2-5m.

Stratum 3: 1 = 0m (absent), 2 = <0.5m, 3 = 0.5-1m, 4 = 1-2m, 5 = >2m.

Stratum 4: 1 = <0.1m , 2 = 0.1-0.5m, 3 = >0.5m.

Table 3-3: **Size in hectares, remnant age and time since last fire for each bushland remnant.**

REMNANT	**AREA (ha) (n=16)**	**REMNANT AGE (years) (n=7)**	**FIRE/DISTURBANCE HISTORY (years) (n=7)**
Yanchep Nat. Park	2799	93	8
Trigg Dune Reserve: TD1	22.4	25	11
TD2	8	25	11
TD4	16	25	11
Bold Park	338	40	40
Mount Claremont	45	40	40
Woodman Point Reserve	120	120	100
Hepburn Heights	110	N/A	N/A
Warwick Reserve	43	N/A	N/A
Tuart Hill Bushland	9	N/A	N/A
Mount Henry Bushland	13	N/A	N/A
Landsdale Farm School	16	N/A	N/A
Marangaroo Conservation Reserve	28.1	N/A	N/A
Jandakot Airport	100+	N/A	N/A
Perth Airport	400	N/A	N/A
Talbot Road Reserve	90	N/A	N/A
Average	259.5	52.6	31.57

3.2 ANALYSIS

The pitfall trapping data and relevant environmental variables were stored in a Microsoft™ *Access* database, with various summary tables derived from these for analysis. Sites surveyed twice (originally in 1993-1996 and again in 1996-1997-BP1, BP5, TD2 and TD4) are treated as discrete and separate sites for both survey periods and in all subsequent analyses.

Analysis of the data was carried out in two stages. The first stage involved examining all sites, to document the species present, and to determine the extent of spatial partitioning within and between remnants across the geological formations of the Swan Coastal Plain. In addition, the relevance of using the total carabid assemblage, or a component (non-volant or volant) for investigating the effects of habitat fragmentation, or assessing conservation, was examined. The null hypotheses for this research are:

1. there is no difference in the carabid assemblage structure between or within the geological formations of the Swan Coastal Plain; and
2. there is no difference between the classification of the sites based on presence/absence data of the total carabid assemblage or a component (volant or non-volant) of it.

Total species richness values were derived by summing the total number of species collected over the 12 month trapping period at each site. Cluster routines in the *Statistica*™ (1995) program were used with presence/absence data to determine site similarities and to determine the degree of similarity between sites using presence/absence data. Sites were then classified using the Euclidean distance measure, followed by hierarchical agglomeration fusion classification (flexible UPGMA, beta = –0.1).

Standard multiple regression routines in the *Statistica*™ (1995) program were used to analyse the relationship between total, volant and non-volant species richness, and selected species abundances at each site with the synthetic environmental variables generated by *Bioclim* (Busby 1986a; Busby 1986b). Species abundances analysed were

Gnathoxys crassipes, G. granularis, Promecoderus scauroides, Simodontus australis, Sarticus iriditinctus, Notonomus mediosulcatus, Scaraphites lucidus, S. silenus, Lecanomerus verticalis and *Notagonum* sp. 1. Remaining species abundances were too low to analyse.

The second stage of the data analysis investigated the temporal and spatial distributions of carabid species on the Quindalup Dune System specifically. Summary tables of total carabid assemblages were generated for sites and seasons on the remnants Woodman Point Reserve, Mount Claremont Reserve, Bold Park, Trigg Dune Reserve and Yanchep National Park. Sites BP3 and BP4, located on Cottesloe Sands of the Spearwood Dune System, were included in these analyses to investigate differences in assemblage structure between soil types within a single remnant.

Summary tables of species richness by sample period by site were derived by summing the total number of species collected during each sampling period for each site. Total diversity was calculated for each Quindalup dune site using Shannon's Index H' and the Evennes J', using the method outlined by Rossbach and Major (1983).

$$J' = \frac{H'}{\mathrm{Log}_e S}$$

where $H' = \sum p_i \ln p_i$ and p_i is the frequency of the i'th species and S is the number of species recorded. Maximum diversity gives a J' value of 1 and no diversity, a value of 0.

Cluster analysis routines in the *Statistica*™ (1995) program were used to describe similarities between sites based on a) presence/absence data, and b) percent transformed total abundance data. The sites were then classified using the Euclidean distance measure and flexible UPGMA (beta = –0.1), as previously outlined. Untransformed abundance data were used to determine the similarities of the sample periods irrespective of site or year.

The Standard multiple regression routine in the *Statistica*™ (1995) software program was used to analyse the relationship between the environmental variables and the total, volant and non-volant species richness, and the abundance of *Carenum scaritoides, Scaraphites lucidus, S. silenus, Gnathoxys crassipes, G. granularis, Promecoderus scauroides, Sarticus iriditinctus, Simodontus australis, Notagonum* sp. 1 and *Lecanomerus verticalis.* The remaining species were too low in number or too restricted in distribution to facilitate analysis.

3.3 FIRE & DISTURBANCE

Over the study period there were a number of factors, which resulted in sites being sampled for reduced periods, or in fewer than ten traps being collected at the end of particular sampling periods.

How *et al.* (1996) reported that fire affected the trapping programs at several sites. Talbot Road Reserve sites TR2, TR3 and TR4 were badly damaged by fire in early December 1993 (How *et al* 1996). An intense fire occurred 25 m from the trapping grid at BP4 on the evening of 16 December 1993. Perth Airport site PA8 was completely burnt by an extensive fire in early March 1994. Several fires occurred at Warwick Road Reserve during the survey, with part of WR1 and all of WR2 on December 12 1995 (How *et al.* 1996).

The 16 ha fragment at Trigg Dune Reserve was subject to an intense fire during the night of 31 December 1996. The latter fire completely consumed the central third of the fragment, destroying the entire trapline. Several traps in each trapline set subsequent to the fire were interfered with by locals or by animals, resulting in a smaller sampling effort at this site.

Foxes in the area of the northern Yanchep site YP1 destroyed about half of the traps set for the first three sampling periods until suitable cages were devised and placed over the individual traps. The cages were constructed of commercial chicken wire over a 60 x 60x 20 cm iron frame and barbed wire was looped around the frame edge to inhibit digging. Tent pegs were used to secure the cage into the ground.

3.4 TAXONOMY & DISTRIBUTION

As New (1998) stated, a major impediment to Australian carabids being fully utilised in ecological studies is our ignorance of the group as a whole and of individual species. In addition, many species descriptions are extremely old, they vary in the level of detail, are difficult to access, and are often based on singular or few specimens. The number of specimens collected during this survey (and of the Quindalup Dune System in particular) has provided an opportunity to fully redescribe a number of species including descriptions of genital gross morphology. An identification key for the species encountered in this study was developed. It takes into account intraspecies variation in morphological features. This study also begins to clarify distribution patterns and to assign ecological information to individual species.

Measurements were taken using a stereo microscope with vernier calipers and expressed in millimetres. Body length was measured from the apical margin of the labrum to the apex of the elytra (T-L). Length of pronotum was taken along the midline (P-L). Fore tibia length was measured from the femur joint to tip of 1st tibial tooth (FT-L).

The gross genital morphology of all non-volant (flightless) specimens collected from the Quindalup Dune System sites was described using a technique developed by Liebherr (1990). Specimens were relaxed in a mixture of soapy distilled water and 2% acetic acid, dissected out and cleared overnight in cold 10% potassium hydroxide. Once cleared, the pH of dissected parts was neutralised in dilute acetic acid. Larger species (*Scaraphites* spp. and *Gnathoxys granularis*) which are heavily keratinised, required extended relaxation over two days. Dissected male genitalia were placed in glycerine for examination. Examination of the female reproductive tract was prevented due to poor preservation of the soft internal tissues by the ethylene glycol used in the pitfall traps. External female morphology was described without removal from the specimen from females fully everted after relaxation using the technique mentioned above.

Species distribution maps, prepared using Arcview™, for *Scaraphites lucidus*, *Scaraphites silenus*, *Carenum scaritoides*, *Gnathoxys crassipes*, *G. granularis*, *Simodontus australis* and *Promecoderus scauroides* were developed from collections held in the Western Australian Museum, Agriculture W.A. and the Australian National Insect Collection. Maps are given for each species and specimen records are presented in Appendix I.

CHAPTER 4:

DIVERSITY OF CARABIDAE FROM THE QUINDALUP DUNE SYSTEM.

4.1 INTRODUCTION

In general, Western Australian carabids have attracted very little attention since being first described by such illustrious 19th century authors as P.F.M.A. Dejean (*Simodontus australis* 1827), J.O. Westwood (*Scaraphites (Scarites) silenus* 1842; *Gnathoxys granularis* 1842; *Carenum scaritoides* 1843), M. de Chaudoir (*Scaraphites lucidus* 1863; *Feronia (Notonomus) mediosulcata* 1865; *Feronia (Steropus) iriditincta 1865*), F.L. Laporte de Castelnau (*Promecoderus scauroides* 1867) and T.S. Sloane (*Gnathoxys crassipes* 1898). Despite several of these species having widespread distributions (such as *Carenum scaritoides* and *Simodontus australis*) few specimens to reside in the Western Australian Museum or in the Australian National Insect Collection (Tom Weir, pers. comm.). Initial and subsequent descriptions of these species and their synonyms have relied upon reference to a small numbers of specimens which failed to consider variation within or between populations (Westwood 1842, 1843; Chaudoir 1863; Castelnau 1867; Sloane 1898).

Like most taxonomies based on specimens collected in the 1800's, many of the type specimens are housed in European institutions or have been difficult to locate (Moore *et al.* 1987), causing difficulties in undertaking systematic revisions of these groups. Even Sloane, during his many studies, could not consult many of Castelnau's types, which are housed in the Genoa Civic Museum (Bänninger 1940). It was not until Bänninger's (1940) revision of the Pamborini, Ozaenini and Scaritini of Australia that many of these types were collectively compared, allowing rationalisation of the taxonomy of these groups as well as development of keys to the genera studied. Moore (1965) also carried out a number of revisions, consolidating the taxonomy of a number of important genera, although many of the larger genera still require revision (Moore *et al.* 1987).

Many Australian carabid species appear to be uncommon, often known from few specimens from a limited number of localities (New 1998). Information on life history, habitat use and present and past distribution is extremely limited. The surveys of

Quindalup bushland remnants (1993-1997) produced a large number of specimens of several species, and provided an opportunity to more fully describe them, with detailed observations upon variation and genital morphology for the first time.

A detailed study of morphological variation both within and between carabid taxa existing on the Quindalup Dune System will aid their identification and understanding of their ecological roles and distributional boundaries. This in turn may assist the use of local carabids as indicators of environmental change as well as their conservation as a whole.

4.2 MATERIAL

This review of the taxonomy of selected Carabidae is based primarily on specimens representing 10 species from surveys of Woodman Point Reserve, Mount Claremont Reserve, Bold Park, Trigg Dune Reserve and Yanchep National Park conducted between 1993 and 1997. These specimens are currently housed in the School of Natural Sciences (Environmental Management), Edith Cowan University, and the (NAG####) registration number series refers to this collection only.

Specimens of these taxa currently held in the Western Australian Museum and AGRICULTURE W.A. were also examined as secondary material. These specimens, in addition to records obtained from the Australian National Insect Collection (ANIC), were used to generate distribution maps for most of the non-flying species. Appendix D lists the secondary material examined (from the Western Australian Museum and AGRICULTURE W.A.), and the locality data from all three sources (including Institution registration number if known). A glossary of terms adapted from Matthews (1980), Nichols (1989) and Lawrence and Britton (1994) used in this Chapter is included in Appendix E.

Below are abbreviations of collectors and museums listed in the material examined.

List of Abbreviations of Collectors

JD	J. Dell
JMW/AFL	J.M. Waldock & A.F. Longbottom
JMW/KG/JW	J.M. Waldock, K. Goodwell & J. Webb
JMW/MSH	J.M. Waldock & M.S. Harvey
JMW/PLW	J.M. Waldock & P.L. West
MSH/JMW	M.S. Harvey & J.M. Waldock
NAG	N.A. Guthrie
RH	R. How
JMW	J.M. Waldock *et al.*

Other Abbreviations Used

F	female
M	male

Museum Acronyms given in the Type Data History for each Species (taken from Moore et al. 1987).

ANIC (MMUS)	Australian National Insect Collection, (on permanent loan from the Macleay Museum, University of Sydney) CSIRO, Canberra, A.C.T., Australia.
ANIC (Sloane Coll.)	Australian National Insect Collection, CSIRO, Canberra, Australia.
BMNH	The British Natural History Museum, London, U.K.
MNHP	Muséum National l'Histoire Naturelle, Paris, France.
NMV	Museum of Victoria, Melbourne, Vic., Australia.
OUM	Oxford University, Oxford, U.K.
ZMM	Moscow State University, Russian Federation.

4.3 SYSTEMATICS

There is comparatively little literature on carabid taxonomy and identification in Australia (New 1998) despite the existence of a large body of primary literature. Identification of specimens can involve exhaustive searches through this literature followed by consultation of institutional collections. Even then species identification can be fraught with problems as many groups within the Carabidae have not been adequately revised since the turn of the century (Moore *et al.* 1987).

A number of keys have been developed to partially rectify this problem but they vary widely in their scope and user-friendliness. The most comprehensive key, covering all beetle groups within Australia, was devised by Lawrence & Britton (1994). While relying on a certain level of anatomical knowledge, this key only provides subfamily and tribal level identification and therefore is not really suitable for amateurs or for generic or species level identification.

The generic keys developed by Matthews (1980), while limited to genera occurring in South Australia, are adequate for both amateur and specialist to obtain a generic-level identification for most specimens found in similar eremaean, mallee and dry sclerophyll habitats outside that state. Based on the picture-key system devised by the US Army, these keys use little jargon and are renditions of standard dichotomous keys in the taxonomic literature (Matthews 1980). However, identification to species-level still requires accessing either the primary literature for most groups or institutional collections, or both.

A number of workers over the last thirty years have begun to amalgamate the primary literature to form species-level keys for certain groups. The most completely revised group to date is the small subfamily Cicindelinae by Freitag (1979). Both Moore (1960, 1962, 1963, 1965, 1966, 1972 and others) and Baehr (1984, 1986, 1987, 1989, 1990, 1992, 1993, 1994, 1995, 1996, 1997) have systematically revised various genera occurring in sub-tropical, tropical and mountainous regions in northern and eastern Australia. However many of the large genera or those occurring in the western third of the continent have not been revised.

4.4 CHAPTER OUTLINE

As an initial step towards revising certain groups occurring in this state and providing a basic classification key for carabids in Western Australia, a key was developed from material obtained during extensive surveying of the Quindalup Dune System in the Perth Metropolitan Area. The style of key is based upon Matthews (1980) in that it employs the use of diagrams to illustrate generic characters. The characters employed represent a modification of those used in species-level keys provided by Bänninger (1940), Sloane (1890, 1893, 1898, 1902) and Moore (1965), and those based on the author's own observations.

The key is designed to be expanded as further taxa are encountered by the author, and to that end some couplets represented by single species at present contain information only pertaining to either genus or tribal level. For example *Promecoderus scauroides* (Broscinae) was the only species of that genus collected but ten further *Promecoderus* species could potentially be encountered (Moore *et al.* 1987), so only the characters used to separate the genus from other broscines were employed.

Since the aim of this chapter is to produce a complete key of the carabids present on the Quindalup Dune System, all carabid species collected (both volant and flightless) from this dune system are represented in the key.

The key is supported by redescriptions of nine non-volant species:

- *Gnathoxys crassipes*
- *G. granularis*
- *Promecoderus scauroides*
- *Notonomus mediosulcatus*
- *Sarticus iriditinctus*
- *Simodontus australis*
- *Carenum scaritoides*
- *Scaraphites lucidus*
- *S. silenus*

taking into account variation within and between populations, and including descriptions of gross external genital morphology for the first time. A new species of *Gnathoxys* (*G. pannuceus* sp. nov.), is described and includes male external genital morphology.

The chapter concludes with a discussion dealing firstly with, the relevance of volant species presence in these remnants with regard to their known distributions, and secondly, the importance of the Quindalup Dune System (and the Swan Coastal Plain) in influencing the distribution of the non-flying carabids. Finally, the conservation status of these species is explored with relevance to the paucity of known biology and threats to populations in general.

4.5 KEY TO QUINDALUP DUNE SYSTEM CARABIDAE

1. a) Mesepimeron reaches midcoxae, i.e. midcoxae not bounded by mesosternum (i) and meta sternum (ii) plates (Fig. 1a) 2

   b) Mesepimeron does not reach midcoxae, i.e. midcoxae bounded on lateralside by mesosternum (iii) and metasternum (iv) plates (Fig.1b) 5

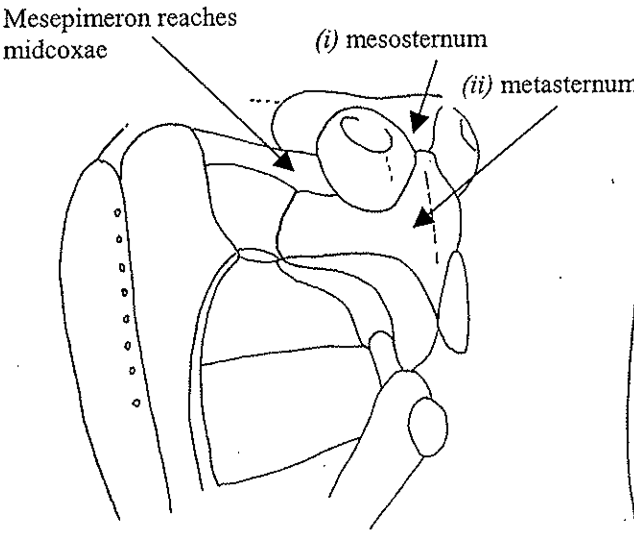


Figure 1a

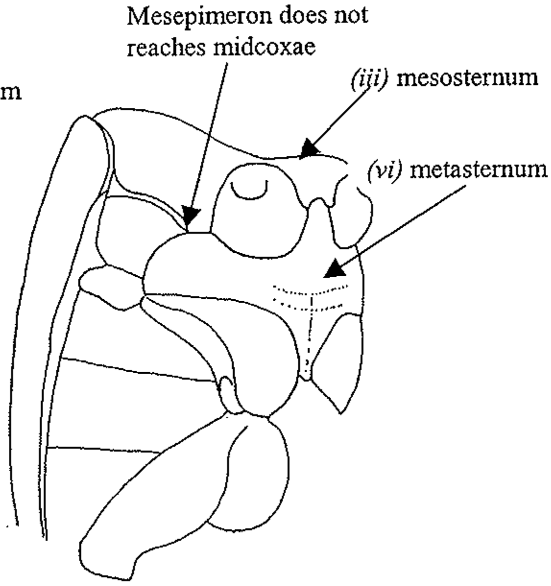


Figure 1b

2. a) Legs not fossorial (i); without antennal groove (ii); fore coxal cavity open behind; bright metallic green in colour (Fig. 2a).
CARABINAE: *Calosoma schayeri* Erichson 1842

b) Fossorial legs (iii); antennal groove present (iv); fore coxal cavity closed behind; dark, nonmetallic in colour (Fig. 2b).
SCARITINAE: 3

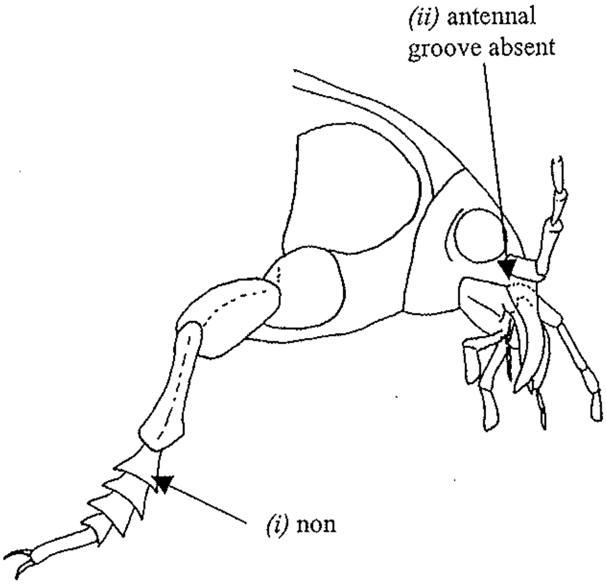


Figure 2a

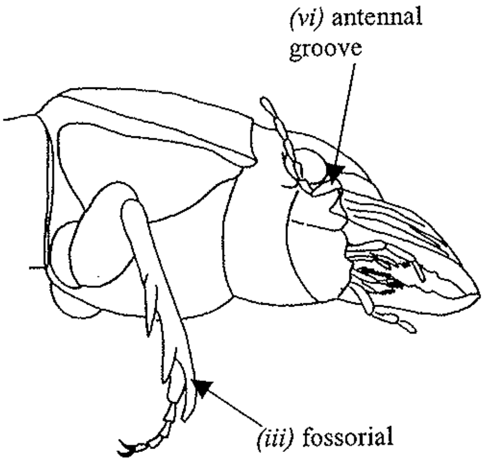


Figure 2b

3. a) Forespur set in front of 2nd tibial tooth (i)(Fig. 3a); palpi securiform (Fig. 3b); setigerous puncture on ventral side of fore femur near joint with tibia (Fig. 3c); hind body longer than wide, gracile in appearance; dull or shiny black to dark maroon in colour.

Carenum scaritoides Westwood 1843

b) Forespur set behind 2nd tibial tooth (ii)(Fig. 3d); palpi filiform (Fig.3e); no setigerous puncture on ventral side of fore femur near joint with tibia (Fig. 3f); hind body squat, heavy in appearance; entirely black without metallic lustre.

Scaraphites..............................4

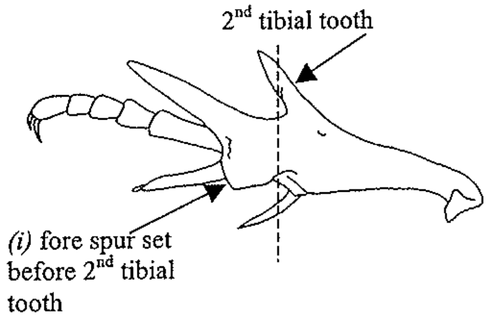


Figure3a

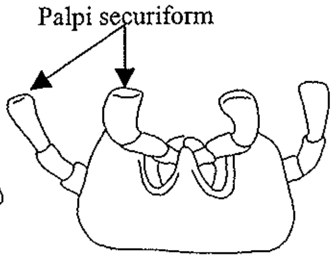


Figure 3b

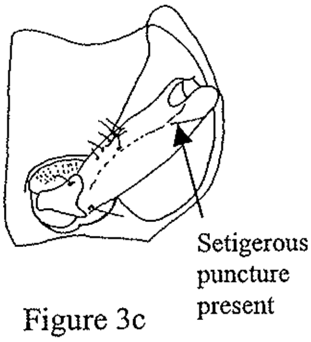


Figure 3c

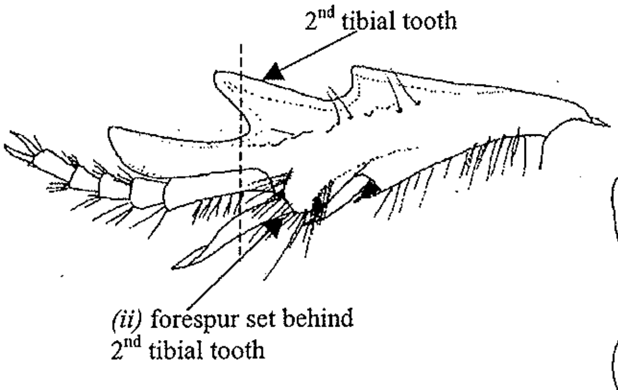


Figure 3d

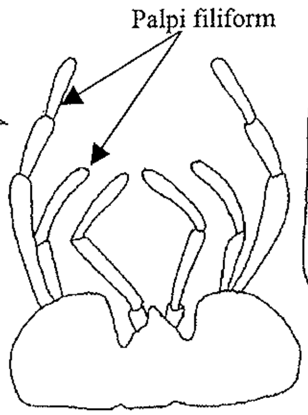


Figure 3e

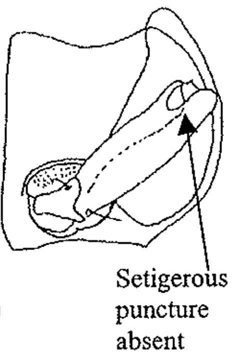


Figure 3f

4. a) Elytral border wide at humeral angles, edge interrupted just behind shoulder to form a "hook" or humeral prominence projecting outwards (i) (in some larger animals there is slight angle to tip of prominence); elytral shape is of a longish oval, with sides weakly curved (ii); posteriorly the prothorax is strongly sinuate on each side, angles sharp, subrectangular (iii) (Fig. 4a).

Scaraphites lucidus Chaudoir 1863

b) Elytral border continuous at shoulders, no hook or humeral prominence projecting at humeral angles (iv); elytra with very rounded sides (v); widely and weakly truncate or rounded prothorax base with hind angles not prominent (vi) (Fig. 4b).

Scaraphites silenus (Westwood 1842)

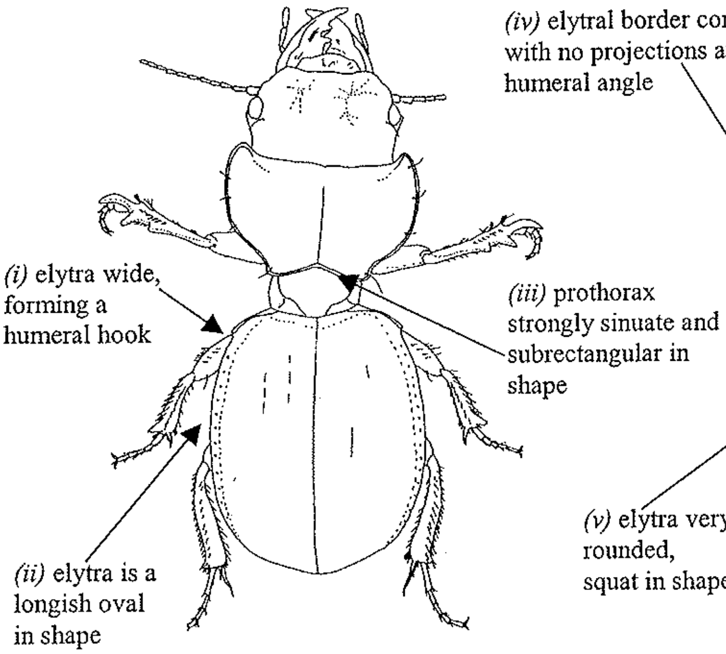


Figure 4a

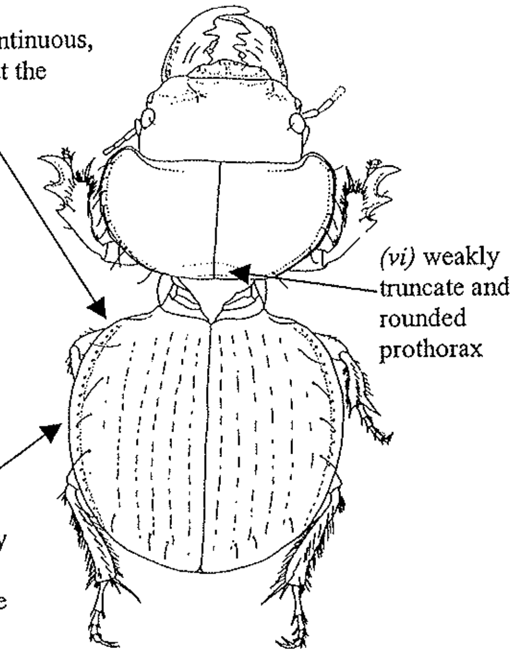
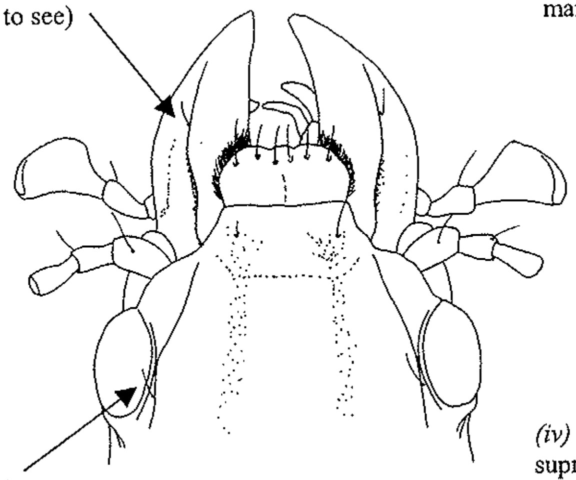


Figure 4b

5. a) Mandibular scrobe with seta (i); one supraorbital bristle (ii) (Fig. 5a).
BROSCINAE...6

b) Mandibular scrobe with no seta (iii); one or two supraorbital bristles (iv) (Fig. 5b) 9

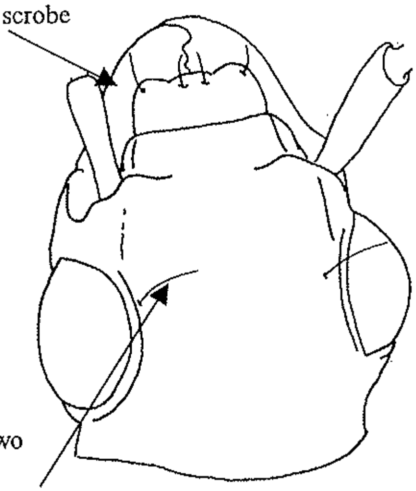
(i) seta in mandibular scrobe (sometimes hard to see)



(ii) one supraorbital seta or bristle

Figure 5a

(iii) no seta in mandibular scrobe



(iv) one or two supraorbital setae or bristles

Figure 5b

6. a) Outer edge of foretibia without teeth (Fig. 6a).
Promecoderus scauroides Castelnau 1867

b) Outer edge of foretibia with teeth (Fig. 6b)
Gnathoxys...............................7

No projections, teeth or extensions on outer edge of

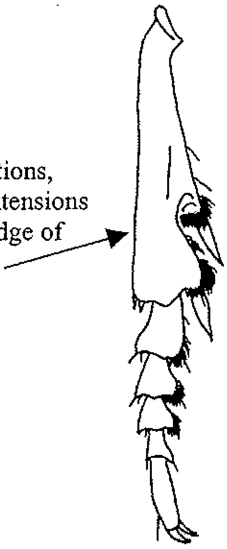


Figure 6a

Teeth or projections on outer edge of foretibia

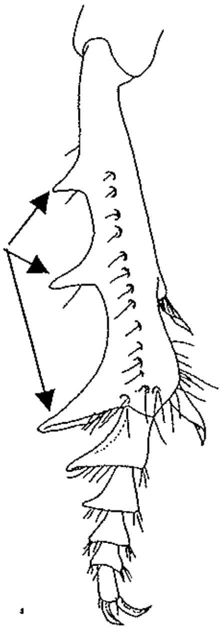
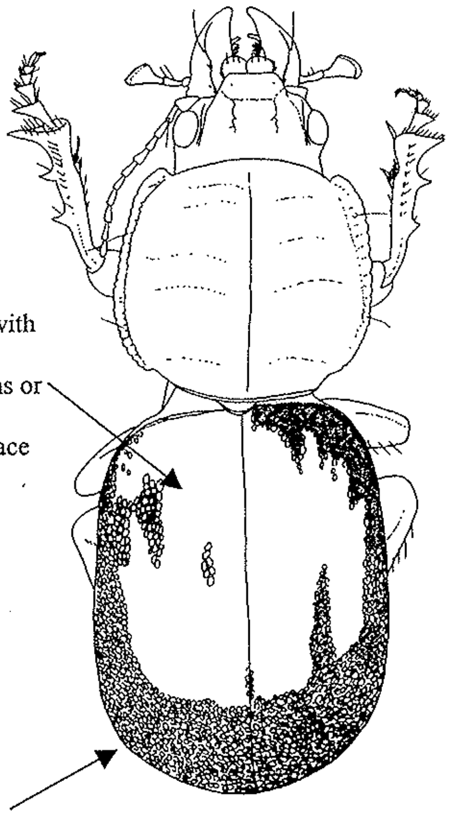


Figure 6b

7. a) Large, 3-5 cm in length, subrectangular in shape; thick band of granulations along edge of elytral border increasing in density towards apical declivity (i); elytra with areas of granulations or smooth on dorsal surface (ii); colour ranging from jet black to black with olive metallic lustre.

Gnathoxys granularis Westwood 1842

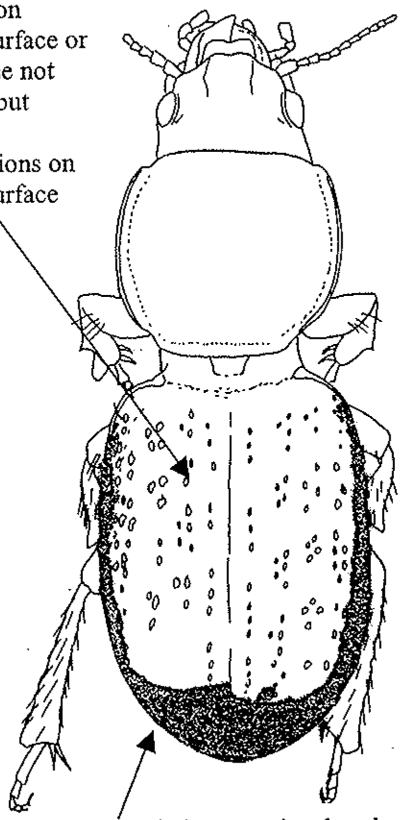
b) Small, about 1.5 cm in length, oval in shape; granulations restricted to the apical declivity and sometimes as a thin band along elytral border (iii); elytra foveate on dorsal surface or otherwise not smooth but without granulations on dorsal surface (iv); dark in colour 8



(ii) elytra with areas of granulations or smooth on dorsal surface

(i) thick band of granulations along edge of elytral border increasing in density towards apical declivity

Figure 7a



(iv) elytra foveate on dorsal surface or otherwise not smooth but without granulations on dorsal surface

(iii) granulations restricted to the apical declivity and sometimes as a thin band along elytral border

Figure 7b

8. a) Head subquadrate, clypeus convex with long mandibles; elytra short and convex with four rows of clusters of punctures on each elytron, punctures of first series closest to elytral suture in single row, second in double row, third and fourth quite irregular (i); legs stout; globular prothorax smooth (ii); colour ranges from glossy black to almost green or brown sheen over black, overall body shape is stout (Fig. 8a).
Gnathoxys crassipes Sloane 1898

b) Head broader than long, clypeus oncave and with heavy large mandibles; elytra longer than wide, fine lines forming creases over entire surface (iii); legs relatively heavy and thickset; prothorax globular with fine, incomplete lateral creases across dorsum (iv); jet black in colour; overall shape is bulky, thickset and heavy (Fig. 8b).
Gnathoxys pannuceus sp. nov.

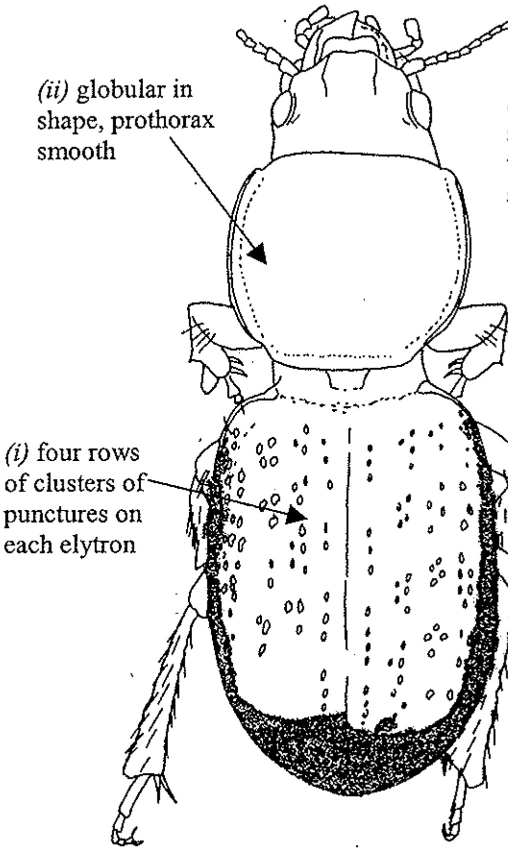


Figure 8a

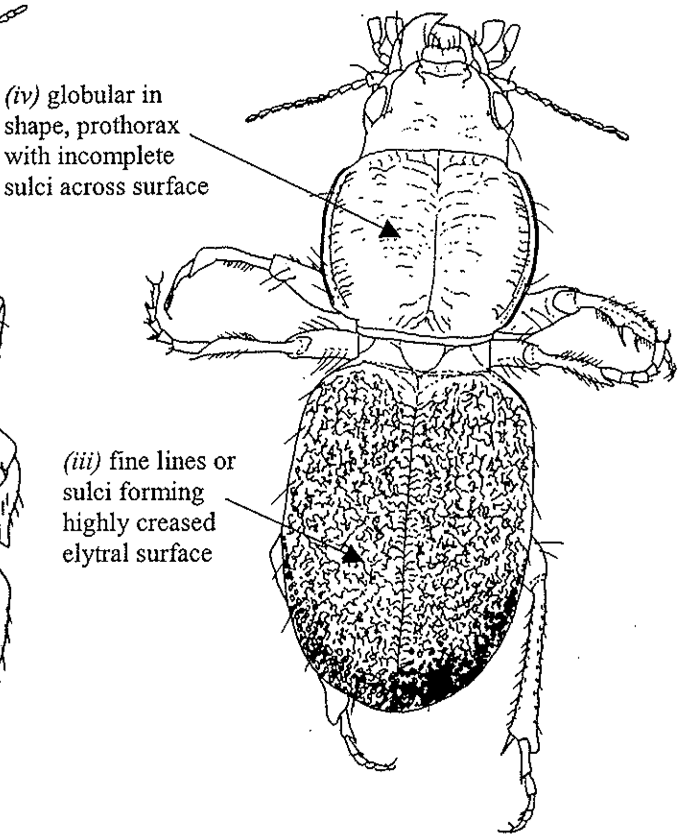


Figure 8b

9. a) One supraorbital bristle **10**

b) Two supraorbital bristles **12**

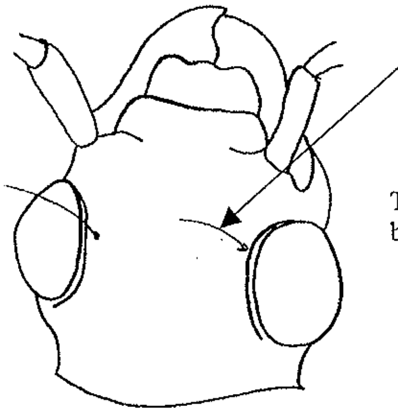


Figure 9a

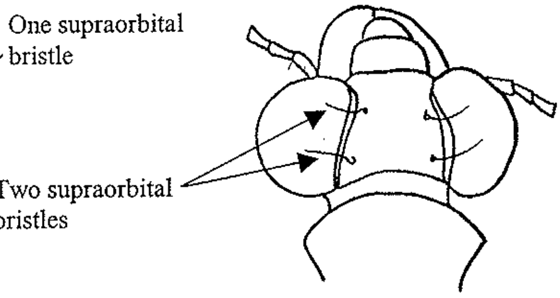


Figure 9b

10. a) Antennae pubescent from base of 4th segment (Fig. 10a)
CALLISTITAE:...*Hormacrus latus* Sloane 1898

b) Antennae densely pubescent from middle of 3rd segment (Fig. 10b).
HARPALINAE..**11**

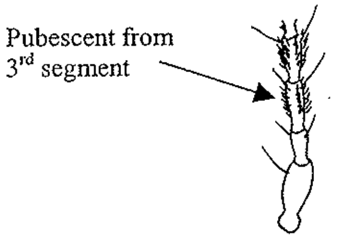


Figure 10a

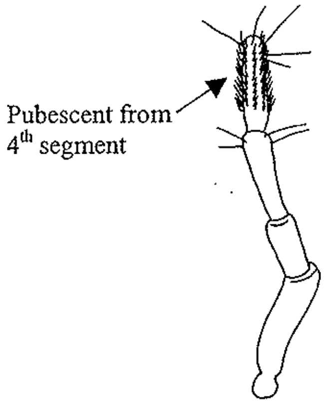


Figure 10b

11. a) Sternites with one pair of long setae positioned either side of midline. (near)..................*Lecanomerus* sp.

b) Sternites with numerous setae spread across width. (near)......................*Euthenaris* sp.

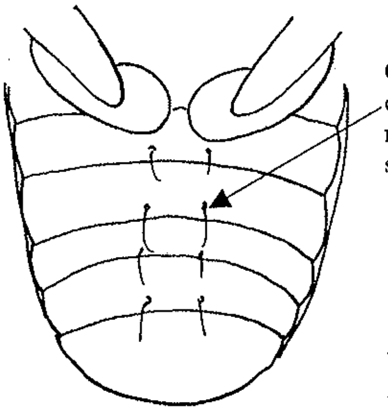

One pair of setae on either side of midline on each sternite

Figure 11a

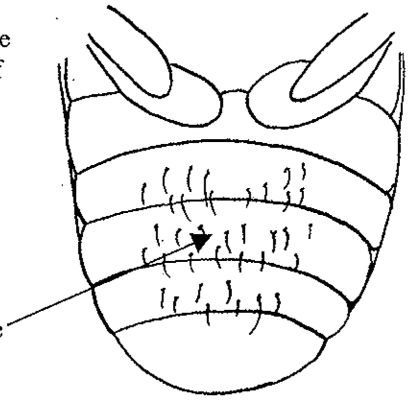

Numerous setae on each sternite

Figure 11b

12. a) Apices of elytra rounded, no abdominal tergites visible (Fig. 12a) **13**

b) Apices of elytra truncate often with last abdominal sternite visible (Fig. 12b) **17**

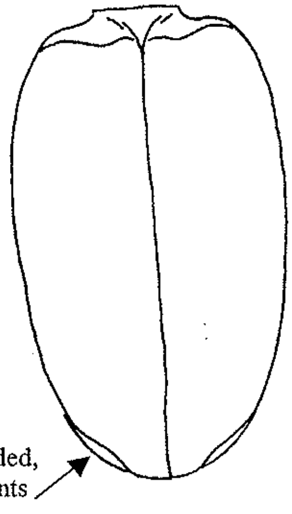

Elytra apice rounded, abdominal segments not visible

Figure 12a

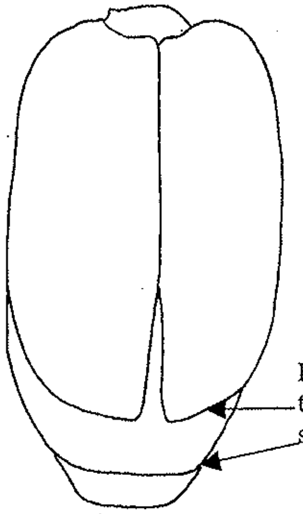

Elytral apice truncate, abdominal segments visible

Figure 12b

13. a) Mentum with bifid middle tooth (Fig.13a).
PTEROSTICHINAE:................................**14**

b) Mentum with simple tooth (Fig. 13b)
AGONINAE: *Notagonum*.......................**16**

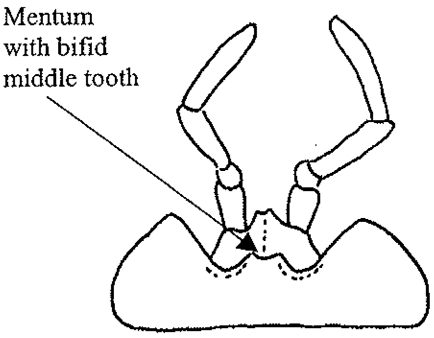


Figure 13a

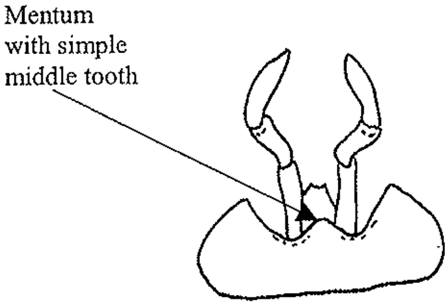


Figure 13b

14. a) Three terminal abdominal sternites grooved or sulcate(Fig. 14a); basal border present on elytra; scutellary striole absent; pore absent on anterior elytra.

Simodontus australis (Dejean 1828)

b) Abdominal sternites smooth, i.e. not grooved or sulcate; basal border present on elytra (i); scutellary striole present (ii); pore present at point where 1st and 2nd striae unite (iii) (Fig. 14b)
....**15**

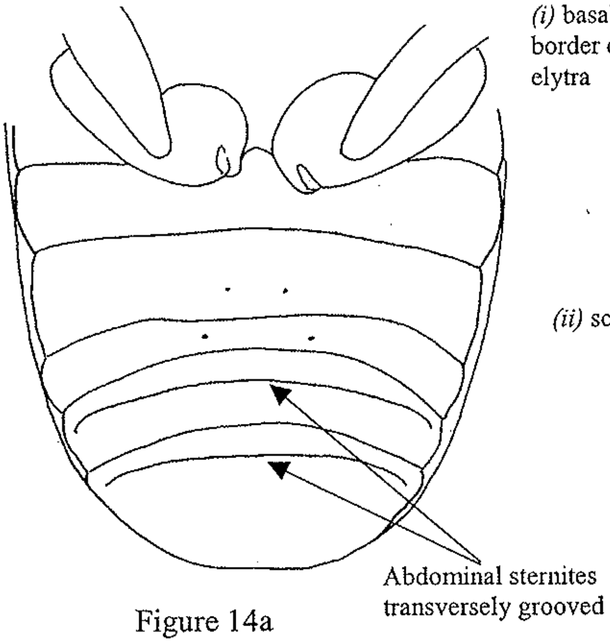


Figure 14a

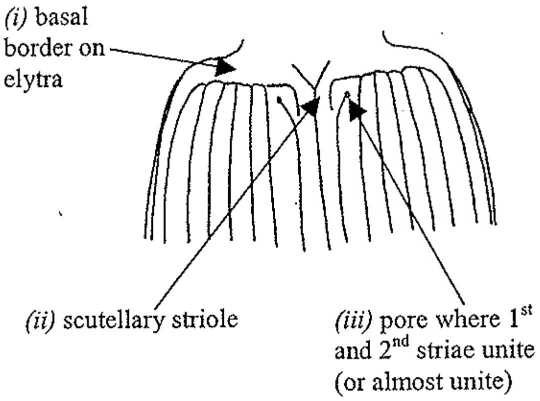


Figure 14b

15. a) Margin of pronotum narrow (i); pronotum sulcate forming "u" shape on either side at base of pronotum(ii) (Fig. 15a).

Notonomus mediosulcatus (Chaudoir 1865)

b) Margin of pronotum expanded, forming an extension at the posterior of pronotum.

Sarticus iriditinctus (Chaudoir 1865)

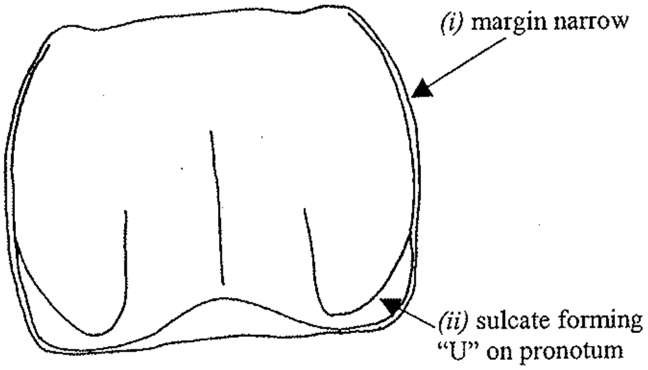


Figure 15a

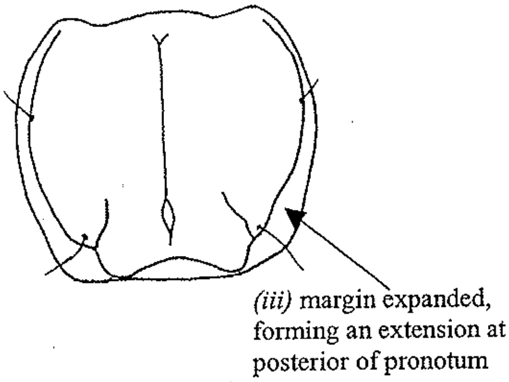


Figure 15b

16. a) Six rows of pits or fovea down length of each elytron (i); foviate striole present (ii), heavy pitting at basal margin of prothorax (iii) (Fig. 16a); total length of animal about 6 mm; colour variable from golden brown to blackish.

Notagonum sp.

b) Six striations (not pitted or foveate) down length of each elytron (iv); striole present (v); dorsal prothorax smooth (vi) (Fig.16b); total length of animal about 10-11 mm; colour dark olive to brown with a metallic sheen.

Notagonum submetallicum (White 1846)

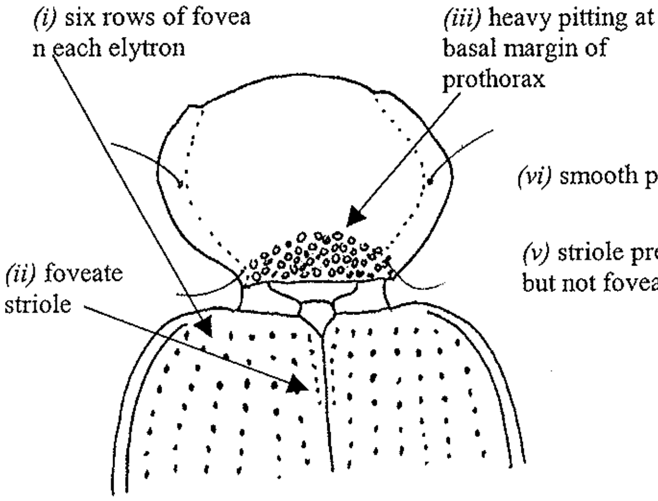


Figure 16a

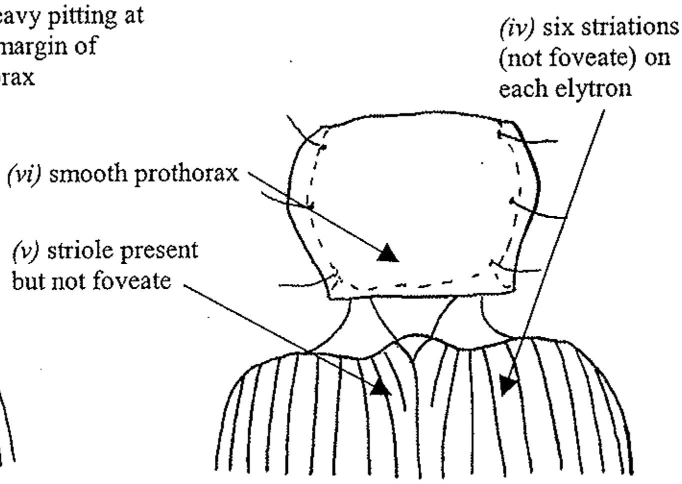


Figure 16b

17. a) Neck constricted (i); eyes large, swollen and protruding (ii); prothorax roughly triangular in shape (iii); colour satin metallic black (Fig. 17a).

PENTAGONICINAE: *Scapodes boops* Ericson 1842

b) Neck not constricted; eyes large but not protruding (iv); prothorax square to rectangular in shape (v); legs pale in colour, body mottled or patchy (Fig. 17b) **18**

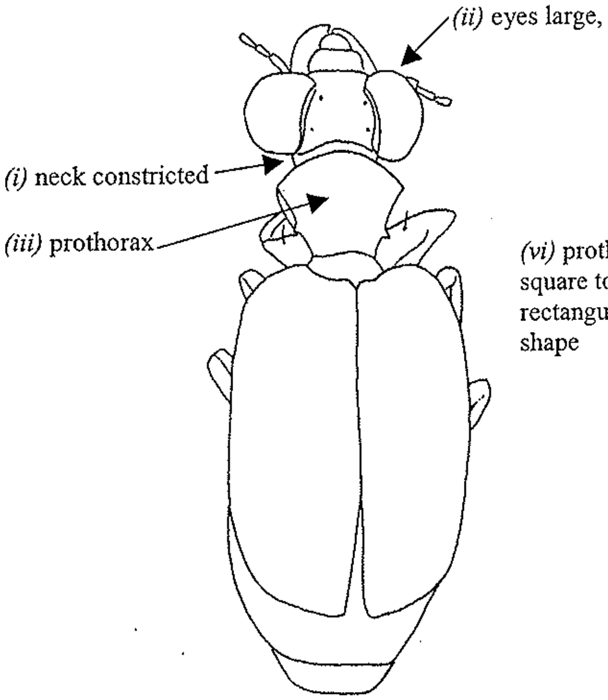


Figure 17a

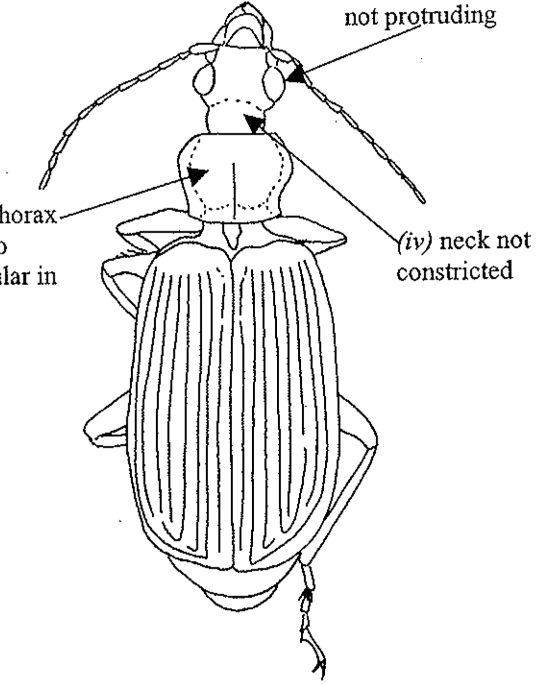


Figure 17b

18. a) Hind tibial spur more than half as long as 1st tarsal segment (Fig. 18a)
TRIGONODERINAE: (near) *Sarothrocepis*

b) Hind tibial spur short (Fig. 18b) – **LEBIINAE**............**19**

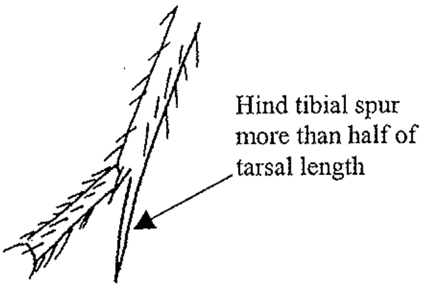


Figure 18a

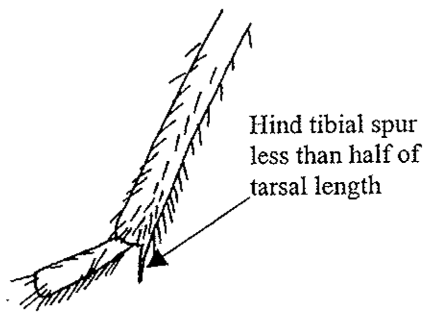


Figure 18b

19. a) Fourth segment of hind tarsus bilobed (Fig.19a), anterior edge of elytra simple, black longitudinal patches on pale elytra.

Trigonothops sp.

b) Fourth segment of hind tarsus simple, leading edge of elytra with large medial indentation (Fig. 19b), overall colour mottled with darker prothorax.

Speotarsus sp.

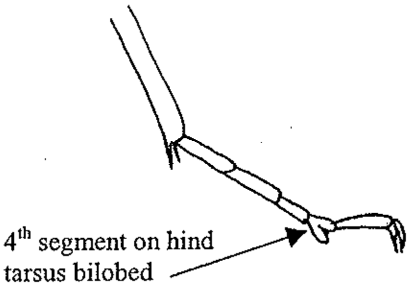


Figure 19a

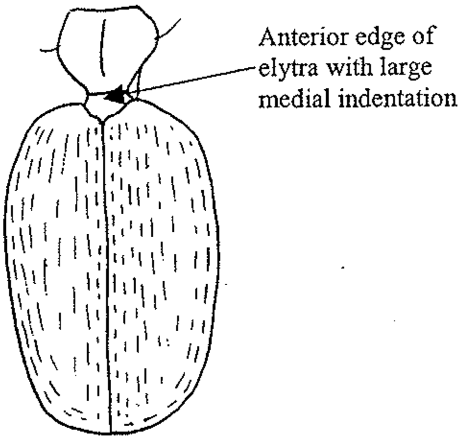


Figure 19b

4.6 REDESCRIPTIONS OF SELECTED NON-FLYING CARABIDAE FROM QUINDALUP DUNES.

4.6.1 THE BROSCINAE

4.6.1.1 Genus *Gnathoxys*

The majority of *Gnathoxys* species occur in the south-western region of Western Australia. Of the 16 recognised species, seven are not recorded from this state: *G. barbatus, G. humeralis, G. irregularis, G. murrumbidgensis, G. submetallicum, G. sulcicollis* and *G. tesselatus*. According to Moore *et al.* (1987) most of these species are found in localised areas along the Murray-Darling River system. The only exceptions to this are *G. tesselatus*, which is found near Port Essington in the Northern Territory (a doubtful locality as *G. granularis* was also reported from there by Westwood, and no other specimens from either species have been collected there since) and *G. sulcicollis*, which is reportedly from central Australia (no type locality reported by Moore *et al.* 1987). Only *G. punctipennis* has been found in both Western Australia and South Australia. All other *Gnathoxys* species occur in the South-Western Botanical province of Western Australia. *Gnathoxys granularis* also occurs along the northern coastal region. The discovery of a new species at Woodman Point Reserve in the Perth Metropolitan Area and the presence of several currently unidentified forms in collections (Western Australian Museum, AGRICULTURE W.A. and the Australian National Insect Collection; N.A. Guthrie, unpublished observations) indicates that this genus requires an immediate revision. It is highly likely that more *Gnathoxys* species occur in poorly surveyed areas of south-western Australia.

Gnathoxys Westwood

Gnathoxys Westwood, 1842:89. Type species: none designated

Gnathoxys crassipes Sloane

Key Figure 14a; Text Figures 4.1a, 4.2a, 4.3a.

Gnathoxys crassipes Sloane, 1898: 446; syntypes from Geraldton and Rottnest Island, W.A. (ANIC and SAMA).

MATERIAL EXAMINED

Bold Park: BP1 (1993-94), 31°57'11"S 115°45'50"E, dry pitfall, 23 November-24 December 1993, RH, 1 M (NAG0042); same site, wet pitfall, 6 January-18 March 1994, MSH/JMW, 1 F (NAG0041); same site, 18 March-19 May 1994, MSH/JMW, 1 F (NAG0040); BP1 (1996-97), 31°57'12"S 115°46'31"E, wet pitfall, NAG, 10 October-21 November 1996, 1 F (NAG0982); same site, wet pitfall, 21 November 1996-2 January 1997, NAG, 3 M (NAG1018, 1019, 1024); same site, wet pitfall, 2 January-14 February 1997, NAG, 2 M (NAG1022, 1023); same site, wet pitfall, 14 February-1 April 1997, NAG, 1 F (NAG1074); same site, wet pitfall, 1 April-9 May 1997, NAG, 1 F (NAG1216).

Bold Park: BP3, 31°56'30"S 115°46'27"E, dry pitfall, 24 January-5 February 1994, RH, 4 M (NAG0581-584).

Bold Park: BP4, 31°56'29"S 115°46'16"E, dry pitfall, 23 November-24 December 1993, RH, 3 M (NAG0289-291); same site, dry pitfall, 5 October-20 November 1995, RH, 1 F (NAG0039).

Bold Park: BP5 (1996-97), 31°57'07"S 115°45'59"E, wet pitfall, 2 January-14 February 1997, NAG, 1 M (NAG1015); same site, wet pitfall, 14 Februrary-1 April 1997, NAG, 1 F (NAG1009).

Bold Park: BP6, 31°56'00"S 115°46'26"E, dry pitfall, 5 October-20 November 1995, RH, 1 F (NAG0035), 1 M (NAG0038).

Mount Claremont Reserve: MC1, 31°57'40"S 115°46'60"E, dry pitfall, 1-12 December 1994, RH, 5 M (NAG0494-497, 662); same site, wet pitfall, 21 March-4 May 1995, JMW/MSH, 1 M (NAG1824), 1 F (NAG1825).

Mount Claremont Reserve: MC2, 31°57'39"S 115°45'56"E, wet pitfall, 4 November 1994-19 January 1995, JMW/MSH, 1 F (NAG0036), 1 M (NAG0037); same site, dry pitfall, 1-12 December 1994, RH, 1 F (NAG0492), 2 M (NAG0490, 491); same site, wet pitfall, 19 January-21 March 1995, MSH/JMW, 1 F (NAG0123).

Trigg Dune Reserve: TD2 (1995-96), 31°52'30"S 115°45'35"E, wet pitfall, 28 November 1995-29 January 1996, MSH/JMW, 1 M (NAG0505); same site, wet pitfall, 29 January-28 March 1996, JMW/PLW, 1 F (NAG1748), 2 M (NAG1749, 1750); TD2 (1996-97), 31°52'31"S 115°45'44"E, wet pitfall, 14 February-1 April 1997, NAG, 1 M (NAG1010); same site, wet pitfall, 9 May-19 June 1997, NAG, 1 F (NAG1354).

Trigg Dune Reserve: TD4 (1995-96), 31°52'45"S 115°45'17"E, wet pitfall, 28 November 1995-29 January 1996, MSH/JMW, 2 M (NAG0319, 320); same site, wet pitfall, 29 January-28 March 1996, JMW/PLW, 1 F (NAG1745); TD4 (1996-97), 31°52'36"S 115°45'41"E, wet pitfall, 21 November 1996-2 January 1997, NAG, 3 F (NAG0998, 1040, 1078), 2 M (NAG1002, 1036); same site, wet pitfall, 2 January-14 February 1997, NAG, 1 M (NAG1016); same site, wet pitfall, 9 May-19 June 1997, NAG, 1 F(NAG1336).

Woodman Point Reserve: WP1, 32°07'47"S 115°45'23"E, wet pitfall, 24 June-1 September 1994, JMW/AFL, 1 F (NAG1810); same site, wet pitfall, 4 November 1994-19 January 1995, JMW/MSH, 2 F (NAG0306, 1806); same site, dry pitfall, 14 November-11 December 1994, JD, 1 M (NAG0294); same site, wet pitfall, 19 January-21 March 1995, MSH/JMW, 1 F (NAG0684); same site, wet pitfall, 21 March-4 May 1995, JMW/MSH, 1 M (NAG0299); same site, wet pitfall, 4 May-6 July 1995, JMW/MSH, 1 F (NAG0611).

Woodman Point Reserve: WP2, 32°07'50"S 115°45'28"E, wet pitfall, 24 June-1 September 1994, JMW/AFL, 1 F (NAG1801); same site, wet pitfall, 1 September-4 November 1995, JMW/AFL, 1 F (NAG0655); same site, dry pitfall, 14 November-11 December 1994, JD, 1 F (NAG0292), 1 M (NAG0293); same site, wet pitfall, 19 January-21 March 1995, MSH/JMW, 2 M (NAG0295, 296); same site, wet pitfall, 21 March-4 May 1995, JMW/MSH, 1 F (NAG1817), 1 M (NAG1818).

Woodman Point Reserve: WP3, 32°07'58"S 115°45'29"E, dry pitfall, 1-12 March 1995, JD, 1 F (NAG0301), 1 M (NAG0302).

Woodman Point Reserve: WP4, 32°07'58"S 115°46'29"E, wet pitfall, 24 June-1 September 1994, JMW/AFL, 1 F (NAG1794); same site, wet pitfall, 19 January-21 March 1995, MSH/JMW, 1 M (NAG0190); same site, wet pitfall, 21 March-4 May 1995, JMW/MSH, 1 M (NAG0186).

Yanchep National Park: YP1, 31°31'00"S 115°39'18"E, wet pitfall, 2 January-14 February 1997, NAG, 1 M (NAG1014); same site, wet pitfall, 14 Februrary-1 April 1997, NAG, 1 F (NAG1013).

Yanchep National Park: YP2, 31°34'07"S 115°40'55"E, wet pitfall, 10 October-21 November 1996, NAG, 1 F (NAG0796); same site, wet pitfall, 21 November 1996-2 January 1997, NAG, 2 M (NAG0996, 997); same site, wet pitfall, 14 Februrary-1 April 1997, NAG, 2 M (NAG1011, 1012).

DIAGNOSIS

Gnathoxys crassipes is separated from the other members of *Gnathoxys* by the presence of four rows of fovea on the each elytron. The first row consists of a single line of foveae, the second, a double row, and the third and fourth rows consist of increasingly irregular clusters. In his treatment of this species, Sloane (1898) gave a brief species diagnosis, not repeated here, which did not clearly differentiate *G. crassipes* from the other foveate *Gnathoxys*.

DESCRIPTION

Measurements.

Description based on specimen NAG0041 (Figure 4.1a) except where specified. Total length = 16.4 mm; elytra length/width = 9.5/6.6 mm; pronotum length/width = 4.8/5.6 mm; head length = 3 mm; foretibia length = 3.1 mm.

Colour.

Entirely black without sheen, yellow eyes.

Head.

Mandibles long and heavy, no teeth on straight edge, slightly curving inward at apex. Outer edge strongly curved towards apex, left mandible overlaps slightly at apex when closed. Mandible dorsal surface smooth. Deep and wide mandibular groove laterally positioned, length approximately half total mandible length. A single seta without puncture ring positioned at apex of groove.

Single seta on medial surface of 2nd segment and on ventral surface of basal segment of maxilla palp. Cluster of 3 setae on either distal extremity of basal maxilla. Cluster of setae occurs on ventral surface of 2nd segment of labial palps. Medial margin with 2 fine setae on anterior mentum, and 1 seta on either side of extremities of submentum. Labrum slightly broader than long, bifid with complete medial sulcus and rounded, fringed anteriorly by seta under the margin and 3 pairs of stiff setae on anterior dorsal margin. Single posteriorly positioned supraorbital setae just medial to supraorbital sulcus which runs anteriorly to terminate just behind mandibular groove. Latero-medial sulcus forms slight depression in line with posterior eye, running forward and strengthening on the clypeus, terminating with punctate seta in front but not joining lateral margins of labrum. Clypeus medially and anteriorly depressed and slightly rounded. Eyes are round, convex and not prominent, with orbits slightly swollen below eyes posteriorly. Antenna short, moniliform with single seta on scape and segments 4-11 covered dorsally and ventrally with thick short setae.

Prothorax.

Pronotum very rounded and subspherical, extensions at head insertion point almost non-existent. Strong medial sulcus almost reaches anterior margin. Pronotal margin very narrow with 3-5 seta on anterior ¼ and 2-3 seta on posterior ¼ of margin. Basal margin thickened and upturned slightly with angles quadrate. Dorsal surface of pronotum smooth.

Elytra.

Elytra convex to rectangular in shape, slightly longer than wide with widely rounded apex. Shoulders project strongly from short peduncle. Elytral margin not prominent, but narrow with widely spaced setae along anterior half. Surface granulated on apical declivity (posterior ¼ of elytra length), and extending along the lateral elytral margin. Dorsal surface of each elytron with 4 rows of small fovea extending down length. From midline, 1st row of singular fovea, 2nd in double row, 3rd and 4th irregular and paired fovea, most in depressions.

Legs.

Forelegs- A single seta on ventral surface of trochanter. Linear cluster of setae along medial two thirds of ventral anterior edge of femur. On opposite side, 3 evenly spaced setae. On dorsal surface cluster of setae extends along entire length of femur. Femur narrower dorsally. Anterior surface of tibia has 3 setae down midline, opening distally. Series of stiff setae on inner edge of tibia runs from upper femoral joint, terminating just posterior to cleaning organ. The cleaning organ claw same size as the apical claw. Fringe of fine setae runs from cleaning organ past apical claw to distal end of tibia above tarsus insertion point. Two sub-oblique triangular teeth on outer tibial edge. On the posterior side of each tooth a short, stiff seta which opens distally is positioned. Four distally opening punctate setae form row down posterior midline of tibia. Apical tooth is flattened, broad and rounded. Tarsal segments are triangular with outer edge extended, diminishing in tarsomeres 3, 2 and 1. Stiff and thickened setae on distal margin of each tarsomere; final segment filiform with 2 lateral setae. Claws short and curved.

Midlegs- Cluster of setae on anterior ventral surface of coxa and 1 on ventral surface of trochanter. Two clusters of setae in curved linear line, 1 on anterior surface and 1 on posterior surface of femur join large cluster of setae on dorsal surface. Tibia flattened and broad apically with 4 linear rows of short punctate setae on anterior and posterior surfaces. Apical tooth is large and flattened with slight hook to apex. Fringe of setae occur around tarsal insertion point. The 2 apical claws are of similar length to apical tooth. Tarsi are triangular without extensions but with same setal arrangement as anterior tarsi.

Hindlegs- Apical coxal margin has 2 punctate seta and basal margin 3 punctate setae. Posterior and dorsal surfaces of trochanter have thick clusters of setae. Femur with double curving row of setae on anterior-ventral surface and thick cluster of setae on dorso-anterior surface. Tibia not flattened, with 5-7 disjunct linear rows of punctate setae down tibial length. Posterior setae tend to be longer than anterior setae. On outer edge 8 very weak and small blunt serrations or teeth have short setae on their posterior side. Apical teeth are short and inserted together on the tibia. Apical tooth is squat, rounded and subrectangular. Tarsi identical to midtarsi in all respects.

Abdomen.

Thick cluster of curling setae, extends in front of anterior legs on convexed prosternum, cluster wider anteriorly, lateral to midline. Small cluster of punctate setae occurs directly anterior to each, very weak, proepimeron tubercular extension. Posterior ventrites bisetose medially with final pair on apical margin.

Female Genitalia.

Description based on specimen NAG1817. Styli identical, curved dorsally with dorsal surface slightly concave. On outer edge of styli a lip is present, with fine setae on inner and outer edges. Transverse crease forms slight "neck" at apical fifth of stylus. Stylus length 2.45 mm.

Male Genitalia.

Description based on specimen NAG1015. Male genitalia are illustrated in Figure 4.2a. Genital ring wider at apex, slightly convex without lateral contortion and 4.2 mm long. Ring simple without apical shelf or other extension. Asymmetrical parameres, left paramere with fringe of setae extending along anterior half, right paramere simple, peg-like. Penis 3.5 mm long, thick, slightly curved, orifice on the dorsum, displaced to right.

Variation.

Eye colour variable in tone (either pale yellow, golden or black). Up to 12 setae can be present on the elytral margin and odd seta can be located on the ventral surfaces other than mentioned. All setal arrangements mentioned vary in the number of setae both between individuals and within individuals. The proepimeron tubercles range in size from non-existent to extremely weak and small. The most plastic characters, morphologically speaking are the number and extent of both anterior tibia teeth and fovea on the elytra.

The teeth can be quite large and distinct in some individuals whereas in others they are found to be quite small and close together. Both these conditions can also occur within the same individual. This may be an erosion artefact of burrowing behaviour as well as morphological plasticity.

The fovea on the elytra always follow the pattern of four rows of increasingly irregular fovea but the extent or completeness of each individual row down the length of the elytra varies between both elytra of the same individual and between individuals. One individual (NAG1825: MC1, 21 March-4 May 1995) had a series of faint regular, very small, punctures between the fovea rows, this is the only case of secondary pitting on the elytra surface. There does not however, seem to be either sexual or regional-based differences in any of these characters.

Distribution.

A fairly widespread species, found in most areas of the south-west, extending to Eneabba in the north and Albany in the south (Figure 4.3a). The apparent eastern boundary of its distribution is the western Wheatbelt region and it appears to be absent from the high rainfall regions of the Karri Forest and the southern Jarrah Forest.

Remarks.

Sloane (1898) first described this species from specimens collected from Rottnest Island and Geraldton by A.M. Lea. He suggested that *Gnathoxys crassipes* is allied to *Gnathoxys obscurus* Reiche and that the two species might represent the extremes of the possible size range of this taxon. *Gnathoxys crassipes*, while having a distinctive elytral pattern of fovea is very similar in size and shape to most other *Gnathoxys* species in the south-west.

Gnathoxys granularis Westwood

Key Figures 1a, 5b, 6b, Text Figures 4.1c, 4.2c, 4.3b.

Gnathoxys granularis Westwood, 1842:89, figs 2, 2a-c; syntypes (possible), OUM, from Port Essington, N.T. (locality doubtful).

Gnathoxys blissii Macleay, 1866:lviii; syntypes, whereabouts unknown, from Swan River, W.A. Synonomised by Csiki, E. (1928).

MATERIAL EXAMINED

Yanchep National Park: YP1, 31°31'00"S 115°39'18"E, wet pitfall trap, 10 October-21 November 1996, NAG, 1 F (NAG0786);

Yanchep National Park: YP2, 31°34'07"S 115°40'55"E, wet pitfall trap, 10 October-21 November 1996, NAG, 1 F (NAG0795); same site, wet pitfall trap, 1 April-9 May 1997, NAG, 1 M (NAG1075); same site, wet pitfall trap, 9 May-19 June 1997, NAG, 1 M (NAG1164).

DIAGNOSIS

A large heavily built *Gnathoxys*, typically black, often with a bronze to olive metallic sheen, heavy foretibia wide and spade-like in appearance. Differentiated from other members of the genus by rectangular shape, subquadrate pronotum, pronotal margin creased, relatively small head, subquadrate elytra with dorsal surface generally smooth, apical declivity, mesal elytra suture, lateral and anterior surfaces finely and densely granulated.

DESCRIPTION

Measurements.

Description based on specimen NAG1076 (Figure 4.1b). Total length = 27.1 mm; elytra length/width = 16.6/10.6 mm; pronotum length/width 9.0/1.1 mm; head length = 5.5mm; foretibia length = 5.4 mm.

Colour.

Shiny black with bronze to olive metallic lustre all over, yellow to orange eyes, anterior edge of penultimate palp segment reddish.

Head.

Large heavy mandibles with deep mandibular groove and one anteriorly positioned seta lacking puncture ring. No mandibular teeth present. Labrum bifid with rounded anterior edges and fringing setae under margin, 3 pairs setae on anterior dorsal margin, posterior mesal crease extending half labrum length. One supra orbital seta situated in supraorbital crease running forward to distal corner of clypeus. Shallow medial depression above eye, lateral crease at base of clypeus connecting front of antennal grooves. First pair of setae on this crease directly in front, half length of 2nd pair of clypeus setae. Antennae short, not reaching more than half length of pronotum. One seta on scape and fine setae from segment 5 to end of antenna. Distal segment of labium palps very secruiform with 1 seta on distal ends of segments 1 and 2. Apical mentum palp very secruiform with 2 setae on ventral surface of 3rd segment. Two seta on either side of gula extremities and 1 pair on extremities of submentum.

Prothorax.

Faint mesal sulcus present on subquadrate pronotum, extensions of pronotal shoulder at head insertion point. Pronotal margin strongly creased, becoming weakly creased along basal edge. Two setae on margin, 1stpositioned in anterior third, 2nd in posterior third. Faint lateral wrinkling across pronotum, strongest over posterior half, fading anteriorly. Lateral regions of pronotum just mesal of margins, slightly swollen.

Elytra.

Subquadrate in shape, deep dorso-ventrally and wider posteriorly. Elytral margin very narrow, not prominent. Strong mesal elytral suture complete down length. Fine dense granulations on apical declivity, lateral edges and anterior shoulders of elytra. Granulations begin to lose form, becoming larger dorsally and anteriorly. Upper mesal dorsal surface smooth with sparse fine hairlike sulci. Along each lateral margin 12 fine seta spread evenly.

Legs.

Forelegs- One seta on ventral trochanter, setae in semi-linear line on mesal anterior ventral femur surface, 2 setae on posteriormesal half and 1 seta on distal third of femur surface. Linear line of setae on ventral tibial surface. Two setae on posterior surface of 2nd tibial tooth, each tooth has an anteriorly positioned seta at tooth base. On dorsal tibial surface linear row of setae divides distally, one row anteriorly above apical prong and cleaning organ, other terminating at anterior surface of apical tooth (flattened and broad). Tarsal segments flattened and extended on outer distal side, less so distally with final segment not extended. Fringe of small spines on distal margin of each segment, increasingly prominent distally. Final segment has 2 laterally positioned long setae and claws sub-equal to half segment's length.

Midleg- Fringe of setae on ventral surface of trochanter. Two curved linear rows of setae along length of femur, 1 on ventral-posterior, 1 on dorso-posterior surfaces. Linear rows of stiff setae along length of posterior, dorsal and ventral surfaces of tibia. Apical tooth obliquely triangular and flattened, similar in size to apical prongs. Tarsi filiform with setae on lateral ventral surface, getting longer distally on each segment.

Hindlegs- Linear line of thick setae on posterior edge of heavy rounded trochanter approximately 1/3 of femoral length. On posterior ventral surface curved linear arrangement of long seta positioned down femur. All surfaces of the posterior tibia covered in linear lines of short setae. Apical prongs equal in length and apical fringe of setae on tibial distal margin. Hind tarsi similar to midtarsi, with fewer setae on ventral surface.

Abdomen.

Ventrites bisetose and mesally placed, final pair on apical edge of final ventrite. Large protrubercle extension of proepimeron, on each side.

Female Genitalia.

Description based on specimen NAG0786. Stylis long, flattened and bladelike, not concave on dorsum; 6 thin setae on inner edge of each stylis.

Male Genitalia.

Description based on specimen NAG1164 (Figure 4.2b). Penis large, heavily chitinised, simple and symmetrical, orifice dorsally located. Parameres dissimilar, left reduced and possessing large extension on outer edge, right paramere simple with thick brush of setae extending from lower apex to basal third.

Variation.

The granulations on the elytra may extend from the apical declivity either side of the elytral suture, or appear in patches on the upper dorsal surface. Eye colour may vary from yellow, or orange to black. No discernible sexual characters exist apart from females possessing filiform apical palp segments rather than secruiform as in the males.

Distribution.

Generally found on coastal sands south from Perth to Shark Bay in the north (Figure 4.3b).

Remarks.

This large distinctive species differs from all other known members of the genus by its overall shape and predominance of granulations rather than fovea on the elytra. This implies is that it may be only distantly-related to other south-western Australian *Gnathoxys* species.

Gnathoxys pannuceus, sp. nov.

Key Figure 14b; Text Figures 4.1b, 4.2b.

MATERIAL EXAMINED

Woodman Point Reserve, Western Australia, WP2 32°07'50" S 115°45'28" E, wet pitfall trap, 4 November 1994-19 January 1995, JMW/MSH, holotype male (NAG0713).

DIAGNOSIS

This species is similar in overall appearance and size to *Gnathoxys crassipes* but is easily distinguished from it and other south-western *Gnathoxys* species by a number of features. *Gnathoxys pannuceus* sp. nov. is heavy in appearance with a large head relative to overall size. The pronotum is strongly globular in shape with a distinct medial sulcus and faint wrinkles on the otherwise smooth dorsal surface. The pronotum and elytra margins have fine long setae in greater abundance than other similarly sized *Gnathoxys*. The most obvious character which separates this species from all others in the genus is the striking elytral pattern. Where *G. granularis* has distinct granulated areas on the elytra, and the other typical elytral pattern of south-western *Gnathoxys* are series of fovea, punctures or similar depressions, this species has a highly distinctive reticulated pattern. No visible resemblance to other described *Gnathoxys* species can be discerned.

DESCRIPTION

Measurements.

Description based on specimen NAG0713 (Figure 4.1c). Total length = 13.3 mm; elytral length/width = 7.6/5.9 mm; pronotum length/width = 4.3/5.1 mm; head length = 3.0 mm; foretibia length = 2.9 mm.

Colour.

Entirely black without bronze or olive sheen, distal edge of palps pale wheat colour and dark orange eyes.

Head.

Very long heavy mandibles approximately two thirds of head length, slightly curved downward. Inner mandible edge straight and toothless, curved toward apex with deep overlap of mandible apices. Mandibular groove wide and shallow, approximately half mandible length, mandibular ridge very narrow along all of its length. Single seta at apex of groove and non-setiferous puncture on outer curve of mandibles near apex. Single seta on medial surface of 2nd segment and on ventral surface of basal segment of maxilla palp. Cluster of 3 setae on either extremity of basal maxilla. Cluster of setae on ventral surface of 2nd segment of labial palps. Two fine setae on anterior mentum medial margin and 1 on either side of extremities of submentum. Labrum is slightly broader than long, bifid and rounded. Medial sulcus extremely faint. Fringe of setae under the anterior margin with 3 pairs of setae on dorsal anterior margin. Outer labrum edges are yellow with remainder reddish brown. Eyes are round, convex and not prominent or overly large. Antenna short, moniliform with single seta on scape and segments 4-11 covered dorsally and ventrally with thick short setae. Supraorbital seta is positioned posteriorly to eye with supraorbital sulcus running forward to terminate just posterior to mandibular ridge. Latero-medial sulcus on either side of head, initiated in line with anterior half oxeye, is deep and runs directly forward to lateral extremities of clypeus where it deepens further. Clypeus is medially and anteriorly depressed, and has 1 mid and 2 lateral creases medially aligned.

Prothorax.

Pronotum very rounded, subspherical with very weak extensions at head insertion point. Narrow pronotal margin, with setae in anterior and posterior thirds of margin. Medial sulcus fine and strong, reaching forward to anterior margin. Lateral wrinkles traverse pronotum surface, strongest near medial sulcus, lateral margins and towards basal margin. Basal margin thickened and blunt.

Elytra.

Subquadrate in shape, elytra slightly longer than broad with rounded sides and apex. Thick, short peduncle with heavy shoulders projecting. Very thin elytral margin with 5-6 setae evenly spaced along anterior two thirds of margin. Apical declivity finely granulated, extending over posterior one sixth of elytra. Granulations extend along lateral margins, fading anteriorly. Along dorsal edge of the apical declivity 4 setae are evenly spaced on each elytron. Dorsal surface of elytra finely creased and wrinkled with extremely irregular sulci, producing the effect of "crumpled aluminium foil re-flattened".

Legs.

Foreleg: Trochanter ventral surface has 1 punctate seta. Femur has 1 cluster of setae on anterior ventral edge, 2 setae on posterior ventral edge, 3 setae on centre of posterior dorsal edge and a cluster centrally positioned on dorsal surface. Two teeth present on outer tibial edge, upper one smaller, both have one seta positioned on posterior distal margin. Linear arrangement of 3 setae down midline in line with antennal cleaning organ. Along inner edge of tibia is row of fine hair-like setae terminating at cleaning organ. Apical tooth faces distally and is rounded, flattened. Tarsomeres triangular with outer lateral edge extended, weakening distally towards 2nd tarsomere. Three or four stiffened setae on both tarsomere edges. Apical tarsomere filiform with 2 setae on lateral edges, tipped with symmetrical short curved claws.

Midleg: Coxae with cluster of setae on anterior surface, 1 seta on ventral surface and one on the ventral trochanter. Curved linear cluster of setae on anterior femoral surface. Sparse cluster of setae on posterior and dorsal femoral surfaces. Femur widened dorso-ventrally. Tibia flattened and broad apically, with linear rows of stiff setae orientated distally on anterior and posterior surfaces. Triangular apical tooth with stiffened setae forming a fringe around distal surface of tibia at tarsus insertion point. Two similar sized apical teeth inserted below tarsus. Tarsal arrangement identical to foretarsus.

Hindleg: Coxae with 2 setae on apical and basal margins. Cluster of setae on posterior and dorsal surfaces of trochanter. Long setae in curved linear clusters on posterior and ventral surfaces of the femur. Long setae sparsely distributed on distal ventral and dorsal third of femur. Tibia elongate, flattened with widened distal end. Rounded apical tooth broad and short. Tibia edge serrated weakly, serrations with rounded points. Stiffened short setae in linear rows thickly covering tibial surfaces. Shortened apical teeth, equal in length set below tarsal insertion point. Tarsal arrangement identical to anterior tarsus.

Abdomen.

Prosternum with wrinkles around sparse cluster of setae in front of each leg (widest anteriorly), wrinkles continue onto proepimeron, tubercles reduced to slight swollen areas between anterior coxa. Ventrites bipunctate medially, with final pair positioned on apical margin.

Male Genitalia.

Genital ring ovoid in shape with thin edges and no extensions (Figure 4.2c). Slight concavity to ring toward basal third. Penis is thick, with no curvature, small hook at apex. Orifice dorsally placed behind apex. Left and right sides of penis not symmetrical, with left (or ventral view) possessing extension on upper surface near orifice. Parameres dissimilar, left with extension on inner edge, extending to paramere apical third. Right paramere larger and thicker, with thick setal brush extending from apex to mid-length. This paramere is almost equal to penis in length.

Distribution.

Only known from the type locality.

Remarks

While being similar in size and shape to *G. crassipes* and other similar foveate *Gnathoxys* species from south-western Australia the relationship between these species and *G. pannuceus* is currently unclear. Surveys of surrounding bushland remnants to Woodman Point Reserve are required to determine the distribution and the variability of this species.

ETYMOLOGY

The specific epithet is derived from the Latin *pannuceus*, wrinkled, shrivelled, describing the characteristics of the elytra.

4.6.1.2 General Comments On Gnathoxys

Examination of all *Gnathoxys* specimens collected in this survey in addition to those held within the Western Australian Museum, indicates that sexual dimorphism is exhibited in the apical segments of maxillae and labial palps. Males have securiform apical segments while females are filiform. The extent to which this is developed varies between both species and individuals.

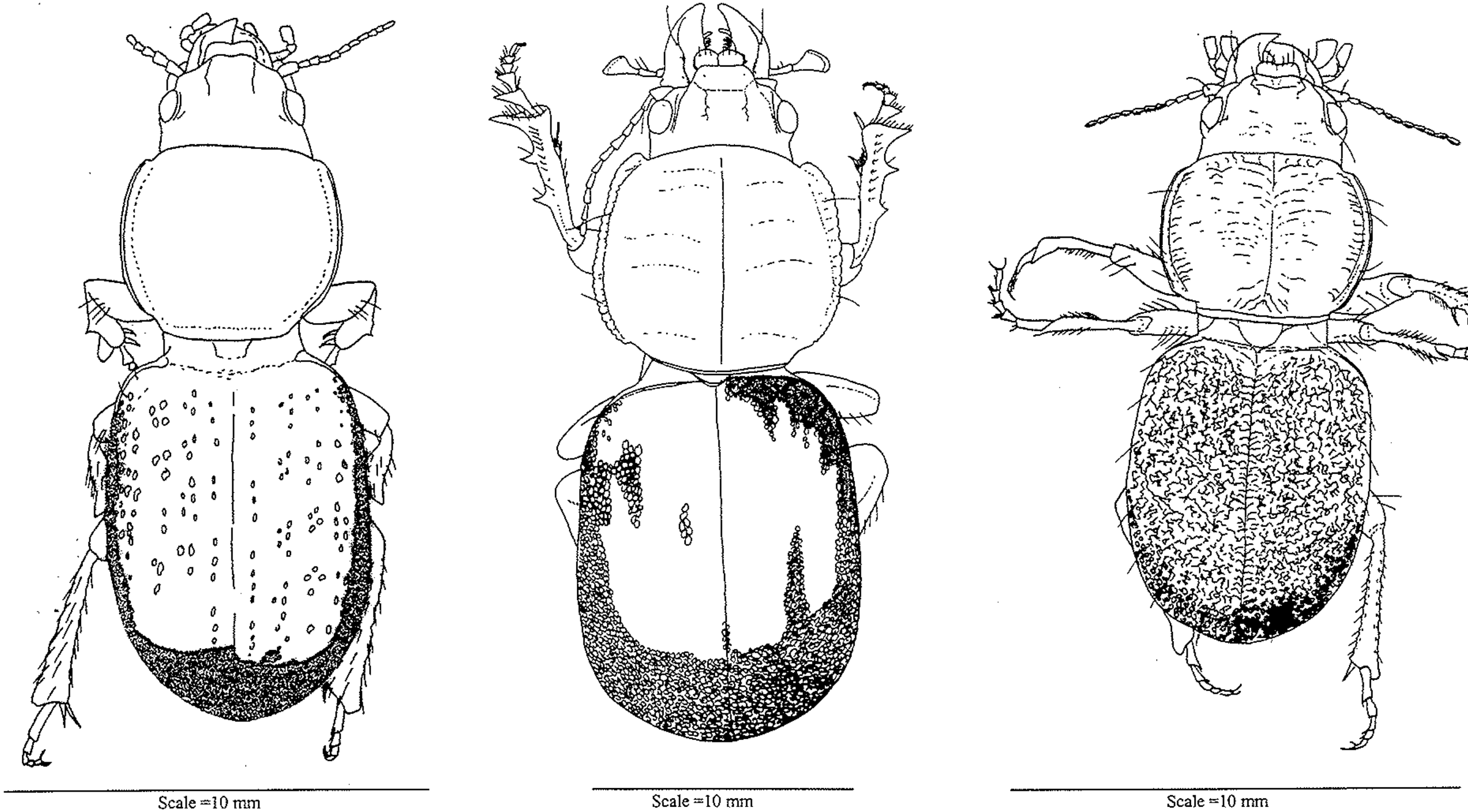


Figure 4-1: **Dorsal view of a) *Gnathoxys crassipes* (specimen NAG0041), b) *G. granularis* (specimen NAG1104) and c) *G. pannuceus* (specimen NAG0713).**
Note :scale bar = 10 mm.

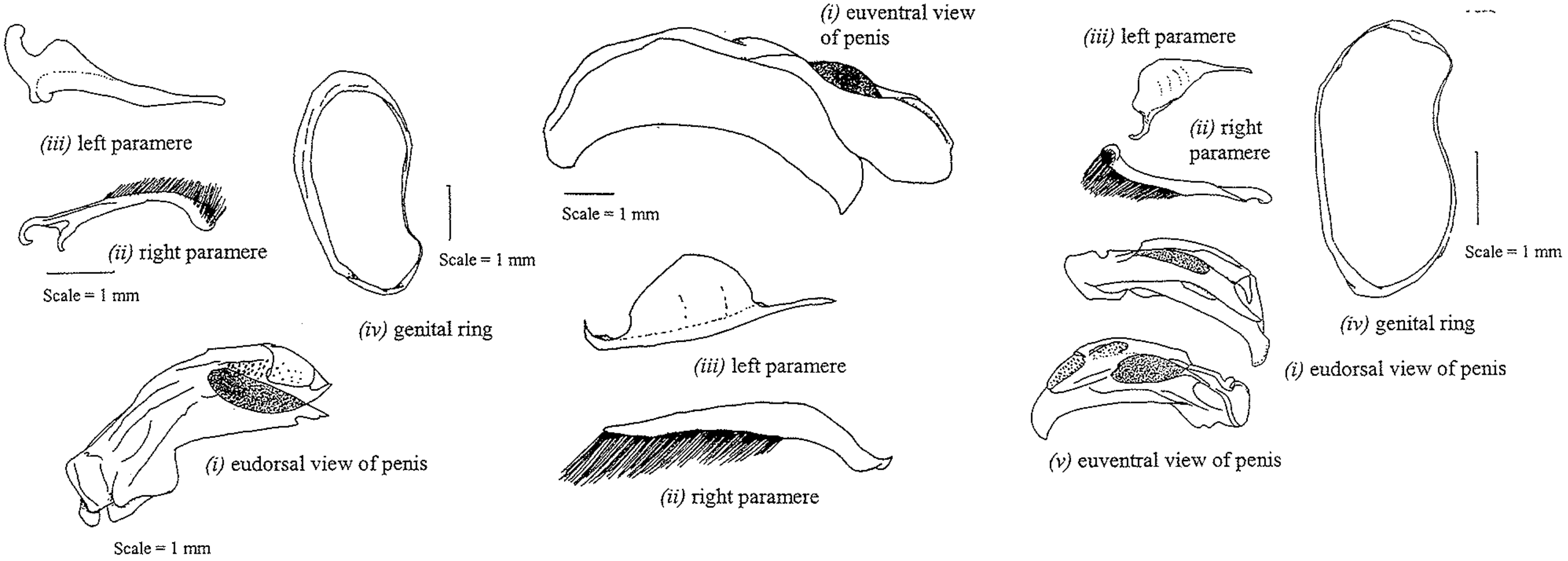


Figure 4–2a

Figure 4–2b

Figure 4–2c

Figure 4-2: Male genitals of a) *G. crassipes* (specimen NAG1015), b) *G. granularis* (specimen NAG1075) and c) *G. pannuceus* (specimen NAG0713).

Structures illustrated are (i) penis, (ii) right paramere, (iii) left paramere, (iv) genital ring (not illustrated for *G. granularis*), (v) penis in ventral view (*G. pannuceus* only). Scale bar = 1 mm in all diagrams (all structures in Figures 4.2 b & c to scale).

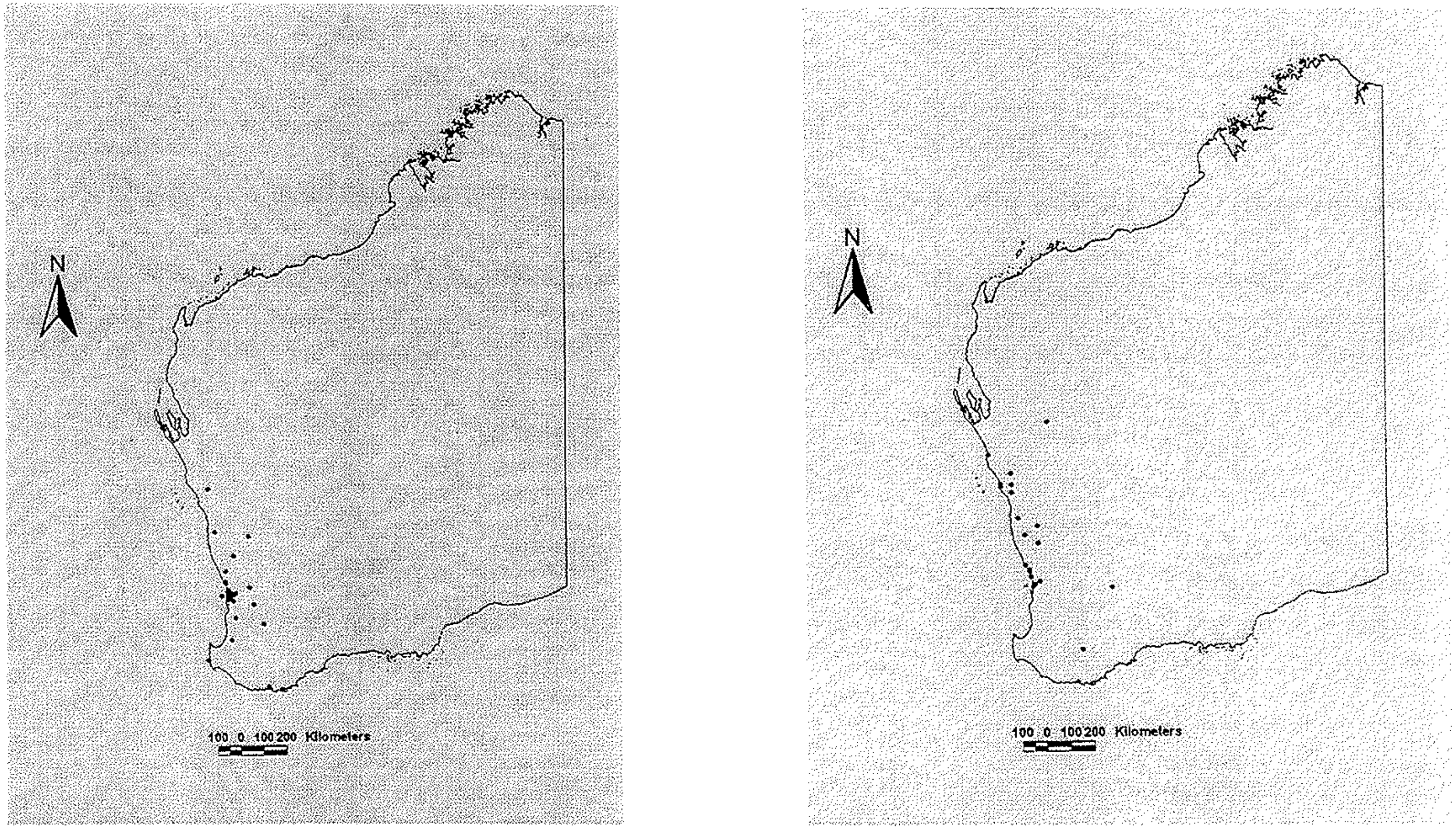


Figure 4-3: Distribution of a) *G. crassipes* and b) *G. grannularis* in Western Australia
Maps based on specimens and records held in the Western Australian Museum, AGRICULTURE WA and the Australian National Insect Collection (ANIC).

4.6.1.3 *Promecoderus scauroides*

Within the Australian Broscini the largest genus is *Promecoderus* with 51 known species identified by Moore *et al.* (1987). Primarily separated from their closest relatives by the lack of teeth on the outer edge of the foretibia, and the presence of a median tooth on the mentum, the species within this genus are weakly differentiated, making species identifications difficult. Moore *et al.* (1987) recognised nine species as occurring in the south-western region of Western Australia (*P. albaniensis* Castelnau 1867, *P. anguliceps* Sloane 1898, *P. clivinoides* Guérin-Méneville 1841,, *P. distinctus* Sloane 1890, *P. dyschiriodes* Guérin-Méneville 1841, *P. intermedius* Sloane 1898, *P. ovipennis* Sloane 1898, *P. subdepressus* Guérin-Méneville 1841 and *P. scauroides* Castelnau 1867; Moore *et al.* 1987). Very little is known of the distributions of these various species and their relationships, both evolutionary and ecological. As this genus is speciose with many species possessing localised distributions, it may be possible to identify relationships with abiotic factors and previous environments (such as Gondwanan habitats etc).

SYSTEMATICS

***Promecoderus* Dejean**

Promecoderus Dejean, 1829: 25. Type species: *Promecoderus brunnicornis* Dejean, 1829 by monotypy.

Cnemacanthus Gray, 1832:276. Type species: *Cnemacanthus gibbosus* Gray, 1832 by monotypy.

Anheterus Putzeys, 1868:345. Type species: *Promecoderus gracilis* Germar, 1868 by monotypy.

Acallistus Sharp, 1886:362. Type species: *Acallistus simplex* Sharp, 1886 by monotypy

DIAGNOSIS

The diagnosis for the genus is given by Sloane (1890), not repeated here, as it is still adequate today. However, as descriptions and keys have previously been based on male specimens (Sloane 1890), a revision of the genus incorporating female characters is required to further clarify species relationships and to rectify various anomalies in the taxonomy.

Promecoderus scauroides Castelnau

Key Figure 6a; Text Figures 4.4, 4.5, 4.6.

Promecoderus scauroides Castelnau, 1867:83; syntypes (possible), MCG, male specimen from Swan River, W.A.

MATERIAL EXAMINED

Bold Park: BP1 (1993-94), 31°57'12"S 115°46'31"E, wet pitfall, NAG, 29 August-10 October 1996, 1 M (NAG0862), 1 M (NAG0864); same site, wet pitfall, NAG, 10 October-21 November 1996, 1 F (NAG0904); same site, wet pitfall, NAG, 1 April-9 May 1997, 1 M (NAG1250), 1 M (NAG1256), 1 M (NAG1257).

Bold Park: BP3, 31°56'30"S 115°46'27"E, wet pitfall, J.M. Waldock *et al.*, 20 July-24 September 1993, 1 F (NAG0043); same site, wet pitfall, 24 September-19 November 1993, unsexed (NAG1775).

Bold Park: BP4, 31°56'29"S 115°46'16"E, wet pitfall, MSH/JMW, 20 May-20 July 1993, unsexed (NAG1787); same site, wet pitfall, J.M. Waldock *et al.*, 20 July-24 September 1993, 1 F (NAG0521), 1 M (NAG0523); same site, wet pitfall, 24 September-19 November 1993, 1 F (NAG0045), 1 M (NAG0046), unsexed (NAG1779); same site, dry pitfall, 18-31 October, RH, 1 F (NAG0191).

Bold Park: BP5 (1993-94), 31°57'14"S 115°46'16"E, wet pitfall, MSH/JMW, 20 May-20 July 1993, 1 F (NAG0687); same site, wet pitfall, J.M. Waldock *et al.*, 20 July-24 September 1993, 1 F (NAG0520); BP5 (1996-97), 31°57'07"S 115°45'54"E, wet pitfall, NAG, 29 August-10 October, 1 F each (NAG0768, 770, 771, 772, 776), 1 M each (NAG0759, 760, 773); same site, wet pitfall, NAG, 1 F each (NAG0872, 874, 962), 1 M each (NAG0848, 853, 854, 855, 871, 873, 961, 965, 966, 974); same site, wet pitfall, NAG, 9 May-18 June 1997, 1 F each (NAG1418, 1419, 1426, 1474- 1476, 1500, 1595),1 M each (NAG1316, 1371-1373, 1414-1417, 1469-1473, 1477-1480, 1486-1488, 1495-1499, 1596); same site, wet pitfall, NAG, 18 June-1 August 1997, 1 F each (NAG1212-1215).

Mount Claremont Reserve: MC1, 31°57'40"S 115°46'60"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, 1 F each (NAG0672, 674), 1 M (NAG673); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 1 F each (NAG0401, 403), 1 M (NAG0402); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 1 F (NAG0005), 1 M (NAG0006); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 1 F (NAG1826), 1 M (NAG1827); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 1 F each (NAG0139-141), 1 M each (NAG0142-144, 148-150).

Mount Claremont Reserve: MC2, 31°57'39"S 115°45'56"E, wet pitfall, JMW/AFL, 1 September-4 November 1994, 1 F each (NAG0475-478), 1 M (NAG474); same site, dry pitfall, RH, 1-28 November, unsexed (NAG0621); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 1 M (NAG0047); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 1 M (NAG0624); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 1 F each (NAG0702, 706, 707), 1 M each (NAG0700, 701, 703-705,708), 2 F, 4 M (NAG0698).

Trigg Dune Reserve: TD1, 31°52'09"S 115°45'38"E, wet pitfall, MSH/JMW, 13 July-25 September 1995, 1 F (NAG0325); same site, wet pitfall, MSH/JMW, 25 September-28 November 1995, 1 F each (NAG0391, 395, 397, 399), 1 M each (NAG0393, 394, 396, 398).

Trigg Dune Reserve: TD2 (1956-96), 31°52'30"S 115°45'35"E, wet pitfall, MSH/JMW, 13 July-25 September 1995, 1 F each (NAG0481, 487, 509-511, 516, 518, 519), 1 M each (NAG0488, 512-515, 517); same site, wet pitfall, MSH/JMW, 25 September-28 November 1995, 1 F each (NAG0369, 371), 1 M each (NAG0368, 370); TD2 (1996-97), 31°52'31"S 115°45'44"E, wet pitfall, NAG, 10 October-21 November 1996, 1 F each (NAG0931, 938, 946, 947), 1 M each (NAG0948, 949); same site, wet pitfall, NAG, 1 April-9 May 1997, 1 F each (NAG1241, 1242), 1 M each (NAG1243-1246); same site, wet pitfall, NAG, 9 May-18 June 1997, 1 M (NAG1355, 1427); same site, wet pitfall, NAG, 18 June-1 August 1997, 1 F each (NAG1357, 1437, 1438), 1 M each (NAG1117, 1331, 1358, 1439).

Trigg Dune Reserve: TD4 (1995-96), 31°52'45"S 115°45'17"E, wet pitfall, MSH/JMW, 13 July-25 September 1995, 1 F (NAG0639), unsexed (NAG1767); same site, wet pitfall, MSH/JMW, 25 September-28 November 1995, 1 F each (NAG0355, 356, 358-360), 1 M each (NAG0353, 354, 357, 361, 362), unsexed (NAG1769, 1772, 1773, 1774); TD4 (1996-97), 31°52'36"S 115°45'41"E, wet pitfall, NAG, 10 October-21 November 1996, 1 F each (NAG0788, 790, 791, 793, 794, 803, 807-813, 815, 816, 823-827, 829, 830, 1097-1100, 1104, 1105, 1107-1109, 1571-1587, 1616-1633), 1 male each (NAG0792, 814, 817, 828, 1094, 1101, 1103, 1106, 1569, 1570, 1601-1615); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, unsexed (NAG1079); same site, wet pitfall, NAG, 1 April-9 May 1997, 1 male each (NAG1251-1254, 1264, 1265), 1 unsexed (NAG1221); same site, wet pitfall, NAG, 9 May-18 June 1997, 1 F each (NAG1365, 1366, 1391, 1392, 1394-1397), 1 M each (NAG1334, 1335, 1337, 1339, 1340, 1364, 1389, 1390, 1393)same site, wet pitfall, NAG, 18 June-1 August 1997, 1 F each (NAG1116, 1119-1121, 1145, 1146, 1158), 1 M each (NAG1115, 1118, 1147-1154, 1159-1160).

Woodman Point Reserve: WP1, 32°07'47"S 115°45'23"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, unsexed (NAG1812); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 8 F, 3 M (NAG0600); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, unsexed (NAG1808); same site, wet pitfall, JMW/MSH, 21 Marvh-4 May 1995, unsexed each (NAG1759-1761); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 5 F, 7 M (NAG0612);

Woodman Point Reserve: WP2, 32°07'50"S 115°45'28"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, unsexed (NAG1802); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 5 F, 8 M (NAG0659); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 8 F, 11 M (NAG0710); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, unsexed each (NAG1819); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 6 F, 5 M (NAG0721);

Woodman Point Reserve: WP3, 32°07'58"S 115°45'29"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, unsexed (NAG1798); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 1 M (NAG0681);

Woodman Point Reserve: WP4, 32°07'58"S 115°46'29"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, unsexed (NAG1795); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 7 F, 2 M (NAG0609); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, unsexed (NAG1791); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 1 F (NAG0187); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, unsexed (NAG1813).

Yanchep National Park: YP2, 31°34'07"S 115°40'55"E, wet pitfall, NAG, 29 August-10 October 1996, 1 F each (NAG0831, 843, 845), 1 M each (NAG0833, 841, 842, 844, 846, 847); same site, wet pitfall, NAG, 10 October-21 November 1996, 1 F each (NAG0797, 798, 801, 834, 385, 837, 838), 1 M each (NAG836, 840), unsexed (NAG0799); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 1 M (NAG1000); same site, wet pitfall, NAG, 1 April-9 May 1997, 1 M (NAG1219); same site, wet pitfall, NAG, 9 May-18 June 1997, 1 F each (NAG1508, 1163), 1 M (NAG1165); same site, wet pitfall, NAG, 18 June-1 August 1997, 1 F each (NAG1111, 1112, 1198, 1199).

DIAGNOSIS

The description of this species by Castelnau (1867), while somewhat brief, is still adequate, and is repeated here. Revision of the genus however may require this diagnosis to be revised.

> *Promecoderus scauroides*: length 4'-5'; black, brilliant; head smooth, with a most feeble transverse impression behind the eyes; thorax semicircular, truncated in front, globular, having two transverse impressions, one in front, and the other behind, and a longitudinal sulcate in the middle, extending to the posterior margin; elytra oval, with longitudinal striae, not extending to the lateral margin; a punctiform impression and a short longitudinal sulcate on the posterior part of the margin; lower side of the body of a shiny brown; segments of the abdomen having on each side a punctiform impression, which extends in the form of a short oblique sulcate towards the centre; labrum black; palpi, mandibulae, and antennae, brown; thighs black, with the tibiae generally brown; tarsi reddish.

DESCRIPTION

Measurements.

Description based on specimen NAG1117 (Figure 4.4) unless specified. Total length = 11.2 mm; elytra length/width = 5.6/3.8 mm; pronotum length/width = 2.7/3.1mm; head length =2.1 mm; foretibia length= 1.6 mm.

Colour.

Entirely dark brown with a bronze sheen, eyes black, antenna dark brown, becoming paler towards the distal end.

Head.

Inner edge of mandibles straight, no teeth visible, small hook terminating. Left mandible slightly longer than right, not overlapping. Mandibular dorsal surface levigate, with mandibular groove reduced to wide and shallow lateral depression. Single seta positioned at apex of each groove. Palps filiform with 1 seta on penultimate segment of maxilla palps and 2 on penultimate mentum palp segment. Clusters of 3 setae on either side of lateral extremities of basal margin of maxilla. Mentum wide laterally, narrow medially in region of single medial tooth. On either side of midline directly posterior to the tooth is a single seta directed laterally. Two pairs of setae positioned along submentum.

No median sulcus occurs on quadrate labrum, not bifid anteriorly. Three pairs of setae present, directed anteriorly on that margin. Antennal segments beadlike and hirsute from 4th segment. When folded back along body, antenna reach almost to posterior third of pronotum. Single seta on dorsal surface of scape. Eyes rounded, neither protruding nor large, 1 supra ocular seta positioned above posterior third of each eye. Postocular area slightly swollen but not overly so. Supra ocular sulcus close to eye becomes shallow as it moves forward, terminating at inner basal margin of mandible. Extremely weak transverse crease marks basal margin of clypeus, broader than long, narrowing anteriorly with 1 setiferous puncture on anterior lateral angles.

Prothorax.

Levigate, globular and convex, pronotum has very weak median sulcus fading anteriorly. No extensions or projections at head insertion point. Margin very narrow laterally and basally, where it is not thickened, upturned or sinuous. Basal margin rounded. Two setiferous punctures on lateral margin, 1 in anterior half, 2nd in posterior third.

Elytra.

Ovoid, longer than wide, narrowing posteriorly to sharp apex, shoulders not thickened or projecting. Eight or nine striations or rows of fine punctures very close together on each elytron. Peduncle short and wide. Elytral margin narrow and complete down length, 1 setiferous puncture in anterior lateral fifth and 3 in posterior third. Apical declivity not marked by granulations, fovea or punctures.

Legs.

Forelegs: On ventral trochanter, 1 setiferous puncture opens anteriorly. Cluster of 4-5 setiferous punctures on medial third of anterior ventral edge. Opposite this, on posterior ventral edge cluster of 2 setiferous punctures. On distal third of posterior surface is a single seta. Three stiff setae on outer edge of ventral tibial surface, evenly spaced, in distal half; on inner edge of same surface 3 identical setae in medial half. No teeth or projections mark outer edge of tibia. Forespur and cleaning organ spur similar in size. Equal-sized fine setae form cleaning organ comb beginning above cleaning organ spur and terminating on anterior distal edge. Starting on inner posterior edge, setae form a comb on distal margin below tarsus insertion point, terminating on outer distal edge. Anterior tibial surface is smooth, glabrous and slightly convex. Tarsomeres 1-4 expanded, triangular, 5th is filiform. Tarsomeres 1-4 have 3-5 setae on lateral distal edges and on lateral ventral edges a row of stiffened setae. Ventral surfaces of tarsomeres 1-3 squamose. Distal tarsomere has row of 3 setae on ventral lateral edge. Tarsus terminated by identical claws slightly longer than basal tarsomere.

Midlegs: One setiferous puncture on the anterior ventral surface of coxa and ventral trochanter. Loose cluster of 5-6 setiferous punctures scattered across medial third of ventral anterior area of femur. A short thickened seta on dorsal distal third of femur. On dorsal and ventral surfaces longitudinal rows of 8-10 distally opening setiferous punctures. Tibia ovoid in cross-section distally, distal margin has fringe of stiffened setae. No teeth or projections present on tibia. Forespur narrow and inserted on ventral distal edge, 2 secondary spurs are inserted below it. First of these secondary spurs is 1/3 of apical spur length, 2nd smaller still (hardly longer than a distal margin seta). Basal (first) tarsomere subequal to mid forespur length, less dilatate than anterior basal tarsomere but not truly filiform. Tarsomeres 2-4 weakly dilatate with similar setal arrangements as anterior tarsus. On ventral surface of tarsomeres 1-3 squamose setae are less dense than anterior tarsus and confined to distal half of each segment.

Hindlegs: One setiferous puncture on anterior margin of coxa. Trochanter ovoid and smooth, subequal to 1/3 of hind femoral length. One setiferous puncture on femur opposite distal end of trochanter. Femur widens dorso-ventrally slightly, distally. Thickened setae on anterior distal half of tibial surface and on inner surface. Fringe of stiffened setae along distal edge. Forespur and anterior spur set below tarsus insertion point on inner edge. Setal arrangement of tarsus identical to fore-tarsus but all hind-tarsomeres are not dilatate and not squamose.

Abdomen.

Smooth with no projections, setae or other particularities (unremarkable). Distal four ventrites bisetose medially.

Female Genitalia.

Description based on specimen NAG1199. Styli identical and short, 1.2 mm long, curved dorsally with dorsal surface marginally concave. Sparse fine setae on inner edge.

Male Genitalia.

Figure 4.5. Genital ring comparatively large, longer than wide and laterally convex. Penis 1.8 mm long, gently curved, lower surface slightly concave, apex flared slightly, dorsum extended with orifice just posterior to apex on dorsum. Lateral surfaces granulate towards dorsal margin. Parameres dissimilar, left paramere larger, with comb of long setae on distal half. Right paramere elongate, becoming extremely narrow in distal third, apex swollen.

Variation.

Individuals that appear to be newly emerged adults (as determined by the softness of the elytra to slight pressure, indicating level of exoskeleton hardening) tend to exhibit a sheen ranging in colour from dark olive to bronze. One male individual (NAG1606) was a pale orange brown colour, becoming golden yellow on the coxa and extremities. Anterior and mid tarsi of females are not dilate or squamose ventrally. The sexes are otherwise indistinguishable.

Little morphological variability was evident and very uniform setal arrangements were observed amongst individuals both within and between populations.

Distribution.

According to Moore *et al.* (1987) *Promecoderus scauroides* is found through the western third of Western Australia, however records show that it has only been captured in several localities within the south-western region (Figure 4.6). As species recognition is difficult in this genus other unidentified specimens may exist in collections, which extend the known distribution.

Remarks.

In his short discussion of *Promecoderus scauroides*, Sloane (1890) stated that in M. Putzeys' "Revision" the species was dismissed with a short comparison made with *P. clivinoides*. *P. scauroides* was considered by Putzeys (cited in Sloane 1890) to differ marginally from *P. clivinoides* by the prothorax being less narrowed and expanded in front, and more narrowed behind; the elytra more oval, its widest point being behind the mid point, more convex and more superficially striate.

Both these two species and *P. dyschirioides* Guérin-Méneville would be keyed out to couplet bb. in Sloane's (1890) key on the basis that males (along with a further eight species from Victoria and New South Wales) possess a narrow fourth anterior tarsal joint that is barely spongiose on the ventral surface. *P. dyschirioides* was also considered to differ marginally from *P. clivinoides* by Putzeys (cited in Sloane 1890). Sloane (1890) suggests that the former is a small form of the latter. It is argued here, therefore that all three species. *P. clivinoides, P. dyschirioides* and *P. scauroides* could represent the morphological variation of a single species. Direct comparison of the type specimens of these three species and genetic analysis of various populations will test this suggestion.

Observations on foraging behaviour of *Promecoderus* suggest that they may climb trees in search of prey, despite being non-flying and terrestrial (Moore *et al.* 1987). Two unidentified female *Promecoderus* were collected from *Acacia* trees during a foliage arthropod fogging experiment near Northam in the Wheatbelt region of Western

Australia (October 1999). Gut content analysis of these two females and two males collected during this study (NAG1251, NAG1252) indicate that at least one female and specimen NAG1251 had recently fed on several beetles. Several tarsi and aedeagi were present in each gut. Exoskeleton debris was also present but in pieces, precluding further identification at this time.

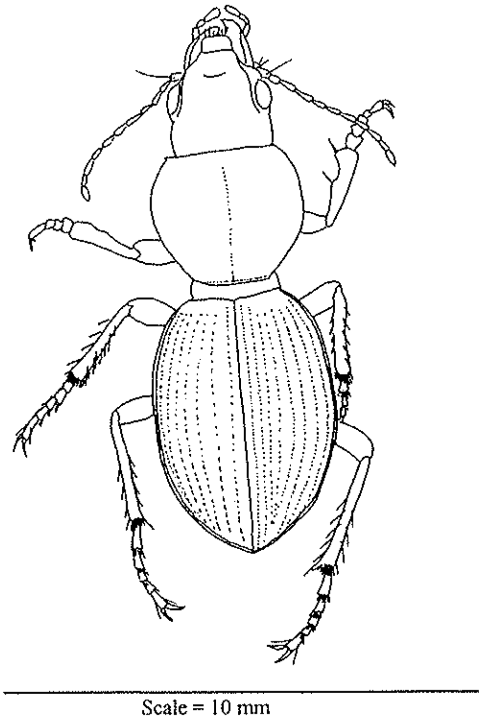


Figure 4-4: **Dorsal view of *Promecoderus scauroides* (specimen NAG1117)**

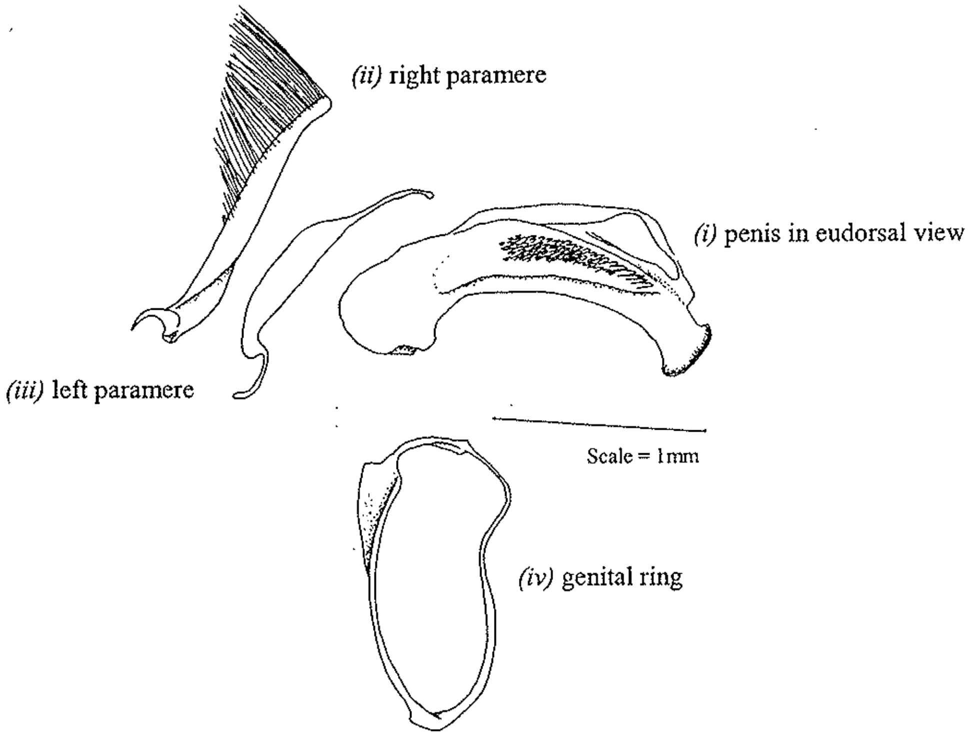


Figure 4-5: **Male genitalia of Promecoderus scauroides (specimen NAG1117).** Structures illustrated are (i) penis, (ii) right paramere, (iii) left paramere, (iv) genital ring. all structures to scale.

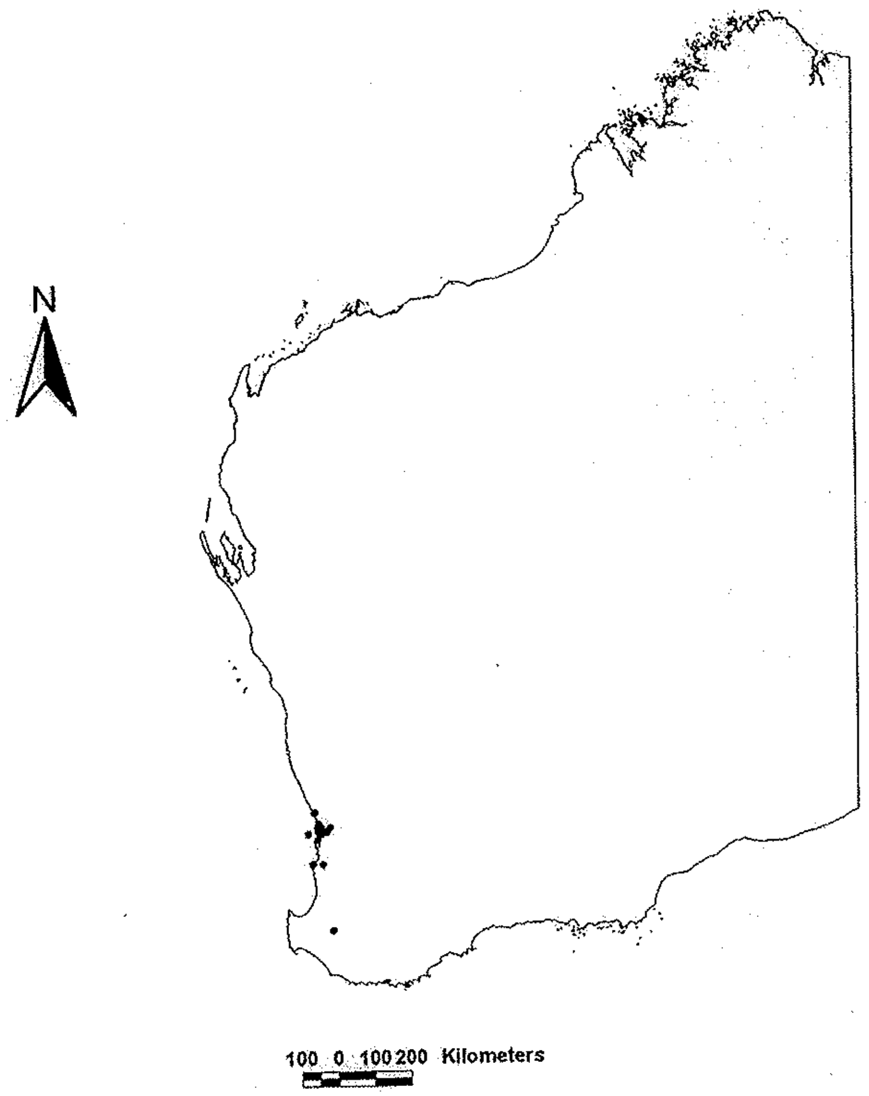


Figure 4-6: **Distribution of *Promecoderus scauroides* in Western Australia**
Based on specimens and records in the Western Australian Museum, AGRICULTURE WA and the Australian National Insect Collection (ANIC)

4.6.2 THE PTEROSTICHINAE

4.6.2.1 Genus *Notonomus*

There are 105 recognised species with 8 subspecies within *Notonomus,* the majority of which occur in forested localities along the east coast from northern Queensland to south-eastern South Australia, with other species in Tasmania and Bass Strait Islands (Moore 1965; Moore *et al.* 1987). The genus extends extra-limitally to New Caledonia (Moore 1965; Moore *et al.* 1987). *Notonomus mediosulcatus* is the only known species found in Western Australia but there is the potential for undescribed species to occur in the forests of the south-western region of Australia.

SYSTEMATICS

Notonomus Chaudoir

Notonomus Chaudoir, 1865:83; Type species: *Notonomus triplogenioides* Chaudoir, 1865 by subsequent designation (Moore, 1965).

Orbitus Motschulsky, 1865:247; Type species: *Orbitus purpuripennis* Motschulsky, 1865 by monotypy.

Neuropates Motschulsky, 1865:263; Type species: Neuropates pristonychoides Motschulsky, 1865 by subsequent designation (Csiki, 1930:112).

Ternox Motschulsky, 1865:268; Type species: *Ternox obsoletus* Motschulsky, 1865 (= *Notonomus molestrus* Chaudoir, 1865) by monotypy.

Adetipa Castelnau, 1867:70; Type species: *Adetipa punctata* Castelnau, 1867 by monotypy.

DIAGNOSIS

The generic description was given by Chaudoir (1865) and repeated by Moore (1965) in his study of the Pterostichinae, and therefore is not repeated here. Relationships within the genus may be complicated. Moore (1965) suggests that *N. aeneomicans* Chaudoir is a member of what appears to be a large species complex. Identification is extremely difficult and to that end *N. triplogenioides* was designated as the type species (Moore 1965).

Notonomus mediosulcatus (Chaudoir)

Feronia (Notonomus) mediosulcatus Chaudoir, 1865:88; holotype, male, MNHP, from southern Australia (as Australie meridionale). Synonomised by Chaudoir, M de (1874).

Adetipa punctata Castelnau, 1867:71; lectotype, MCG, from Clarence River, N.S.W., designation by Straneo, 1936:253.

Feronia occidentalis Castelnau, 1867:134; lectotype, MCG, from King George Sound, W.A., designation by Straneo, 1936:253.

Feronia satanas Castelnau, 1867:135; lectotype, male, MCG, from King George Sound, W.A., designation by Straneo, 1936:253.

MATERIAL EXAMINED

Bold Park: BP1 (1996-97), 31°57'12" S 115°46'31" E, wet pitfall, 18 June-1 August 1997, NAG, 1 M (NAG1505).

DIAGNOSIS

Sloane's (1902) diagnosis is given here:

> Oval, convex, Black; elytra often of a greenish or purple colour. Head oval, convex. Prothorax broader than long (4 x 4.5 mm), rounded on sides, a little more strongly so posteriorly than anteriorly; basal angles widely rounded, not the least marked; posterior marginal puncture on edge of border; lateral basal impressions deep, foveiform. Elytra oval (9 x 5.3 mm) four inner striae strongly impressed, 5-7 obsolete, third 2-punctate. Prosternum with anterior margin bordered. Intercoxal declivity rounded. Length 14-16, breadth 4.7-5.3 mm.

DESCRIPTION

Measurements.

Description based on specimen NAG1505 (Figure 4.7). Total length = 6.3 mm; elytra length/width = 3.5/2.4 mm; pronotum length/width = 1.6/2.1; head length = 0.8 mm; foretibia length = 0.7 mm.

Colour.

Upper and lower body colour shiny black, eyes black. Slight brunneus tinge to basal pronotal edge and palps. Antenna and tibio-tarsus deep orange to mid brunneus.

Head.

Large protruding compound eyes, smooth unmarked dorsal surface. Two orbital setae, 1st post orbital, 2nd anterior to orbital. Labrum 2/3 length of mandibles with fringing set of 3 pairs of setae on anterior edge. One pair of widely spaced setae on anterior edge of clypeus. Antennae elongate, scape with single elongate seta on anterodorsal surface near apex, thick covering of setae on antenna, 4-6 longer setae on distal end of each antennomere. Maxillae palps filiform with 2nd segment half size of 1st and distal segments, basal segment of labium palp with 2 setae on dorsal surface. Single seta on extreme lateral portion of basal maxillae. Constricted submentum with 1 setal pair on extreme lateral regions.

Prothorax.

Sub-oval to sub-quadrate in shape with dorsal sulcus fading just before basal margin. Slight pronotal shoulders at head insertion point. Complete narrow pronotal margin with 1 pair of long seta on anterior third of margin, 2nd pair of long seta in basal corner of pronotum with minute setal tubercle. Margin furrow forming "U", dividing basal margin in half on each side.

Elytra.

Thick elytral basal border present, seven complete striae with scutellary striole on 2nd stria extending one sixth of elytra length. Elytra margin with 10-12 setae, five in anterior quarter, others evenly spaced along remaining length. Three pairs of setae on third elytral interval in posterior two thirds. Elytral margin forming upturned lip along length to carina at posterior quarter.

Legs.

Femora robust on all legs, wide and equal to tibiae in length. One seta on anterior protrochanter surface. One long seta on ventero-distal profemur. Antennal cleaning spur on distal third, equal to third of tibia length. Final tarsal segment elongated and third of total tarsal length. All other tarsal segments secruiform, enlargening basally. On all segments ventral fringe of setae with a long seta on lateral edges of each segment, final segment seta equal to half its length, long unserrated apical claws. One seta on mid trochanter and mid coxa at anterio-ventral position. Two setae on ventral mid femur (1 distal, 1 medial) cluster of short thick setae on distal anterior dorsal region of mid femur adjacent to tibio-femoral joint. Linear cluster of thick setae on posterior surface of mid tibia. On anterior-ventral and anterior-dorsal surfaces linear rows of spines, each being length of tibial width, increasing distally, apical spines on distal tibial surface. On mid and posterior tarsus, 1st and 5th tarsal segment equilength, segments 2-4 half length of 5th. Small venterior-lateral spines on basal tarsal segment, lateral setae on each segment similar to anterior tarsus. Posterior trochanter half length of posterior femur, 2 fine setae on distal ¼ of femur near trochanter crease. 1 seta on distal ½ of ventral femur above trochanter. Tibia delicate with fine setae on distal 1/3 of posterior surface, spines on anterior-ventral and anterior dorsal surfaces, increasing in size distally.

Abdomen.

Medial projection of proepimeron between anterior coxae with margin and semi oval in shape. Three pairs of medial setae on posterior three ventrites.

Male Genitalia.

Genital ring relatively large and ovoid, becoming narrow towards apex, small extensions on lower edges. Penis sub-equal to genital ring in length and strongly curved with dorsal orifice, otherwise simple. Parameres dissimilar, left conchoid, right reduced (Figure 4.8).

Distribution.

The known distribution of *Notonomus mediosulcatus* suggests a Bassian distribution. However, Moore *et al.* (1987) suggested that this species is confined to the south-western region of Western Australia. Specimens in the AGRICULTURE W.A. collection from Albany, Bedfordale, Bridgetown, Bunbury, Geraldton, Harvey and Jarrahwood, indicate that in this state, the species may be confined to the south-west.

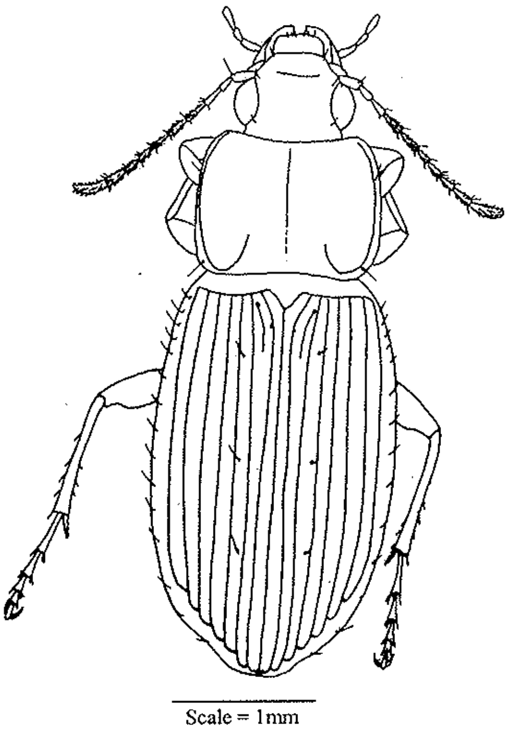


Figure 4-7: **Dorsal view of *Notonomus mediosulcatus* (specimen NAG1505).**

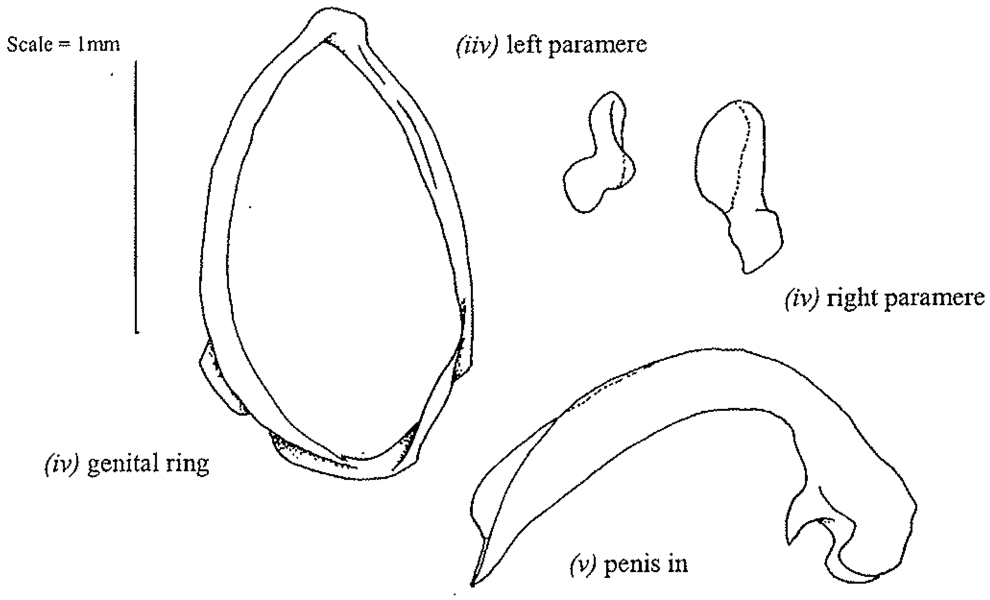


Figure 4-8: **Male genital structures of *Notonomus mediosulcatus* (specimen NAG1505).**

Structures illustrated are (i) penis, (ii) right paramere, (iii) left paramere, (iv) genital ring, all structures to scale.

4.6.2.2 Genus *Sarticus*

Sarticus specimens were not found in the Western Australian Museum, and therefore satisfactory species identification is currently impossible. Based on locality information given in both Sloane (1889) and Moore *et al.* (1987) only four species are known to occur in the south-western region of Australia. Of these, only *S. iriditinctus* has been collected from areas around the Swan River. The specimens listed below conform to de Chaudoir's brief description (cited in Sloane 1889) and are therefore currently considered to be *S. iriditinctus*.

SYSTEMATICS

Sarticus Motschulsky

Sarticus Motschulsky, 1865:265; Type species: *Sarticus orbicollis* Motschulsky, 1865 (= *Feronia (Steropus) obesula* Chaudoir, 1865) by subsequent designation.

DIAGNOSIS

A generic diagnosis is given by Moore (1965) and repeated here:

Mentum moderately emarginate; sides of sinus divergent. Median tooth notched or bifid; paraglossae small, glabrous; antennae filiform, with three basal segments glabrous; postocular orbits small. Pronotum orbiculate; margins bisetose; pro- and mesosterna glabrous. Elytra fused, contorted at apex; basal border variable or absent; stria variable; scutellary strioles on the first intervals; discal pores confines to third intervals, marginal pores well marked, forming continuous series; humeri rounded; hind wings vestigial; legs slender; anterior tarsi of male with three basal segments dilatate and squamose beneath. Aedeagus very uniform, orifice on dorsum; parameres dissimilar, the left conchoid, the right reduced.

Sarticus iriditinctus (Chaudoir)

Feronia (Steropus) *iriditinctus* Chaudoir, 1865: 100; holotype, male, MNHP, from Swan River, W.A.

MATERIAL EXAMINED

Bold Park: BP1 (1996-1997), 31°57'12"S 115°46'31"E, wet pitfall, 21 November 1996-2 January 1997, NAG, 1M (NAG1706).

Bold Park: BP3, 31°56'30"S 115°46'27"E, wet pitfall, 18 November 1993-6 January 1994, JMW/KG/JW, 1M (NAG1782).

Yanchep National Park: YP2, 31°34'07"S 115°40'55"E, wet pitfall, 9 May-19 June 1997, NAG, 1 F (NAG1122).

DIAGNOSUS

A striking carabid, *Sarticus iriditinctus* is glossy black with a strong iridescent or metallic sheen. Overall shape is a longer than wide ovoid, with a prominent head. Large eyes and long antennae (sub-equal to half body length). The pronotum lateral margins are well rounded, dorsum slightly concave. Distinctive sulcus on posterior pronotal margin. Elytra long ovoid with gently curving margins, flattened, seven striations present on each elytron, weak carina at apical declivity. Legs long, hind tibia and tarsus sub-equal to elytral length.

DESCRIPTION

Measurements.

Description based on specimen NAG1782 (Figure 4.9), unless specified. Total length = 10.4 mm; elytra length/width = 6.5/3.9 mm; pronotum length/width = 2.5/3.1 mm; head length = 1.3 mm; foretibia length =1.5 mm.

Colour.

Entirely glossy black with a strong iridescent or metallic sheen. Antennae and palps deep brown orange in colour.

Head.

Large spherical eyes with 2 supra orbital setae, one at posterior angle and one at anterior angle of each eye. Head smooth, convex, unmarked by sulci. On anterior angles of clypeus single setae set at anterior edge on each side.

Prothorax

Pronotum smooth with strong dorsal medial sulcus, complete to anterior edge. Oval in shape, pronotum longer than wide, slightly convexed lateral margins. Single seta in lateral anterior half of narrow and shallow margin, second seta on basal margin edge. Weak anterior extensions of pronotum at head insertion point. Anterior margin strongest while basal margin weakly sinuous. Posterior angles extended and flared, shallowly delineated by strong sulcus onto posterior third of dorsum on each side.

Elytra.

Long and ovoid in shape, length of elytron three times wide, flattened with no visible hind wings. Anterior basal border with short scutellary striole. Seven striae present, seventh not reaching anterior basal border. First and second striae not completely united (pore present at anterior end of 1st stria). Third elytral interval with three setiferous punctures evenly spaced down length. Lateral margin narrow and shallow with 12-14 setiferous punctures. Weak carina present at apical declivity.

Legs.

Forelegs- One seta on anterior surface of trochanter. On medial half of femur two setae on posteror-ventral surface. Directly above tibial joint on same surface is a seta in shallow crease. On distal half of anterior dorsal femoral surface run longitudinally an arc of several short spines. Cleaning organ third of the tibial length, four rows of ventral spines out of phase, and five spines distally on the posterior surface of the tibia. First and distal tarsal segments filiform, 2nd almost same length, and 3rd and 4th segments short. Spines on tarsal ventral surface,most prominent on 1st segment, and long setae on lateral sides of each.

Midlegs- Single seta each on ventral surface of coax and trochanter. Three widely spaced setae on mesal half of anterior femoral surface. Small spines on anterior-dorsal surface extending on dorsum distally. On each tibial surface, one longitudinal row of spines getting larger distally. First and second apical teeth almost identical in size. First tarsal segment longest, spines on ventral surface. Tarsal segments filiform with seta on ventral surface.

Hindlegs- Single seta on trochanter-femoral crease (which is half the length of the trochanter). One seta on the distal half of the femoral posterior ventral surface. A small spine is present on the distal quarter of the dorsal femoral surface. The hind tibia is equal in length to the femur. Irregularly spaced spines present on all surfaces of the hind tibia. The first tarsal segment is half the length of the tibia, 2nd segment sub-equal to 1st, and 3rd and 4th segments sub-equal to the 2nd. Distal segment subequal to first segment. Spines present on ventral surface of all tarsal segments apart from distal one.

Abdomen.

Bisetose on final three ventrites, with small proepimeron extension between anterior coax. Otherwise not remarkable.

Male Genitalia..

The genital ring is slightly convexed with narrow sides and a small extension of the basal edge. The ring narrows abruptly in the apical half to form a sharp apex. The penis is slightly curved with the orifice on the dorsum. Parameres are dissimilar with the left conchoids and the right marginally smaller (Figure 4.10).

Variation.

Amongst the three individuals collected only the number of spines on the dorso-anterior femoral surfaces of the anterior and midlegs varied. Male specimen NAG1706 possessed almost none whereas the female (NAG1122) had almost identical setal arrangement to the described male NAG1782. The only external visible sexual difference is the expanded anterior tarsal segments with the squamose ventral surfaces and no ventral spines in the males. The fourth segment of the anterior tarsi of the males also possesses long setae rather than being squamose. Condition of the female (NAG1122) precluded description of the external genital features.

Distribution.

At present *S. iriditinctus* is only known from the type locality (Swan River, W.A.) and Bold Park and Yanchep National Park on the Quindalup Dune System. Further collecting may locate it in bushland remnants present on other landforms, but currently any further comments on its distribution are not possible.

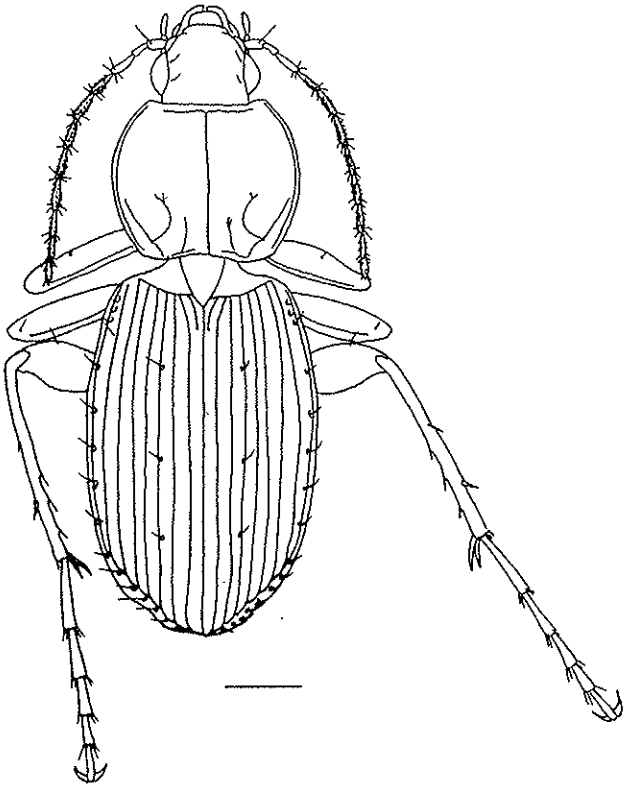


Figure 4-9: Dorsal view of *Sarticus iriditinctus* (specimen NAG1782).

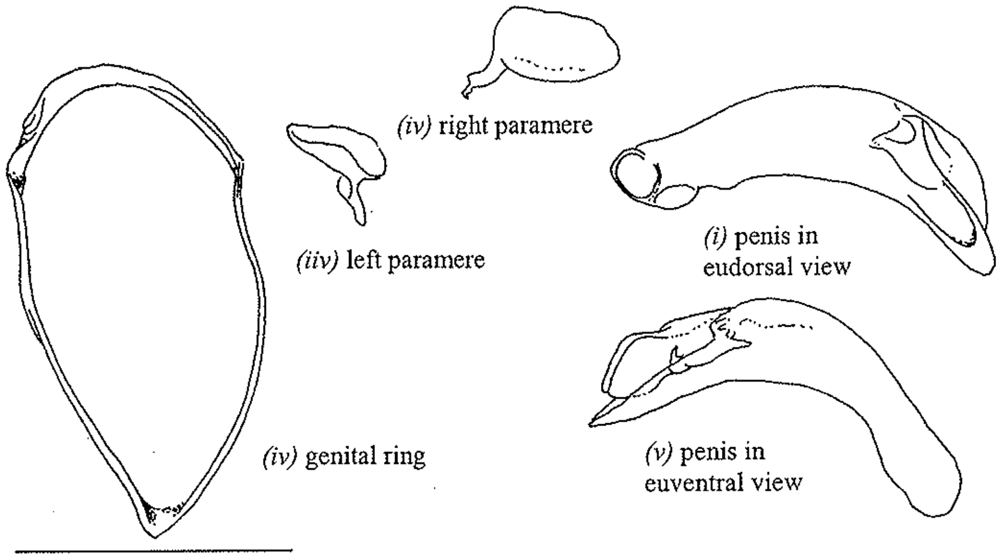


Figure 4-10: Male genitals of *Sarticus iriditinctus* (specimen NAG1782). Structures illustrated are (i) penis in dorsal view, (ii) right paramere, (iii) left paramere, (iv) genital ring, (v) penis in ventral view, all structures are to scale.

4.6.2.3 Genus *Simodontus*

The Pterostichine genus *Simodontus* currently consists of 18 species within the subgenera *Simodontus* and *Trochoglymmus* Stran. (Moore 1965; Moore *et al.* 1987). Most of these species appear to occur along the south eastern coast, extending into the Murray-Darling Basin of Victoria and New South Wales (Moore *et al.* 1987). Four species are found outside of this area, *S. brunneus* (Castelnau 1867); *S. occultus* Sloane 1898; and *S. sexfoveatus* (Chaudoir 1878) and *S. australis* (Dejean 1828). The former is found along the south western and southern coastal regions, where as S. *occultus* and *S. sexfoveatus* are only found in the lower south western region of Western Australia. In contrast, S. *australis*, as its name suggests is distributed right across the southern portion of the continent (Moore *et al.* 1987).

SYSTEMATICS

Simodontus Chaudoir

Simodontus Chaudoir, 1843:412; Type species: *Simodontus aeneipennis* Chaudoir, 1843 by monotypy.

DIAGNOSIS

The generic description provided by Chaudoir (1843; cited in Moore 1965) is presented here:

> Mentum moderately emarginate, sides of sinus strongly divergent; median tooth variable; paraglossae slender, glabrous; antennae filiform, with three basal segments glabrous; postocular orbits very small. Pronotum trapezoidal; margins bisetose; pro- and mesosterna glabrous. Elytra fused, fully striate, bordered at base; apices contorted; scutellary strioles usually present, on the second intervals; discal pores confined to third intervals, all on or near the third striae; hind wings reduced; anterior tarsi of male with three basal segments dilatate and squamose beneath. Adeagus slender, the median lobe tubular, with orifice on dorsum; parameres small, conchoid.

Simodontus australis (Dejean)

Feronia australis Dejean, 1828:262; syntypes (possible), MNHP, from Sydney, N.S.W. Synonymised by Tschitschérine (1890) and Csiki (1930).

Orthomus antipodus Motsculsky, 1865:259; syntypes (possible), ZMM, from Melbourne (as Port Phillip, Victoria).

Simodontus elongatus Chaudoir, 1873:111; syntypes (possible), males, MNHP, from southern Australia (as *Australie meridionale*).

MATERIAL EXAMINED

Bold Park: BP1 (1993-94), 31°57'11"S 115°45'50"E, wet pitfall, 18 March-19 May 1994, MSH/JMW, 1 M (NAG0044); BP1 (1996-97), 31°57'12"S 115°46'31"E, wet pitfall, 29 August-10 October 1996, NAG, 23 M (NAG0733, 898, 1655-1675), 2 F (NAG0743), 14 F (NAG1640-1653); same site, wet pitfall, 10 October-21 November 1996, NAG, 8 F (NAG0915, 994, 995, 1054-1058), 8 M (NAG1059-1066); same site, wet pitfall, 21 November 1996-2 January 1997, NAG, 12 M (NAG1085, 1136, 1679-1688), 17 F (NAG1689-1705); same site, wet pitfall, 2 January-14 February 1997, NAG, 5 F (NAG1095, 1130-1133), 5 M (NAG1125-1129); same site, wet pitfall, 14 February-1 April 1997, NAG, 2 F (NAG1591, 1592), 1 M (NAG1593); same site, wet pitfall, 1 April-9 May 1997, NAG, 33 F (NAG1217-1225, 1229-1232, 1236-1239, 1258-1261, 1276-1282), 15 M (NAG1226-1228, 1233-1235, 1249, 1262, 1263, 1283-1288) same site, wet pitfall, 9 May-18 June 1997, NAG, 17 M (NAG1162, 1177-1180, 1189-1191, 1315, 1442-1449), 48 F (NAG1166-1176, 1181-1188, 1192-1197, 1308-1314, 1450-1464); same site, wet pitfall, 18 June-1 August 1997, NAG, 6 F (NAG1138, 1141, 1323, 1332, 1333, 1502), 7 M (NAG1204, 1324-1326, 1503, 1504).

Bold Park: BP3, 31°56'30"S 115°46'27"E, wet pitfall, 18 March-19 May 1994, MSH/JMW, 1 M (NAG0571), 2 F (NAG0572, 573).

Bold Park: BP4, 31°56'29"S 115°46'16"E, wet pitfall, 20 May-20 July 1993, MSH/JMW, 5 F, 2 M (NAG1788); same site, wet pitfall, 24 September-18 November 1993, JMW/MSH, 1 M (NAG1780); same site, wet pitfall, 18 November 1993-6 January 1994, JMW/MSH, 1 M (NAG1777); same site, wet pitfall, 18 March-18 May 1994, MSH/JMW, 1 M (NAG1754), 1 F (NAG1753).

Bold Park: BP5 (1993-94), 31°57'14"S 115°46'16"E, wet pitfall, 20 May-20 July 1993, MSH/JMW, 2 M (NAG0688, 689); BP5 (1996-97), 31°57'07"S 115°45'54"E, wet pitfall, 29 August-10 October 1996, NAG, 3 F (NAG0752, 756, 758), 1 M (NAG0757); same site, wet pitfall, NAG, 10 October-21 November 1996, 4 F (NAG0876, 878, 879, 903), 5 M (NAG0875, 877, 880, 959, 960); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 27 F (NAG1076, 1090, 1518-1532, 1535-1544), 26 M (NAG1533, 1534, 1545-1568); same site, wet pitfall, NAG, 2 January-14 February 1997, 6 F (NAG1376-1381), 6 M (NAG1382-1387); same site, wet pitfall, NAG, 14 February-1 April 1997, 3 F (NAG1359-1361), 2 M (NAG1362, 1363); same site, wet pitfall, NAG, 1 April-9 May 1997, 18 F (NAG1478-1491, 1501, 1597-1599), 3 M (NAG1492-1494); same site, wet pitfall, NAG, 9 May-18 June 1997, 29 F (NAG1290, 1291, 1294-1301, 1303-1306, 1318, 1319, 1367-1369, 1404-1410, 1465, 1465, 1466), 11 M (NAG1289, 1292, 1293, 1302, 1307, 1317, 1370, 1411, 1412, 1467, 1468); same site, wet pitfall, NAG, 18 June-1 August 1997, 12 F (NAG1201, 1205, 1206, 1208, 1209, 1211, 1327, 1328, 1420-1423), 7 M (NAG1202, 1203, 1207, 1210, 1329, 1424, 1425).

Mount Claremont Reserve: MC1, 31°57'40"S 115°46'60"E, wet pitfall, JMW/MSH, 4 May-6 July 1995, 2 F (NAG0145, 146), 1 M (NAG0147).

Mount Claremont Reserve: MC2, 31°57'39"S 115°45'56"E, wet pitfall, JMW/MSH, 21 March-4 May 1995, 2 F (NAG0623); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 17 F, 6 M (NAG0697).

Trigg Dune Reserve: TD1, 31°52'09"S 115°45'38"E, wet pitfall, MSH/JMW, 13 July-25 September 1995, 1 F (NAG0625); same site, wet pitfall, MSH/JMW, 25 September-28 November 1995, 1 M (NAG0392).

Trigg Dune Reserve: TD2 (1995-96), wet pitfall, MSH/JMW, 13 July-25 September 1995, 13 F (NAG0437-440, 479-486, 513), 1 M (NAG0400); same site, wet pitfall, MSH/JMW, 25 September-28 November 1995, 1 F (NAG0381); TD2 (1996-97), 31°52'31"S 115°45'44"E, wet pitfall, NAG, 10 October-21 November 1996, 1 F (NAG0932); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 1 F (NAG1123); same site, wet pitfall, NAG, 1 April-9 May 1997, 1 F each (NAG1247, 1267-1271), 1 M each (NAG1272-1275); same site, wet pitfall, NAG, 9 May-18 June 1997, 14 F (NAG1338, 1341-1350, 1353, 1428-1430), 8 M (NAG1351, 1352, 1431-1436) same site, wet pitfall, NAG, 18 June-1 August 1997, 3 F (NAG1139, 1440, 1441), 2 M (NAG1140, 1330).

Trigg Dune Reserve: TD4 (1995-96), 31°52'45"S 115°45'17"E, wet pitfall, MSH/JMW, 13 July-25 September 1995, 3 F (NAG0636), 2 F (NAG637), 2 F (NAG638), 1 M (NAG0640); TD4 (1996-97), 31°52'36"S 115°45'41"E, wet pitfall, NAG,10 October-21 November 1997, 1 F (NAG0822); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 1 F (NAG1003), 1 M (NAG1080); same site, wet pitfall, NAG, 1 April-9 May 1997, 1 M (NAG1255); same site, wet pitfall, NAG, 9 May-18 June 1997, 1 F each (NAG1398-1403), 1 M (NAG1388);same site, wet pitfall, NAG, 18 June-1 August 1997, 3 F (NAG1144, 1156, 1157);

Woodman Point Reserve: WP1, 32°07'47"S 115°45'23"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, 51 F, 20 M (NAG1811); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 5 F, 2 M (NAG0599); same site, wet pitfall, JMW/MSH, 4 November-19 January 1995, 5 F, 8 M (NAG1807); same site, wet pitfall, MSH/JMW, 19 January-21 March 1995, 4 F, 4 M (NAG0685); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 3 F (NAG1762), 2 F (NAG1763), 2 F (NAG1764), 3 M (NAG1765), 3 M (NAG1766); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 50 F, 18 M (NAG0613).

Woodman Point Reserve: WP2, 32°07'50"S 115°45'28"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, 4 F, 1 M (NAG1803); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 5 F, 2 M (NAG0660), 1 F (NAG1708), 1 F (NAG1709); same site, wet pitfall, JMW/MSH, 4 November-19 January 1995, 66 F, 62 M (NAG0709); same site, wet pitfall, MSH/JMW, 19 January-21 March 1995, 2 F, 4 M (NAG1799); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 26 F, 13 M (NAG1816); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 92 F, 39 M (NAG0720).

Woodman Point Reserve: WP3, 32°07'58"S 115°45'29"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, 11 F, 1 M (NAG1797); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 1 M (NAG1758); same site, dry pitfall, JD, 14 November-11 December 1994, 1 M (NAG0642); same site, wet pitfall, JMW/MSH, 4 November-19 January 1995, 1 F (NAG1755), 1 M (NAG1756), 1 M (NAG1757); same site, wet pitfall, JMW/MSH, 21 March-4

May 1995, 1 F (NAG1752); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 42 F, 9 M (NAG0683).

Woodman Point Reserve: WP4, 32°07'58"S 115°45'29"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, unsexed (NAG1796); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 1 F, 1 M (NAG0608), 1 M (NAG1789); same site, wet pitfall, JMW/MSH, 4 November-19 January 1995, 3 F, 2 M (NAG1792); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 1 F (NAG0189), 1 M (NAG0188); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 35 F, 14 M (NAG1814).

Yanchep National Park: YP1, 31°31'00"S 115°39'18"E, wet pitfall, NAG, 10 October-21 November 1996, 1 M (NAG0832).

Yanchep National Park: YP2, 31°34'07"S 115°40'55"E, wet pitfall, NAG, 18 June-1 August 1997, 1 F (NAG1113).

DIAGNOSIS

A diagnosis adapted from Sloane (1898) is presented here:

Oval, subconvex; head moderately large; prothorax laevigate, transverse; elytra with third stria hardly narrower than fourth; prosternum margined on base; mesosternal episterna punctate, metasternal episterna elongate. Black (or piceous-black), shining; under surface piceous; legs and antennae brownish.

DESCRIPTION

Measurements.

The following description is based on specimen NAG1545 (Figure 4.11). Total length = 6.5 mm; elytra width/length = 2.52 mm/3.5 mm; pronotal width/length =1.54 mm/2.1 mm; foretibia length = 0.13 mm.

Colour.

Colour ranges from dark brown to black, antenna, legs, and palps slightly paler reddish brown. Individuals considered to be newly emerged are generally paler brown (as the exoskeleton hardens they become darker in an anterior to posterior direction).

Head.

Antenna long with bead like segments, final segment filiform. First segment after scape half length of 2nd. On distal end of each segment 4-5 long setae and basal three segments glabrous (other segments covered with fine short setae). Single seta on dorsal distal surface of scape. When folded back along the animal the antenna reaches basal margin of pronotum.

No teeth present on straight inner edge of mandibles, with smooth dorsal surface. Mandibular groove wide, shallow with no rugosa or striations on groove. Palps filiform with cluster of 4-5 short setae on dorsal surface of penultimate and ultimate distal segments of labial and maxillae palps. Mentum deep with bifid medial tooth and large basal margin. One seta present on each side of the lateral extremities of basal maxillae margin and laterals of submentum.

Quadrate labrum not bifid with 3 pairs of setae on anterior dorsal margin, fringing setae from anterior ventral margin sparse and short. Clypeus long and quadrate with 1 setiferous puncture on lateral corners. Basal margin marked by transverse shallow sulcus initiated weakly at mandible basal edge, becoming stronger towards midline. Eyes large, round and protruding. Postocular region not restricted, 2 supraorbital seta present, 1st posterior to eye, 2nd anteriorly. Head otherwise smooth and convex.

Prothorax.,

Pronotum trapezoid in shape, laevigate, transverse, with narrow margin and widest point at middle. Laterals slightly rounded, shallowly convex dorsum with shoulder extensions at head insertion point. Strong medial sulcus weakens anteriorly, not reaching anterior margin. In anterior third of lateral margins, one setiferous puncture. Basal margin weakly sinuous, with dorso-lateral sulcus extending from basal margin anteriorly 1/3 of pronotum length.

Elytra.

Ovoid in shape, rounded sides, margin narrow with setiferous punctures along laterals extending to apical declivity. Elytra fused completely to abdomen, hind wings absent. On each elytron 7 stria, with 3 setiferous punctures evenly spaced down 3rd elytral interval. Puncture at juncture of striole and 2nd striae not touching.

Legs.

Forelegs- One setiferous puncture on ventral surface of trochanter and middle of posterior ventral edge of femur. On distal fifth of posterior edge of femur one setiferous puncture. Two thickened setae on anterior surface (1 distal, 1 on middle third), 2 on distal half of dorsal surface. Femur laterally compressed, wider medially. Four thickened setae form row down length of posterior tibial surface, increasing in size distally and terminating at outer distal margin. On inner posterior margin 4 smaller thickened setae form second row, terminating at cleaning organ. Forespur positioned posterior to cleaning organ. Carina on posterior surface, initiated at forespur insertion point, terminating at distal margin. Fringe of fine setae between it and apical tooth. Anterior tarsomeres with 2 latero-distal setae either side. Basal tarsomeres dilatate and squamose beneath. Final tarsomere not dilatate, terminated by equal sized claws.

Midlegs: Coxa with 1 setiferous puncture on basal lateral margin. Trochanter with 1 setiferous puncture on lateral ventral margin. On medial 1/3 of anterior femoral surface 1 setiferous puncture, on distal 1/3 of anterior dorsal edge, a cluster of 3 thickened setae. Femur laterally compressed. On posterior dorsal edge, 8 fine setae form row down length of tibia. Double row of thickened setae on anterior surface, terminating at distal edge. Fringe of setae surrounds distal edge and apical tooth placed posteriorly on margin. Basal and terminating tarsomeres longer than apical tooth, 2nd tarsomere almost as long, 3rd and 4th tarsomeres shorter and slightly dilatate. Setal arrangement identical to anterior, but not squamose beneath.

Hindlegs: On basal margin near coxal attachment 1 setiferous puncture. Trochanter ovoid, long and smooth, approximately half the femoral length. Above distal end of trochanter on ventral surface of femur 1 setiferous puncture. Femur smooth and slightly laterally compressed. Tibia equal in length to femur, thickened setae on posterior and anterior edges of the ventral surface. Apical tooth long, inserted distally to the setae fringe on the edge. Tarsomeres not dilatate, with row of short spines on each ventral surface.

Abdomen.

Laevigate, bisetose medially on ventrites. Apical and penultimate ventrites with transverse sulcus close to anterior margin of both. Rounded posterior extension of the proepimeron margined.

Female Genitalia.

External morphology consists of short stylis, conical, with 3 tufted points on outer edge and 3 smaller spines on lateral margins.

Male Genitalia.

Penis slender with tubular median lobe, orifice on dorsum, parameres small, conchoid and dissimilar (Figure 4.12). When everted in natural position, and viewed ventrally, penis hooks to the right without twisting in either dorsal or ventral directions.

Variation.

The anterior tarsi of females differ from the male in that the basal segments are not dilatate or squamose; in addition, stout spines occur on the ventral edges of each tarsomere which are slender. No other visible external sexual characters are present.

Little morphological variation is apparent either within or between remnant populations. One individual (NAG1181) had two incomplete stria on the left elytron, forming a "U" and an inverted "U" shape below it.

Distribution.

This species is found along the coastal regions of the southern half of the continent and into the Murray-Darling basin where open forests are found (Moore 1987) (Figure 4.13).

Remarks.

Like other Pterostichinae in Australia, almost no life history data are available for any member of the large genus *Simodontus* and identification of individual species will be hampered until the older types are re-examined in detail (Moore 1965). According to Moore (1987) *S. australis* is capable of flight. However, none of the 1133 individuals collected had functional hind wings, suggesting that the Perth Metropolitan population of this species may in fact be flightless. Further sample collection is required to determine the wider distribution of this flightless population and its relationship to other populations of *S. australis*.

Sloane (1898) suggested that *Simodontus australis* is the commonest member of the genus in south-western Australia. He also noted minimal morphological variation in this species across its range; a specimen from Melbourne differed only slightly in having a slightly more prominent elytral basal border compared to specimens collected from the Swan River. Western Australian representatives of *S. australis* appeared to be more variable in both size and the elytral stria as well as the external angles of the basal borders (Sloane 1898).

Both Blackburn (1889) and Sloane (1898) remarked on the inadequacy of Chaudoir's original descriptions of the genus and the ramifications this has for identification of the various species. Dejean's (1828) extremely short description of *S. australis* could fit a variety of species as well (Blackburn 1889).

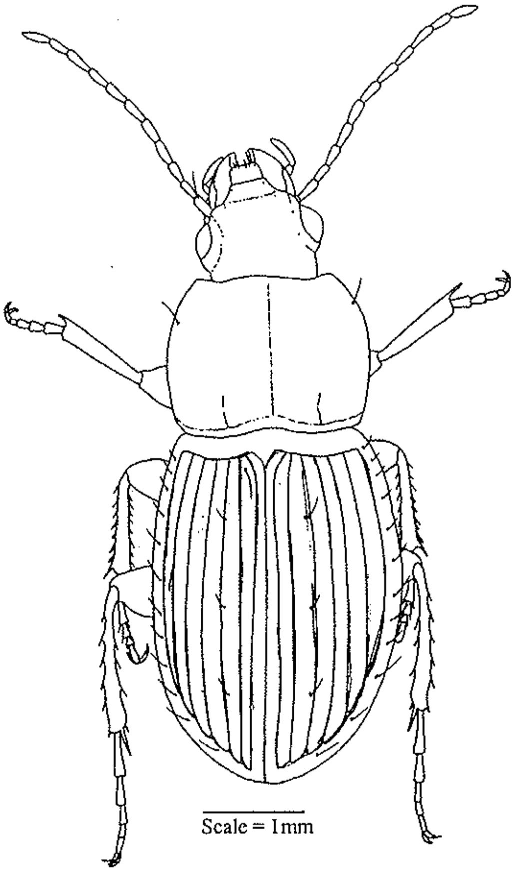


Figure 4-11: **Dorsal view of *Simodontus australis* (specimen NAG1545).**

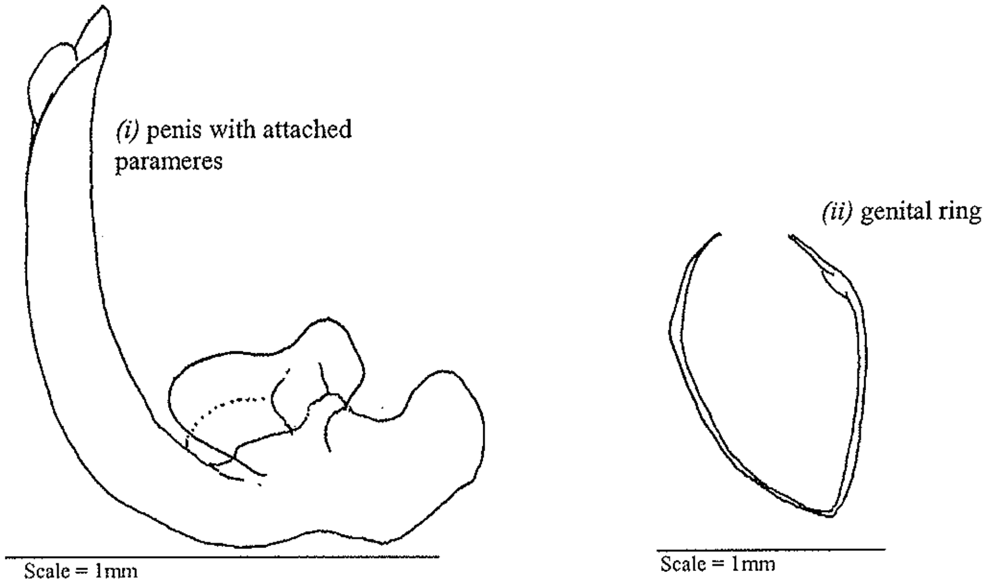


Figure 4-12: Male genitals of *Simodontus australis* (specimen NAG1545). Structures illustrated are (i) penis in right lateral view with attached simple parameres, (ii) genital ring (incomplete).

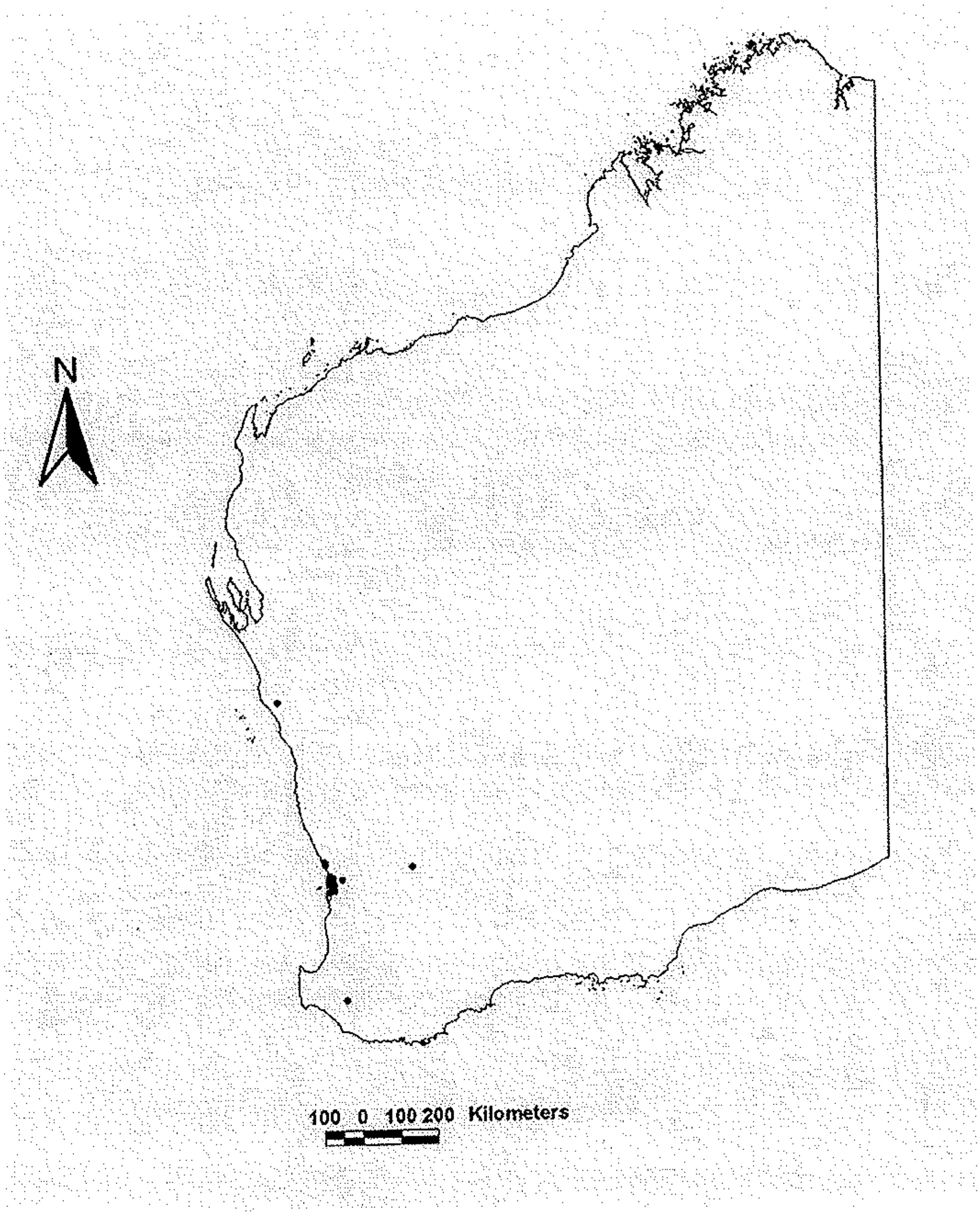


Figure 4-13: Distribution of *Simodontus australis* in Western Australia
Based on specimens held in the Western Australian Museum. WA AGRICULTURE and the Australian National Insect Collection.

4.6.3 THE SCARITINAE

4.6.3.1 *Carenum scaritoides*

SYSTEMATICS

***Carenum* Bonelli**

Carenum Bonelli, 1813: 479; Type species: *Carenum bonellii* Westwood, 1842 by monotypy; Bonelli misidentified this insect as *Scarites cyaneus* Fabricius, 1775 (Moore, *et al.* 1987).

Arnidius Boisduval, 1835:23; Type species: *Arnidius marginatus* Boisduval, 1835 by montypy.

Eutoma Newman, 1838:170; Type species: *Eutoma tinctilatus* Newman, 1838 by monotypy.

Carenoscaphus Macleay, W. J. 1887:120; Type species: *Carenum quadripunctatum* Macleay, 1863 by subsequent designation.

Calliscapterus Macleay, W. J. 1887:121; Type species: *Carenum campestre* Macleay 1865, by subsequent designation.

Platythorax Macleay, W. J. 1887:122; Type species: *Carenum rectangulare* Macleay, 1864 by original designation.

Chariscapterus Sloane, 1888:1111; Type species: *Carenum cupreomarginatum* Blackburn, 1888 by original designation.

Paliscaphus Sloane, 1888:1117; Type species: *Paliscaphus felix* Sloane, 1888 by monotypy.

Carenum scaritoides Westwood

Key Figures: 3a, 3b, 3c; Text Figures 4.14, 4.15, 4.16.

Carenum scaritoides Westwood, 1843:191-192, fig. , syntypes (possible), OUM or BMNH, from Port Philip, Vic. (as W.A.).

Carenum intermedium Westwood, 1849:203: syntypes (possible) OUM or BMNH, from Australia.

Carenum atronitens Macleay, W. J.1864:137; possible syntype, ANIC (MMUS), 1 specimen from South Australia.

Carenum oblongum Macleay, W. J.1864:138; holotype, ANIC (MMUS), from South Australia or the Northern Territory.

Carenum nigerrimum Macleay, W. J. 1865:176; syntypes, ANIC (MMUS), 4 specimens from South Australia.

Carenum ambiguum Macleay, W. J.1865:177; syntypes, ANIC (MMUS), 3 specimens from King George Sound, W.A.

Carenum striatopunctulatum Macleay, W. J. 1865:178; holotype, ANIC (MMUS), from Murrumbidgee, N.S.W.

Carenum subquadratum Macleay, W. J.1865:177; holotype, ANIC (MMUS), from South Australia.

Carenum atronitens Castelnau, 1867:52; possible syntypes, MCG, from Gawler, South Australia.

Carenum gawlerense Macleay, W. J.1869:59; *nom.nov.* for *Carenum atronitens* Castelnau, 1867.

Carenum ignotus Sloane, 1892:427; holotype, ANIC (Sloane Coll.), hindbody only, from between York and Yilgarn, W.A.

MATERIAL EXAMINED

Woodman Point: WP1, 32°07’47”S 115°45’23”E, wet pitfall, JMW/MSH, 1 F (NAG0610).

Woodman Point: WP2, 32°07’47”S 115°45’23”E, wet pitfall, 1 September-4 November 1994, JMW/AFL, 1 M (NAG0654).

Woodman Point: WP3, 32°07’58”S 115°45’29”E, wet pitfall, JMW/MSH, 3 M (NAG0678-680).

Woodman Point: WP4, 32°07’58”S 115°46’29”E, wet pitfall, 21 March-4 May 1995, JMW/MSH, 1 M (NAG0185).

Mount Claremont: MC1, 31°57'40"S 115°46'60"E, wet pitfall,24 June-1 September 1994, JMW/AFL, 2 F (NAG0665, 666), 2 M (NAG0667, 668); same site, 11-31 October 1994, dry pitfall, RH, 2 F (NAG0054, 55), 1 M (NAG0057); same site, 4 November 1994-19 January 1995, wet pitfall, JMW/MSH, 2 F (NAG0003, NAG0004); same site, 1 September-4 November 1994, wet pitfall, JMW/AFL, 3 F (NAG0405, 406, 411), 6 M (NAG0404, 407-410, 412); same site, 1-12 March 1995, dry pitfall, RH, 1 F (NAG0128); same site, 21 March-4 May 1995, wet pitfall, JMW/MSH, 1 F (NAG1828); same site, 4 May-6 July 1995, wet pitfall, JMW/MSH, 3 F (NAG0131, 136, 138), 5 M (NAG0130, 132-135, 137).

Mount Claremont: MC2, 31°57'39"S 115°45'56"E, 4 November 1994-19 January 1995, wet pitfall, JMW/MSH, 2 F (NAG0017, NAG0018); same site, 4 May-6 July 1995, wet pitfall, JMW/MSH, 1 F (NAG0695).

Trigg Dune Reserve: TD2, 31°52'31"S 115°45'46"E, wet pitfall, 9 May-19 June 1997, NAG, 1 M (NAG1356).

Trigg Dune Reserve: TD4, 31°52'45"S 115°45'17"E, wet pitfall, 25 September-28 November 1995, MSH/JMW, 2 F (NAG0327, 329), 1 M (NAG0328); TD4, 31°52'36"S 115°45'41"E, wet pitfall, NAG, 10 October-21 November 1996, 1 F (NAG0818), 1 M (NAG0819); same site, 18 June-1 August 1997, NAG, 1 F (NAG1155).

Yanchep National Park: YP1, 31°57'40"S 115°46'60"E, wet pitfall, 29 August-10 October 1996, NAG, 1 F (NAG0734); same site, 10 October-21 November 1996, NAG, 1 F (NAG0784); same site, 18 June-1 August 1997, 1 F (NAG1143).

DIAGNOSIS

Carenum is distinguishable from all other scaritine carabid genera by the anterior forespur being set before, or anterior to, the 2nd tibial tooth, securiform final palpi segments, and a setiferous puncture on the distal ventral surface of the fore-femur (unique to *Carenum* species). The only *Carenum* species for which *Carenum scaritoides* could be mistaken is *Carenum devastator* Cast. Both species are similarly black in colour and occur on the Swan Coastal Plain (Moore *et al.* 1987). The latter differs from *C. scaritoides* by being larger in size (about 35 mm), broader overall and having oval elytra rather than the more cylindrical shape of *C. scaritoides*. The mandibles of *C. devastator* are irregularly rugose on their dorsal surface as compared to striate in *C. scaritoides* (Moore 1963).

DESCRIPTION

Measurements

The following description is based on specimen NAG0327 (Figure 4.14). Total length = 26.5 mm; elytra length/width = 14.3/8.4 mm; pronotum length/width = 6.6/8.2; foretibia length = 4.5 mm.

Colour.

Entirely nonmetallic black, teneral individuals may range in colour from entirely dark maroon to black anteriorly with a maroon elytra.

Head.

Mandibles heavy and relatively short, sub-equal to head length. Left mandible 3-dentate, 1st tooth large, 2nd small, ventrally placed, 3rd visible dorsally, slightly smaller than 1st. Right mandible 4- dentate, 1st and 2nd teeth almost identical in size, 3rd tooth small, ventrally positioned under 1st, 4th slightly smaller than 2nd. Mentum has large middle tooth, two posteriorly-centrally positioned setiferous punctures on either side. Two setiferous punctures laterally placed on submentum, outer one behind lateral edge of mentum base. Labium palps securiform, 2nd segment four pairs of setae dorsally positioned. Maxillae palps securiform but less so than labium palps, galea palps longer than lacinia. This structure lacks a terminating hook, and has 2 distinct separate rows of setae, upper or dorsal row setae long and thick, consisting of many setae, lower or ventral row shorter, less in number with a stronger curve to each seta.

Head quadrate in shape, slightly broader than long, convexed slightly. Frontal sulcus (positioned dorso-laterally) curves toward outside attachment point of mandible on either side. Two setiferous orbital punctures, one directly above each eye, other at hind angle behind each eye. Lower edge of orbit not projecting anteriorly when viewed laterally. Eyes somewhat prominent, not overly large. Setiferous puncture present on either side, anterior to point of curvature of sulcus on clypeus. Fore margin of clypeus developed into four projections; two minor projections over centre of labrum, outer two over lateral edges of labrum, projecting to about half labral length. Labrum small, with 3 pairs of setae on anterior dorsal margin. Moniliform antennae, thickly pubescent with long setae from 4th segment,2nd and 3rd segments have a few long setae on distal edge, last segment filiform.

Prothorax.

Convex, laevigate with rounded sides, subquadrate, with weak basal angles. Weak medial sulcus terminates before faint anterior margin, shoulders forming small projections at head insertion point. Narrow pronotal margin with one seta at extreme anterior of border, 2nd in middle third of border, and final seta at extreme posterior third of border. Pronotum base truncate to peduncle.

Elytra.

Oval, elongate, convexed, laevigate rounded apical declivity. Shoulders thickened, folded over slightly. Anterior line of 3 setae occurs between shoulders on each elytron, extra seta in middle of each elytron in anterior fifth. Narrow elytral border margin with closely positioned setiferous punctures, extending onto apical declivity. Setiferous puncture in middle of right elytron in posterior third. Elytral surface otherwise smooth.

Legs.

Forelegs: Ventral surface of trochanter with 1 setiferous puncture. Cluster of six setae on medial half of anterior ventral femoral edge. At mid-point of posterior ventral femoral edge and on distal quarter of same edge are two setiferous punctures. On medial fifth of dorsal surface, one setiferous puncture, and on lower half of distal anterior surface, one seta with two directly above on upper half. Foretibia narrowly palmate with relatively thin teeth, which are delicate in appearance,. Anterior surface smooth, slightly convex, posterior surface slightly concave. Forespur set before and distal to, 2nd outer tibial tooth. One setiferous puncture at posterior angle of base of 2nd tibial tooth. Cluster of setae on distal edge of same tooth, extending to medial edge of 1st tibial (apical) tooth. Fringe of setae on distal edge of tibia, extending along inner edge to above cleaning organ. On posterior surface of tibia, row of 5-7 setiferous punctures on inner edge. Extending from medial third of inner edge a row of raised setiferous punctures runs to outer edge distal to 2nd tibial tooth (on left anterior tibia a double row occurs, on right tibia second row reduced to single raised setiferous puncture at midpoint of posterior surface). On medial posterior edge of 2nd tibial tooth, one distally opening setiferous puncture. Posterior surface marked by two carinae down inner and outer edges, and another one from cleaning organ spur, distally to tarsal insertion point. Forespur, 1st tibial tooth and cleaning organ spur all have carinae on their posterior surfaces. Distal posterior surface extended under forespur to form small slightly hooked projection. Basal or first tarsomere has three setae on inner edge along length. On distal edge of tarsomeres 1-4 each with a cluster of 3-4 setae forming, at an angle, a fringe on either side. Two setae on anterior or upper distal edge of final tarsomere.

Midleg: One setiferous puncture occurs on ventral trochanter. On anterior surface of femur a curved linear cluster of 11 setiferous punctures opening ventrally, running from medial fifth and terminating on distal third. Linear cluster of 8 setiferous punctures in middle third of dorsal posterior femoral edge, and 4 distally opening setiferous punctures in a row, running from dorsal anterior edge, terminating at mid-point of distal third of femur. On mid-tibia all setae are angled down longitudinal axis, 7 setae in line along anterior midline, 10 in line along ventral edge, 7 in line along dorso-ventral surface, 8 along dorsal surface, 5 along dorso-posterior surface, and 4 along posterior midline. Acute small external apical spine has distal pointing ventral setae. Short, straight anterior tibial spur, inner tibial spur slightly longer with marginal curve. Six extremely short setae distal edge between apical spine and anterior spur, 3 similar setae between anterior and inner spurs. Midtarsi structure is similar to that of anterior tarsi.

Hindlegs: One setiferous puncture on lateral anterior margin of each leg. On medial ventral edge of convexed and ovoid trochanter, one setiferous puncture is present. Trochanter sub-equal to 1/3 of femoral length. Small cluster of setae on extreme medial 1/5 of dorsal femoral surface, hidden when leg is in normal position. Hind tibia long and thin, sub-equal to femoral length. Acute external or outer apical spine inserted below setal fringe circumscribing distal edge. Tibial surfaces characterised by longitudinal rows of setae; 7 along anterior midline, 3 on dorso-anterior distal half, 10 on ventral anterior distal half and 6 on posterior distal half. Posterior tibial spur extremely long and acute, inserted below outer spine. Hind tarsi are also similar to anterior tarsi in structure.

Abdomen.

Bisetose medially on ventrites 3, 4 and 5. On posterior margin of ventrite 6 a cluster of three pairs of setiferous punctures medially situated.

Female Genitalia.

Description based on specimen NAG0327. Styli 2.24 mm long, curved and concave dorsally. On inner and outer edges are a row of fine setae (4- 6 on each edge). Apex black.

Male Genitalia.

Description based on specimen NAG0819 (Figure 4.15). Genital ring thickened and heavy, length equal to penile length (2.94 mm), not overly convexed laterally. Penis is relatively stout, lower edge concave with distinctive flared and elongate lower apex. Orifice dorsally located on flared apex. Parameres similar, curved similarly to lower penile margin which they lie against. Paramere apex is slightly swollen and fringed in long fine setae.

Variation.

Morphological variation exists but none of it can be ascribed to between-population variability. Setal arrangements are very much uniform among all individuals but numbers of setae or setiferous punctures exhibit both limited variation between individuals and between left and right sides of individuals. Anterior elytral setae generally consist of two clusters, one on each elytron, of 1 row of three to a maximum of 2 rows of three, either in or out of phase. The average was two rows of two; one individual (NAG0610) from Woodman Point lacked the cluster on the left elytron, a further individual from Woodman Point (NAG0678) possessed only one seta in this position on each elytron, as well as lacking both the extra anterior setae on the elytra. In a few individuals one extra seta was present on the foretibia, usually on the distal portion of the 2nd tibial tooth or on the distal portion of the apical tooth. The character which appears to vary most is the number of setiferous punctures on the posterior margin of ventrite six. The most common variation is that of four setae evenly and widely spaced along the margin. Some individuals have unevenly numbered clusters on either lateral of the margin, with two or three setae in each cluster being the most common. The proximal prosternal setiferous puncture differed among some individuals. Generally specimens possessed two setiferous punctures but some individuals either lacked just the seta, or in some cases the puncture was lacking also. A few individuals possessed two setiferous punctures on the right side.

In general, the morphological variation among the sample studied appears to be quite low, consisting of the addition or lack of only one or two setae for any one character. The general pattern of setation is otherwise uniform.

Distribution.

Carenum scaritoides is known from a number of localities outside the Swan Coastal Plain in Western Australia (Figure 4-16). Several of these localities are on main highways, but this species' distribution may prove to bewithin the south-western region of Western Australia.

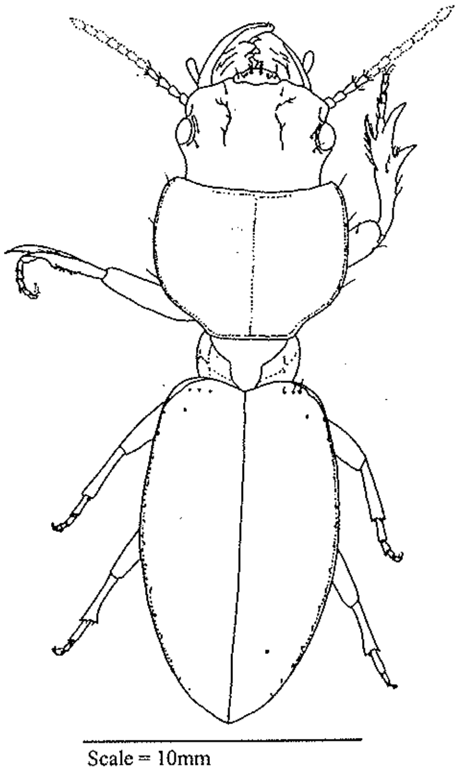


Figure 4-14: Dorsal view of *Carenum scaritoides* (specimen NAG0327).

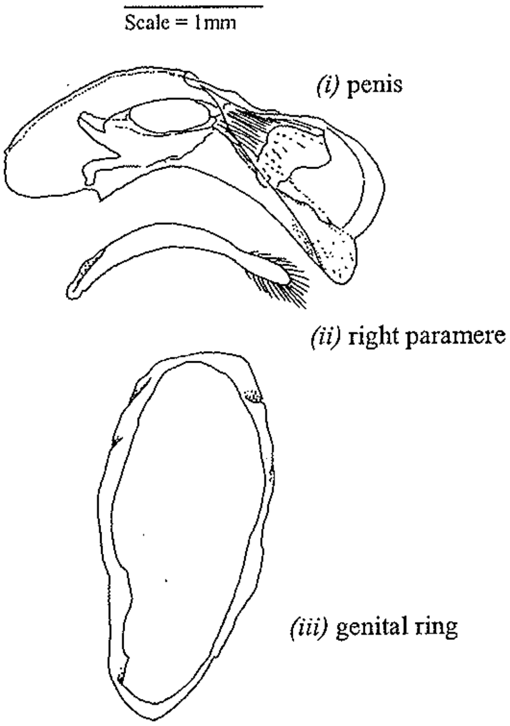


Figure 4-15: Male genitals of *Carenum scaritoides* (specimen NAG0819).
Structures illustrated are (i) penis, (ii) right paramere (left is identical), (iii) genital ring, all structures to scale.

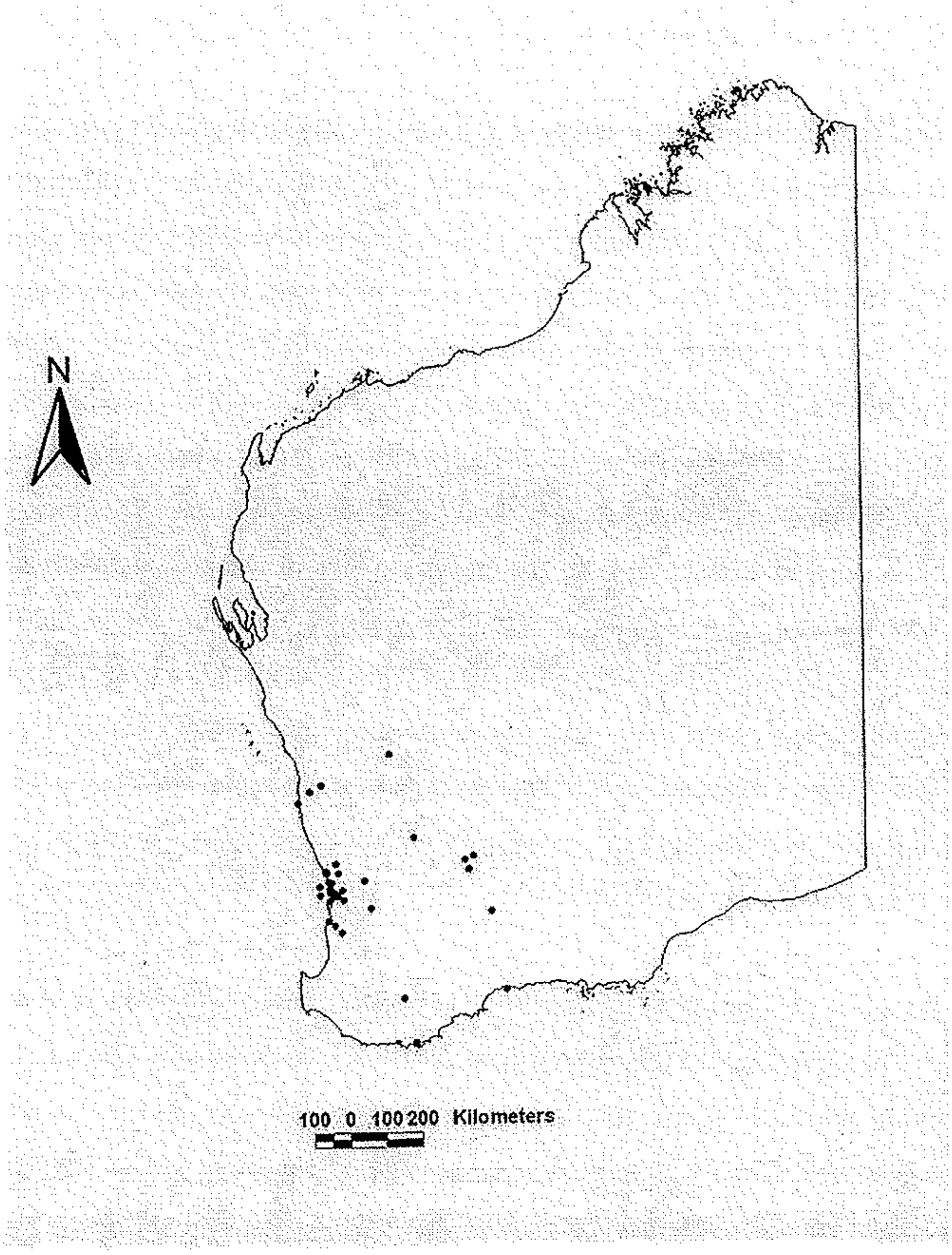


Figure 4-16: Distribution of *Carenum scaritoides* in Western Australia
Based on specimens held in the Western Australian Museum, WA AGRICULTURE and the Australian National Insect Collection.

4.6.3.2 Genus *Scaraphites*

Members of *Scaraphites* are large, aggressive predatory carabids which generally inhabit coastal areas of Australia (Moore *et al.* 1987). All nine species are large in size (22-51 mm; Bänninger 1940) and inhabit similar environments of tall open shrubland or low open woodland on sandy soil (Moore *et al.* 1987). Dietary information is generally lacking, but it is known that *Scaraphites rotundipennis* feeds on scarab larvae (McQuillan 1983) and anecdotal evidence suggests that some species (*Scaraphites lucidus* and *S. silenus*) will feed on anything they can subdue (including small vertebrates such as skinks and rodents, and mygalomorph spiders). It is likely that this genus is a generalist predator, with the maximum size of the prey determined only by mandible size and ability to subdue the potential prey. Distributions of the individual species therefore may be controlled by the maximum size of the prey items that each species can control rather than a physical or physiological parameters. In the drier arid areas this genus is replaced, in the large predatory beetle niche, by *Euryscaphus* which is much larger andwith much more powerful mandibles (thereby capable of accessing a much larger maximum prey size).

Five *Scaraphites* species occur in the south-western area of Western Australia (*S. lucidus* Chaudoir 1863; *S. silenus* (Westwood 1842); *S. humeralis* Castelnau 1867; *S. lenaeus latipennis* Macleay 1863; and *S. l. pacificus* Sloane 1888), of these only *S. silenus* is known to be widely distributed across the south-west. The first three listed species have been recorded on the Swan Coastal Plain. While *S. lucidus* and *S. silenus* are still being caught in various locations on the Plain, *S. humeralis* has not been recorded for several decades. As the range of this species coincides with areas of intensive urban development over the last few decades it is possible that *S. humeralis* has become extinct on the mainland of Australia. Although the differences between *S. humeralis* and *S. lucidus* are very slight, with the former possessing a densely granulate apical declivity, slightly broader prothorax and a slightly longer anterior tibia than the former, Bänninger (1940) retained *S. humeralis* as a full species. However, it is also recorded from Rottnest Island and this may be an island form that had succeeded in recolonising the mainland.

SYSTEMATICS

Scaraphites Westwood

Scarites (Scaraphites) Westwood, 1842:157-158. Type species: *Scarites (Scaraphites) macleaii* Westwood, 1842 by monotypy.

The form of the last joint of the palpi and the position of the forespur behind the 2nd tibial tooth of the anterior tibia was used by Sloane (1893) to differentiate this genus from other scaritine genera with a closed buccal cavity. A number of species were erected by various workers (Sloane, Macleay and Westwood) on the basis of several variable characters such as the pre-ocular sulcus and pre-ocular projections. Sloane (1893, 1905) attempted to rationalise the taxonomy of this group but he did not have access to many of Castelnau and Blackburn's original types (Bänninger 1940). It was Bänninger (1940) who was able to clarify the taxonomy, synonymising a number of species. Many of the characters previously used to define species were shown to be unimportant and exhibited variability within a species. Bänninger emphasised the taxonomic importance of punctures on the elytral lateral declivity, the form of the humeral angles of the elytra and the structure of both the prothorax and the tibiae. Bänninger (1940) presented a concise and clear generic diagnosis which is repeated here:

> Palpi filiform, last joint not triangular or securiform. Triangular projection of clypeus at each side of labrum wanting or scarcely marked. Suborbital grooves to receive the antennae single, not divided. Paragenae not separated from submentum by a sharp oblique groove beginning at hind angle of mentum. Base of elytra without ocellate punctures. Elytra without a costa at sides, lateral border visible from above in its whole length. Upper side of front tibia apically with three strong teeth, without additional denticulations above the upper tooth. The bifurcation of the two lower teeth, seen from behind, of variable position with regard to the insertion of the tarsi. Entirely black, without metallic lustre.

The only genus which might be confused with *Scaraphites* is *Euryscaphus* Macleay. While both genera are large, black non-flying carabids with large mandibles they differ in the structure of the palpi (*Scaraphites* possessing filiform palpi, whereas *Euryscaphus* has securiform palpi) and the structure of the anterior tibia. The forespur on the inner side of the anterior tibia is positioned distally to the 2nd tibial tooth on the outer side in all *Euryscaphus* species. All *Scaraphites* species have the forespur positioned medially or behind the 2nd tibial tooth. The overall shape of the elytra differs in these genera as well, *Scaraphites* elytra tend to be slightly longer than broad, *Euryscaphus* elytra in contrast, tend to be broader than long, with an acute apex (almost cordate).

Scaraphites lucidus Chaudoir

Key Figures: 2b, 3d, 3e, 3f, 4a; Text Figures: 4.17a, 4.18a, 4.19a.

Scaraphites lucidus Chaudoir, 1863:111-120, 187-188, 223-225, syntypes (possible), MNHP, Melbourne, Victoria; Banninger (1940) indicates that the type locality should in be south-western Australia.

MATERIAL EXAMINED

Bold Park: BP1, 31°57'11"S 115°45'50"E, wet pitfall, JMW/MSH, 20 July-24 September 1993, 2 M (NAG0096, 99), 3 unsexed (NAG1726-1728); same site, wet pitfall, JMW 24 September-18 November 1993, 8 F (NAG0229, 233-235, 238, 243, 244, 254), 24 M (NAG223-228, 230-232, 236, 237, 240-242, 245-253, 255), 9 unsexed (NAG0239, 256, 1736-1742); same site, dry pitfall, RH, 24-29 August 1993, 1 F (NAG0101), 1 M (NAG0102); same site, dry pitfall, RH, 18-31 October 1993, 2 F (NAG0106, 109), 5 M (NAG0103-105, 107, 108); same site, wet pitfall, J.M. Waldock, 18 November 1993-6 January 1994, 8 F (NAG170-173, 178-180, 182), 6 M (NAG0090, 174-177, 181); same site, dry pitfall, RH, 23 November-24 December 1993, 2 F (NAG0112, 115), 4 M (NAG0111, 113, 114, 116); same site, wet pitfall, MSH/JMW, 6 January-18 March 1994, 2 F (NAG0091, 98), 6 M (NAG0092, 94, 95, 97, 587, 588); same site, wet pitfall, MSH/JMW, 18 March-19 May 1994, 1 M (NAG0093); same site, dry pitfall, RH, 24January-5 February 1994, 1 F (NAG0100); same site, dry pitfall, RH, 5 October-20 November 1995, 1 M (NAG0110); BP1, 31°57'12"S 115°46'31"E,wet pitfall, NAG, 29 August-10 October 1996, 12 F (NAG0728, 731, 736, 857-859, 861, 887, 892, 893, 895, 1634), 26 M (NAG0723, 724, 729, 730, 737, 740-742, 849, 850, 857, 860, 881-885, 888-891, 894, 896, 897, 900, 901); same site, wet pitfall, NAG, 10 October-21 November 1996, 12 F (NAG0907, 908, 914, 918, 919, 921-923, 981, 1067, 1068, 1071), 28 M (NAG0905, 906, 909-911, 913, 916, 917, 920, 954, 975-980, 983, 984, 986-989, 991-993, 1069, 1070, 1072, 1073), 2 unsexed (NAG0985, 1823); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 10 F (NAG1017, 1020, 1028, 1047, 1049, 1051, 1082, 1134, 1677, 1678), 12 M (NAG1021, 1025-1027, 1045, 1046, 1050, 1052,1083, 1084, 1135, 1676); same site, wet pitfall, NAG, 2 January-14

February 1997, 1 M (NAG1124); same site, wet pitfall, NAG, 14 Febraury-1 April 1997, 1 F (NAG1588),2 M (NAG1589, 1590).

Bold Park: BP3, 31°56'30"S 115°46'27"E, wet pitfall, JMW/MSH, 20 July-24 September 1993, 5 M (NAG0012-16); same site, wet pitfall, JMW, 24 September-18 November 1993, 5 F (NAG0203, 210, 211, 213, 221), 15 M (NAG0204-209, 212, 214-220, 222), 4 unsexed (NAG1729-1732); same site, dry pitfall, RH, 18-31 October 1993, 1 F (NAG0010), 1 M (NAG0011); same site, wet pitfall, J.M. Waldock, 18 November 1993-6 January 1994, 10 F (NAG0151, 152, 154, 155, 157, 161, 163, 165, 166, 169), 7 M (NAG0153, 156, 158, 162, 164, 167, 168), 1 unsexed (NAG0159); same site, dry pitfall, RH, 23 November-24 December 1993, 1 F (NAG0008), 1 M (NAG0009); same site, dry pitfall, RH, 24January-5 February 1994, 1 F (NAG0580).

Bold Park: BP4, 31°56'29"S 115°46'16"E, wet pitfall, JMW/MSH, 20 July-24 September 1993, 2 F (NAG0506, 507), 1 M (NAG0508), 2 unsexed (NAG1720, 1721); same site, wet pitfall, JMW, 24 September-18 November 1993, 4 F (NAG0083-85, 88), 14 M (NAG0072-0082, 86, 87, 89); same site, dry pitfall, RH, 18-31 October 1993, 5 M (NAG0192-196); same site, wet pitfall, J.M. Waldock, 18 November 1993-6 January 1994, 8 F (NAG0062-65, 67-69), 3 M (NAG0066, 70, 71); same site, dry pitfall, RH, 23 November-24 December 1993, 5 M (NAG0284-288); same site, dry pitfall, RH, 24January-5 February 1994, 1 F (NAG00061), 1 M (NAG0060); same site, dry pitfall, RH, 5 October-20 November 1995, 1 F (NAG0059), 1 M (NAG0058).

Bold Park: BP5, 31°57'14"S 115°46'16"E, wet pitfall, MSH/JMW, 20 May-20 July 1993, 1 F (NAG0686); same site, wet pitfall, JMW/MSH, 20 July-24 September 1993, 2 M (NAG0303, 304), 2 unsexed (NAG1722, 1723); same site, dry pitfall, RH, 24-29 August 1993, 3 M (NAG0281-283); same site, wet pitfall, JMW 24 September-18 November 1993, 2 F (NAG0258, 260), 10 M (NAG0257, 259, 261-268), 1 unsexed (NAG1733); same site, dry pitfall, RH, 18-31 October 1993, 2 F (NAG0200, 202), 4 M (NAG0197-199, 201); same site, wet pitfall, J.M. Waldock, 18 November 1993-6 January 1994, 1 F (NAG0118); same site, dry pitfall, RH, 23 November-24 December 1993, 2 M (NAG0589, 590); same site, wet pitfall, MSH/JMW, 6 January-18 March 1994, 1 M (NAG0117); same site, dry pitfall, RH, 5 October-20 November 1995, 2 M (NAG0119, 120); BP5, 31°57'07"S 115°45'54"E, NAG, 29 August-10 October 1996, 3 F (NAG0750, 755, 777), 16 M (NAG0751, 753, 754, 761-767, 769, 774, 775, 778-780); same site, wet pitfall, NAG, 10 October-21 November 1996, 8 F (NAG0852, 867, 869, 954, 958, 963, 968, 971), 14 M (NAG0865, 868, 870, 950-953, 955-957, 964, 969, 972, 973); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 5 F (NAG1031, 1033, 1034, 1037, 1038), 2 M (NAG1032, 1035); same site, wet pitfall, NAG, 14 February-1 April 1997, 1 F (NAG1008); same site, wet pitfall, NAG, 1 April-9 May 1997, 1 F (NAG1594).

Bold Park: BP6, 31°56'00"S 115°46'26"E, dry pitfall, RH, 5 October-20 November 1995, 4 F (NAG0048-50, 53), 2 M (NAG0051, 52).

Mount Claremont Reserve: MC1, 31°57'40"S 115°46'60"E, wet pitfall, JMW/AFL, 24 June-1 September 1994, 1 M (NAG0669); same site, wet pitfall, JMW/AFL, 1 September-4 November 1994, 1 F (NAG0414), 6 M (NAG0413, 415-419); same site, dry pitfall, RH, 11-31 October 1994, 1 F (NAG0056), 2 M (NAG0121, 160); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 1 F (NAG0001), 1 M (NAG0002); same site, dry pitfall, RH, 1-12 December 1994, 1 M (NAG0493); same site, wet pitfall, MSH/JMW, 19 January-21 March 1995, 1 M (NAG0122); same site, wet pitfall, JMW/MSH, 1 M (NAG0129).

Mount Claremont Reserve: MC2, 31°57'39"S 115°45'56"E, wet pitfall, JMW/AFL, 1 September-4 November 1994, 6 F (NAG0452, 456, 459, 464, 466, 473), 18 M (NAG0449-451, 453-455, 457, 458, 460-463, 465, 467-471), 3 unsexed (NAG0472, 1734, 1735); same site, dry pitfall, RH, 11-31 October 1994, 1 M (NAG0007); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 7 F (NAG0020, 28-30, 32-34), 9 M (NAG0019, 21-27, 31); same site, dry pitfall, RH, 1-12 December 1994, 1 M (NAG0489); same site, wet pitfall, MSH/JMW, 19 January-21 March 1995, 3 F (NAG0124-126); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 1 M (NAG0696).

Trigg Dune Reserve: TD1, 32°07'47"S 115°45'23"E, wet pitfall, MSH/JMW, 13 July-25 September 1995, 1 F (NAG0326).

Trigg Dune Reserve: TD2, 32°07'47"S 115°45'23"E, wet pitfall, MSH/JMW, 13 July-25 September 1995, 2 F (NAG0430, 431), 14 M (NAG0420, 422-429, 432-436), 1 unsexed (NAG0421); same site, wet pitfall, MSH/JMW, 25 September-28 November 1995, 3 F (NAG0376, 377, 380), 5 M (NAG0372-375, 378, 379); same site, wet pitfall, MSH/JMW, 28 November 1995-29 January 1996, 4 F (NAG0501-504); same site, wet pitfall, JMW/PLW, 29 January-28 March 1996, 1 M (NAG1747); TD2, 32°52'31"S 115°45'44"E, wet pitfall, 10 October-21 November 1996, 10 F (NAG0928-930, 934, 936, 937, 939-941, 943), 4 M (NAG0927, 933, 944, 945); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 1 F (NAG1030), 1 M (NAG1029).

Trigg Dune Reserve: TD4, 32°07'47"S 115°45'23"E, wet pitfall, MSH/JMW, 25 September-28 November 1995, 11 F (NAG0330, 332, 334, 335, 338, 339, 346, 347, 349, 351, 1719), 11 M (NAG0331, 333, 336, 337, 341-345, 348, 350), 3 unsexed (NAG0352, 1743, 1744); same site, wet pitfall, MSH/JMW, 28 November 1995-29 January 1996, 3 F (NAG0363, 365, 366), 2 M (NAG0364, 367); TD4, 32°52'36"S 115°45'41"E, wet pitfall, 10 October-21 November 1996, 5 F (NAG0804-806, 821, 1096), 6 M (NAG0787, 802, 820, 1092, 1102, 1600); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 1 F (NAG0999).

Woodman Point Reserve: WP1, 32°07'47"S 115°45'23"E, wet pitfall, JMW/AFL, 1 September-4 November 1994, 2 F (NAG0597, 598), 1 M (NAG596); same site, wet pitfall, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 1 F (NAG0305); same site, dry pitfall, JD, 14 November-11 December 1994, 2 F (NAG0270, 271), 4 M (NAG0269, 272-274); same site, dry pitfall, RH, 1-12 March 1995, 1 F (NAG0297); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 1 F (NAG0298).

Woodman Point Reserve: WP2, 32°07'50"S 115°45'28"E, wet pitfall, JMW/AFL, 1 September-4 November 1994, 2 F (NAG0652, 653); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 1 M (NAG0714); same site, wet pitfall, JMW/MSH, 21 March-4 May 1995, 1 unsexed (NAG1815); same site, wet pitfall, JMW/MSH, 4 May-6 July 1995, 1 M (NAG0719).

Woodman Point Reserve: WP3, 32°07'58"S 115°45'29"E, wet pitfall, JMW/AFL, 1 September-4 November 1994, 3 F (NAG0307, 310, 318), 9 M (NAG0308, 309, 311-317); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 4 F (NAG0591, 592, 594, 595), 1 M (NAG593); same site, dry pitfall, RH, 1-12 March 1995, 1 F (NAG0297).

Woodman Point Reserve: WP4, 32°07'58"S 115°46'29"E, wet pitfall, JMW/AFL, 1 September-4 November 1994, 2 F (NAG0601, 603), 4 M (NAG0602, 604, 606, 607), 3 unsexed (NAG605, 1724, 1725); same site, wet pitfall, JMW/MSH, 4 November 1994-19 January 1995, 2 F (NAG0183, 184).

DIAGNOSIS

Scaraphites lucidus is distinguishable from other *Scaraphites* by the possession of a sparsely granulate elytral border with a humeral projection at the elytral shoulders. The prothorax is strongly sinuate laterally, with strong basal angles which have a setiferous puncture. The border of the prothorax is narrow and reflexed, strongly sinuate basally.

DESCRIPTION

Measurements

Measurements taken from female specimen NAG0899 (Figure 4.17a). Total length: 34.75 mm; elytra length/width = 20.05/15.15 mm; pronotal length/width = 7.8/13.6 mm; head length = 6.1 mm; mandibular length = 4.65 mm; mandibular width at base = 2.75 mm; foretibia length = 9.28 mm.

Colour.

Entirely black without metallic lustre or sheen.

Head.

Mandibles are very large, powerful and heavy, each with a sharply curving apical hook. Dorsal surface characterised by striations terminating at teeth on inner edge. When closed, mandibles overlap considerably, left over right, with teeth interlocking completely. Lateral mandibular groove reduced to area defined by large upper and lower prominent ridges within which are further striations. On left mandible, 4 teeth present, 1st relatively small and placed near apical hook, striations on dorsal surface anterior and lateral to this tooth absent. Second tooth much larger and positioned at midpoint along mandibular length. Third tooth similar in size to 1st and hidden under labrum. Ventrally placed under 1st, 4th tooth is extremely small. Right mandible has three teeth, 1st is positioned towards apical hook and has no striations anterior or lateral to it on dorsal surface. Blunt 2nd tooth equal in size to 1st, and tiny 3rd ventrally positioned in relation to 2nd.

Palps filiform, with basal segment of labial palp possessing a double row of six setae on dorsal surface. Labial palp segments relatively long. Mentum large, depressed medially, with lateral margins flared with transverse creases on margins; single medial tooth with wide base. Basal margin of mentum notched either side of midline. Three setiferous punctures on either side of submentum directly under mentum and one setiferous puncture on either side of anterior gena, in addition to gula present on ventral throat.

Quadrate head, broader than long, not compressed anteriorly, convex and levigate. Single supraorbital seta at posterior angle of each eye. Eyes not prominent. Irregular depression (or frontal sulci), anteriorly with many branches, positioned forwards of anterior half of eye, faint extension reaches posterior eye margin, not extending past eye. Clypeus broad and convexed in middle, projections on either side of labrum extremely small. Labrum fluted with two pairs of setiferous punctures on either side.

Prothorax.

Prothorax laterally sinuate towards posterior, basal angles strong, subrectangular, with a setiferous puncture. Basal margin entire, with strong sinuation. Lateral margins narrow with 3-4 setiferous punctures on anterior two thirds. Medial sulcus strong posteriorly, terminating posterior to anterior margin.

Elytra.

Slightly longer than broad and strongly convexed; with wide border at shoulders (or humeral angles) forming projections directed laterally; border narrows, becoming sparsely granulate near setiferous umbilicate punctures on lateral margins, with setae extending onto dorsal edge of opaque apical declivity. The elytral dorsum above apical declivity smooth but with 6-8 faint incomplete striations on each elytron.

Legs.

Forelegs: Single setiferous puncture on distal edge of ventral trochanter surface. On medial edge of posterior femoral surface there is 1 setiferous puncture in addition to one on the distal third of the femoral posterior ventral edge. A row of 6 setae is present on the medial half of the ventral anterior femural edge. Femur deepened dorso-ventrally. Foretibia wide, heavy and palmate with row of long setae along entire tibial length on upper and lower edges of inner side. On distal half of anterior surface runs a row of 6 setiferous punctures down midline of tibia. On outer edge are two tibial teeth, the first positioned approximately in middle of tibia. First tooth widened with trailing or medial edge forming narrow lateral extension of tibia or shelf. Second tibial tooth, distal to first, is right-angled on distal edge which itself is distal to forespur insertion point; apex of this tooth slightly hooked posteriorly; apical tooth long and curved towards posterior. A fringe of long setae extends from the forespur insertion point, along distal edge of tibia and terminating above cleaning organ on the inner side. Cleaning organ spur, forespur and apical tooth sub-equal in length. Cleaning organ spur held under palm or distal end of tibia. A carina runs from its insertion point back to tibial joint, with 2 setiferous punctures on medial half. Two setiferous punctures on outer posterior edge of second tibial tooth. Stiff setae form a fringe on ventral edges and distal end of each tarsomere. Basal tarsomere sub-equal to forespur length. Tarsomeres 1-4 are half length of basal, ultimate tarsomere with equal sized claws.

Midleg: Single setiferous puncture on ventral trochanter, femur dorso-ventrally thickened with cluster of setae forming curved row along lower anterior surface and on dorsal surface, third cluster on distal third of dorsal surface. Distal end of tibia expanded; 8 thick rows of long setae, 1 along each edge. External apical tooth of midtibia acute. Two inner apical teeth equal in size to basal tarsomere and inserted below tarsi (identical in structure to fore tarsi).

Hindlegs: One setiferous puncture on lateral anterior margins of coxae and posterior ventral margin of trochanter. Small cluster of short stiff setae on extreme medial end of femoral dorsal surface, hidden by coxae in life. Five setae form row along posterior ventral femoral surface, 5 more form loose cluster on distal third of anterior surface. Posterior tibia equal to femoral length, flatted dorso-ventrally and slightly dilated at apex, with rows of setae along each edge. Two inner apical spurs inserted below tarsus insertion point. Second spur twice length of the other. Basal tarsomere equal to second inner apical spur in length, remaining tarsomeres are half its length with setal arrangements identical to the fore tarsi.

Abdomen.

The midline area of the prosternum is swollen slightly, forming a longitudinally raised area. The final four ventrites are bisetose down the midline.

Female Genitalia.

Description based on specimen NAG0169.

Heavily sclerotized, 4.1 mm long with a carinae present on the posterior edge of both styli. On the basal inner margin of each stylus six stiff short hair like seta occur. A further three are on the opposite, outer margins. The overall shape of the stylus is flat, slightly curving medially.

Male Genitalia.

Description based on specimen NAG0450 (Figure 4.18a). Genital ring convexed, 5.9 mm in length with a wide apical lip. Penis and parameres are heavily sclerotized. Penis is simple, blade like and laterally convexed, with an expanded apex. Length of the penis is 6.9 mm. Orifice positioned at apex on dorsal surface. Parameres are long (5.3 mm), simple and symmetrical with sparse seta at apex. Parameres curve, following penile shape. When everted both penis and parameres hook to the left lateral (from the dorsal position), and then curve dorsally back toward the midline, with the parameres splayed away from the penis.

Variation.

This species exhibits very little morphological variation within or between populations. The sexes are almost identical with no obvious difference in elytral shape. However, overall size does vary amongst individuals caught during any one trapping period. Larger individuals possess progressively larger and heavier foretibia and mandibles.

Distribution.

Scaraphites lucidus has been collected in the coastal regions of the south-west between the Gardener River and the northern Perth Metropolitan Area (Figure 4.19a). Specimens have also been collected from the catchment of the Murchison River. Within the Swan Coastal Plain this species has been collected from both coastal suburbs and suburbs adjacent to the Swan River System. This would suggest that this species may be associated with dune and riverine environments. This is supported by the lack of specimens collected from remnant bushland areas associated with other water bodies (Western Australian Museum records; see Appendix D).

Scaraphites silenus Westwood

Scaraphites silenus Westwood, 1842:81-90, fig., syntypes, OUM or BMNH, from Swan River, W.A.

Scarites bacchus Westwood, 1842: 81-90, fig., syntypes, OUM, from Swan River, W.A.

Scaraphites heros Castelnau, 1867:30-38, syntypes, MCG, NMV from Champion Bay, W.A.

Scaraphites masteri Macleay, 1869:58-70, holotype, AM, from Mt. Baker, W.A.

MATERIAL EXAMINED

Trigg Dune Reserve, TD1, 31°52'09"S 115°45'38"E, wet pitfall trap, JMW/MSH, 13 July-25 September 1995, 6 M (NAG0321-324, 385, 387), 5 F (NAG0382-385, 386); same site, wet pitfall, MSH/JMW, 25 September-28 November 1995, 1 M (NAG0388), 1 F (NAG0389); same site, MSH/JMW, 28 November 1995-29 January 1996, 1 M (NAG0498), 2 F (NAG0499, 500).

Bold Park, BP1, 31°57'12"S 115°46'31"E, wet pitfall trap, NAG, 29 August-10 October 1997, 1 F (NAG0886), 1 M (NAG0899); same site, wet pitfall, NAG, 10 October-21 November 1996, 1 F (NAG0912); same site, wet pitfall, NAG, 21 November 1996-2 January 1997, 1 F (NAG1049).

Yanchep National Park, YP1, 31°31'00"S 115°39'18"E, wet pitfall trap, NAG, 10 October-21 November 1996, 3 F (NAG0781-783); same site, wet pitfall, NAG, 18 July-1 August 1997, 1 M (NAG1142).

DIAGNOSIS

Scaraphites silenus can be distinguished from other *Scaraphites* by possessing several key characters; a wide prothorax with a rounded or weakly truncate base, hind angles usually absent, if present extremely weak. The elytral border is not widened, thickened or possesses projections of any description. The elytra tends to be slightly longer than broad, in males the sides are rounded, females tend to be longer and less rounded. Larger males are very rounded, almost globular.

DESCRIPTION

Measurements

Measurements taken from male specimen NAG0899, unless specified. Total length = 34.1 mm; elytra length/width = 18.2/16.7 mm; pronotal length/width = 8.7/14.8 mm; head length = 4.9 mm; mandibular length = 6.2mm; mandibular width at base = 3.2 mm; foretibia length: 9.3 mm.

Colour.

Entirely glossy black without metallic lustre.

Head.

Large and heavy mandibles with strong curving apical hook. On mandibular dorsal surface prominent longitudinal ridges run from basal margin anteriorly, curving toward teeth on inner surface. Mandibles 4 - dentate; on left 1st tooth simple and obliquely angled, 2nd large and centrally placed, 3rd visible dorsally but much smaller than 1st tooth. Ventrally positioned under 2nd tooth and hidden from dorsal view, 4th tooth is equal in size to 3rd tooth. Right mandible has two large teeth, visible from dorsum, 1st or apical tooth has minor double cusps and other a single cusp. On ventral of right mandible surface, 2 tiny teeth positioned under 2nd tooth. Mandibular groove ridged longitudinally, shallow, wide and extending to just beyond apical teeth. Filiform palpi, last joint not securiform. Mentum palpi with 4 pairs of setae on dorsal surface of basal segment. Mentum large, rounded with thin middle tooth, depressed along sulcus extending from external basal corner towards basal margin of middle tooth on either side. Basal margin notched either side of midline of mentum. Bi-setiferous punctures on extremities of submentum.

Head quadrate, slightly broader than long, eyes round, small and not protruding. One setiferous puncture at hind angle behind eye. Surface smooth and slightly swollen between eyes, head depressed anteriorly towards clypeus. Irregular depression with 1 setiferous puncture dorso-laterally positioned anterior to eye on clypeus. Labrum much wider than long, with flared anterior margin, weak medial sulcus, depressed at 45° to medial on either side and four setiferous punctures evenly spaced along anterior margin.

Prothorax.

Very rounded base, widely and weakly truncate with hind angles not dentate. Medial sulcus complete, joining anterior margin. Lateral margins extended and rounded at head insertion point. Margin narrow and upturned with 5- 6 setiferous punctures along laterals.

Elytra.

Elytral border continuous at shoulders, no prominence projecting at humeral angles. Elytra very rounded, slightly longer than broad. Margin narrow, with setiferous punctures along laterals and apical declivity. Dorsal surface of elytra smooth with 6-8 rows of striations on each elytron.

Legs.

Forelegs- On anterior trochanter there is 1 setiferous puncture on ventral surface. Cluster of setae in linear arrangement positioned on medial half of anterior ventral surface of femur. On posterior ventral edge 3 setae are spaced evenly along femoral length. Tibia appears heavy, with 3 setae on medial third of inner surface. Along midline of tibial anterior surface 7 setiferous punctures open in an anterior apical direction. Along posterior inner edge are 11 thickened setae, terminating distally to cleaning organ. Fringe of setae connects cleaning organ and tarsus insertion point on apical margin. On medial third of posterior surface, 2 setiferous punctures positioned close to either edge. Cleaning organ and forespur similar in length and carinate. Forespur set distally to 2nd tibial tooth on outer tibial edge. Tibial teeth are right angled distally, with a single setiferous puncture on posterior side of 1st tooth. The 2nd tibial tooth is larger and twice length of 1st. The apical tooth approximately half length of tibia, hooked laterally and is heavy. First tarsomere of foretarsus is filiform, approximately 1/3 shorter than apical tooth. Setiferous punctures on lateral and distal edges. Tarsomeres 2-4 triangular with setae positioned on distal edge. Terminating tarsomere filiform with 2 setae above equally sized claws. Under the claw insertion point, a projection of the posterior surface forms a small lip.

Midleg: On lateral edge of mid coxa, anterior to leg joint is 1 setiferous puncture. Ventral trochanter also has 1 setiferous puncture. Curved row of setiferous punctures extends along ventral edge of anterior surface of femur. Corresponding row on dorsal surface. Scattered setiferous punctures on distal third of anterior surface and 1 on mid point of ventral surface. Thickened setae in 3 rows along length of mid tibia on anterior and posterior surfaces. A carina along anterior midline on apical third of tibia. Apical tooth acute, above spur insertion point (both of which are equal in size and smaller than anterior spur). Tarsal structure is identical to anterior tarsus.

Hindlegs: On anterior margin and ventral surface of coxa are single setiferous punctures. Cluster of setae on extreme distal end of anterior femoral surface (when the leg is held normally these setae are hidden under the lateral edge of the coxa). Down length of ventral surface of femur is a curved row of setae, terminating at lower joint. Small cluster of distally pointing setae on extreme distal end of anterior surface near lower joint. Hind tibia longer than hind femur and thin, with linear clusters of setae down length. Apical tooth small and blunt with fringe of setae on outer side. Forespur three times length of inner spur, both inserted together on distal edge below apical tooth. Tarsus identical to middle and anterior tarsus.

Abdomen.

Bipunctate medially on the ventrites, otherwise unremarkable.

Female Genitalia.

Coxite approximately 5.2 mm in length, thick and curved dorso-ventrally with 7 setae on the inner and outer edges.

Male Genitalia.

Paired equal parameres, 5.6 mm in length with a fringe of short sparse setae at the apex on either side of the penis (Figure 4.18b). The penis is large, 12 mm in length, curved and widened distally, apex blade like. When everted (seen dorsally), reproductive structure bends to the left lateral, with parameres splayed away from the penis base which curves dorsally and medially.

Variation.

This species exhibits very little morphological variation with very uniform character and setal arrangements between individuals. Variation between the sexes appears to be restricted to the overall shape of the elytra. Males tend to possess very broad and short elytra with very rounded sides. Females have slightly longer and less rounded elytra. Overall size does not differ between the sexes (total length: males 30- 40.1mm; females 27.65- 37 mm).

Distribution.

Scaraphites silenus has been collected extensively across the south western portion of Western Australia. Collection records would suggest that this species is relatively common west of a line drawn between Geraldton in the north and Esperance in the south and is absent from the high rainfall areas of the extreme southern tall forests. Specimens have also been collected from the eastern Wheatbelt, suggesting that the range may extend into semiarid areas. They have also been collected on the Swan Coastal Plain away from riverine or swampy areas.

General Comments On Scaraphites.

While being relatively easy to catch, many of the records used to generate distribution maps for both species were collected prior to 1950. For animals collected on the Swan Coastal Plain this is significant as many of these localities are now urbanised. Populations of *S. silenus* exist in most of the surveyed major native bushland remnants in the Perth Metropolitan Areas surveyed (see Chapter 5). The suggestion made earlier in this Chapter that *S. lucidus* appears to be restricted to coastal and riverine systems is also supported by these data. This species was notably absent from Bassendean, Ridge Hill Shelf and Spearwood Dune System sites (other than those discussed in Chapter 5). As the south west coastal region is becoming increasingly urbanised *S. lucidus* could be isolated within fragmented populations along its distribution. Likewise, many areas in which *S. silenus* had been collected from are now cleared of the natural vegetation but evidence suggests that populations are still present in most bushland remnants in the Wheatbelt (CALM, unpublished data).

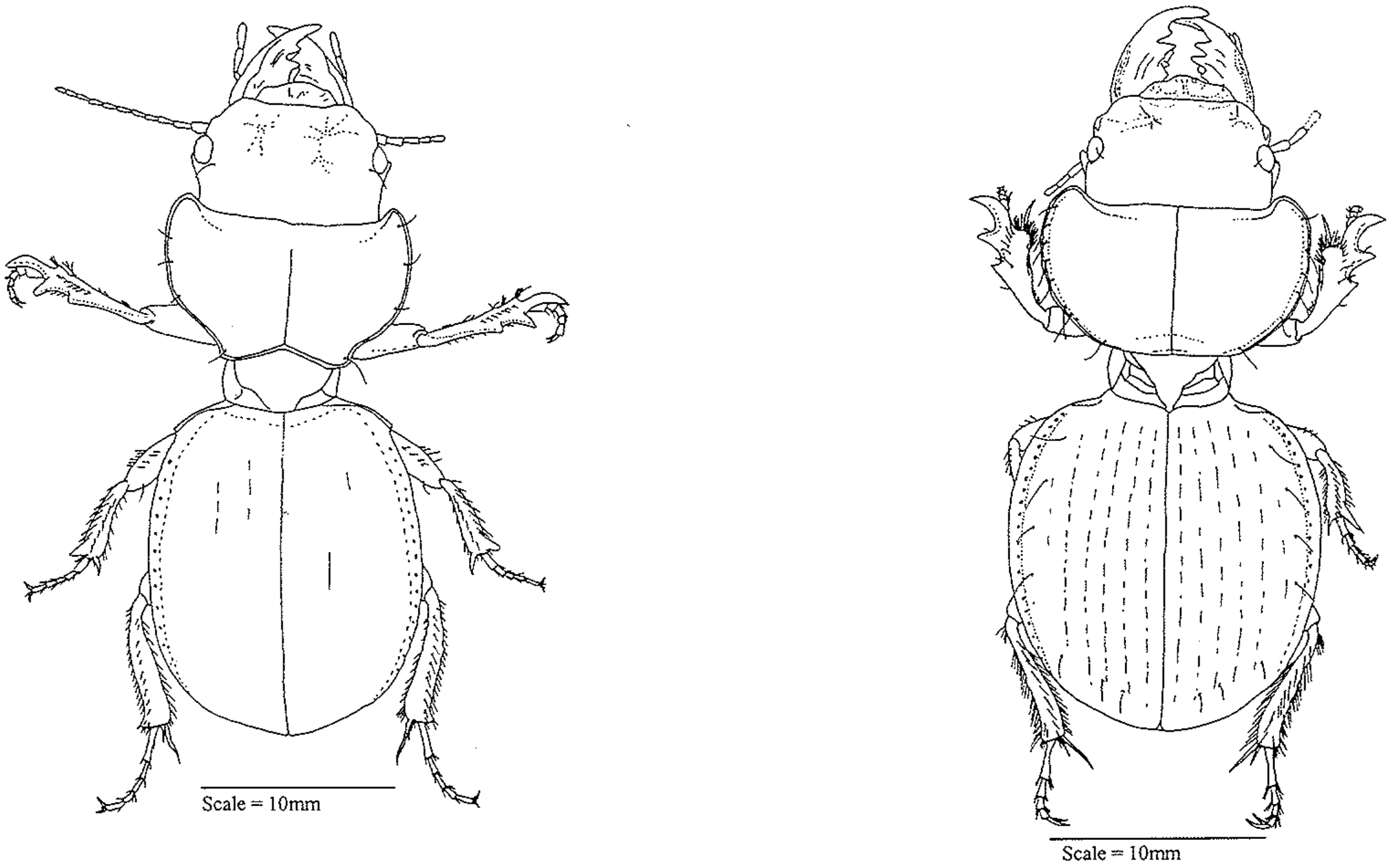


Figure 4–17a

Figure 4–17b

Figure 4-17: Dorsal view of a) *Scaraphites lucidus* (specimen NAG0899) and b) *S. silenus* (specimen NAG0321)

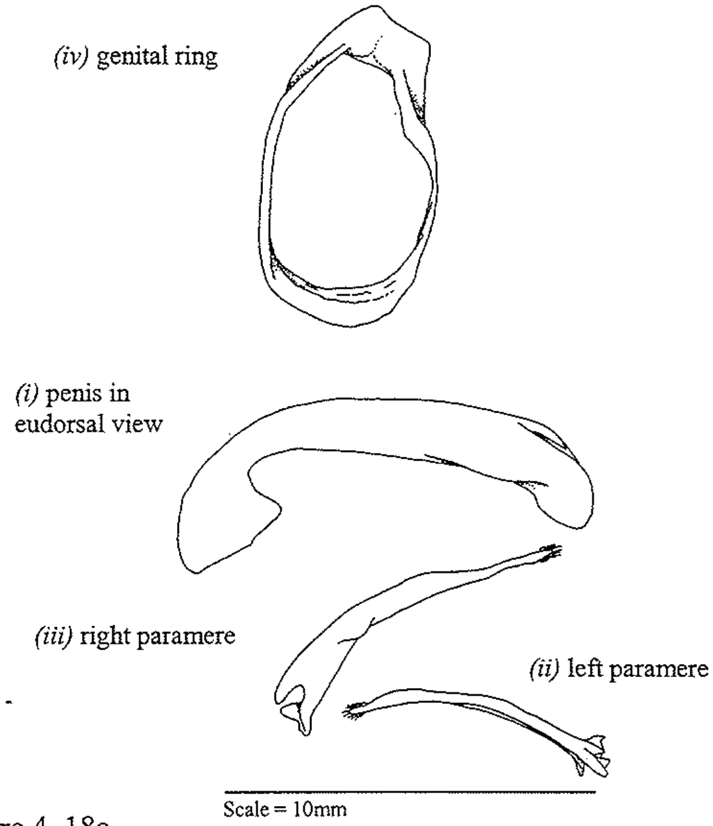


Figure 4–18a

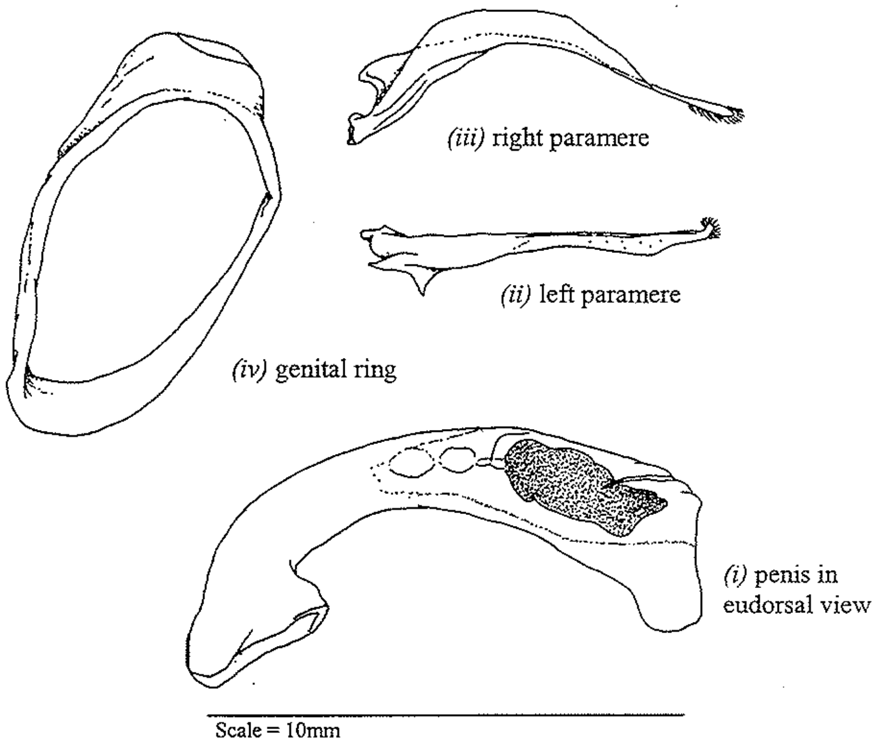


Figure 4–18b

Figure 4-18: Male genitals of a) *S. lucidus* (specimen NAG0450) and b) *S. silenus* (specimen NAG0321).
Note: penis and parameres to scale for a) and all structures to scale for b).

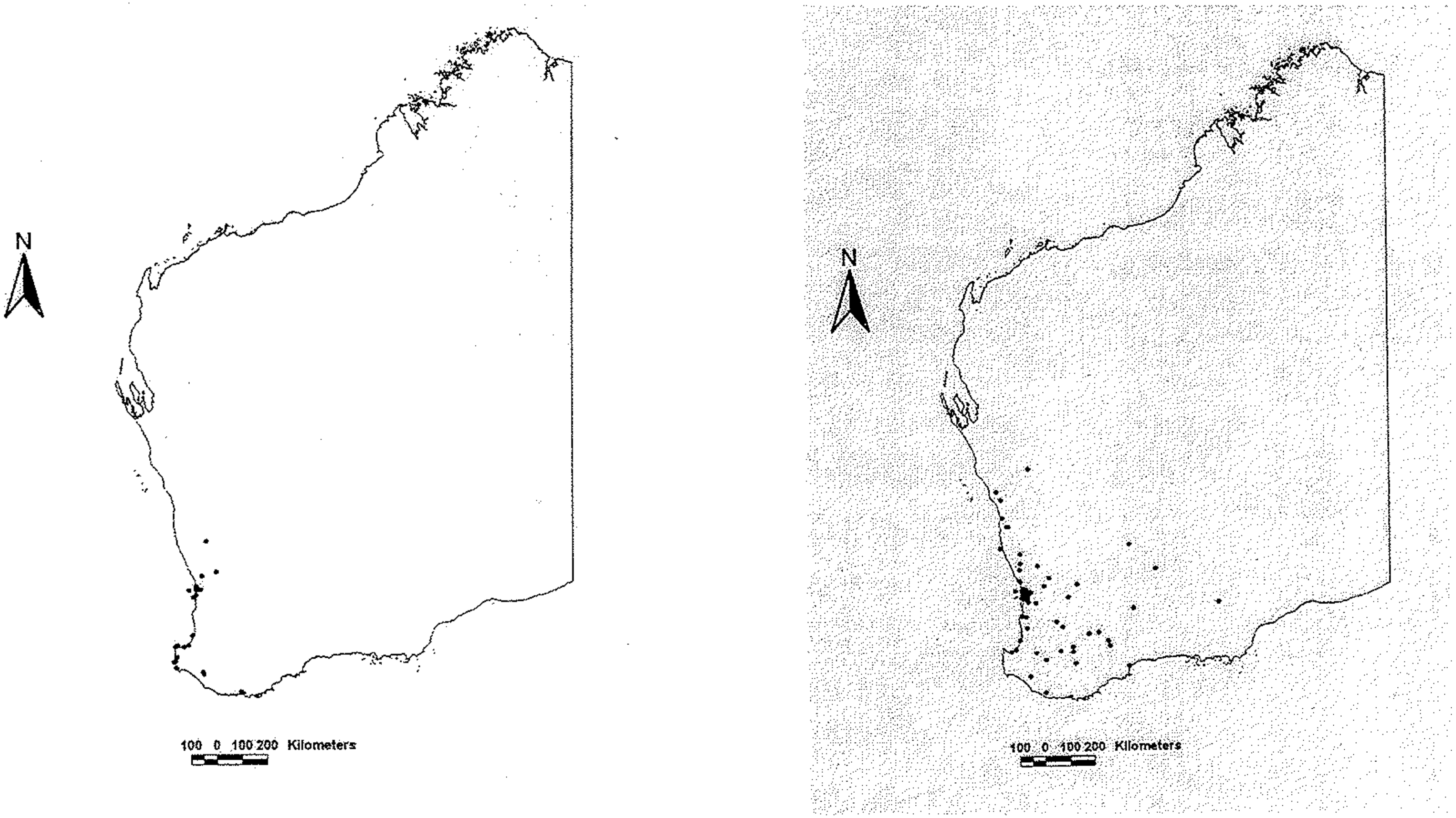


Figure 4-19: Distribution of a) *S. lucidus* and b) *S. silenus* in Western Australia
Based on specimens and records held in the Western Australian Museum, AGRICULTURE WA and the Australian National Insect Collection (ANIC)..

4.7 DISCUSSION

The diversity of carabids in the south west region of Western Australia is in the order of 168 species from 65 genera across 12 subfamilies (Moore *et al.* 1987). Three subfamilies are represented by one genus (Carabinae; *Calosoma*, Odacanthinae; *Gestroania*, Masoreinae; *Sarothrocrepis*) with the most speciose subfamily being the Psydrinae (3 genera, 85 species; Moore *et al.* 1987). The majority of these species are represented by specimens from one or few localities and their true distributions are unknown.

Ten subfamilies and twenty species of carabid are currently known from the Quindalup Dune System. Half of these species are fossorial non-fliers which have been discussed previously in this Chapter. The remaining species are briefly discussed below.

Two agonine species (*Notagonum submetallicum, Notagonum* sp.1) were collected. Seven described species of *Notagonum* occur in Australia (with *N. submetallicum* widespread in southern regions and the only species described from Western Australia) with other *Notagonum* present in Fiji, New Guinea and Indonesia (Moore *et al.* 1987). All species are terrestrial, volant predators in moist environments (Moore *et al.* 1987).

The largest flying carabid represented is *Calosoma schayeri* (Carabinae), one of two species of this genus which are widespread in Australia. *Calosoma* is also present in southern Indonesia and New Caledonia. This taxon is a nocturnal caterpillar predator on both foliage and the ground (Moore *et al.* 1987).

The Harpalinae are represented by two species. Members of *Lecanomerus* are present in New Guinea, New Caledonia and New Zealand. Generally a forest floor litter dweller, *L. verticalis* is the only representative known from the Swan Coastal Plain but there are about twenty five other species present in Australia (Moore *et al.* 1987). The second species, *Euthenaris (?)comes* is the only member of this genus in Western Australia (Moore *et al.* 1987).

Two genera represent the Lebiinae, *Trigonothops* is an arboreal bark hunter on *Eucalyptus* trees, with two species present in south-western Australia (*T. longiplaga* and *T. occidentalis*; Moore *et al.* 1987). The second taxon, *Speotarus lucifugus lucifugus* is a cavernicolous, terrestrial, volant predator with a distribution in the drier areas west of the Murray-Darling Basin. While specimens are known from caves at Nullarbor, Jurien Bay and Ashford (Moore *et al.* 1987) this is the first record of this subspecies on the Swan Coastal Plain and at Yanchep National Park. It probably is associated with the limestone caves which are a feature of the Park.

Scopodes boops represents the second of the two main groups of *Scopodes* (Pentagonicinae) (Moore 1963). Widespread across Australasia, this genus is a diurnal, volant predator similar in habits to the cicindelid tiger beetles. Many undescribed forms occur in the western two thirds of Australia.

The final volant taxon represented is *Sarothrocrepis parvicollis* (Masoreinae). Two other species are present in south-western Australia (*S. benefica, S. inquinata*) but others are known through Australasia, Indonesia and the Philipines (Moore *et al.* 1987). Generally an arboreal bark predator, in Australia it is associated with *Eucalyptus* trees (Moore *et al.* 1987).

Hormacrus latus (Callistinae) is an endemic flightless predator of the southern regions of Western Australia (Sloane 1898). A second species from this genus is from South Australia (Moore *et al.* 1987). Little else is known about either species. The specimen represented in this collection was caught in a live vertebrate pitfall trap (see Appendix H).

Little can be said with certainty about whether these genera represent Archaic, Gondwanan or Oriental elements. The relationships between Australian members of these subfamilies and that of the rest of the world have yet to be delineated. Systematic collecting and reviews of the subfamilies within the context of Australia as well as within the world view using modern cladistic analysis and DNA tests (such as the review of the Broscinae by Roig-Junent 2000) are required to understand their biogeographic relationships.

However, the presence of undescribed species and range extensions for other species indicate that the Quindalup Dune System remnants and surrounding areas may be important refuge sites despite their degraded nature. Further surveying may show that apparently rare or restricted taxa are actually widespread both within the Swan Coastal Plain as well as elsewhere in Australia. Until systematic surveying of areas outside the Swan Coastal Plain are carried out hypotheses about the importance of the Plain in maintaining these species can not be conclusively proven.

CHAPTER 5:

PITFALL TRAPPING RESULTS

5.1 INTRODUCTION

Invertebrate diversity studies within the urban environment have generally concentrated on species of interest to humans (such as mites, lice, fleas, various beetles, Diptera and Hymenoptera, termites, wood borers, roaches and spiders; Frankie *et al.* 1978; Zungoli 1986, 1988; Robinson 1990, 1992, 1994, 1996; Appel 1996; Anon 1998). However, few studies of urban invertebrates have examined the effects of habitat fragmentation on the endemic assemblages.

In Europe, invertebrates have experienced urbanisation and human-induced habitat fragmentation for hundreds of years. Despite this, the effects of habitat fragmentation are still being seen in various assemblages. Davis (1982) found that specialist endemic insects had become extinct while eurytopic and synanthropic insects had increased over a 50 year period in urban London parks. Frit fly (Insecta: Diptera: Chloropidae) species richness was found to be negatively affected by urbanisation and associated habitat alteration in St. Petersberg (Kozlov and Zvereva 1997). Local forest insects were found to be existing in fragmented populations in the greater urban area of that city (Kozlov 1996). Czechowski (1982) found similar results, with local carabid species common outside of the urban area of Warsaw, but occurring in highly fragmented and isolated populations in parks and reserves within. Terterian *et al.* (1994) found similar results for all invertebrates encountered in the city of Yerevan, Armenia, as Zapparoli (1997) did in Rome.

Various terrestrial invertebrate groups have been studied under the influence of disturbance on the Swan Coastal Plain (ants: Rossbach and Majer 1983; Majer and Brown 1983; Burbidge *et al.* 1992; arachnids, myriapods and insects: Harvey *et al.* 1997; How *et al.* 1996). These studies indicate that some specialist groups may already be becoming rare, with other more generalist species possibly expanding their ranges. However, as many of these species are also present elsewhere in surrounding areas, only preliminary conclusions can currently be drawn regarding the effects of fragmentation and other forms of disturbance within the Australian urban environment.

This chapter presents the results of the pitfall trapping survey of the terrestrial carabid beetle assemblages present in the bushland remnants of the Swan Coastal Plain in the Perth Metropolitan Area. In addition, a series of questions was asked: does the fauna vary between years, with season, between fragments, and finally, does death pitfall trapping comprehensively sample the carabid diversity? The results of the trapping program are presented, followed by a discussion and conclusions drawn from these data.

5.2 ANALYSIS

The analysis of wet pitfall trapping data collected between 1993-1997 on the Swan Coastal Plain is presented in this chapter in two main sections. The first section deals with the entire Swan Coastal Plain carabid assemblage collected during this period. Each Dune System's carabid assemblage is briefly described in terms of overall numbers of individuals, as well as numbers of subfamilies, genera and species.

Carabid wet pitfall samples were collected from 39 discrete sites in 14 remnants situated across four geological systems or landforms on the Swan Coastal Plain (Quindalup, Spearwood and Bassendean Dune Systems, and the Ridge Hill Shelf) between 1993-1997. Each site was sampled for a total of 12 months in three groups (1993-1994; 1994-1995; 1995-1996), except for two sites each in Bold Park and Trigg Dune Reserve (BP1, BP5, TD2 and TD4), which were sampled for a second 12 month period (1996-1997). This second sampling period is treated in all analyses as four separate sites, thereby bringing the number of sites for analysis to 42 in 14 remnants. Because the sampling was staggered across several years direct comparisons of the individual sampling periods is not possible (see Table 3.1 for sampling periods), therefore assessment of the carabid assemblages across all 42 sites is restricted to overall or total values at the end of the 12 month period.

Data analysis was carried out by examining the entire carabid assemblage, and then breaking it into the component volant and non-volant assemblages for all manipulations.

Species richness and remnant area relationships were therefore determined for the total carabid assemblage as well as the volant and non-volant components individually. Similarity classifications of the sites were likewise generated for the total and component assemblages using presence/absence data.

To determine the influence of certain environmental parameters on the presence and abundance of the carabid assemblage across the remnants examined, the standard multiple regression routines in the *Statistica*™ (1995) software package were employed. Synthetic climatic parameters for temperature and precipitation were generated in the *Bioclim* climatic data program for the 39 sites. A correlation matrix was derived for the sixteen synthetic parameters and is provided in Appendix A5. To produce a statistically robust regression the following protocol was used to eliminate variables or parameters to elevate the case (site): predictor (variable or parameter) ratio to ≥ 5. Initially, the parameters with a correlation of $R^2 = <0.11$ with individual dependant variables (i.e. Total, Volant or Non-volant species richness, abundances of *Scaraphites lucidus, S. silenus, Gnathoxys crassipes, G. granularis, Promecoderus scauroides, Notonomus mediosulcatus, Sarticus iriditinctus, Simodontus australis, Notagonum* sp. 1, and *Lecanomerus verticalis*) were excluded. Secondly, independent parameters that were very strongly correlated, $R^2 = >0.9$, with each other were also excluded.

The second section is concerned with the carabid fauna of the Quindalup Dune sites. A detailed description of the fauna caught, subfamilies represented and the overall abundances is presented. Once again, the data are examined in terms of the total and component volant and non-volant assemblages.

Comparisons between the species richness and evenness values for the total and component assemblages are presented. Abundances across all Quindalup Dune System sites and sample periods are summarised for relevant species by use of three-dimensional graphs. Dendrograms for the non-volant assemblage are presented, indicating similarity of the sites by presence/absence data, percent transformed abundances, and untransformed abundance data for the individual sample periods.

The effects of environmental factors on the activity periods of the carabid assemblage present in the Quindalup Dune System remnants surveyed were determined using the standard multiple regressions in the *Statistica*™ (1995) software package. A correlation matrix was derived for the twenty five environmental parameters scored for each sampling period and is presented in Appendix A6. As previously, to produce robust regressions a protocol was used to eliminate variables or parameters to elevate the case (sample period-site or date code): predictor ratio to ≥5. Parameters with a correlation of $R^2 = <0.2$ with individual dependent variables (i.e. non-volant species richness and abundances of *Carenum scaritoides, Scaraphites lucidus, Scaraphites silenus, Simodontus australis, Gnathoxys crassipes, Gnathoxys granularis, Sarticus iriditinctus, Lecanomerus verticalis, Notagonum* sp. 1 and *Promecoderus scauroides*) were eliminated. Data used for the variables "Fire Age" and "Fragment Age" were found to be unreliable, so on this basis these two variables were eliminated from the analysis. Finally, independent variables that were very strongly correlated, $R^2 = >0.9$, with each other were also excluded.

5.3 RESULTS

5.3.1 SWAN COASTAL DUNE SYSTEM CARABIDS: COMPOSITION AND RICHNESS

A total of 3049 specimens of 37 species from 26 genera representing 11 subfamilies were collected. Of these taxa, 13 species are classified as flightless or non-volant (see Moore *et al.* 1987).

The carabid assemblages (and abundances) of the remnants surveyed (irrespective of between site variation) using wet pitfalls are presented in Table 5.1. Carabid abundances for each site and individual sampling periods are presented in Appendix B. The carabid assemblage was found to decrease in species richness towards the centre of the Swan Coastal Plain, with the most speciose areas being Quindalup and Bassendean Dunes, and the Ridge Hill Shelf (highest value of 12 species in the Quindalup, 17 species in the Bassendean remnants and 15 species on the Ridge Hill Shelf). If treated as a well sampled discrete unit, the junction between the Spearwood and Bassendean Dune Systems had the poorest carabid assemblage of all regions, with only three species.

Seventeen species were found on one geological system exclusively; of these *Gnathoxys pannuceus, Carenum scaritoides, Carenum* sp. 1 and *Neocarenum* sp. 1 are flightless species (Table 5.1). The restricted species' distributions across the geological formations is biased towards both the Quindalup and the Bassendean Dune Systems (5 and 8 restricted species respectively). *Gnathoxys pannuceus, Notagonum submetallicum, Calosoma schayeri, Euthenaris* sp. 1 and *Teropha* sp. were restricted to the Quindalup Dune System. *Carenum* sp. 1 and, *Cenogmus* sp. 1 were restricted to Cottesloe Sands, with Genus 1 sp. D and *Notospheophonus* sp. restricted to Karrakatta Sands, of the Spearwood Dune System. *Neocarenum* sp. 1, *Notagonum* sp. 2, *Chlaenius greyanus, Egodroma* sp. 1, *Euthenaris* sp. 2, *Phorticosomerus* sp. 1, *Catadromus lacordarei* and *Platycoelus* sp. 1 were only found on the Bassendean Dune System. Only Genus 1 sp. A was restricted to the Ridge Hill Shelf (Table 5.1).

Most of the volant species showed disjunct distributions across the remnants, often being present on the Quindalup and Bassendean Dunes as well as the Ridge Hill Shelf, but absent from Spearwood Dune remnants. In contrast, non-volant species were more consistent, often found in several remnants within a landform. For example, *Gnathoxys crassipes* was consistently found in all Quindalup and Bassendean Dune remnants and three out of five Spearwood Dune remnants (Table 5.1). *Scaraphites lucidus* was only collected from remnants associated with Quindalup Soils (this includes BP3 and BP4, while being situated on Cottesloe Sands of the Spearwood Dune System, they are within the unfragmented interior of Bold Park).

Promecoderus scauroides, Simodontus australis, Sarticus iriditinctus, Lecanomerus verticalis and *Notagonum* sp. 1 were present on all geological formations. Of these, *Simodontus australis* and *Lecanomerus verticalis* were the only species present at Landsdale Farm School and Marangaroo Conservation Reserve which are situated on the geological boundary of the Spearwood and Bassendean Dune Systems. *Gnathoxys crassipes* was absent from these junction sites and at the Ridge Hill Shelf sites. *Scaraphites silenus* was also absent from the Ridge Hill Shelf remnants in addition to Spearwood Dune Karrakatta Sand sites. (Table 5.1).

Overall carabid abundances were greatest in Quindalup Dune remnants, with 856 specimens recorded from Woodman Point alone. The lowest total abundance was at the Marangaroo Conservation Reserve, with four specimens (Table 5.1). Bold Park and Trigg Dune Reserve sites had lower combined abundances (over both 1993/1995 and 1996 surveys) than Woodman Point (Table 5.1). The average number of individuals per species within each remnant ranged between 1.3 – 71.5 (Marangaroo Conservation and Woodman Point Reserves respectively), average across the Plain being 18.71 individuals/species/remnant (n = 42, stdev = 20.14). Between year differences within the Quindalup Bold Park sites (BP1 & BP5 1993/1994 vs BP1 & BP5 1996/1997) were not significant ($t_{0.05}$ = 0.16, d.f.= 36). Likewise, between year differences within Trigg Dune Reserve (TD2 & TD4 1995/1996 vs TD2 & TD4 1996/1997) were also not significant ($t_{0.05}$ = 0.16, d.f.= 36) (Table 5.1).

Relationships were found between the carabid fauna and the size of the remnant areas. The r values of the regressions between the total number of carabid species ($r = 0.3782$, $p < 0.05$; Figure 5.1), and the number of volant species ($r = 0.3776$, $p < 0.05$; Figure 5.2) and the log of remnant area were statistically significant. However, these r values are very low and indicate that only about 14 % of the variation in total and volant species richness is accounted for by remnant area. The non-volant species richness and log of remnant area correlation was not significant ($r = 0.1912$, $p > 0.05$; Fig 5.3). In this case, the variable remnant area accounted for less than 4 % of the variation in the non-volant species richness.

Table 5-1: Species Richness, abundances and numbers of individuals per species per remnant for all Swan Coastal Plain remnants, with between year differences for Bold Park (1993/1996) and Trigg Dune Reserve (1995/1996).

Note HH - Hepburn Heights, LS - Landsdale Farm School, MR - Marangaroo Conservation Reserve, WR - Warwick Road Reserve, TR - Talbot Road Reserve, TD - Trigg Dune Reserve, TH - Tuart Hill Reserve, BP - Bold Park, MC - Mount Claremont Reserve, PA - Perth Airport, JA - Jandakot Airport, WP - Woodman Point Reserve. YP - Yanchep National Park; individs/spec/remnant = abundance/species richness per remnant.

			QDS					SDS-C		SDS-K			SDS/BASS		BASS		RHS
habit	**subfamily**	**taxon**	**BP QUIN**	**MC**	**TD**	**WP**	**YP**	**BP SPEAR**	**HH**	**MH**	**TH**	**WR**	**LS1**	**MR**	**JK**	**PA**	**TR**
NON	Broscinae	*Gnathoxys crassipes*	12	5	16	15	7	0	5	0	7	3	0	0	1	23	0
NON	Broscinae	*Gnathoxys granularis*	0	0	0	0	4	0	0	0	0	0	0	0	0	0	5
NON	Broscinae	*Gnathoxys pannuceus*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
NON	Broscinae	*Promecoderus scauroides*	67	41	200	119	28	13	8	4	0	3	0	0	0	30	15
NON	Pterostichinae	*Notonomus mediosulcatus*	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
NON	Pterostichinae	*Sarticus iriditinctus*	1	0	0	0	1	1	0	0	1	0	0	0	2	1	6
NON	Pterostichinae	*Sarticus sp. 1*	0	0	0	0	0	0	0	0	14	0	0	0	0	0	19
NON	Pterostichinae	*Simodontus australis*	372	28	78	641	2	12	8	0	2	2	0	2	2	0	15
NON	Scaritinae	*Carenum scaritoides*	0	28	7	1	3	0	0	0	0	0	0	0	0	0	0
NON	Scaritinae	*Carenum sp. 1*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
NON	Scaritinae	*Neocarenum sp. 1*	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
NON	Scaritinae	*Scaraphites lucidus*	253	59	91	38	0	80	0	0	0	0	0	0	0	0	0
NON	Scaritinae	*Scaraphites silenus*	3	0	14	0	4	0	3	0	0	0	5	1	2	59	0
volant	Agoninae	*Genus 1 sp. a*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
volant	Agoninae	*Genus 1 sp. b*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
volant	Agoninae	*Genus 1 sp. c*	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
volant	Agoninae	*Genus 1 sp. d*	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0
volant	Agoninae	*Notagonum sp. 1*	6	0	22	25	1	0	0	2	0	0	0	0	0	19	521
volant	Agoninae	*Notagonum sp. 2*	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
volant	Agoninae	*Notagonum submetallicum*	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
volant	Carabinae	*Calosoma schayeri*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
volant	Chlaeninae	*Chlaenius greyanus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
volant	Harpalinae	*Cenogmus sp. 1*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
volant	Harpalinae	*Egadroma sp. 1*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
volant	Harpalinae	*Euthenaris sp. 1*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
volant	Harpalinae	*Euthenaris sp. 2*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
volant	Harpalinae	*Lecanomerus verticalis*	18	1	0	0	3	28	1	12	2	0	0	1	66	20	16
volant	Harpalinae	*Notospeophonus sp. 1*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
volant	Harpalinae	*Phorticosomerus sp. 1*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
volant	Lebiinae	*Microlestes sp. 1*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
volant	Lebiinae	*Speotarus lucifugus*	1	0	1	2	0	1	0	0	0	0	0	0	0	2	4
volant	Lebiinae	*Trigonothops sp. 1*	0	1	0	4	1	0	0	0	0	0	0	0	0	0	0
volant	Pentagonicinae	*Scopodes boops*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
volant	Pterostichinae	*Catadromus lacordarei*	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
volant	Pterostichinae	*Platycoelus sp. 1*	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
volant	Pterostichinae	*Teropha sp.*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
volant	Trigonoderinae	*Sarothrocrepis sp. 1*	0	0	1	2	0	0	0	0	0	0	0	0	0	0	2
		ABUNDANCE	735	163	430	856	56	135	27	41	27	8	5	4	74	175	616
		SPECIES RICHNESS	11	7	9	12	12	6	7	6	6	3	1	3	6	17	14
		INDIVIDS/SPEC/REMNANT	66.82	23.29	47.78	71.33	4.67	22.5	3.86	6.83	4.5	2.67	5	1.33	12.33	10.29	44

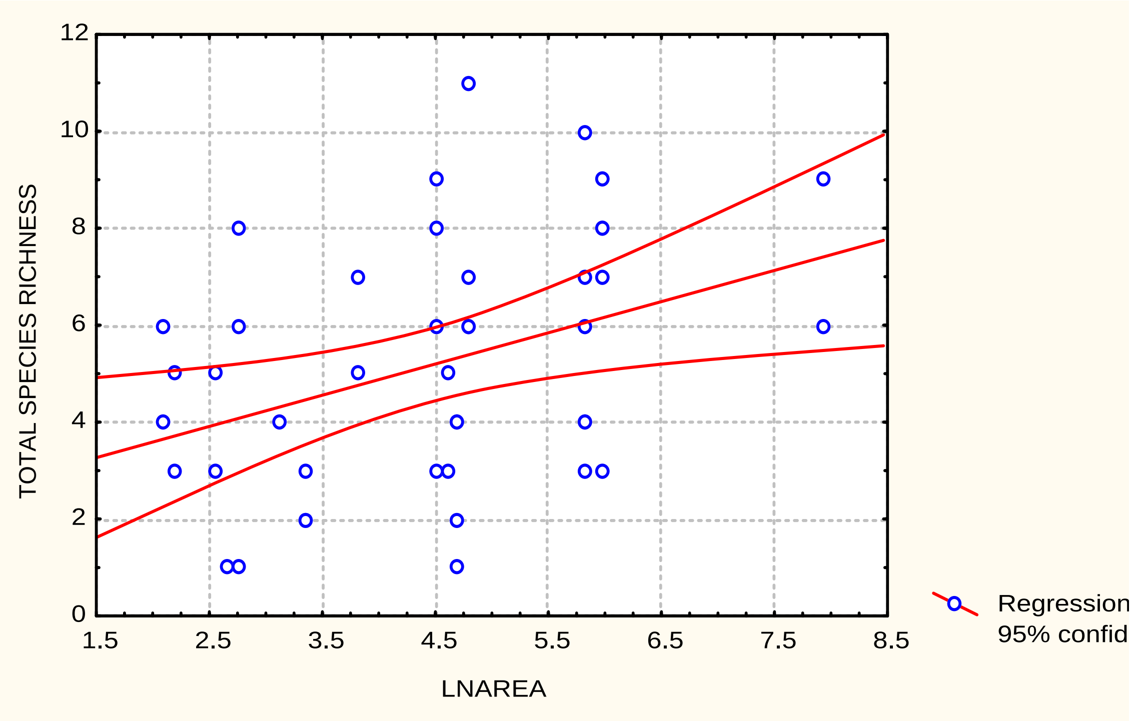


Figure 5-1: **Relationship between total species richness and area of remnant. Correlation r= 0.3782.**

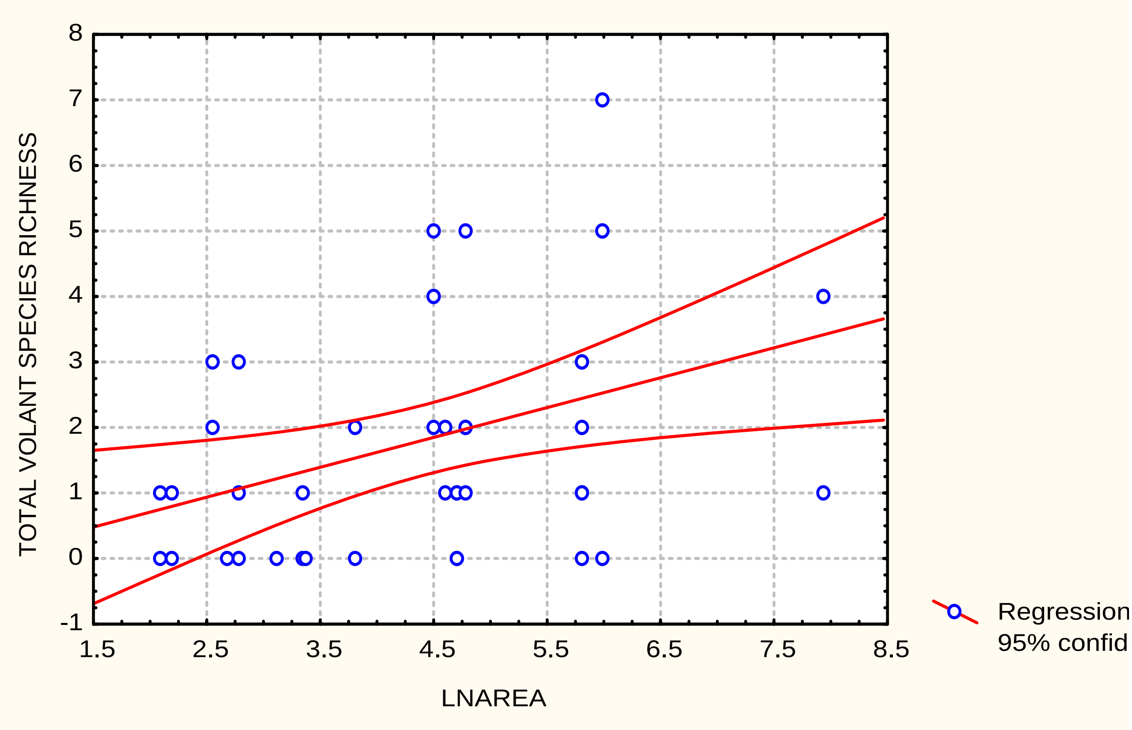


Figure 5-2: **Relationship between volant species richness and area of remnant. Correlation r= 0.3776.**

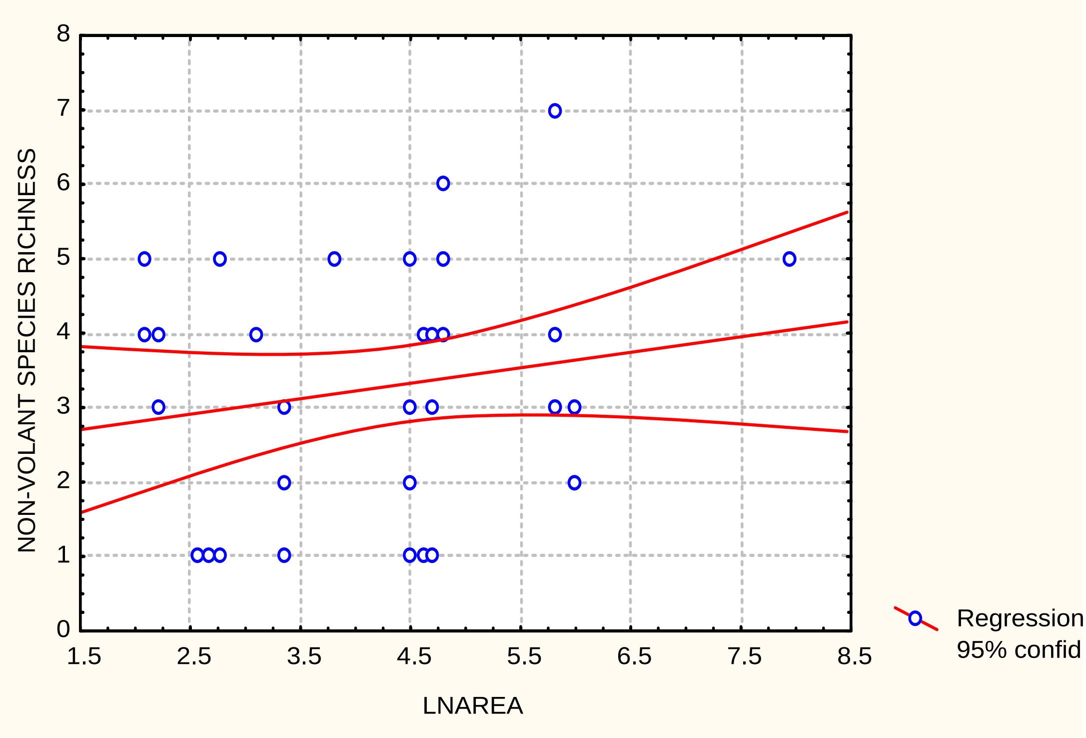


Figure 5-3: Relationship between non-volant species richness and area of remnant. Correlation r= 0.191.

The species richness values for the individual sites are presented in Appendix G, and a summary table of these data is presented in Table 5.2. The range of species richness across all sites was 1 – 11 (mean = 5.1). The non-volant species richness across all sites varied between 1 – 7 (mean = 3.3), whereas volant species richness varied between 0 – 7 species (mean =1.8). It is important to note that no volant individuals were collected from 12 of the 42 sites.

There was an insignificant increase in the total species richness values on the Quindalup Dune sites between the 1993/1995 and 1996/1997 surveys (the mean increased from 5.9 to 7.3 species; Mann-Whitney U-test $_{\text{critical (n1 =11; n2 =6)}}$= 13; p> 0.05; Table 5.2). Of the four sites surveyed twice, only TD4 dropped in species richness (and this was the only site directly affected by fire during the survey). The non-volant species richness at BP1 increased by 4 species and at the other 3 sites by 1 species. Only BP1 had an increase in volant species richness (three species). The total, volant and non-volant species richness varied significantly between the four geological systems of the Swan Coastal Plain (total species richness: Kruskal-Wallis H (6, n=42) =20.866, p= 0.0019; volant: H (6, n=42) = 22.145, p=0.0011; non-volant: H (6, n=42) = 12.469, p= 0.0523; Table 5.2).

Table 5-2: Average species richness values for the total, non-volant and volant carabid assemblages collected at 42 sites across four geological systems on the Swan Coastal Plain between 1993-1997.
Averages, ranges and standard deviations are calculated for each of the four geological systems [mean ± SD (n)] where n= number of sites surveyed within a geological system. Note: QDS- Quindalup Dune System (93-96 and 96-97 treated as separate groups); SDS-C – Cottesloe Sands; SDS-K- Karrakatta Sands (Spearwood Dune System); K/BDS- junction of the Spearwood and Bassendean Dune Systems; BDS- Bassendean Dune System; RHS- Ridge Hill Shelf.

SITES	QDS (93/96)	QDS (96/97)	SDS-C	SDS-K	K-BDS	BDS	RHS
TOTAL AVERAGE	5.9 ± 2.3 (11) 3 – 11	7.3 ± 1.8 (6) 6 – 10	3.5 ± 1.8 (6) 1 – 6	3.3 ± 1.5 (6) 1 – 5	1.7 ± 0.6 (3) 1 – 2	5.8 ± 2.6 (6) 3 – 9	6.5 ± 2.6 (4) 3 – 9
VOLANT AVERAGE	1.5 ±1.6 (11) 0 – 5	2.2 ± 1.3 (6) 1 – 4	0.8 ± 0.8 (6) 0 – 2	1 ± 1.3 (6) 0 – 3	0.3 ± 0.6 (3) 0 – 1	0.3 ± 2.7 (6) 0 – 7	3.8 ± 1.3 (4) 2 – 5
NON-VOLANT AVERAGE	4.5 ± 0.9 (11) 3 – 6	5.2 ± 1 (6) 4 – 7	2.7 ± 1.4 (6) 1 – 4	2.2 ± 1.3 (6) 1 – 4	1.3 ± 0.6 (3) 1 – 2	2.5 ± 1 (6) 1 – 4	2.8 ± 1.73 (4) 1 – 5

5.3.2 *SWAN COASTAL PLAIN CARABIDS: SIMILARITY OF ASSEMBLAGES*

The data used to construct the presence/absence similarity dendrograms presented in Figures 5.4, 5.5 and 5.6 are presented in Appendix B. A similarity dendrogram based on the presence/absence of all carabid species is presented in Figure 5.4. Figures 5.5 and 5.6 are presence/absence similarity dendrograms, based on the volant and non-volant carabid assemblages respectively.

The 55% level of similarity was used as at this level the site groupings showed the most information. Higher or lower similarity levels were either too generalised or no real relationships were revealed (ie sites were showing little interpretable relationship between each other). The clusters defined were of sites with similar species assemblages. In general these clusters represent both vegetation variation and geological differences between and within remnants. It is because of this reason that Clusters formed of single sites were given as much attention as those with several sites. This is discussed at length in the Discussion Section of the Chapter. It is, however, acknowledged that the small data set presents problems with analysis and defining the amount of real biological meaning in the outcomes.

At the 55% similarity level 21 separate clusters are apparent (Figure 5.4). The site most different in its overall carabid assemblage was PA6 with 9 carabid species. Thirteen other clusters form singular linkages at this level (WP2, TR4, TR1, YP2, PA7, MH2, BP1 (1996), YP1, TH2, JK2, MH1, HH3 and BP5 (1996), representing all four geological systems.

The 8th linkage consists of sites PA5 and TR3 (situated between singular linkages MH2 and BP1 (1996)). Likewise, sites WR1 and TH1 form the 12th linkage between singular linkages TH2 and JK2.

Sites TR2, HH1 and PA8 form the 15th linkage. The Bassendean Dune soil associated sites JK1, LS1, MR1 and HH2 (Karrakatta Sands- Spearwood Dune System) form the 17th linkage.

The 18th linkage is formed entirely by Quindalup sites. MC1, MC2, TD2 (1996) and TD4 (1996) form one section of this linkage and the other consists of sites WP1, WP3, WP4 and TD4 (1995). Bold Park sites BP3, BP4 and BP5 (1993) plus TD1 form the 20th linkage. Finally, the 21st linkage consists of the Quindalup sites BP1 (1993), TD2 (1995) and Spearwood sites HH2 and WR2, plus Spearwood/Bassendean junction site MR2.

Overall, Quindalup Dune System sites (and associated sites BP3 and BP4) cluster together at the 55% similarity level. However, the sites surveyed a second time (BP1 1996, BP5 1996, TD2 1996 and TD4 1996) do not show a closer similarity to the previous surveys (BP1 1993, BP5 1993, TD2 1995 and TD4 1995) than to the other Quindalup Dune System sites. Bassendean Dune System associated sites (JK1, LS1 and MR1) cluster together at the 58% similarity level, in addition, Karrakatta Soil sites TH1, WR1 and TH2 (along with JK2) cluster together at the 65% similarity level. Generally though, within remnant or within landform associations are very weak.

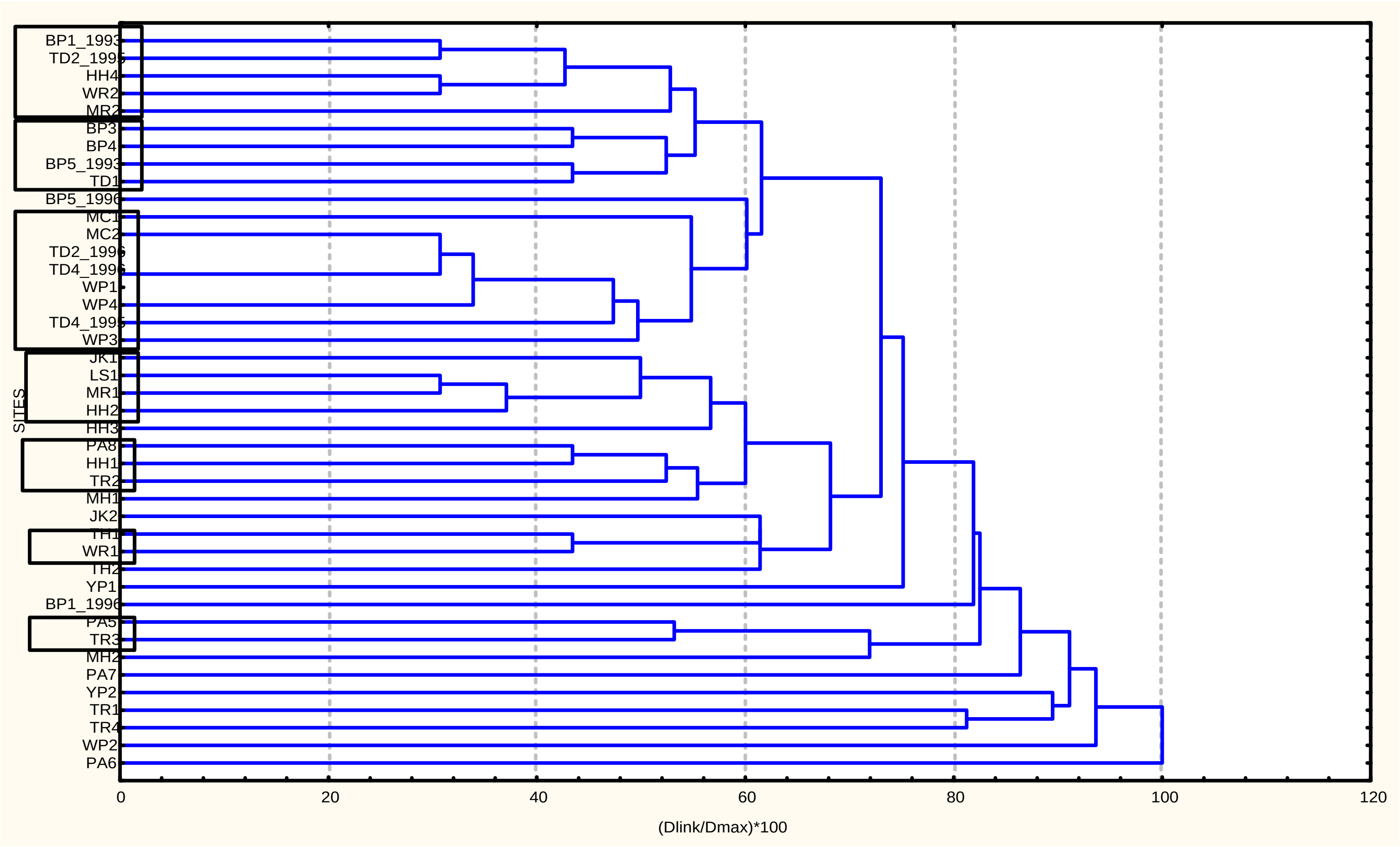


Figure 5-4: Dendrogram of site similarity based on all carabid species collected between 1993-1997. Euclidean distances and UPGMA clustering used. Results are based on presence/absence data for all sites sampled. Shorter branches indicate a higher similarity between sites. (Dlink/Dmax)*100 represents the % of the range from the maximum to the minimum distance in the data (Statistica manual vol III, 1995, pp. 3179).

The similarity dendrogram based on presence/absence data for the volant carabid assemblage is presented in Figure 5.5. Ten linkages are apparent at the 55% similarity level, with the most different volant carabid assemblage occurring at site PA6. Sites PA7, TR1 and TR4 form three further single linkages (with five, four and five species respectively).

Quindalup sites TD4 (1995) and WP2 form the 5th linkage, while the 6th linkage consists of sites representing all four landforms of the Swan Coastal Plain (BP1 (1993), BP3, PA5, TR3- Quindalup, Spearwood, Bassendean Dune Systems and Ridge Hill Shelf respectively). The 7th linkage is formed by Quindalup sites MC1 and YP2. Sites MH2 and BP5 (1996) form the 8th linkage and sites JK1 and MH1 form the 9th linkage.

The final and 10th linkage comprises the remaining sites. However, this linkage forms several separate groups. The first or upper group (sites BP1 (1993), MC2, TD1, TD2 (1995), PA8, LS1, MR1, HH1, HH3, TH1, WR1 and WR2) is a default group entirely based on the lack of any volant specimen being collected at these sites.

Sites BP4, JK2, MR2, HH4 and TH2 form a distinct group below the 55% similarity level based on the singular presence of *Lecanomerus verticalis* only. The group containing sites HH2, BP5 (1993), TD2 (1996), TD4 (1996), WP1 and YP1, is based on the presence of one species only (which is not *L. verticalis*). The presence of *Notagonum* sp. 1 and one other species defines the final subgroup containing sites WP3, WP4 and TR2.

The majority of volant species were found to be present at one site; four species were present at two sites; two species at three sites and one species at six sites. Both *L. verticalis* and *Notagonum* sp. 1 were present at 19 sites (both species were present at the majority of sites). Almost all volant species were collected in extremely low numbers, only *L. verticalis* and *Notagonum* sp. 1 were collected in large numbers.

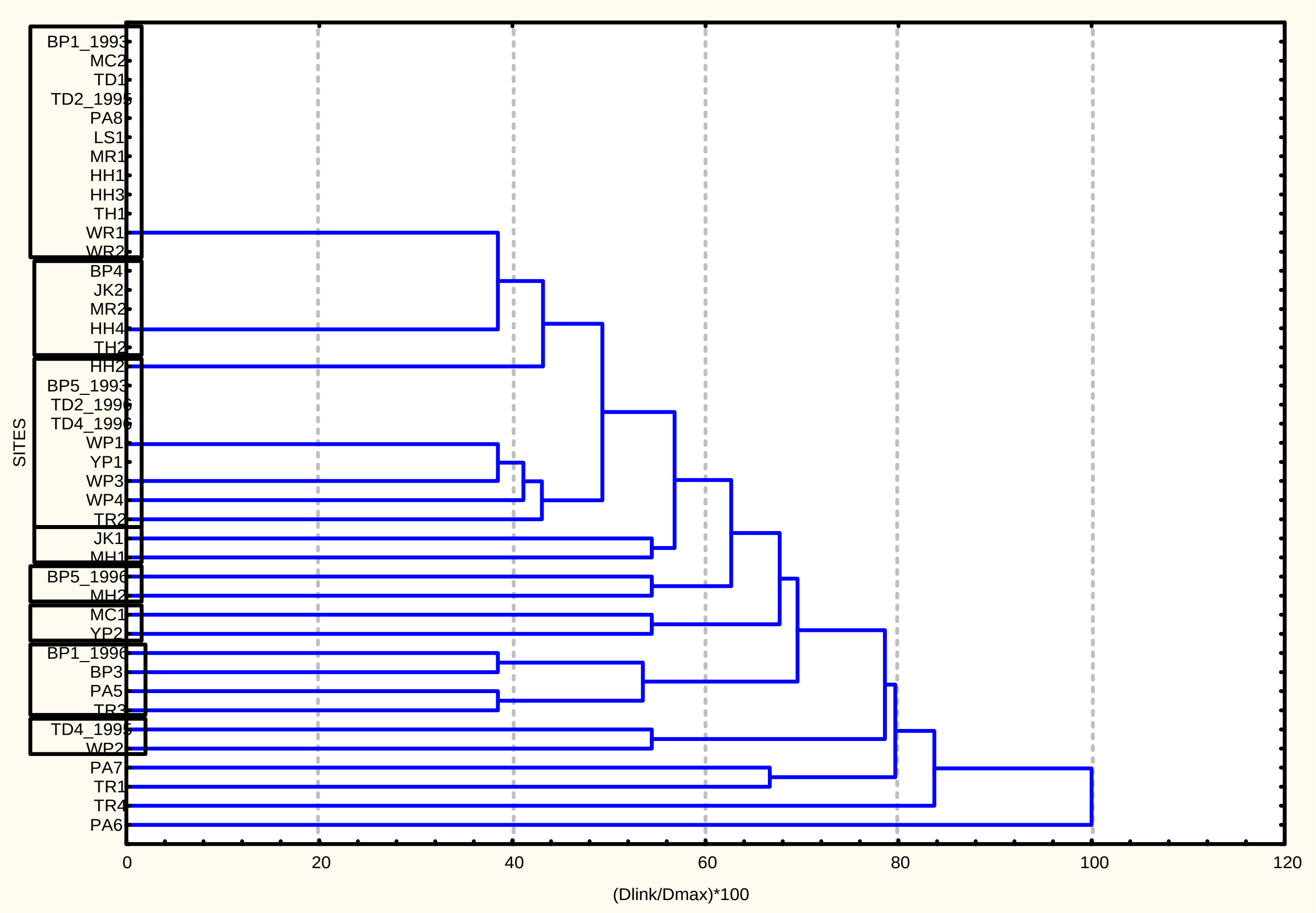


Figure 5-5: Dendrogram of site similarity based on volant species carabid species collected between 1993-1997
Euclidean distances and UPGMA clustering used. Results are based on presence/absence data for all sites sampled. Shorter branches indicate a higher similarity between sites. (Dlink/Dmax)*100 represents the % of the range from the maximum to the minimum distance in the data (Statistica manual vol III, 1995, pp. 3179).

For the non-volant carabid assemblage (Figure 5.6), at the 55% similarity level 18 clusters are apparent. Sites YP1, TR1, YP2, TH2, WR1, TH1 HH3, PA8, PA7, JK2 and BP1 (1996) form individual linkages. Quindalup site YP1 has the most different non-volant carabid assemblage, followed closely by YP2 and TR1, each with 5 species. The 8th linkage consisted of Ridge Hill Shelf sites TR3 and TR4, whereas the 9th linkage comprised of Karrakatta Cottesloe Sands sites MH1 and MH2, and HH1 respectively, along with TR2 and Bassendean Dune site PA6.

Spearwood and Bassendean junction sites MR1 and MR2 form the 12th linkage (next to singular linkage PA7), while the 13th linkage comprises Bassendean sites JK1 and PA5, junction site LS1 and Cottesloe Sand site HH2.

The 16th linkage is formed of Quindalup and associated sites BP5 (1993), TD1, BP3 and BP4 respectively. Quindalup sites also form the 17th linkage. This cluster separates into two components, WP2 and WP3 (with six and four species respectively), and the remaining sites with identical species assemblages of five species each. TD4 (1995) and TD4 (1996) also fall into this group.

The remaining Quindalup sites, TD2 (1995), BP5 (1996) and BP1 (1993) cluster with HH4 and WR2 (Cottesloe and Karrakatta Sands respectively) to form the 18th linkage.

Close associations between sites were primarily exhibited within remnants, and looser associations within landforms at similarity levels above 55%. The tightest associations were observed for the Quindalup sites. These formed three main groups, the first two comprised of sites from Bold Park and Trigg Dune Reserve; and the final group consisted of the other sites with highly similar carabid assemblages.

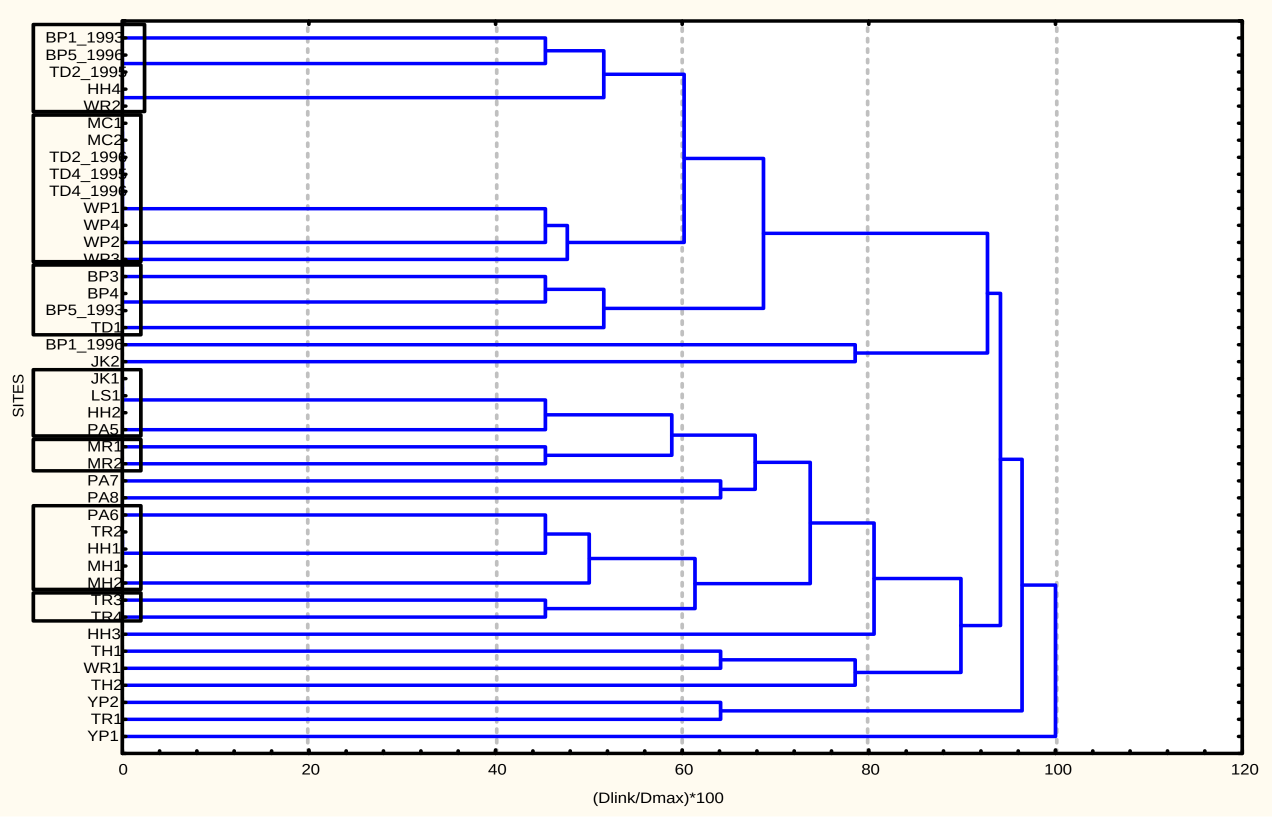


Figure 5-6: Dendrogram of site similarity based on non-volant carabid species collected between 1993-1997

Euclidean distances and UPGMA clustering used. Results are based on presence/absence data for all sites sampled. Shorter branches indicate a higher similarity between sites. (Dlink/Dmax)*100 represents the % of the range from the maximum to the minimum distance in the data (Statistica manual vol III, 1995, pp. 3179).

5.3.3 SWAN COASTAL PLAIN BIOGEOGRAPHIC PARAMETERS.

Maritime climatic conditions influence the annual average temperature and rainfall of the Swan Coastal Plain. Relatively cool temperatures occur in a south west to north east direction, while a warmer gradient runs from the south east to the north western regions of the Plain (Figure 5.7). Precipitation on the Plain is more varied, with more precipitation occurring along the eastern margins of the Plain (Figure 5.8). Combined, the temperature and precipitation gradients reflect the increasingly arid environment of the northern Swan Coastal Plain.

To obtain a statistically robust regression (case (site): variable (environmental parameter) ratio ≥ 5 for all dependant variables) nine parameters (environmental parameters with a correlation of $R^2 = 0.11$ with individual dependant variables or were highly correlated with each other, $R^2 = 0.9$) were eliminated. The correlation matrix is presented in Appendix A5.

Taken as a whole, the synthetic parameters explained differing amounts of the variance in the total, volant, and non-volant carabid species richness and abundances of various species. These parameters as a group did not significantly explain the amount of variance in the abundance of *Gnathoxys crassipes, G. granularis, Notonomus mediosulcatus, Sarticus iriditinctus, Scaraphites silenus* or *Notagonum* sp.1 (Table 5.3).

In contrast, as a group these parameters significantly explain 13.76 % of the variance in the Total ($R^2 = 0.371$), 26.32 % of the variance in the Non-volant ($R^2 = 0.513$) and 20.16 % of the variance in the Volant carabid species richness ($R^2 = 0.449$; Table 5.3). The amount of variance in the abundance of *Simodontus australis* explained by the parameters as a group was 28.41 % ($R^2 = 0.533$), 8.53 % of the variance in the abundance of *Promecoderus scauroides* ($R^2 = 0.292$; Table 5.3). For abundances of *Scaraphites lucidus* ($R^2 = 0.645$) and *Lecanomerus verticalis* ($R^2 = 0.403$) this group of synthetic parameters explain 41.60 % and 16.24 % of the variance (Table 5.3).

Individual parameters did not explain significant amounts of unique variance in the Total, Volant or Non-volant carabid species richness, abundances of *Gnathoxys* *crassipes, Scaraphites silenus, Notonomus mediosulcatus, Sarticus iriditinctus,* or *Notagonum* sp. 1 (Table 5.3).

The unique variance in abundance of *Gnathoxys granularis* was explained by a single parameter (precipitation of the driest month – RDRYM; Table 5.3). The parameter, precipitation of the driest quarter (RDRYQ), singularly explained the unique variance in abundances of *Promecoderus scauroides* and *Simodontus australis* (Table 5.3)

Two synthetic parameters, temperature of the wettest quarter (TWETQ) and precipitation of the coolest quarter (RCLQ) explained significant amounts of unique variance in the abundance of *Lecanomerus verticalis* (Table 5.3).

Unique variances in *Scaraphites lucidus* abundances were also explained by three synthetic parameters, temperature of the wettest quarter (TWETQ), precipitation of the wettest quarter (RWETQ) and precipitation of the warmest quarter (RWETQ; Table 5.3).

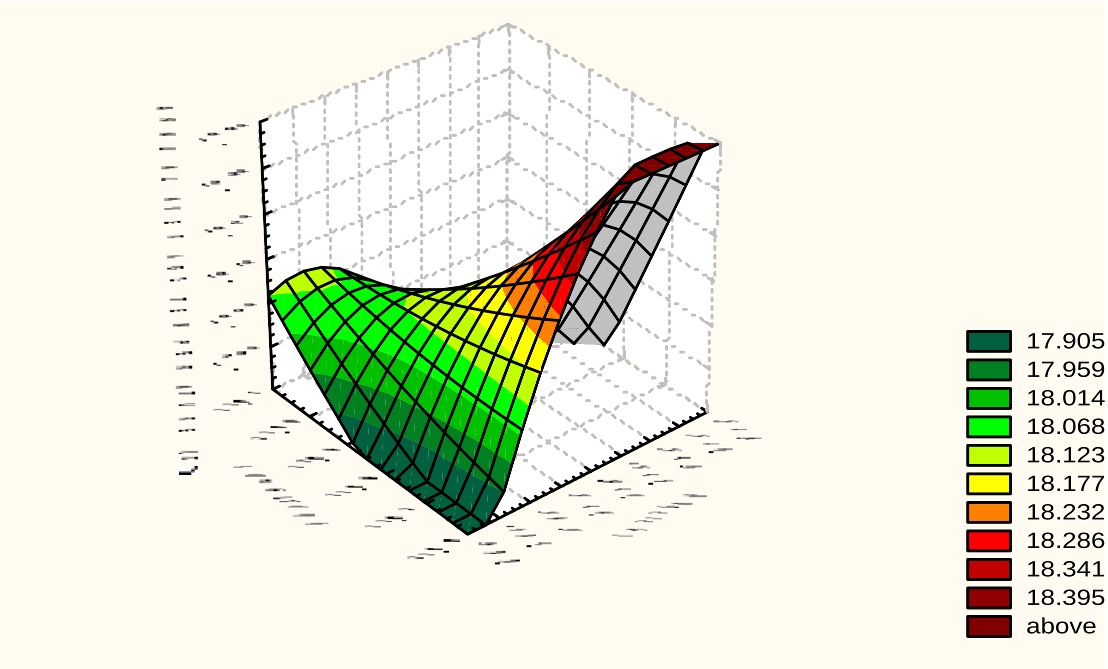


Figure 5-7: Synthetic annual average temperature gradient for the Swan Coastal Plain in longitudinal and latitudinal directions.

Temperature measurements developed in the Bioclim (Busby 1985) software program.

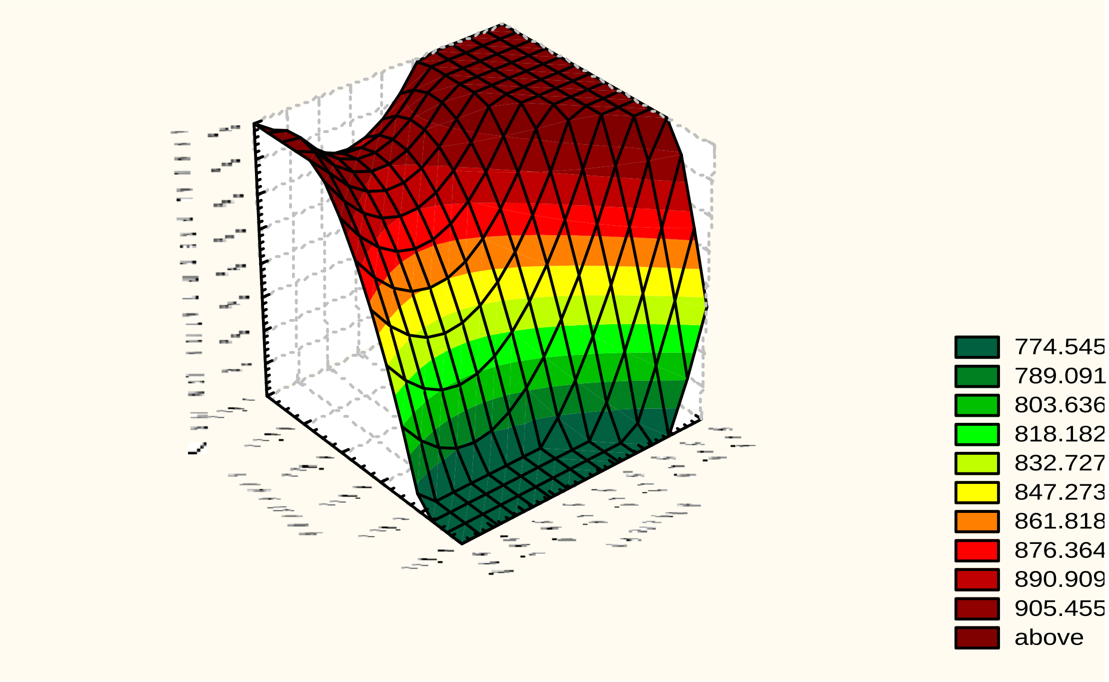


Figure 5-8: Synthetic annual precipitation gradient for the Swan Coastal Plain in longitudinal and latitudinal directions.

Precipitation measurements developed in the Bioclim (Busby 1985) software program.

Table 5-3: **Multiple regression co-efficients (R^2) values for the individual Bioclim synthetic environmental variables, and the multiple regression co-efficient value (R^2 Value#) associated with the selected Bioclim synthetic variables.** With the Total, Volant and Non-volant species richness values, and Abundance values for selected species for all sites on the Swan Coastal Plain. Note: n= 42 sites; – = not included in regression; significance levels: * = $p< 0.05$, ** = $p< 0.01$, *** = $p< 0.001$, **** = $p< 0.0001$; see Pp 46, Chapter 3 for explanations of Bioclim variable codes.

Bioclim Predictor Variables	**Total Species Richness**	**Volant Species Richness**	**Non-volant Species Richness**	***Gnathoxys crassipes* Abundances**	***Gnathoxys granularis* Abundances**	***Promecoderus scauroides* Abundances**	***Notonomus mediosulcatus* Abundances**	***Sarticus iriditinctus* Abundances**	***Simodontus australis* Abundances**	***Scaraphites lucidus* Abundances**	***Scaraphites silenus* Abundances**	***Lecanomerus verticalis* Abundances**	***Notagonum* sp.1 Abundances**
TANN	0.644	0.964	-	-	0.891	-	-	-	0.894	-	-	0.970	0.971
TMNCM	0.835	0.966	0.931	-	-	-	-	0.923	-	0.934	0.903	0.964	0.973
TMXWM	-	0.975	0.947	-	0.963	-	-	0.904	0.936	0.980	0.969	-	0.980
TSPAN	-	-	-	-	-	-	-	-	-	-	-	-	-
TCLQ	-	-	-	-	-	-	-	-	-	-	-	-	-
TWMQ	-	0.975	0.864	-	0.954	-	-	-	0.940	0.912	0.895	0.967	0.976
TWETQ	-	0.789	0.814	-	-	0.640	-	0.812	0.764	0.821***	0.757	0.681**	0.829
TDRYQ	-	-	-	-	-	-	-	-	-	-		-	-
RANN	-	-	-	-	-	-	-	-	-	-	-	-	-
RWETM	-	-	-	-	-	-	-	-	-	-		-	-
RDRYM	0.771	-	0.729	0.483	0.801*	0.592	0.452	0.754	0.770	0.827	0.809	0.680	0.854
RCVAR	0.816	0.857	0.840	0.775	-	0.822	-	-	0.840	0.878	-	-	0.878
RWETQ	-	0.865	0.918	-	0.875	0.732	-	0.937	0.871	0.937**	0.900	0.811	0.938
RDRYQ	0.858	-	0.930	0.834	0.843	0.868*	0.454	0.917	0.915*	0.930	-	-	0.931
RCLQ	0.832	0.906	0.895	-	-	-	-	0.908	-	0.911	0.896	0.877*	0.918
RWMQ	0.572	0.844	-	0.212	0.826	-	0.025	0.828	-	0.901*	0.859	-	0.902
R^2 Value#	0.371**	0.449*	0.513**	0.109	0.274	0.292*	0.112	0.203	0.533***	0.645****	0.270	0.403**	0.347

5.3.3.1 Summary Findings of the Swan Coastal Dune System Carabids.

The significant findings of the study of the carabid assemblage present in the bushland remnants of the Swan Coastal Plain are presented below.

- 37 species from 26 genera representing 11 subfamilies were collected between 1993 and 1997 across the four landforms of the Swan Coastal Plain (Quindalup, Spearwood and Bassendean Dune Systems, and the Ridge Hill Shelf).
- The most speciose assemblage was the Bassendean Dune System with 17 species; the least richest landform was the junction between the Karrakatta Soils and Bassendean Dune System (with 3 species).
- 17 species were collected from single landforms (the majority of which were volant species), whereas most non-volant species were present across several landforms.
- The total, volant and non-volant species richness varied significantly between the landforms of the Plain.
- There were relationships between species richness and remnant area. The relationships between total and volant species richness and log of remnant area were significant, but the relationship with non-volant species richness was not significant. In all three cases the variable remnant area accounted for less than 15% of the variation in the species richness between sites.
- Vegetation community and soil structure differences are reflected in the carabid assemblage similarities between sites. Quindalup sites showed greatest similarities, whereas sites situated on Karrakatta Soils (Spearwood Dune System), Bassendean Dunes System and the Ridge Hill Shelf showed greater similarity to each other than within other remnants. As these sites are situated in various types of Banksia woodland it may be the structure of the vegetation rather than the species composition that is being reflected.
- Climatic parameters derived from precipitation and temperature data accounted for approximately one quarter or less, of the variance in total, volant or non-volant species richness. These parameters, as a group, accounted for variable amounts of variance in abundance of only 4 carabid species. In contrast, several

individual climate parameters accounted for the variance in abundances of several species.

5.3.4 THE QUINDALUP DUNE SYSTEM CARABIDS: COMPOSITION, RICHNESS AND EVENNESS.

A total of 2375 specimens representing 20 ground beetle (Carabidae) species were collected from wet pitfall traps set in Woodman Point Reserve, Mount Claremont Reserve, Bold Park, Trigg Dune Reserve and Yanchep National Park between the years 1993 and 1997. The volant component of this collection consisted of 124 specimens from 10 species in seven subfamilies. The remaining 2251 specimens comprised of ten non-volant (flightless) species, representing three subfamilies.

Table 5-4: Species list and total abundance from all sites of ground beetles caught in wet pitfall traps in the Quindalup bushland remnants, Bold Park, Yanchep Nation Park, Woodman Point, Mount Claremont and Trigg Dune Reserves.
Traps set with ethylene glycol as the fixative. (%) = number of each species as a percent of total number (2375) specimens collected.

GENUS	SPECIES	SUBFAMILY	HABIT	TOTAL ABUNDANCE (%)
Notagonum	*submetallicum*	Agoninae	volant	1 (0.04)
Gnathoxys	*pannuceus*	Broscinae	flightless	1 (0.04)
Calosoma	*schayeri*	Carabinae	volant	1 (0.04)
Euthenaris	*sp. 1*	Harpalinae	volant	1 (0.04)
Scopodes	*boops*	Pentagonicinae	volant	1 (0.04)
Notonomus	*mediosulcatus*	Pterostichinae	flightless	1 (0.04)
Teropha	*sp.*	Pterostichinae	volant	1 (0.04)
Sarticus	*iriditinctus*	Pterostichinae	flightless	3 (0.13)
Sarothrocerepis	*sp. 1*	Trigonoderiae	volant	3 (0.13)
Gnathoxys	*granularis*	Broscinae	flightless	4 (0.17)
Speotarus	*lucifugus*	Lebiinae	volant	5 (0.21)
Trigonothops	*sp. 1*	Lebiinae	volant	6 (0.25)
Scaraphites	*silenus*	Scaritinae	flightless	21 (0.88)
Carenum	*scaritoides*	Scaritinae	flightless	44 (1.85)
Lecanomerus	*verticalis*	Harpalinae	volant	50 (2.11)
Notagonum	*sp. 1*	Agoninae	volant	54 (2.27)
Gnathoxys	*crassipes*	Broscinae	flightless	55 (2.32)
Promecoderus	*scauroides*	Broscinae	flightless	468 (19.71)
Scaraphites	*lucidus*	Scaritinae	flightless	521 (21.94)
Simodontus	*australis*	Pterostichinae	flightless	1133 (50.33)

Three subfamilies were each represented by two volant species; the Agoninae by 2 *Notagonum* species, the Harpalinae by *Lecanomerus verticalis* and *Euthenaris* sp. 1, and the Lebiinae by *Speotarus lucifugus* and *Trigonothops* sp. 1. Single species represented the Carabinae (*Calosoma schayeri*), Pentagonicinae (*Scopodes boops*), Pterostichinae (*Teropha* sp.) and Trigonoderinae (*Sarothrocrepis* sp.; Table 5.4).

Of the non-volant assemblage the Broscinae were represented by the most speciose genus, *Gnathoxys* with three species, and a further taxon, *Promecoderus scauroides*. The Scaritinae contained three species, two in the genus *Scaraphites* and one representative of the widespread genus *Carenum*. Finally, the Pterostichinae was also represented by three genera, each with a single species (Table 5.4).

Two non-volant and five volant species were represented by single individuals. These low capture rates for the non-volant species indicate possible overall rarity, very low densities within those particular remnants, or alternatively, trap shyness. Conversely, for these five volant species their presence is probably underestimated due to the nature of the collecting technique used. Pitfall trapping may underestimate arboreal or volant species as the technique targets primarily terrestrial organisms.

Total species richness of the 19 Quindalup sites ranged from 3 - 11 species (= 6.5, stdev = 2.8). The volant species richness ranged from 0 – 3 species (= 3, stdev = 3.5), whereas non-volant species richness ranged from 3 - 7 species (= 4.6, stdev = 1 ;Table 5.5). Samples collected during 1993 to early 1996 from sites in Bold Park, Mount Claremont, Woodman Point and Trigg Dune Reserve suggested a relatively low diversity across all of these sites. A further year of pitfall trapping in Bold Park and Trigg Dune Reserve increased the perceived carabid diversity by seven species (four non-volant, three volant) at BP1, three species (one non-volant, two volant) at BP5 and by one non-volant species at TD2. However, volant carabid diversity dropped by two species at TD4 (Table 5.5).

Table 5-5: Total species richness of terrestrial carabid beetles across all Quindalup Study sites.
* 1993-96. Sites surveyed by How *et al.* (1996); 1996-97 sites surveyed by the author. N/A- not surveyed.

SITE	**BP1 1993**	**BP1 1996**	**BP3**	**BP4**	**BP5 1993**	**BP5 1996**	**MC1**	**MC2**	**TD1**	**TD2 1995**	**TD2 1996**	**TD4 1995**	**TD4 1996**	**WP1**	**WP2**	**WP3**	**WP4**	**YP1**	**YP2**
NON-VOLANT	3	7	4	3	3	4	5	5	4	4	5	5	5	5	6	4	5	5	5
VOLANT	0	3	2	1	1	3	2	0	0	0	0	3	1	1	5	2	2	1	3
TOTAL	**3**	**10**	**6**	**4**	**4**	**7**	**7**	**5**	**4**	**4**	**5**	**8**	**6**	**6**	**11**	**6**	**7**	**6**	**8**

The evenness indices calculated are presented in Table 5.7. The mean evenness value (*J'*) of the total terrestrial carabid assemblage on the Quindalup Dune sites was 0.61 (range 0.18 – 0.91, stdev = 0.2, n = 19). Highest values for the total assemblage was exhibited by YP1 and Quindalup soils associated site BP4 (J'= 0.91) and BP1 (1993) had the lowest value of 0.18. The non-volant evenness values (*J'*) ranged between 0.18 – 0.87 (mean = 0.52, stdev = 0.2, n =19). Once again BP1 (1993) exhibited the lowest value (*J'* = 0.18) and TD2 (1995) had the highest value of 0.87. Both the total and non-volant carabid evenness indices for sites BP1 and BP5 increased between 1993 and 1996, but between 1995 and 1996 the indices decreased at sites TD2 and TD4. There was a significant difference between the total carabid and non-volant carabid assemblage evenness values (T Test $_{\text{critical two-twilws}}$ = 2.093, n = 19, p> 0.05). However, the total and non-volant evenness values for BP1 (1993), MC2, TD1 and TD2 (1995) are the same as no volant individuals were caught a these sites.

The BP1 (1993) value is explained by the numerical dominance of *Scaraphites lucidus* (95.8% of the total non-volant abundance at that site) while YP1 exhibited a very even distribution of abundances across the five non-volant species. Of the four sites surveyed over both sampling periods, both Trigg Dune sites exhibited a decrease in both their total and non-volant evenness index values, whereas both Bold Park sites exhibited an increase. In each of these four sites, the total non-volant carabid abundances also increased between the first and subsequent years of sampling (Table 5.7). Both Trigg sites and BP1 showed modest increases in abundance relative to the first year level (1.33, 2.86 and 4.82 times, respectively). In contrast, abundances at BP5 increased by a massive 11.08 times that recorded in 1993 (Table 5.7). These increases in abundances are the direct result of increases in the number of *Scaraphites lucidus, Simodontus australis* or *Promecoderus scauroides* caught during 1996-1997.

Table 5-6: **Evenness Index values for terrestrial carabid beetles (total and non-volant assemblages) across all Quindalup Dune Study sites.**

SITE	J' TOTAL	J' NON-VOLANT
BP1 1993	0.18	0.18
BP1 1996	0.45	0.39
BP3	0.47	0.29
BP4	0.91	0.65
BP5 1993	0.51	0.42
BP5 1996	0.60	0.51
MC1	0.73	0.67
MC2	0.77	0.77
TD1	0.78	0.78
TD2 1995	0.87	0.87
TD2 1996	0.72	0.65
TD4 1995	0.72	0.60
TD4 1996	0.55	0.44
WP1	0.43	0.41
WP2	0.36	0.25
WP3	0.46	0.41
WP4	0.51	0.45
YP1	0.91	0.80
YP2	0.61	0.41

Table 5-7: Distribution of the total abundances of the 20 carabid species across all sites used to generate the similarity dendrogram in Figure 5-15.

NOTE: Total abundances increased between first and second surveys of TD2 (1995/96= 66, 1996/97= 80, increased by 1.33 times), TD4 (1995/96= 60, 1996/97= 172, increased by 2.86 times), BP1 (1993/94= 72, 1996/97= 347, increased by 4.82 times), BP5 (1993/94= 24, 1996/97= 266, increased by 11.08 times). BP: Bold Park; MC: Mount Claremont; TD: Trigg Dune Reserve; WP: Woodman Point Reserve; YP: Yanchep National Park.

Taxon	BP1_1993	BP1_1996	BP5_1993	BP5_1996	MC1	MC2	TD1	TD2_1995	TD2_1996	TD4_1995	TD4_1996	WP1	WP2	WP3	WP4	YP1	YP2	BP3	BP4	Species Abundance
Gnathoxys crassipes	2	8	0	2	2	3	0	4	2	3	7	6	6	0	3	2	5	0	0	55
Gnathoxys granularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	4
Gnathoxys pannuceus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Promecoderus scauroides	0	6	2	59	19	22	10	17	21	16	136	51	51	2	15	0	28	2	11	468
Notonomus mediosulcatus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sarticus iriditinctus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3
Simodontus australis	1	213	2	156	3	25	2	14	40	8	14	182	318	68	73	1	1	3	9	1133
Carenum scaritoides	0	0	0	0	25	3	0	0	1	3	3	1	1	3	1	3	0	0	0	44
Scaraphites lucidus	69	115	20	49	12	47	2	31	16	30	12	5	5	17	11	0	0	47	33	521
Scaraphites silenus	0	3	0	0	0	0	14	0	0	0	0	0	0	0	0	4	0	0	0	21
Notagonum sp. 1	0	4	1	1	0	0	0	0	4	3	15	1	22	1	1	1	0	0	0	54
Notagonum submetallicum	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
Calosoma schayeri	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Euthenaris sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Euthenaris sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanomerus verticalis	0	5	0	13	1	0	0	0	0	0	0	0	0	0	0	0	3	7	21	50
Speotarus lucifugus	0	1	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	1	0	5
Trigonothops sp. 1	0	0	0	0	1	0	0	0	0	0	0	0	3	0	1	0	1	0	0	6
Scopodes boops	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Teropha sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sarothrocrepis sp. 1	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	3
Site ABUNDANCE	72	357	25	281	63	100	28	66	84	65	187	246	413	92	105	12	44	61	74	2375

Evidence of significant temporal (seasonal or longer-term) changes in abundances of individual carabid species was observed across the sites. There was an increase in captures of *Lecanomerus verticalis* and *Notagonum* sp. 1 during spring to early summer, with few individuals being caught outside this period (Figure 5.9 and Figure 5.10 respectively). This data indicates that both species appear to have warm weather activity periods. As both *L. verticalis* and *Notagonum* sp. 1 are volant collecting technigues toher than pitfall trapping may clarify further the nature and timing of the activity periods of these highly mobile species.

Four species of volant carabid were represented by five or less individuals (*Notagonum submetallicum*, *Sarothrocrepis* sp. 1, *Speotarus lucifugus*, *Trigonothops* sp. 1) and to single specimens of *Calosoma schayeri*, *Euthenaris* sp. 1, *Teropha* sp. and *Scopodes boops* were collected (Table 5.7).

Three species, *Promecoderus scauroides, Scaraphites lucidus and Simodontus australis*, constituted 94.27% of all non-volant carabids collected. *Simodontus australis* was the most abundant (50.33% of all individuals; Table 5.4), and was found at all sites (Table 5.7; Figure 5.9). Highest abundances for this species were recorded at site WP2 (total of 318 specimens), at WP1 (182 specimens) and at BP1 (1996-1997; 213 individuals; Table 5.7).

Simodontus australis was relatively rare in the Bold Park sites, occurring sporadically in low numbers, through the 1993-1994 survey. This species also occurred in low numbers during March-July 1995 at Mount Claremont Reserve and July-November 1995 at Trigg Dune Reserve. Only one specimen each was collected from both Yanchep National Park sites in 1996-1997 (Table 5.7; Figure 5.9).

In contrast, *S. australis* was caught in abundance throughout the year at Woodman Point (1994-1995) and at Bold Park in 1996-1997. Population "pulses" occurred during May-September and again during December-January at both these remnants. At Trigg Dune Reserve during 1996-1997 a "pulse" was observed at TD2 between April and June (Figure 5.9).

Therefore, this species may survive either through late summer as an adult, or in a sub-adult form with only a few adults surviving into their second year.

The second most common species, *Scaraphites lucidus* (23.15% of all non-volant individuals), was present at all suburban sites, but not at either Yanchep site (Table 5.7; Figure 5.10). The largest populations were at site BP1 (total of 184 specimens: 69 in 1993-94; 115 in 1996-97) and BP5 (total of 69 individuals: 20 in 1993-94; 49 in 1996-97; Table 5.7). Distinct seasonality in its abundances is seen in the captures for all Bold Park and Mount Claremont Reserve sites, and to a lesser extent at the Woodman Point and Trigg Dune Reserve sites. The activity period of *S. lucidus* appears to be during late winter to mid-summer, peaking between September and November.

Promecoderus scauroides accounted for 20.79% of all non-volant animals captured and was found in all remnants with the exception of YP1. The most prolific sites for this species were BP5 with 61 individuals (1993-1994= 2; 1996- 1997= 59) and TD4 with 152 (1995-1996= 16; 1996-1997= 136) (Table 5.7; Figure 5.11). During the 1993-1994 survey of Bold Park, *P. scauroides* was absent from BP1 and only six individuals were found there in 1996-1997. From these data, the active season of *P. scauroides* appears to be from autumn to late winter. However, *P. scauroides* individuals were also collected during spring and early summer at Mount Claremont Reserve and Woodman Point Reserve during 1994-1995.

Despite being similar in size to *Scaraphites lucidus*, *Scaraphites silenus* had a more restricted distribution across the sites. A total of 21 individuals were collected from three sites (Table 5.7; Figure 5.12). Three animals were from BP1 (one from each sampling period between 29 August 1996 and 2 January 1997). Four were from YP1 (3 from sampling period 10 October-21 November 1996 and 1 from 18 June-1 August 1997). The remaining 14 animals were from TD1. Little can be said at this point about its activity period but the few specimens collected suggest a possible winter to spring activity similar to *S. lucidus*.

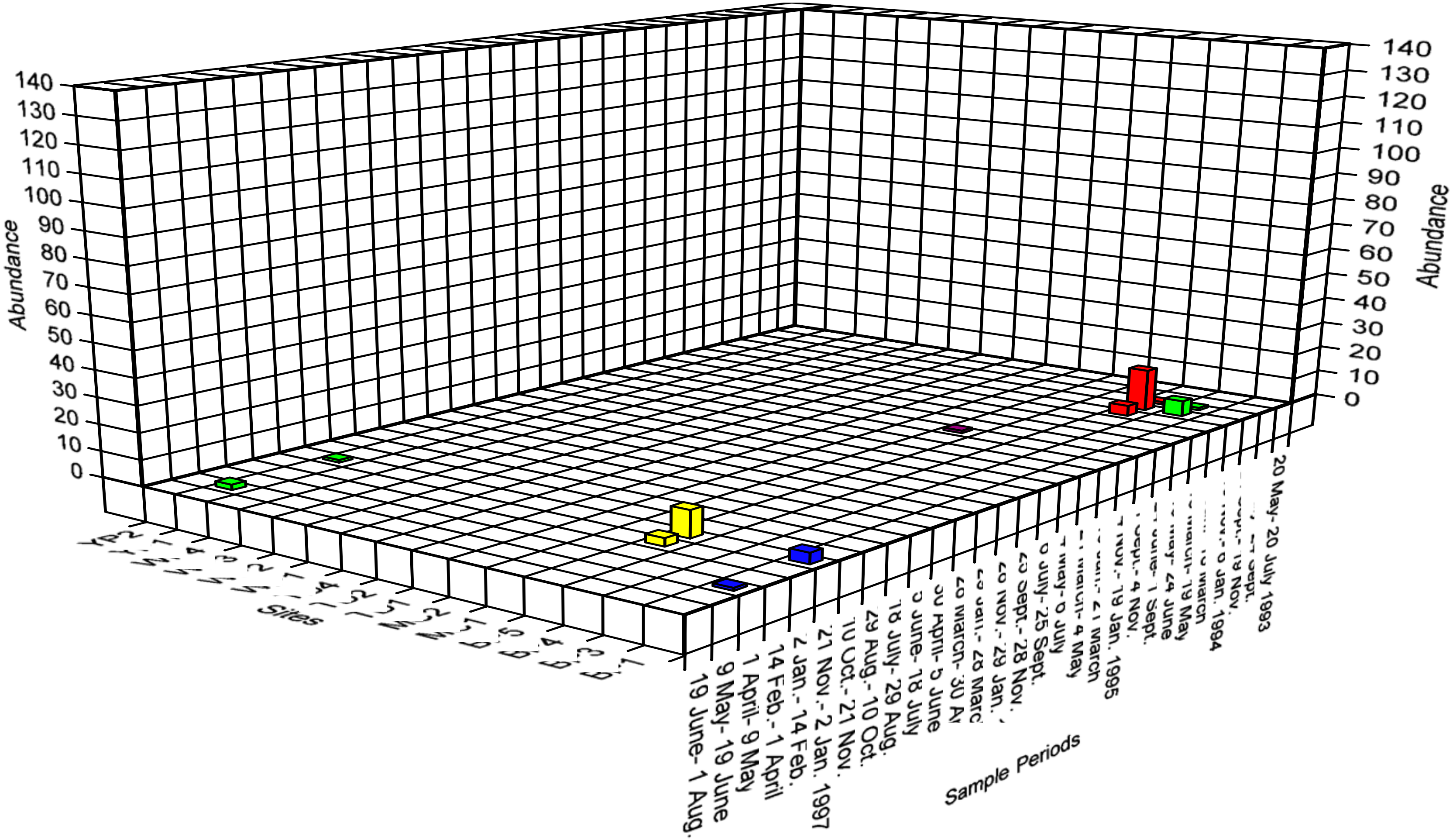


Figure 5-9: Abundances of *Lecanomerus verticalis* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.

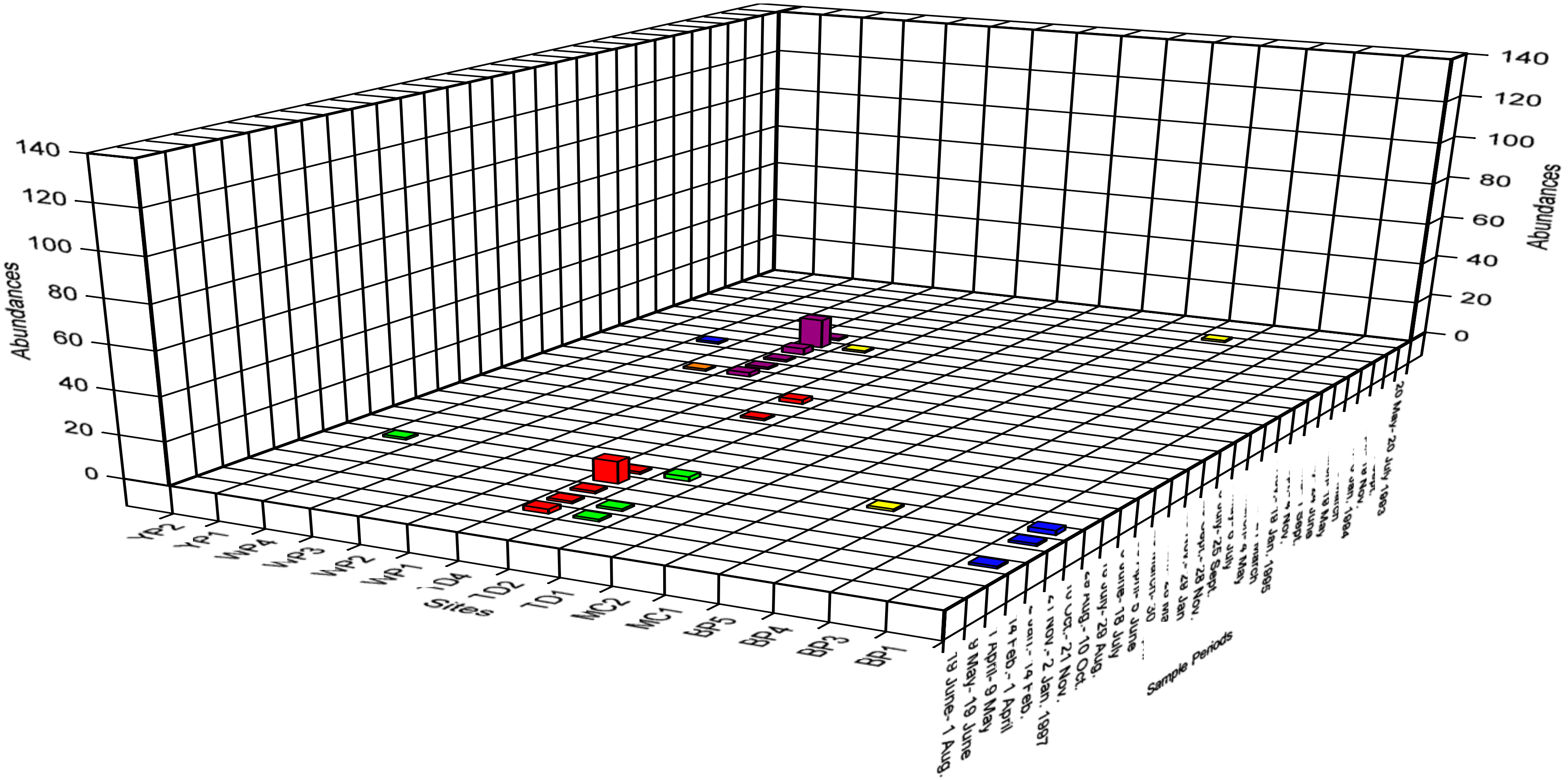


Figure 5-10: Abundances of *Notagonum sp.* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.

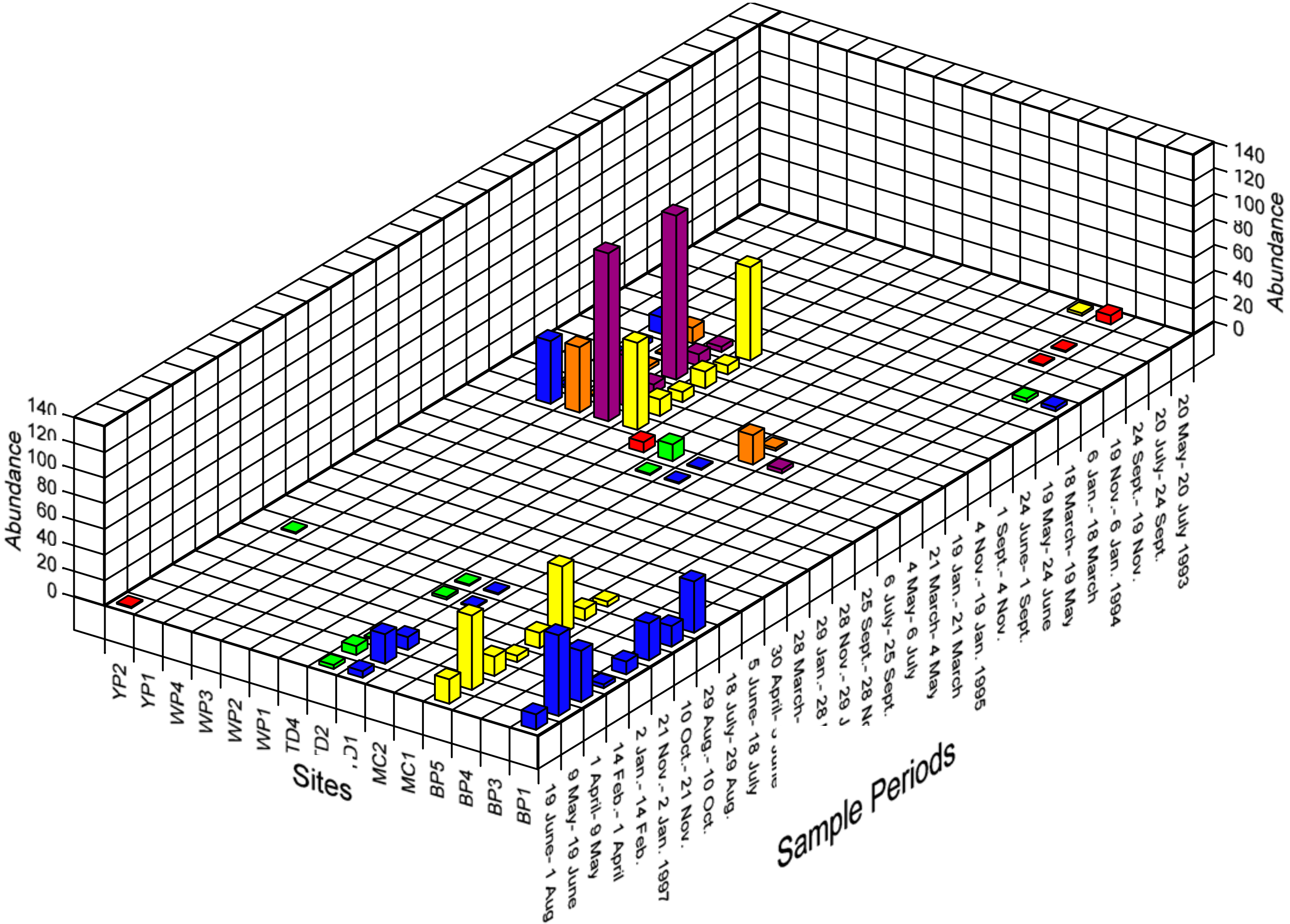


Figure 5-11: Abundances of *Simodontus australis* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.

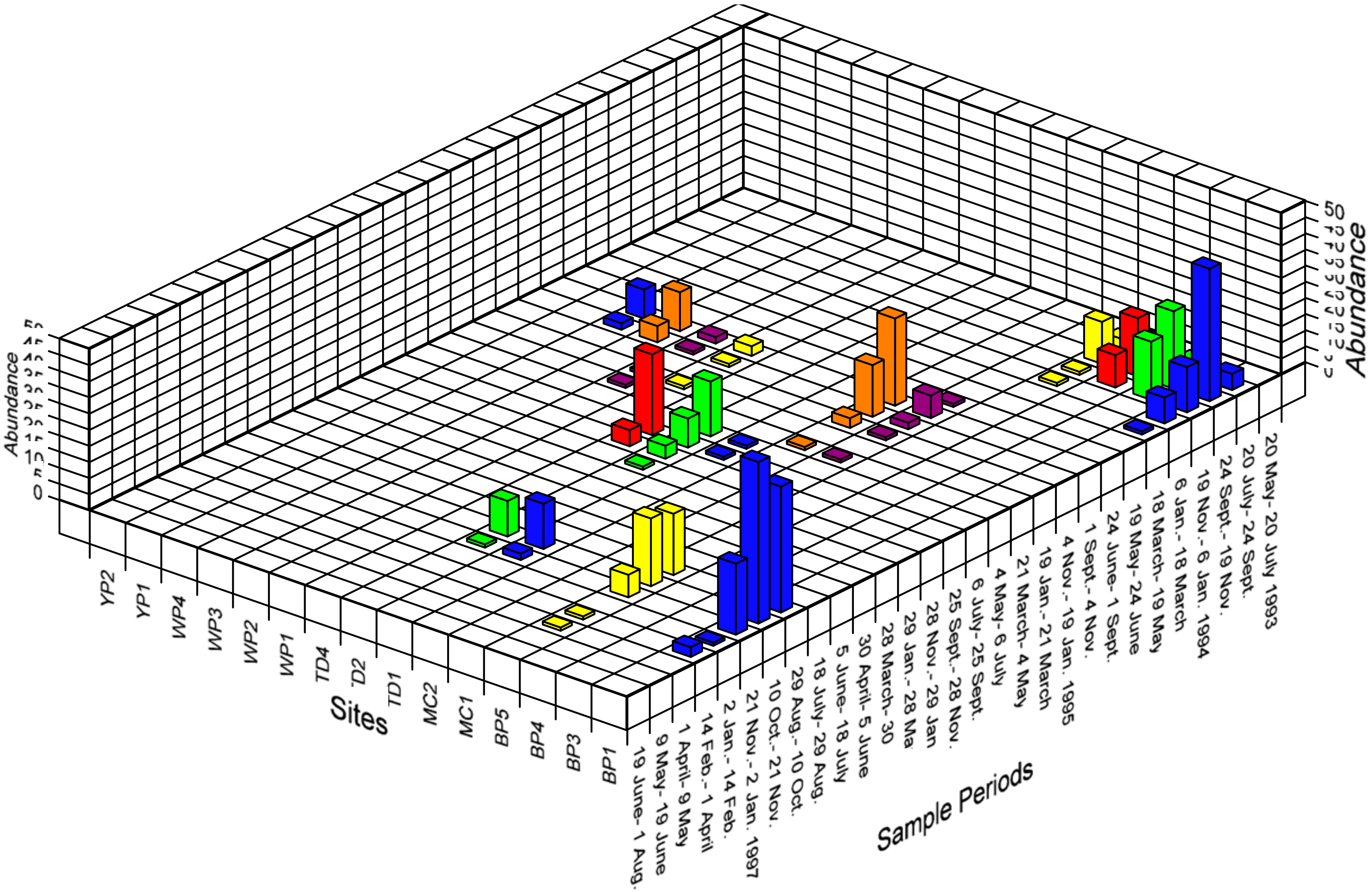


Figure5-12: Abundances of *Scaraphites lucidus* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.

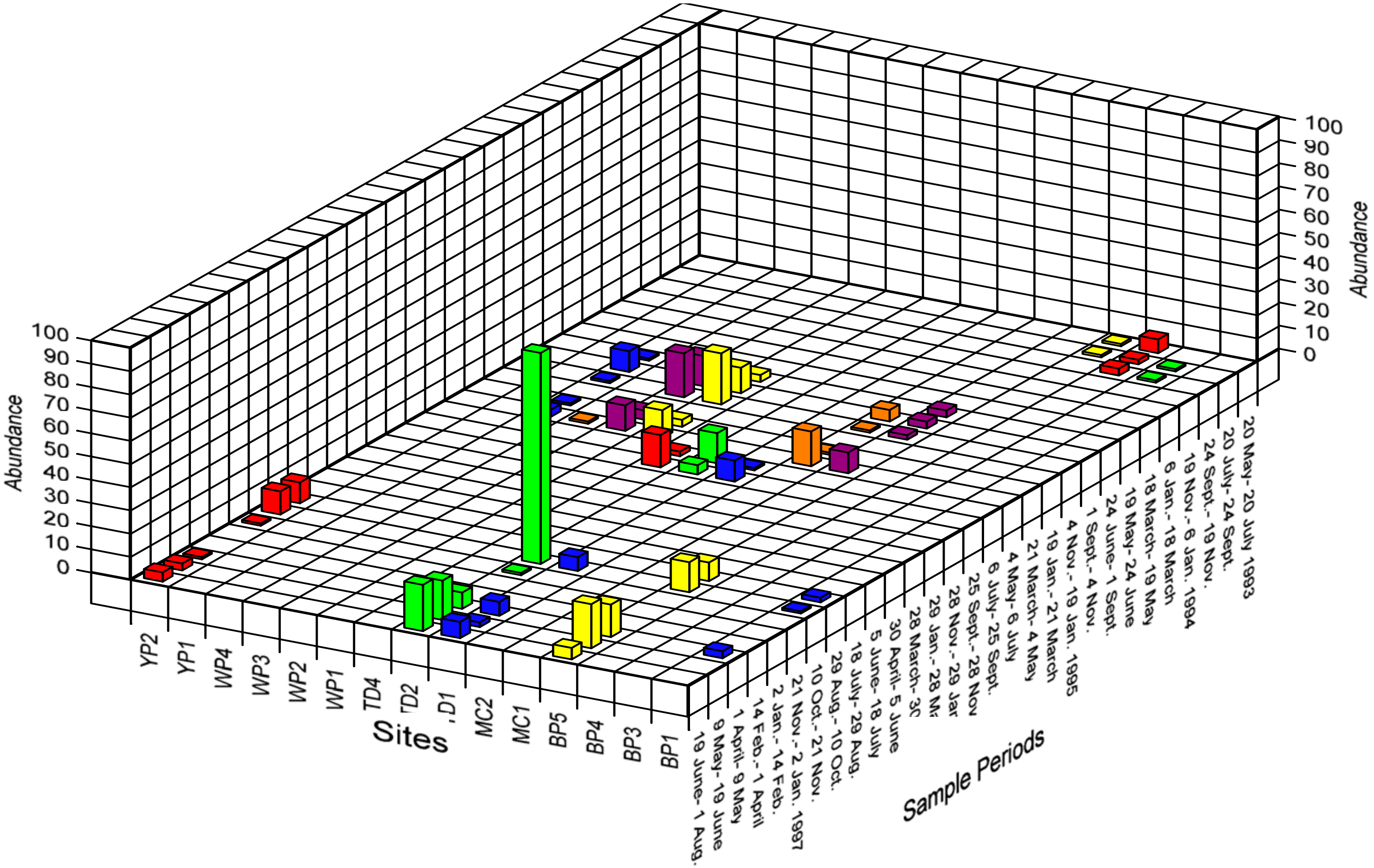


Figure 5-13: **Abundances of *Promecoderus scauroides* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.**

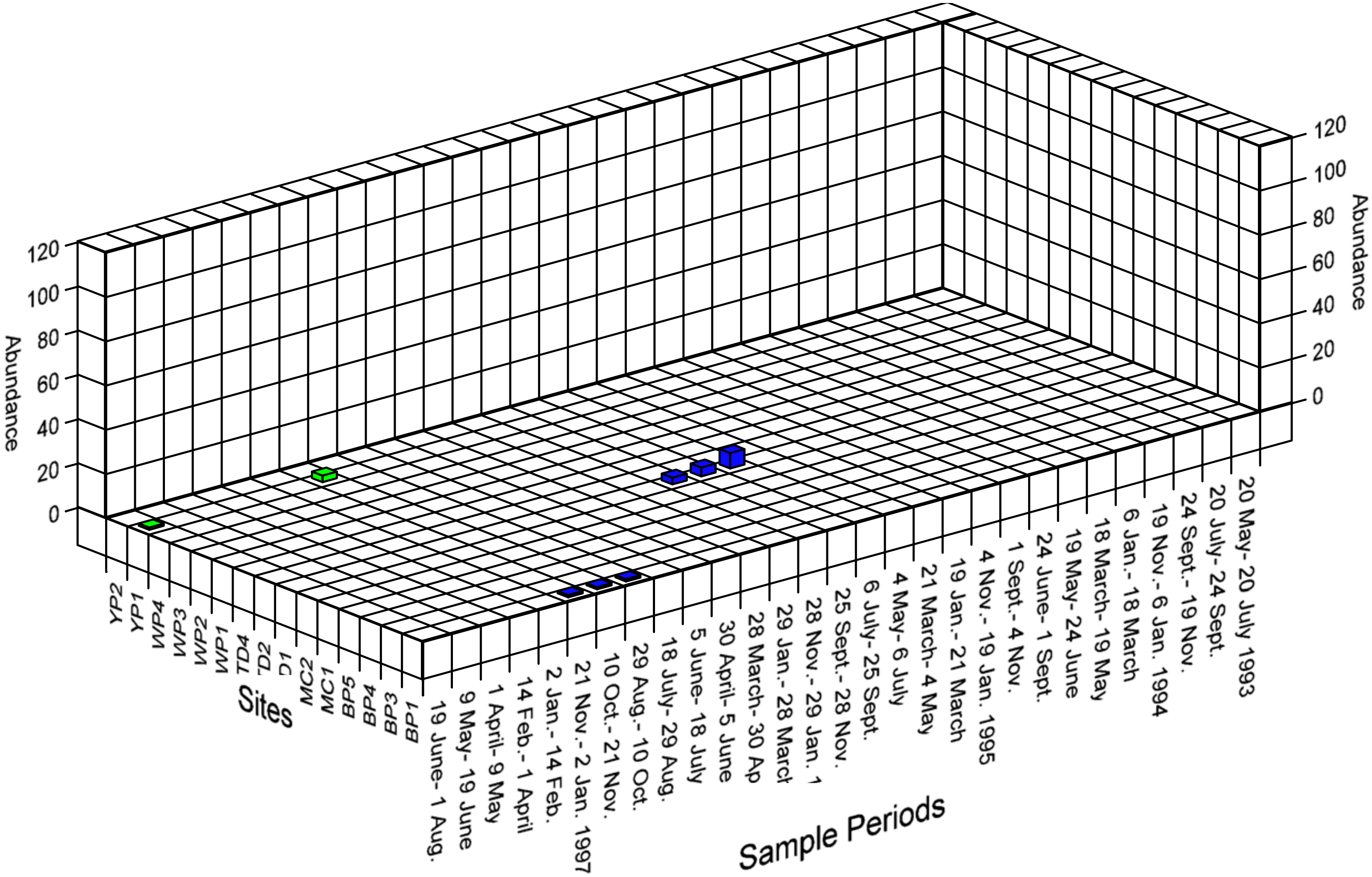


Figure 5-14: Abundances of *Scaraphites silenus* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.

The remaining six non-volant species (*Carenum scaritoides*, *Gnathoxys crassipes*, *Gnathoxys granularis*, *Gnathoxys pannuceus*, *Notonomus mediosulcatus*, and *Sarticus iriditinctus*) are each represented by relatively few individuals and some apparently have restricted distributions among the sites surveyed (Table 5.7). Despite accounting for 60% of the total carabid species richness, these species represent 4.8% of the number of specimens collected. *Carenum scaritoides* was present in nine sites but in low numbers (except for MC1 which had 25 individuals). It was absent from all Bold Park sites, and from TD1 and YP2 (Table 5.7; Figure 5.13). The trapping records indicate that *C. scaritoides* is active through most of the year (Figure 5.13).

Gnathoxys crassipes was absent from the Spearwood Dune sites BP3 and BP4, and from BP5 (1993-1994), TD1 and WP3 in the Quindalup Dune System (Table 5.7; Figure 5.14). This species tended to be active during the hotter months, and only few specimens were collected in late autumn-early winter sampling periods.

Gnathoxys granularis was present at the Yanchep sites and was active during early spring and autumn (two from 10 October-21 November 1997 – YP1 & YP2; one each from 1 April-9 May, 9 May-18 June 1997; Table 5.7). The single specimen of *Gnathoxys pannuceus* was collected from WP2 during late spring-early summer. *Sarticus iriditinctus* was represented by three specimens, two from Bold Park and one from YP2. The final species, *Notonomus mediosulcatus*, was found as a single specimen in BP1 during the final sampling period (18 June – 1 August 1997).

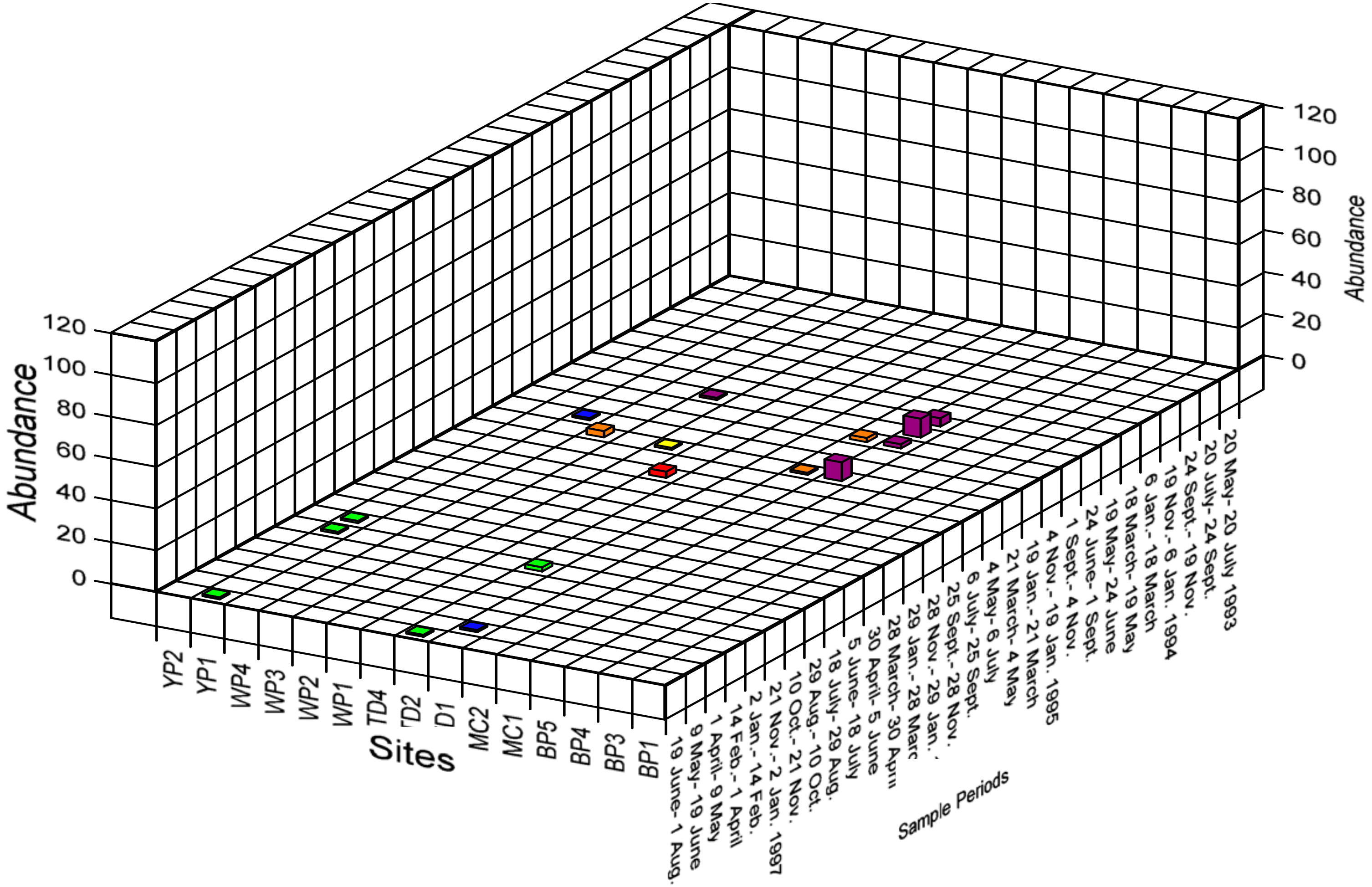


Figure 5-15: Abundances of *Carenum scaritoides* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.

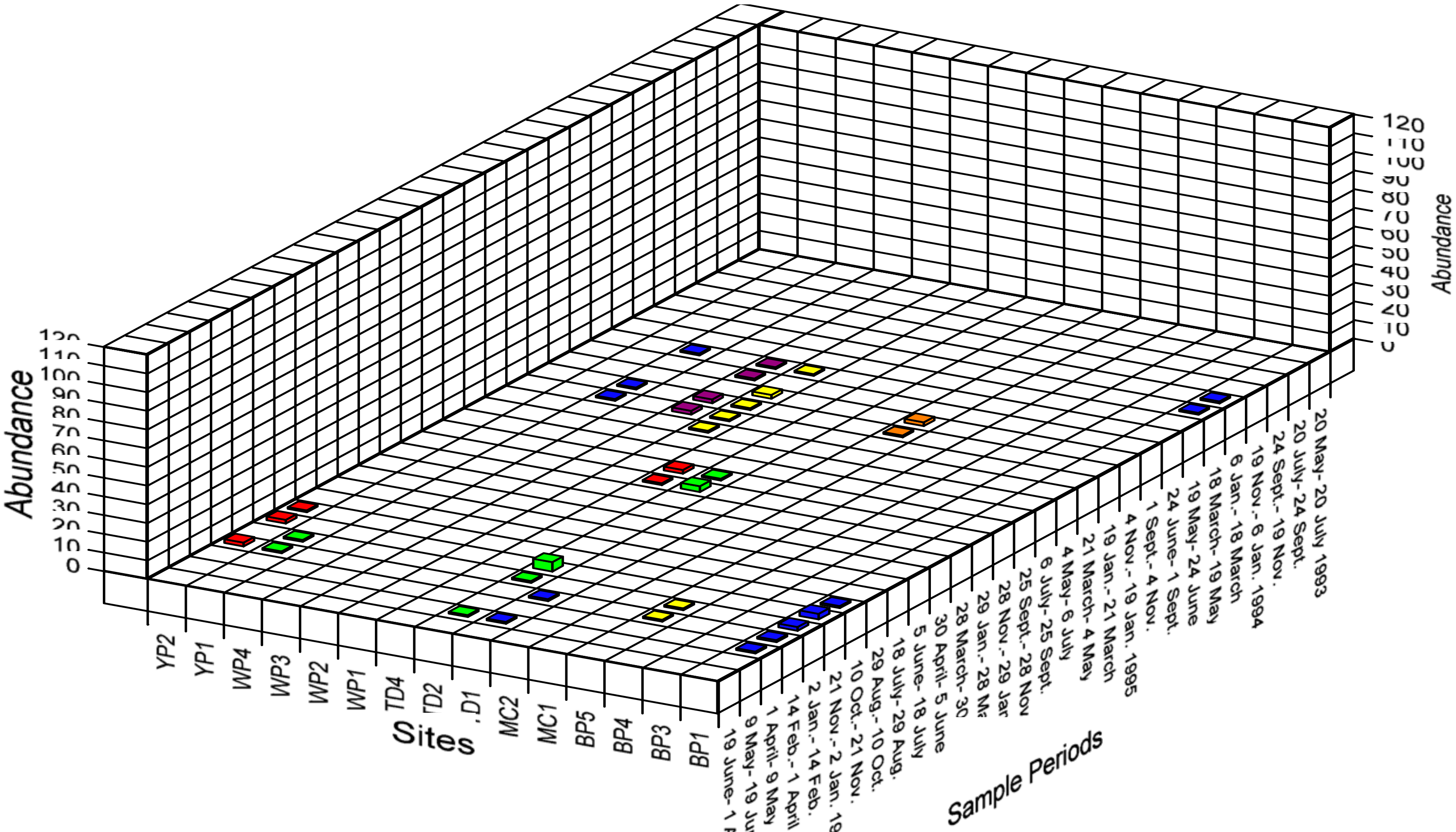


Figure 5-16: **Abundances of *Gnathoxys crassipes* across all Quindalup Dune sites and all sampling periods, based on trapping record data in Appendix G.**

5.3.5 SIMILARITY OF ASSEMBLAGES OF THE QUINDALUP FAUNA

Data used to construct the presence/absence and percent transformed similarity dendrograms based on the non-volant carabid assemblage are presented in Table 5.7. The presence/absence tree dendrogram presented in Figure 5.15 is based on these converted data for each site sampled.

At the 55% similarity level, six clusters are apparent (Figure 5.15). Three sites form individual linkages at this level; both Yanchep sites and BP1 (1996). The two former sites have five species each with three species in common (and *G. granularis* is only found at these sites). BP1, in contrast, recorded seven species, of which two were common to both YP1 and YP2 (*G. crassipes* and *S. australis*), one in common with YP1 only (*S. silenus*) and two with YP2 only (*P. scauroides, S. iriditinctus*).

The fourth cluster was comprised of three of the Bold Park sites surveyed in 1993 and TD1 surveyed in 1995. This cluster is defined by the presence of *Promecoderus scauroides, Scaraphites lucidus* and *Simodontus australis* almost exclusively (in addition to one specimen of *S. iriditinctus* from BP3 and *S. silenus* present at TD1).

Most of the sites situated on the youngest Quindalup remnants group as the fifth cluster. These are all of the Woodman Point sites (as a subgroup), TD2 1995, both 1996 Trigg Dune sites and both Mount Claremont sites. All of these sites, except for WP2 and WP3 (the former with the only record of *Gnathoxys pannuceus*, and the latter without *G. crassipes*) have identical species present. The presence of *Carenum scaritoides* at all of these sites defines the cluster. *Promecoderus scauroides, Simodontus australis* and *Scaraphites lucidus* are also present at all sites, along with *Gnathoxys crassipes* at eight of the nine sites.

The three remaining sites {BP1 (1993), BP5 (1996), TD2 (1995)} form the final cluster. *Simodontus australis, S. lucidus* and *G. crassipes* are present in all three sites. In addition, *P. scauroides* is present at BP5 1996 and TD2 1995 but not BP1 1993.

Four main species, *S. australis, P. scauroides, S. lucidus* and *G. crassipes* (in order of importance), are present at almost all sites, hence it is the presence of the rarer species which define most of the clusters. If these four species are excluded then the sites are defined as follows; BP1 (1996) defined by the presence of *Notonomus mediosulcatus, S. iriditinctus* and *S. silenus*; TD1 by presence of *S. silenus*; MC1, MC2, TD2 (1996) and TD4 (1995 and 1996) by *C. scaritoides*; WP1 by *G. pannuceus*; YP1 by *S. silenus, G. granularis* and *C. scaritoides*; and YP2 by *S. iriditinctus* and *G. granularis*. The remaining sites {BP1 (1993), BP5 (1993, 1996), BP3, BP4 and TD2 (1995)} each produced only the aforementioned widespread species.

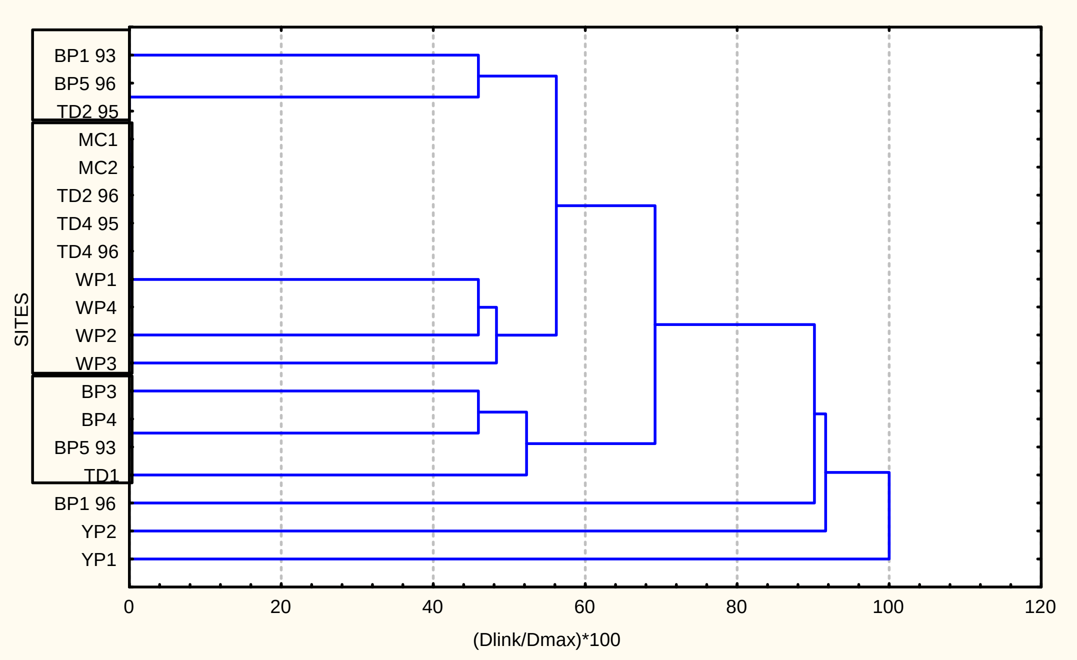


Figure 5-17: Dendrogram of site similarity based on terrestrial non-volant carabid species

Euclidean distances and UPGMA clustering used. Results are based on presence/absence data for all Quindalup Dune sites sampled 1993-1997. Shorter branches indicate a higher similarity between sites. (Dlink/Dmax)*100 represents the % of the range from the maximum to the minimum distance in the data (Statistica manual vol III, 1995 pp. 3179).

Figure 5.16 shows the clustering of sites based on percentage occurrence transformed data (abundance of each species as a percent (%) of the total non-volant abundance at that site; real abundances and transformed values in Table 5.7). At the 55% similarity level, six clusters are apparent (Figure 5.16). The first cluster comprises sites YP2 and TD4 (both 1996-1997). This group is based on a high proportion of *P. scauroides* (>

70% in each site). This species, in each of the other sites, comprises no more than one-third of the total carabids collected.

YP1 and TD1 form separate clusters, and in each at least one-third of the carabids collected was *S. silenus* (50% in TD1). High numbers of one other species (27.3% of carabids in YP1 were *C. scaritoides*, 35.7% of carabids in TD1 were *P. scauroides*) were also seen.

The fourth cluster is also formed by a single site, MC1. The high proportion of *C. scaritoides* (41% of all carabids at that site), in addition to high proportions of both *P. scauroides* (31.1%) and *S. lucidus* (19.7%), define this site. High proportions (47-83%) of *S. australis* characterise the fifth cluster, which comprises all Woodman Point sites, TD2 (1996) and both 1996 Bold Park sites.

The sixth cluster includes two major sub-groups, separated at just below the 55% similarity level. A high proportion (47-62%) of *S. lucidus* and *P. scauroides* (20-26%) occur in TD2 and TD4 from 1995, MC2 and BP4 which form one sub-group. The other sub-group consists of the remaining 1993 Bold Park sites and is almost exclusively dominated by *S. lucidus* (83-95% of the total carabids at those sites).

Table 5-8: Distribution of the Total Abundances of the 10 non-volant carabid species across all Quindalup Dune Sites. % Transformed values in parenthesis used to generate the similarity dendrogram in Figure 5-16.

Taxon	BP1_1993	BP1_1996	BP5_1993	BP5_1996	MC1	MC2	TD1	TD2_1995	TD2_1996	TD4_1995	TD4_1996	WP1	WP2	WP3	WP4	YP1	YP2	BP3	BP4
Gnathoxys crassipes	2 (2.8)	8 (2.3)	0	2 (0.8)	2 (3.3)	3 (3)	0	4	2	3 (5)	7 (4.1)	6 (2.4)	6 (1.6)	0	3 (2.9)	2 (18.2)	5 (13.2)	0	0
Gnathoxys granularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 (9.1)	3 (7.9)	0	0
Gnathoxys pannuceus	0	0	0	0	0	0	0	0	0	0	0	0	1 (0.3)	0	0	0	0	0	0
Promecoderus scauroides	0	6 (1.7)	2 (8.3)	59 (22.2)	19 (31.1)	22 (22)	10 (35.8)	17 (25.8)	21 (26.3)	16 (26.7)	136 (79.1)	51 (20.8)	51 (13.4)	2 (2.2)	15 (14.6)	0	28 (73.7)	2 (3.8)	11 (20.7)
Notonomus mediosulcatus	0	1 (0.3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sarticus iriditinctus	0	1 (0.3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 (2.6)	1 (1.9)	0
Simodontus australis	1 (1.4)	213 (61.4)	2 (8.3)	156 (56.6)	3 (4.9)	25 (25)	2 (7.1)	14 (21.2)	40 (50)	8 (13.3)	14 (8.1)	182 (74.3)	318 (83.1)	68 (75.5)	73 (70.9)	1 (9.1)	1 (2.6)	3 (5.7)	9 (17)
Carenum scaritoides	0	0	0	0	25 (41)	3	0	0	1 (1.3)	3 (5)	3 (1.7)	1 (0.4)	1 (0.3)	3 (3.4)	1 (0.9)	3 (27.3)	0	0	0
Scaraphites lucidus	69 (95.8)	115 (33.1)	20 (83.4)	49 (18.4)	12 (19.7)	47 (47)	2 (7.1)	31 (47)	16 (20)	30 (50)	12 (7)	5 (2)	5 (1.3)	17 (18.9)	11 (10.7)	0	0	47 (88.6)	33 (62.3)
Scaraphites silenus	0	3	0	0	0	0	14 (50)	0	0	0	0	0	0	0	0	4 (36.4)	0	0	0
Abundance	72 (100)	347 (100)	24 (100)	266 (100)	61 (100)	100 (100)	28 (100)	66 (100)	80 (100)	60	172 (100)	245	382 (100)	90 (100)	103 (100)	11 (100)	38 (100)	53 (100)	53 (100)

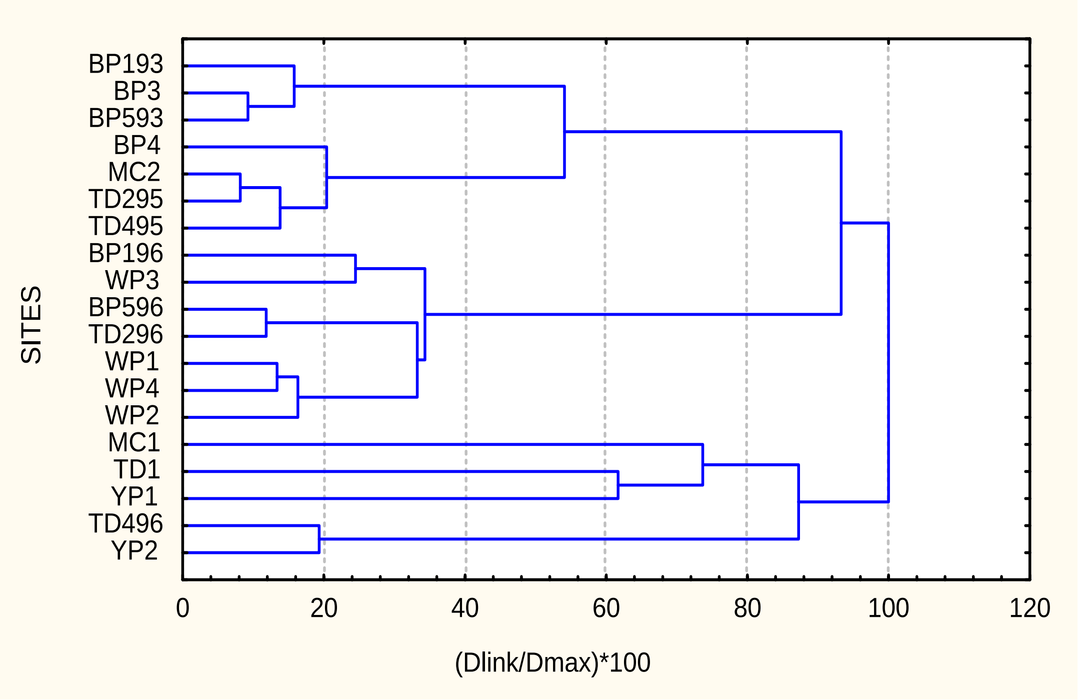


Figure 5-18: Dendrogram of site similarity based on the terrestrial non-volant carabid fauna

Euclidean distances and UPGMA clustering used. Results are based on abundance data expressed as percent occurrence for the Quindalup Dune sites sampled 1993-1997. Shorter branches indicate a higher similarity between sites. (Dlink/Dmax)*100 represents the % of the range from the maximum to the minimum distance in the data (Statistica manual vol III, 1995 pp. 3179).

Sampling periods from 1993 to early 1996 are not equal in length and only roughly corresponded to the same period of time during the year. This fact makes direct comparisons of individual sampling periods between years and sites difficult (see Table 3.1 for sampling period length). However, it is possible to analyse the raw sample period data (species abundance per site per sample) collected during 1996-1997 from Bold Park, Trigg Dune Reserve and Yanchep National Park, as each sample period is around 42 days long ± 2 days (Table 3.1). A similarity dendrogram indicating relative activity levels in each site is presented in Figure 5.17. Four clusters occur at the 34% similarity level.

The most different sample forming the first cluster, a spring sample from TD4, has an extremely high number of *P. scauroides* and few *S. lucidus*. Spring and summer samples from BP1 form a second cluster, characterised by high numbers of *S. lucidus* and *S. australis*. The third cluster of four samples comprises of winter and summer samples from BP1 and BP5 with one autumn BP1 sample. High numbers of *S. australis* and almost no *S. lucidus* define this cluster.

The final cluster comprises all remaining samples. In this cluster, varying abundances of three species, *P. scauroides, S. lucidus* and *S. australis,* account for the minor groupings apparent in this cluster. The first group comprises spring samples (BP5 and TD2) with these three species exclusively. Almost equal numbers of *P. scauroides* and *S. australis* characterise winter TD4 and one autumn BP5 sample, forming the second grouping. Slightly lower numbers of these two species are present in group three (spring YP2, autumn and winter TD2 and autumn TD4 samples). All remaining Yanchep samples, TD2 and TD4 summer samples and BP1 and BP5 autumn samples form a large fourth group characterised by low numbers of any species (especially *G. crassipes* and *C. scaritoides*). The final group in the fourth cluster consists of winter BP1, BP5 and TD2 samples, and BP1 and BP5 summer samples, defined by high numbers of *S. australis.*

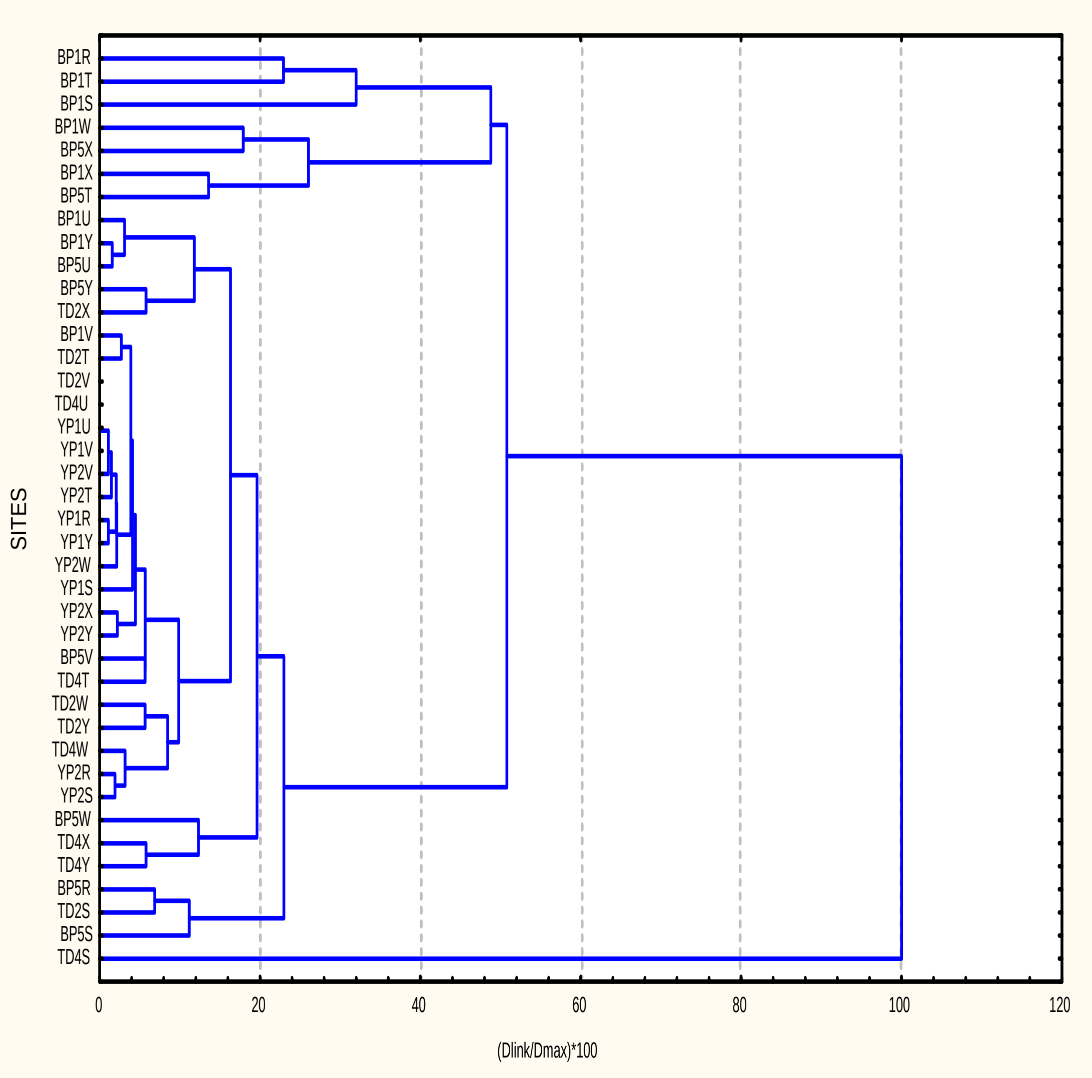


Figure 5-19: Dendrogram of similarity between site-sample periods (otherwise known as date codes)
For Date Code legend see Table 3.1) based on the terrestrial non-volant carabid fauna using Euclidean distances and UPGMA clustering, based on trapping data (see Appendix G for numbers) for the sites sampled 1996-1997. Shorter branches indicate a higher similarity between date codes. Note that at the 48% level of similarity 4 main clusters are apparent.

5.3.6 ENVIRONMENTAL INDICATORS.

Standard multiple regressions were used to determine the relationships between a series of environmental variables measured for the 1996-1997 trapping season and species richness in addition to abundances of particular species. Twenty five environmental parameters were scored for each of the sampling periods during this period. Parameters with very low correlations ($R^2 < 0.2$) with the dependant variables (i.e Non-volant species richness and abundances of *Gnathoxys crassipes, G. granularis, Promecoderus scauroides, Notonomus mediosulcatus, Sarticus iriditinctus, Simodontus australis, Carenum scaritoides, Scaraphites lucidus, S. silenus, Lecanomerus verticalis* and *Notagonum* sp.1) within the correlation matrix of the original twenty five (see Appendix A6 for the correlation matrix) were excluded from all subsequent multiple regressions.

This group of environmental parameters, treated as a whole, did not significantly explain the variance in the non-volant carabid species richness between sampling periods, or the abundances of *Notonomus mediosulcatus, Sarticus iriditinctus, Scaraphites silenus* or *Lecanomerus verticalis* ($p > 0.05$, Table 5.9). However, 30.47% of the variance in the abundance of *Notagonum* sp. 1 ($R^2 = 0.552$) and 12.74% of the variance in the abundance of *Scaraphites lucidus* ($R^2 = 0.357$) were significantly explained by a selection of the environmental parameters as a group (Table 5.9). The variance in abundance of *Gnathoxys crassipes* ($R^2 = 0.466$), *G. granularis* ($R^2 = 0.330$) *Simodontus australis* ($R^2 = 0.578$), *Carenum scaritoides* ($R^2 = 0.480$) and *Promecoderus scauroides* ($R^2 = 0.449$) were also significantly explained by the selected groups of environmental parameters as a whole (Table 5.9).

Individual parameters did not significantly explain the variance in the non-volant species richness, abundances of *Gnathoxys crassipes, G. granularis, Simodontus australis, Sarticus iriditinctus, Scaraphites silenus, Lecanomerus verticalis* or *Notonomus mediosulcatus* (Table 5.9). Stratum 2 % Cover ($R^2 = 0.981$), Leaf Litter Depth ($R^2 = 0.920$) and Distance to Bitumen ($R^2 = 0.944$) parameters explained significant amounts of unique variance in *Notagonum* sp. 1 abundance (Table 5.9). In contrast, only one environmental parameter was found to significantly explain the unique variance in abundances of *Carenum scaritoides* (Stratum 1 % Cover; $R^2 = 0.299$), *Promecoderus scauroides* (Size of Remnant Area; $R^2 = 0.602$) and *Scaraphites lucidus* (Relative Humidity (9am); $R^2 = 0.230$; Table 5.9).

Table 5-9: Multiple regression co-efficients (R^2) values for the individual environmental variables and the multiple regression co-efficient value (R^2 Value#) associated with the selected environmental variables as a set with the Non-volant species richness values, and Abundance values for selected species for all Quindalup sites surveyed 1996-1997.

Note: n = 40 date codes; – = not included in regression; significance levels: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, **** = $p < 0.0001$.

Environmental variables	Non-volant Species Richness	*Gnathoxys crassipes* Abundances	*Gnathoxys granularis* Abundances	*Promecoderus scauroides* Abundances	*Notonomus mediosulcatus* Abundances	*Sarticus iriditinctus* Abundances	*Simodontus australis* Abundances	*Carenum scaritoides* Abundances	*Scaraphites lucidus* Abundances	*Scaraphites silenus* Abundances	*Lecanomerus verticalis* Abundances	*Notagonum* sp.1 Abundances
REMNANT AREA (HA)	0.644	-	0.876	0.602*	-	0.027	0.958	-	0.632	0.389	-	0.918
TRAP. PERIOD (DAYS)	-	-	-	-	-	-	0.251	-	-	-	-	-
FIRE AGE (YRS)	-	-	-	-	-	-	-	-	-	-	-	-
REMNANT AGE (YRS)	-	-	-	-	-	-	-	-	-	-	-	-
PRECIPITATION (MM)	-	0.819	-	-	-	0.780	-	0.668	-	-	0.812	0.823
DIURNAL TEMP (°C)	-	0.935	-	-	0.007	-	-	0.674	-	-	-	0.941
NOCTURNAL TEMP (°C)	-	-	-	-	-	-	-	-	-	-	-	-
REL. HUM (9AM)	-	0.903	-	-	-	-	-	-	0.230*	-	0.813	0.912
REL. HUM (3PM)	-	0.952	-	-	-	0.820	0.822	-	-	-	0.872	0.955
CLOUD HI (OKTAS)	-	0.971	-	-	-	0.917	0.781	-	-	-	0.926	0.973
CLOUD LOW (OKTAS)	-	-	-	-	-	-	-	-	-	-	-	-
SUNLIGHT (HRS)	-	-	-	-	-	-	-	-	-	-	-	-
STRATUM 1 HT	0.925	-	0.944	-	-	-	0.974	0.830	0.887	-	-	-
STRATUM 1 % COVER	0.839	0.701	-	0.807	-	-	-	0.299*	-	-	-	-
STRATUM 2 HT	0.898	-	0.946	0.911	-	-	0.981	0.971	0.898	-	-	0.983
STRATUM 2 % COVER	-	-	-	0.707	-	-	-	0.829	-	0.299	-	0.981*
STRATUM 3 HT	0.946	-	0.780	0.814	0.333	-	0.953	0.918	0.810	-	-	0.947
STRATUM 3 % COVER	-	0.660	-	-	-	-	0.899		-	-	0.553	-
STRATUM 4 HT	0.903	0.652	0.789	-	0.330	-	0.958		0.651	-	-	-
STRATUM 4 % COVER	-	-	-	-	-	-	-		-	-	-	-
LEAFLITTER % COVER	-	-	-	-	-	-	-		-	-	-	0.952
LEAF LITTER DEPTH (CM)	0.819	0.811	-	0.793	-	-	0.818		0.788	-	-	0.920*
DIST. TO BITUMEN (M)	0.875	-	-	-	-	-	-		-	0.508	-	0.944*
NEAREST REMN. (KM)	-	-	0.831	-	-	-	0.963	0.788	-	-	0.552	-
DIST. TO BEACH (KM)	-	-	-	-	-	-	-	-	-	-	-	-
R^2 Value#	0.322	0.466*	0.330*	0.449**	0.121	0.361	0.578**	0.480**	0.357*	0.107	0.258	0.552*

5.3.6.1 Summary Findings of the Quindalup Dune System Carabids

The significant findings of the study of the carabid assemblage present in the bushland remnants of the Quindalup Dune System are presented below.

- 20 species from 16 genera representing 9 subfamilies were collected on the Quindalup Dune System. Single specimens represented 7 species, of which 5 were volant species; and three species (*Simodontus australis*, *Promecoderus scauroides* and *Scaraphites lucidus*) formed 94.27% of the total number of individuals caught.
- Seasonal activity periods differed considerably between species: *S. australis* was active all year but two population pulses occurred in spring and autumn, the only cool weather active species was *P. scauroides* (autumn/winter active), and two species were most active during drier periods (*S. lucidus* active between spring and summer; *G. crassipes* was collected from late spring to autumn).
- Younger dune sites (Woodman Point, Mount Claremont and Trigg Dune remnants) had greater similarity in carabid assemblage structure than older dune sites (Bold Park and Yanchep National Park).
- The environmental parameters estimated for the sampling periods as a whole were not useful in explaining the variance in non-volant species richness between sampling periods, or the variance in abundances of *Lecanomerus verticalis*, *Notonomus mediosulcatus, Sarticus iriditinctus* and *Scaraphites silenus*. The variance in abundances of *Notagonum* sp. 1, *S. lucidus, Gnathoxys crassipes, S. australis, P. scauroides* and *Carenum scaritoides* were accounted for by a several environmental parameters. The individual environmental parameters did not account for the variance in either non-volant species richness or the abundances of the individual species. The exceptions to this were *C. scaritoides, P. scauroides* and *S. lucidus*.

5.4 DISCUSSION

5.4.1 SWAN COASTAL PLAIN CARABIDAE

It appears that, while being somewhat more speciose than other Australian habitats, the Swan Coastal Plain carabid assemblage is of the same order of magnitude, and of a similar range compared to the results of other studies. At least 37 carabid species in 26 genera from 11 subfamilies are present on the Swan Coastal Plain. Of these, 18 species are present on at least one geological formation or landform.

These data are consistent with Lövei and Sunderland (1996) who reported that in the temperate areas of the world 10 to 40 carabid species are usually found within a habitat during any one season. Michaels and McQuillan (1995) collected 18 species (from 16 genera within 10 subfamilies) from Picton, Tasmania. Horne (1992) reported 15 carabid species from southern Victoria and Horne and Edwards (1998) collected 28 species from the western agricultural regions of that state. Melbourne (cited in Melbourne *et al.* 1997) reported collecting 24 species representing 22 genera in Victorian grassland habitats. Carabid species richness was found to vary from one to 10 species in the dry sclerophyll forests of the Eastern Tiers, Tasmania (Michaels and Mendel 1998). The highest number of carabids comprising one assemblage (45 species) was reported by Davies and Margules (1998) in the Wog Wog habitat fragmentation experiment site.

The species richness across individual sites on the Swan Coastal Plain varied between one and eleven species. Similar low levels of species richness (2-9 species) was reported by Melbourne (cited in Melbourne *et al.* 1997). Michaels and McQuillan (1995) also reported low species diversity per site (4-11 species per site). Likewise, site diversity in the Eastern Tiers was low (1-10 species per site; Michaels and Mendel 1998).

Comparisons can be made between the carabids and the reptile fauna (skinks and other smaller lizards especially) of the Swan Coastal Plain surveyed concurrently during 1993-1996. Smaller reptiles such as skinks and geckos are similar in size to the larger carabid species (*Scaraphites* sp., *Gnathoxys granularis* and *Carenum* sp.) and are potential competitors, predators or even prey of these invertebrates. Various accounts exist of specimens of *Scaraphites* sp. consuming skinks, geckos, small mammals (such as small rodents) and mygalomorph spiders when caught in live pitfall traps (R. How, M. Bamford; pers. comm.).

How *et al.* (1996) found that overall reptile species richness, reptile species richness minus skink species and lizard minus skink species richness showed significant positive relationships with the log of remnant area. Skink species were found to be less area dependent. Smaller remnants therefore are important for short to moderate-term survival of skink populations (How *et al.* 1996).

Total species richness did not have a significant relationship with the log of remnant area. This contrasts with Abensperg-Traun *et al.* (1996) who reported a significant relationship between total carabid species richness and remnant area in the Wheatbelt. These authors suggest that larger remnants (which tend to be better connected to other remnants) are more easily colonised by carabids than smaller (and less well connected) remnants. As carabids are considered to be relatively poor fliers compared to other beetle families or are flightless (den Boer 1990) the inability to colonise smaller remnants may be partially responsible for the results of Abensperg-Traun *et al.* (1996). However the level of connectivity between bushland remnants on the Swan Coastal Plain may be sufficiently high enough to allow movement of carabids between them (possibly via native gardens), thereby inhibiting any indication of a significant relationship between species richness and size of remnant area. This evidence indicates that, at least on the Swan Coastal Plain, like skinks (How *et al.* 1996) carabid species are not area dependant, and that small remnants are important in maintaining the resident carabid assemblage.

The four main geological landforms of the Plain (Quindalup, Spearwood, Bassendean Dune Systems and the Ridge Hill Shelf) have formed relatively recently, in geological terms. The Swan River, bisecting the Plain, has existed during this time, affecting soil formation. Physical and climatic environments, influenced by the position of the Plain between the wet and cool south western region of Western Australia and the arid northern coasts and interior, have combined with cool offshore oceanic currents, to form distinct climatic gradients across the Plain. Physical characteristics such as salt loading, nutrient levels, and to a lesser extent soil structure, differs between the landforms and from south to north as a result of these factors.

Plant species and many vertebrate species have adapted to exploit these gradients. Many of these organisms have distributions related to these gradients or are confined by physical barriers such as the Darling Scarp or Swan River. Differences in the carabid assemblage are strongest in an east/west direction (reflecting dune characteristics) and weakest in a north/south direction (the Swan River does not appear to form a zoo-geographical barrier to the carabid assemblage (whereas it does for reptiles; How *et al.* 1996). Quindalup dune and Cottesloe Sands (Spearwood Dune System) sites tended to show the greatest affinity, reflecting the heath and Tuart woodland vegetation of these remnants.

The *Banksia* woodlands (on which the majority of these remaining sites are situated on) of the Spearwood and Bassendean Dune Systems differ markedly in their geomorphology and understory assemblages (Gibson *et al.* 1994). The loose aggregations of sites from these remnants may be reflecting these subtle localised physical and vegetation characters rather than a generalised overall soil profile (as exhibited by the Quindalup sites).

Differences in the environmental parameters measured across the Swan Coastal Plain were minimal, and did not appear to significantly influence carabid species richness or directly influence the distribution of individual species on the Plain. Significant associations between carabid community structure and age of site regeneration and litter depth were found, but no associations with soil pH, proportion of bare soil or litter cover present were found by Michaels and McQuillan (1995). Michaels and Mendel (1998) found no significant association between environmental parameters and the distribution of individual carabid species in the Tasmanian Eastern Tiers.

Notonomus mediosulcatus and *Sarticus iriditinctus* exhibited very restricted distributions, present in several remnants by few specimens. The lack of specimens for these species across sites and also across sample periods may be attributable to the apparent lack of relationships with both sets of environmental parameters.

Gnathoxys crassipes and *G. granularis* had no significant relationship with the set of synthetic environmental parameters across the Swan Coastal Plain. The former is present in all remnants except for Talbot Road Reserve (Ridge Hill Shelf), Landsdale Farm School and Marangaroo Conservation Park (Spearwood/ Bassendean junction sites). *Gnathoxys granularis* was only collected from Yanchep National Park and Talbot Road Reserve. These two remnants may be near the southern limit of this species' range (see distribution map in Chapter 4). The significant relationship with the individual environmental parameter, precipitation in the driest month, suggests that the distribution of *G. granularis* may be influenced by a maximum level of precipitation. On the Swan Coastal Plain *G. crassipes* and *G. granularis* were not significantly correlated with individual seasonal environmental parameters (ie parameters collected for each individual sampling period) but with these parameters as a set.

The significant correlation between environmental parameters (seasonal) and the individual parameter Stratum 1 % cover with *Carenum scaritoides* abundance suggests a cool weather adult activity period and a reliance on a minimum level of herbaceous cover. This species also may be restricted to the Quindalup Dune System on the Swan Coastal Plain.

Scaraphites lucidus was only caught during spring and mid-summer. Significant correlations with both sets of environmental parameters (Plain wide and seasonal) were found in addition to a relationship with the individual seasonal parameter relative humidity (9am). The lack of specimens from Yanchep National Park and non-Quindalup Dune sites (in addition to the distributions presented in Chapter 4) indicates a coastal and riverine distribution. Trigg Dune Reserve and Bold Park may be among the northern limits of its distribution.

In contrast, *S. silenus* showed no correlations with environmental parameters individually or as set for both regressions. Few specimens were collected across the Swan Coastal Plain, but the distribution records (see Chapter 4) indicate that this species is widespread and the lack of specimens here is probably by chance. Generally not found in association with *S. lucidus, S. silenus* appears to have a similar spring activity period and replaces the former species on the older dunes and inland east of the Swan Coastal Plain.

Little is known about the habits of species of *Scaraphites*, except for research on a population of *Scaraphites rotundipennis* (Dejean) on Flinders Island (McQuillan 1983). This genus appears to be an active predator of scarab larvae and its activity periods may be related to that of its principle prey items. Aestivation may account for the inactivity during the remainder of the year.

Horne (1992), Melbourne (cited in Melbourne *et al.* 1997) and Davies & Margules (1998) found that a high proportion of the individuals caught represented single species. Similarly, in the present study on the Quindalup Dune System, *Simodontus australis* accounted for 50% of the individuals caught, with two further species, *Promecoderus scauroides* and *Scaraphites lucidus*, accounting for an additional 44% of the individuals caught on the Quindalup Dune sites. All species were rare prior to 1996, but during 1996-1997 *S. australis, P. scauroides* and *S. lucidus* significantly increased in number in the pitfall traps. Whether this is a cyclic population increase and decrease is unknown, but environmental conditions such as temperature, rainfall, relative humidity and sunlight did not appear to change significantly over the five year trapping period. Despite indications that carabid phenology is affected by abiotic factors (Thiele 1977) it is unclear at present what caused the sudden increase in numbers of individuals caught.

Simodontus australis and *P. scauroides* were present throughout the year, but exhibited population increases in winter. A second population increased also in late spring/early summer for the former species; and during spring/early summer and again during autumn/early winter for the latter species. This evidence indicates possible overlapping cohorts for both species. Horne (1990) reports evidence of two cohorts of previous and current year adult *Notonomus gravis* (Chaudoir) within a population. While it is extremely difficult to differentiate between teneral and old (non-teneral) adults captured in the ethylene glycol used in the pitfall traps, the presence of bronze adults with soft elytra among normal coloured adults with non-depressable elytra would suggest that *S. australis* may also have 2 cohorts in the adult stage simultaneously.

Lecanomerus verticalis exhibited significant correlations with the environmental parameters as a set across the Plain and with the individual parameters, precipitation of the coolest month and temperature of the wettest quarter. No significant correlations were found with the seasonal parameters, either as a set or individually. This suggests that distributions of *L. verticalis* are influenced by cool wet conditions.

Notagonum sp.1 only showed significant correlations with the seasonal parameters as a set and the individual parameters, leaf litter depth and Stratum 2 % Cover. This suggests that leaf litter build up and shrub density is important to the presence of this species.

While the volant carabid assemblage forms the majority of the species collected, the very restricted distributions within remnants and between landforms, produces a relatively uninformative dendrogram (Figure 5.5). The pitfall trapping technique used is designed to capture ground dwelling organisms rather than volant or arboreal species. Therefore, the apparent restricted distributions may be partially attributable to an artifact of the collecting method.

Most sites within a remnant did form discrete clusters on the dendrograms indicates that, for the younger areas of Quindalup Dune Bushland, carabid assemblages within remnants are more similar than between remnants. Also differences between years generally are not as great as between remnants. The non-volant carabid assemblage exhibits a tendency to form clusters within the landforms.

Assemblages did not alter greatly between years at either Bold Park or Trigg Dune Reserve. Two new species were collected in the second year of surveying at Bold Park, site BP1 (*Notonomus mediosulcatus* and *Scaraphites silenus*). The former was the only species caught for the first time in a second year of sampling.

The analysis of percent occurrences from the Quindalup Dune sites indicates that while the assemblage structure is very similar between years at any one locality, the relative abundances can vary significantly between years. The underlying causes for such population changes can not be determined in this study. Lovie and Sunderland (1996) suggested that the larval stage of a carabid is the most vulnerable, examination of the larval biology therefore may indicate what is causing the population variability between years.

Most previous carabid assemblage studies in Australia (Horn 1992; Michaels and McQuillan 1995; Horn and Edward 1997, 1998; Melbourne 1998; Bromham *et al* 1999) indicated that the majority of carabid species are sporadic and low in numbers. However, these studies were based on between 12 and 18 months field data. New (1998) stated "rare carabid taxa of uncertain incidence and consequently low monitoring value will result in few species of carabid will be reliable monitors of environmental change". He also suggested that this apparent rarity was one of the reasons little attention has paid to carabids compared to other more abundant and diverse groups. However this current study shows that, apparently rare taxa (*Simodontus australis, Promecoderus scauroides, Scaraphites lucidus*) collected between 1993 and 1996 can, within a year become abundant enough to be potentially useful as "monitors of environmental change". In addition the very fact that these species do appear to have "boom and bust" years of population change may be a useful attribute if the group is to have a role in monitoring environmental change (similar to the population cycles of Canadian snowshoe hares and lynxes).

Until surveys which are of a long enough duration to encompass carabid species population cycles it is suggested here that New's (1998) label of "rare and consequently low monitoring value" should not be applied.

5.4.2 GENERAL DISCUSSION

Differing assemblages were associated with different landforms of the Swan Coastal Plain (Quindalup, Spearwood and Bassendean Dune Systems, and the Ridge Hill Shelf). As expected, several species were found to be ubiquitous over this area but when combined with more restricted species, these landforms could be identified by their carabid assemblages. Of the 37 species collected in the wet pitfall traps, only two volant species were found on all geological systems compared to five non-volant species. This apparently highly restricted volant assemblage is probably an artifact of using pitfall trapping as the major sampling technique, particularly given their flying habit.

Examination of data obtained from vertebrate pitfall trapping run concurrently with the invertebrate death pitfall traps during 1993-1996 by How *et al* (1996) indicates the extent to which this artifact of trapping occurs. Species richness for several sites may have been higher if individuals caught in vertebrate pitfall traps were included in the analysis. Based on wet pitfall data alone, *Gnathoxys crassipes*, *Neocarenum* sp.1, *Scaraphites silenus* and *Sarticus* sp. are absent from BP3, BP4, JK1, PA5, PA6, PA7, HH3, MH1; JK2, PA8; PA6, TR1, TR3, TR4 and LS1 respectively. But they were collected from vertebrate pitfall traps at these sites. *Neocarenum* sp. 2, *Hormacrus latus* and *Speotarus* sp.2 were only collected from the vertebrate pitfall trap. Six other species were only collected from vertebrate pitfall traps at certain sites and were present in both trap types at others. Without the concurrent vertebrate pitfall trapping these other species would not have been detected.

How (1998) found that to fully document the herpetofauna of Bold Park, sampling was required over a seven year period. During that time he found that only 79% of the fauna was captured in any one year. Of this fauna, the more common species were captured first and the rarer, more habitat restricted species were caught less often, and later in the trapping sequence (How 1998). Furthermore, there was considerable variation between years in assemblages caught. Some species were absent for considerable periods of time between first capture and second occurrence. How (1998) suggests that the sampling effort to adequately document the herpetofauna of a remnant is beyond the normal time period of most environmental impact and management surveys.

Michaels and Mendel (1998) report that only 83% of carabid species were collected in the first twelve months of trapping. The second sampling program (1996-1997) in Trigg Dune Reserve and Bold Park, increased the known species from these remnants by two and seven species respectively. If the other previously surveyed remnants had been included there is the possibility that the fauna collected from the vertebrate traps and those caught at Trigg Dune and Bold Park may have been collected there as well. Similar to that found with the herpetofauna (How 1998), to document the carabid fauna of an area, it may take an intensive sampling effort over several years.

There is evidence for distinct seasonal activity periods for several carabid species. The appearance of these species in the traps is relatively consistent between years and remnants, but the six week trapping period used was too long to clearly correlate individual weather patterns with these activity periods. Relationships with a variety of environmental parameters (both synthetic climatic and seasonal data) however, are indicated.

This study has provided evidence for correlations between seasonal activity periods and several environmental variables for several carabid species on the Swan Coastal Plain. Microclimatic conditions of the carabids' immediate environment (such as in burrows, under leaf litter etc) probably exhort a greater influence on the activity periods that the environmental variables measured. However, these data provide initial information for further phenological studies.

CHAPTER 6:

DISCUSSION AND CONCLUSIONS

6.1 INTRODUCTION

It is well established that insects are major lower level components of the food web in virtually all terrestrial environments (Majer 1980, 1983) and the probable importance of this fauna in maintaining integrity of the ecosystem has been widely documented in the literature. Despite the unquestioned importance of insect populations, the effects of habitat fragmentation on them are largely unknown due to limitations in knowledge about individual species and species interactions. Nevertheless, it is clear that long-term maintenance of habitat fragments in the absence of their constituent insect fauna may be impossible (Saunders *et al.* 1991) because of the loss of diversity and the complexity of insect-driven ecosystem interactions (Fisher 1998). Before the effects of habitat fragmentation on insect assemblages and the flow-on effects to the habitat can be determined, baseline documentation of the insect fauna in a particular habitat is required.

This study set out to document the terrestrial Ground Beetle (Carabidae) assemblage on the Swan Coastal Plain and specifically, the Quindalup Dune System. Systematic documentation of this fauna has not previously been attempted for this region. Therefore, this study constitutes baseline data to aid in the management and conservation of the carabid assemblages present in the bushland remnants of the Metropolitan Area of the Swan Coastal Plain.

This Chapter provides a summary of the major findings of the study, draws comparisons between the carabid assemblages and other major invertebrate groups on the Swan Costal Plain, and examines the special implications of habitat fragmentation for the carabid fauna. In addition, factors which may threaten the persistence of Ground Beetles on the Quindalup Dune System are discussed. Finally, a number of conclusions are drawn and recommendations made regarding carabid conservation in these areas.

6.2 GENERAL DISCUSSION

6.2.1 *CARABID DIVERSITY AND DISTRIBUTION ON THE QUINDALUP DUNE SYSTEM*

The vegetation of the Quindalup Dune System has often been portrayed as having a simple structure and relatively few plant species compared to communities further inland (Speck 1952; Seddon 1972; Cresswell and Bridgewater 1985). Since invertebrate fauna is commonly thought to track vegetation communities in structure and diversity (Greenslade and Greenslade 1984), it was assumed that the invertebrate assemblage of the Quindalup Dune System would also be comparatively simple.

Both sets of assumptions are probably in error. In the first place, detailed studies of the Quindalup Dune System by Powell and Emberson (1981), Keighery *et al.* (1990), Meney (1991) and Mitchell McCotter (1993) revealed both high diversity and structural complexity in its vegetation communities.

Secondly, studies by Yen (1987), Michaels *et al.* (1998) and Michaels (1999) have shown that it would be incorrect to assume invertebrate, or specifically carabid, diversity tracks vegetation diversity or complexity. Siemann *et al.* (1998) report that the relationship between plant and arthropod diversity is much more complicated than first indicated. These authors found that while plant diversity did indicate, to some degree, the arthropod diversity, the different trophic groups had differing responses. For example, herbivore diversity was found to be influenced by plant diversity but it was more strongly correlated with parasite and predator diversity. This suggests that trophic organisations of arthropod assemblages may reveal better correlations with plant diversity or physical variables rather than as arthropods as a group. Areas of high floristic diversity or structural complexity do not necessarily correspond to high levels of beetle diversity. Michaels and Mendel (1998) concluded that conservation measures based on plant species richness were unlikely to be sufficient for carabid conservation. These authors also indicated that areas which had low plant diversity but high numbers of individuals of certain carabid species may be source sites for migration to other areas. However, Crisp *et al.* (1996) found a positive trend between native beetle diversity and native plant diversity.

From the present study of the Quindalup Dune System and the wider Swan Coastal Plain, it appears that carabid assemblages differ across the major geological features, but differences between the older dune systems are less distinct. This may be attributable to associations with the *Banksia* woodlands which reflect fine scale geological associations of the older dune systems.

Within the context of the Quindalup Dune System, samples tend to cluster together on the basis of sampling period and to some extent by site across years. This supports the conclusions of Eyre *et al.* (1986) and Luff *et al.* (1989) who argued that within a broad habitat type, environmental conditions other than vegetation characters, influence carabid distribution. Further work comparing these assemblages with those present in other vegetation associations on the Swan Coastal Plain is required to detect relationships between species, habitat types and regions.

Large between-year variations in carabid species abundances are not obviously correlated with any measured environmental parameters. Intuitively, microclimatic conditions in the immediate surroundings may be more relevant to carabid species abundances. Minimal humidity and temperature levels maintained at the bottom of the tunnel or within the leaf litter may determine the persistence of the fauna in a particular area rather than climatic conditions on a larger scale.

Horne (1990) reported that *Notonomus* individuals were collected sheltering under rocks and logs, and McQuillan (1983) reported that *Scaraphites rotundipennis* shelters within deep burrows. The more stable microclimates in these locations would obviously be buffered to some extent against climatic fluctuations. Information on soil moisture retention and leaf litter production may be of far greater relevance in predicting breeding success, emergence of adults and survival in carabid beetles.

The various surveyed remnants have had varied and, in some cases, extensive histories of disturbance and fragmentation (see Chapter 2). However, as the carabid assemblages are relatively similar across all Quindalup Dune sites it appears that these taxa have been able to persist in each of the remnants despite these influences. Despite this indication of resilience, it should not be forgotten that carabid diversity is generally correlated with remnant size (Abensperg-Traun *et al.* 1996), thereby raising the possibility that some carabid species, perhaps those more susceptible to disturbance, have already become extinct at the localities surveyed.

6.2.2 COMPARISONS WITH OTHER INVERTEBRATE FAUNA

Harvey *et al.* (1997) reported comparable species richness values for Blattodea, baeine wasps, Scolopendrida and Pseudoscorpionida to that reported here for the Carabidae. Opiliones and Scorpionida were found to be slightly less diverse. Conversely, the Araneae were nearly ten times more diverse at each Bold Park, Perth Airport, Tuart Hill and Talbot Road Reserve site examined (Harvey *et al.* 1997). It is likely that comparable levels of diversity among the groups mentioned above will occur in the remaining sites surveyed by How *et al.* (1996), which are yet to be analysed by these authors.

Harvey *et al.* (1997) reported that several arthropod species were confined to the Quindalup Dune sites almost exclusively despite having broader distributions outside this area. For example, *Geogarypus taylori* Harvey (Pseudoscorpionida), and *Missulena granulosa* Hogg (Mygalomorphae) were found only on Quindalup remnants in this survey, even though the former taxon is widespread across the southern region of Australia, and the latter species is found in various habitats across south-western Australia (How *et al.* 1996). Similar distribution patterns are reported here for *Scaraphites lucidus* and *Carenum scaritoides*, with both species restricted to the Quindalup Dunes within the Swan Coastal Plain but are known to occur in other habitats in south western Australia

The number of species and new taxa collected indicate that the Swan Coastal Plain bushland remnants are acting as refuges despite their highly fragmented states. Woodman Point Reserve is particularly important as a refuge for rare and relictual species. Harvey *et al.* (1997) reports that in addition to *G. taylori*, four undescribed arachnids were collected from this remnant. An undescribed *Nesidiochernes* sp. (Pseudoscorpionida; Chernetidae) was also present at Woodman Point in addition to the other Quindalup sites (MC, BP1, BP5; How *et al.* 1996). When *G. pannuceus* is included, it appears that Woodman Point has a particularly unique assemblage of predatory invertebrates compared to other Quindalup Dune remnants and to the wider Swan Coastal Plain environment.

Several undescribed arachnid species were found within the Bold Park-Mount Claremont Reserve area. These include species of *Aname*, the endemic clubionid *Meedo* and the first record of a member of the Lachesaninae (Zodariidae) for Western Australia (How et al. 1996). While the carabid fauna of the Bold Park-Mount Claremont Reserve contained no undescribed species, new locality records for Sarticus iriditinctus and Notonomus mediosulcatus in Bold Park considerably extended the known ranges of these species.

The ant fauna has not been examined from the particular sites covered by this study. However, surveys of similar Quindalup Dune areas by Rossbach and Majer (1983) and Burbidge *et al.* (1992) indicate that the ant fauna consists of about 25 species, which is higher than the carabid fauna reported here. This supports New's (1998) suggestion that in Australian environments ground-dwelling Carabidae are considerably less diverse than ants. .

The diversity of terrestrial carabids of the Quindalup Dune System (and wider Swan Coastal Plain) is comparable to the carabid faunae reported for other Australian habitats. Moreover, it demonstrates that carabids (and especially the non-volant component) represent a significant component of the predatory invertebrate guild. Defining relationships among remnants based on the carabid fauna alone could be misleading, due to the relatively few species involved, the strong temporal influence in community composition, and the lack of information concerning species life history. However, such studies could elucidate more information if they are based on the whole predatory invertebrate guild, with carabids as a component (along with arachnids, chilopods and other predatory insects) rather than a singular group.

6.2.3 FACTORS AFFECTING CARABID POPULATIONS IN QUINDALUP REMNANTS

6.2.3.1 Pesticides

There is increasing awareness of the effects of pesticides on non-target invertebrate species (Duffield and Baker 1990). While there is no direct evidence that pesticides have caused any insect species extinction, there is evidence that they have fragmented and considerably reduced local populations (Samways 1994). As suggested by Thacker and Hickman (1990), the likely exposure routes of pesticides can be predicted from knowledge of the ecology of a particular species or group of insects. The likely exposure routes for carabids in arable land are topical, residual and dietary.

Pesticide use around the perimeter of all remnants studied must be considered as a potential threat to maintaining carabid diversity. Urban residential areas surround Trigg Dune Reserve, and the Bold Park-Mount Claremont Reserve. Yanchep National Park is adjacent to a private cattle farm where the use of pesticides cannot be discounted. While none of the remnant areas have pesticides directly applied within their boundaries, pesticide spray drift, along with general atmospheric fallout, may represent a considerable problem (Yen and Butcher 1997). Various agricultural studies have shown that carabid numbers are reduced after direct exposure to pesticides (Basedow 1990; Duffield and Baker 1990; Thacker and Hickman 1990 and references therein).

Effects due to exposure by pesticide contaminated ground water in carabid burrows of adult and offspring (as eggs or larvae) has not been documented. As many insecticides are designed to disrupt juvenile insect development the incidental effects on carabid egg survival exposed by this route may be an important factor affecting population maintenance.

Pesticides used to control termites, ants and other household insect pests are highly toxic, but are usually delivered directly to the nest or infestation site. However, as insecticides are often transferred through the food chain the broader impact may be considerable. Accumulation of pesticide residues in predatory species can lead to death or to sub-lethal effects including developmental problems and reduction in reproductive success. Recent investigations by Purvis and Bannon (1992) and Kramarz and

Laskowski (1999) suggest that a lack of prey items resulting from effects of pesticides, in addition to direct toxicity may be an important factor in reducing invertebrate predator populations.

Three commercial herbicides are used in Bold Park/Mount Claremont, Trigg Dune and Woodman Point Reserves. Generally, all three chemicals (Roundup-Biactive, also known as Glyphosate 360; Brushoff; and Garlon) are used to control weeds such as veldt grass, Bridal creeper, Geraldton carnation, castor oil and fig trees, and Agaves. Roundup is used all year round in all remnants to spot control weeds, however its use in Trigg Dune Reserve is restricted to the dirt firebreak bordering the northern fragment. In both Bold Park and Woodman Point Reserve, the use of Brushoff is restricted to the cooler months, and Garlon is only used in late summer in Bold Park.

Toxicological information available for Roundup and Garlon indicates that both chemicals have low toxicity to commercial honey bees (Monsanto Material Safety Data Sheet No. 147, 148; Dow AgroSciences Material Safety Data Sheet respectively). The effect on the local invertebrates is unknown, but as precautions are used to limit application to only the plants to be removed any possible effects are probably minimised. However, Kramarz and Laskowski (1999) showed that house flies (*Musca domestica*) at all life stages were killed by exposure to the surfactant linear alkylbenzenesulphonate (LAS). In contrast no significant sublethal effects were found in centipedes (*Lithobius mutabilis*; Kramarz and Laskowski 1999). It is currently unclear how similar, structurally or chemically, this surfactant is to Agral 600, which is used as a wetting agent or surfactant with the chemicals Brushoff and Roundup. It is also unclear whether the susceptibility of the flies to LAS can be extrapolated to other insects and therefore carabids. Alternatively, carabids occupy predatory roles similar to that of centipedes and therefore may show limited or no sublethal effects.

While there is no evidence to suggest that herbicide use has so far affected carabid populations in any of the reserves, a cautionary approach is suggested. Limiting the use of such chemicals around the periphery of reserves and in adjacent gardens can only benefit the native fauna within the remnants and increase their chances of dispersal between remnants.

6.2.3.2 Feral Predators

The impact of feral predators on native Australian vertebrate populations has been well documented (Burbidge and McKenzie 1989). However, comparable studies concerning their effects on invertebrate fauna have not been carried out.

While the feral cat (*Felis catus*) is known to feed on small vertebrates, including small lizards, there is little evidence to show that it actively targets invertebrates as food unless severely starved (D. Algar, pers. comm.).

In contrast, dietary studies on the red fox (*Vulpes vulpes*) show that Orthoptera, Blattodea, Lepidoptera and various Coleoptera (adults and larvae, especially scarab beetles) are targeted as major food sources during summer and autumn (McIntosh 1963; Martensz 1971; Coman 1973; Ryan and Croft 1974). McIntosh (1963) found that centipedes and to a lesser extent, scorpions and spiders were also consumed.

Griffin (1990) in a study of two National Parks north of Perth on the Dandarragan Plain found that fox predation on invertebrates concentrated on beetles, especially carabids. Invertebrates formed approximately 33% by weight of the fox gut contents from individuals caught in September 1989 (Watheroo National Park) and in March 1990 (Watheroo and Alexander Morrison National Parks). Pitfall traps were run concurrently to obtain approximate ratios of invertebrate species present.

Invertebrate species found in gut contents collected in September 1989, were: Carabidae (3 spp.), Tenebrionidae (1 spp.), Scarabaeidae (3 spp.), Scolopendridae (1 spp.) and Scorpionidae (1 spp.). The three carabid species were *Scaraphites* sp. (10% in gut, 25% in trap catch by number), *Neocarenum* sp. (1% in gut, 10% in traps) and *Parroa* sp. (1% in gut, 8% in traps). In comparison, only two carabid species predominated in the March 1990 gut contents (other invertebrates were present). *Gigadema* sp. and *Scaraphites* sp. formed 50% and 4% of the trap catches but only 14% and 3% of the gut contents respectively.

Energy analysis by Griffin (1990) indicated that *Scaraphites* sp. was second to *Urodacus armatus* (Scorpionida) as an energy source. *Scaraphites* sp. were also the second most frequently eaten species. Overall, Griffin (1990) concluded that foxes were selectively taking various carabid species, but was undecided whether this predation influenced abundance levels of these species.

These studies clearly demonstrate that foxes prey on a variety of carabids, although the extent of any impact on carabid abundance or diversity is not clear.

Evidence of fox activity was recorded in all remnants in this study, including frequent trap disruption at YP1 (Yanchep National Park) and at TD2 (Trigg Dune Reserve) after the 31 Dec 1996 fire. Whether the trap disruption was due to simple curiosity or to obtain animals caught in the trap is unknown. In the inner urban remnants incidental predation by foxes, over an extended period of time, could potentially eliminate the larger carabid species from these areas. Control or elimination of foxes in these isolated remnants found in the urban environment may improve the survival of carabids and other ground-dwelling invertebrates in these areas.

6.2.3.3 Further Habitat Fragmentation

Although the major urban bushland remnants are accorded some measure of protection under the current reserve system, they are by no means immune to the threat of further fragmentation. This threat takes two main forms, fire; and urbanisation.

As demonstrated by the arson attack at Trigg Reserve during this study and the fire record for Yanchep National Park, fire can alter the habitat severely for extended periods. The impact of both arson and clearing burns in relatively small remnants can be much greater than in un-fragmented environments. The absence of fire, rather than its presence, appears to have been a major factor in shaping the vegetation of the Quindalup Dune System (see Chapter 2, Woodman Point Reserve History for evidence). Therefore, any outbreaks of fire, however small, can have major impacts on both the immediate survival of carabids and their future persistence in the remnant.

Two recent experiments addressing invertebrate response to fire have assessed the impact on carabid diversity and abundance. Friend and Williams (1993) found that in mallee-heath remnants carabids declined in abundance in the short term after autumn fires, but year to year changes coupled with differences between locality were greater than the observed fire-related trends. Van Heurck *et al.* (1997, unpublished) reported no significant differences in carabid species richness between central Jarrah Forrest sites burnt in autumn and the species richness of sites burnt in spring. These studies suggest that carabid community responses to fire can be influenced by the species present and season of fire occurrence. However, the effects on larval survival during and immediately after such fires have not been documented. This may have more relevance to long term carabid survival in burnt areas rather than adults moving into the area.

Fires which occurred during this study took place during early summer (except for one fire in March at the Perth Airport). While several carabid species such as *Carenum scaritoides, Scaraphites lucidus, S. silenus, Promecoderus scauroides* and *Simodontus australis* are active at this time, infrequent small scale fires which burn over a short time period are unlikely to adversely affect the remnant populations. However, fires, which destroy large areas of a fragment or occur too frequently can impact on the entire local population. Friend (1995) concluded that the impacts of fires in southern forested regions of Australia are only apparent three to five years after the fire. This suggests that fires occurring within five years of each other, even if they are small scale, may have adverse effects on carabid populations within remnants. Re-invasion from neighbouring fragments within the reserve may then be restricted due to the presence of potential barriers such as roads.

The ground habitat of the sites surveyed for this study consists of a mosaic of leaf litter, herbs and grass tussocks and open sandy areas, suggesting that the local carabids (at least the larger species) are capable of making short crossings over open ground. Mader (1984; cited in New 1995) reported that some carabids refuse to cross roads. The differing moisture and radiation levels of typical sealed roads may impede movement of local species between remnants; this could be assessed experimentally.

The premium on land for coastal housing in the Perth Metropolitan Area will almost certainly result in further pressure to develop Trigg Dune, Bold Park and Mount Claremont Reserves for housing. In addition the recent extension of the northern Metropolitan corridor will produce pressure for development of the private land around and possibly within Yanchep National Park.

A highway connecting the inner northern suburbs with Fremantle has been planned for many years. If built as planned, this highway will isolate the western and northern sections of Bold Park. Recent public opinion has persuaded local politicians against any such development in the short term, but the issue is unlikely to remain dormant for long.

The excision of even a small portion from any of the reserves, while not in itself a major threat to maintaining carabid populations, may affect their survival prospects in the advent of disasters such as fire and disease.

6.3 CONCLUSIONS

This study has shown that the Quindalup Dune System and the wider Swan Coastal Plain remnants of the Perth Metropolitan Area possesses unique carabid assemblages which differ only slightly between the most northern and southern remnants. The overall carabid diversity is comparable to some other predatory invertebrates from these areas, but the group is significant given the size and abundance of some carabid species. New records for two apparently rare species, and the discovery of one new species, suggests that further taxa may persist in these remnants, possibly at extremely low densities and with patchy distributions between and within the remnants. Further surveying is an urgent priority.

The Swan Coastal Plain appears to form an overlap zone for species inhabiting the drier regions of the north west and the cooler, wetter forests of the south western region. This is clearly apparent from museum specimen records for larger species such as *Scaraphites silenus*, *S. lucidus* and *Gnathoxys granularis*. Both *Scaraphites* species are not usually found north of the Swan Coastal Plain and *G. granularis* is not normally found south of the Swan River. The selected large scale environmental parameters in the study (which may be more applicable to vertebrate and vegetation studies) are shown to have limited use in explaining either abundances of species or species richness across sites. Assessment of micro-environmental parameters with studies of micro-habitat use by individual species may be more informative for determining the relationship between species abundances seasonally and spatially and species richness.

The terrestrial carabid assemblage differs between the geological features of the Swan Coastal Plain. However, clear distinctions between assemblages on the older *Banksia* community dune sites are presently not possible. The most distinctive assemblage is present on the Quindalup Dune remnants (sites of which show higher associations with each other than other dune sites). This indicates that while possessing some species present on other dune systems, the Quindalup Dune System can not be really considered representative of the total carabid assemblage present on the Swan Coastal Plain.

There is strong evidence for temporal partitioning within the carabid community. There are indications that *Simodontus australis* emerge slightly earlier than *Promecoderus scauroides*, which are of similar size, during the warmer months. *Simodontus australis* also appears to be modal in its abundance through the year. Among the larger species (*Gnathoxys granularis*, *Scaraphites lucidus* and *S. silenus*) there is evidence of spatial partitioning between localities. However the presence of both *Scaraphites* species in Bold Park indicates that partitioning is operating at a local scale. It also provides an opportunity for more detailed studies of habitat and resource partitioning in this genus.

The impact of habitat fragmentation on local carabid fauna is not obvious from the results of this study. At an intuitive level, the remnants surveyed must be important refuges for non-flying carabid species. To ensure the long term survival of these communities of ground beetles, work is required, firstly, in basic phenology. At present almost nothing is known about basic life history parameters. For example, how far do the larger species roam? Do they maintain territories? Can they cross roads? What do they eat through the year? How long do they live; when and how many times do they breed? What are the incidental effects on them, if any, of chemicals used in management of the remnants? How great an impact does predation have on population persistence? This type of information will clarify the overall condition of the populations and their ability to persist in the remnants.

While it is undeniably important to conserve urban remnants and their biota, their history of degradation precludes any pretence of conservation as representatives of natural communities. Therefore, they, in their degraded state, may be of greatest value in promoting conservation as a whole. As relatively harmless, conspicuous and recognizable elements of these communities, carabids may also have greatest value in focusing interest for wider invertebrate conservation.

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For Appendices A and B, sites are listed in a north-south, west-east order, within each landform; Quindalup Dune System: YP- Yanchep National Park, TD- Trigg Dune Reserve; BP- Bold Park; MC- Mount Claremont Reserve; WP- Woodman Point Reserve; Spearwood Dune Systems: HH- Hepburn Heights; WR- Warwick Road Reserve; TH- Tuart Hill Reserve; MH- Mount Henry Bushland; LS- Landsdale Farm School; MR- Marangaroo Conservation Reserve; Bassendean Dune System: JA- Jandakot Airport; PA- Perth Airport; Ridge Hill Shelf: TR- Talbot Road Reserve.

APPENDIX A: SYNTHETIC ENVIRONMENTAL (TEMPERATURE) VARIABLES FOR ALL SWAN COASTAL PLAIN SITES 1993-1997.

Synthetic temperature variables were generated in the *Bioclim*™ (1985) software program, and used in standard multivariate regression analysis, which is presented in Chapter 5. All temperature measurements are in ° C, altitude measurements in metres above sea level, latitude and longitude in decimal degrees. The codes used as as follows; TANN- annual average temperature; TMNCM- mean temperature of the coolest month; TMXWM-maximum temperature of the wettest month; TSPAN-greatest temperature span; TCLQ-temperature of the coolest quarter; TWMQ-temperature of the warmest quarter; TWETQ-temperature of the wettest quarter; TDRYQ-temperature of the driest quarter.

SITE	LATITUDE	LONGITUDE	ALTITUDE	TANN	TMNCM	TMXWM	TSPAN	TCLQ	TWMQ	TWETQ	TDRYQ
YP1	-31.52	115.65	40	18.4	9.3	30.3	21.0	14.0	23.5	14.1	23.4
YP2	-31.57	115.68	40	18.4	9.3	30.2	21.0	14.0	23.5	14.0	23.4
TD1	-31.87	115.76	15	18.2	8.7	30.3	21.6	13.7	23.4	13.7	23.4
TD2 1995	-31.88	115.76	20	18.2	8.8	30.2	21.4	13.7	23.3	13.7	23.3
TD2 1996	-31.88	115.76	20	18.2	8.8	30.2	21.4	13.7	23.3	13.7	23.3
TD4 1995	-31.88	115.76	20	18.2	8.8	30.2	21.4	13.7	23.3	13.7	23.3
TD4 1996	-31.88	115.76	20	18.2	8.8	30.2	21.4	13.7	23.3	13.7	23.3
BP1 1993	-31.95	115.76	20	18.1	8.8	30.0	21.2	13.7	23.2	13.7	23.2

SITE	LATITUDE	LONGITUDE	ALTITUDE	TANN	TMNCM	TMXWM	TSPAN	TCLQ	TWMQ	TWETQ	TDRYQ
BP1 1996	-31.95	115.76	40	18.1	9.3	29.6	20.3	13.8	23.0	13.9	22.9
BP5 1993	-31.95	115.77	40	18.1	9.2	29.7	20.4	13.8	23.0	13.9	22.9
BP5 1996	-31.95	115.78	20	18.1	8.7	30.1	21.4	13.6	23.3	13.6	23.2
MC1	-31.96	115.77	20	18.1	8.8	30.0	21.3	13.7	23.2	13.7	23.2
MC2	-31.96	115.77	20	18.1	8.8	30.0	21.3	13.7	23.2	13.7	23.2
WP1	-32.13	115.76	5	17.9	8.6	29.8	21.2	13.5	23.0	14.6	23.0
WP2	-32.13	115.76	5	17.9	8.6	29.8	21.2	13.5	23.0	14.6	23.0
WP3	-32.13	115.76	5	17.9	8.6	29.8	21.2	13.5	23.0	14.6	23.0
WP4	-32.13	115.76	5	17.9	8.6	29.8	21.2	13.5	23.0	14.6	23.0
HH1	-31.82	115.77	40	18.2	9.2	30.0	20.8	13.8	23.2	13.9	23.1
HH2	-31.82	115.77	40	18.2	9.2	30.0	20.8	13.8	23.2	13.9	23.1
HH3	-31.82	115.77	40	18.2	9.2	30.0	20.8	13.8	23.2	13.9	23.1
HH4	-31.82	115.78	40	18.2	9.1	30.0	20.9	13.8	23.2	13.9	23.2
WR1	-31.84	115.81	40	18.2	9.0	30.1	21.1	13.8	23.3	13.8	23.2
WR2	-31.84	115.82	20	18.2	8.5	30.5	22.0	13.6	23.5	13.6	23.5
TH2	-31.88	115.86	20	18.2	8.4	30.6	22.3	13.5	23.5	13.5	23.5
TH1	-31.88	115.86	40	18.1	8.8	30.2	21.5	13.7	23.3	13.7	23.2
BP4	-31.94	115.77	40	18.1	9.2	29.7	20.5	13.8	23.0	13.9	23.0
BP3	-31.94	115.77	60	18.0	9.3	29.6	20.4	13.8	22.9	13.9	22.8
MH1	-32.03	115.86	20	18.0	8.4	30.3	21.9	13.5	23.3	13.5	23.2
MH2	-32.03	115.86	20	18.0	8.4	30.3	21.9	13.5	23.3	13.5	23.2
LS1	-31.82	115.85	60	18.1	8.9	30.2	21.3	13.7	23.2	13.7	23.2
MR1	-31.83	115.83	60	18.1	9.0	30.1	21.1	13.7	23.2	13.8	23.1
MR2	-31.83	115.83	60	18.1	9.0	30.1	21.1	13.7	23.2	13.8	23.1
JK2	-32.09	115.87	30	18.0	8.6	30.0	21.5	13.5	23.1	13.5	23.0
JK1	-32.09	115.88	30	17.9	8.5	30.0	21.5	13.5	23.1	13.5	23.1
PA5	-31.97	115.97	20	18.1	8.0	30.8	22.8	13.3	23.5	13.3	23.5
PA6	-31.97	115.97	20	18.1	8.0	30.8	22.8	13.3	23.5	13.3	23.5
PA7	-31.98	115.97	20	18.1	8.0	30.8	22.8	13.3	23.5	13.3	23.5
PA8	-31.98	115.97	20	18.1	8.0	30.8	22.8	13.3	23.5	13.3	23.5
TR1	-31.87	116.05	80	18.0	8.1	31.0	22.9	13.2	23.4	13.2	23.4
TR2	-31.87	116.05	80	18.0	8.1	31.0	22.9	13.2	23.4	13.2	23.4
TR3	-31.87	116.06	70	18.0	8.1	31.0	22.8	13.3	23.4	13.3	23.4
TR4	-31.87	116.06	70	18.0	8.1	31.0	22.8	13.3	23.4	13.3	23.4

APPENDIX B: SYNTHETIC ENVIRONMENTAL (PRECIPITATION) VARIABLES FOR ALL SITES ON THE SWAN COASTAL PLAIN 1993-1997).

Synthetic precipitation variables were generated in *Bioclim*™ (1985) software program, and used in standard multivariate regression analysis, which is presented in Chapter 5. Precipitation was measured in mm and the codes used are as follows; RANN- annual precipitation; RWETM- precipitation of the wettest month; RDRYM- precipitation of the driest month; RCVAR- co-efficient of variation of monthly precipitation; RWETQ precipitation of the wettest quarter; RDRYQ-precipitation of the driest quarter; RCLQ-precipitation of the coolest quarter; RWMQ- precipitation of the warmest quarter.

SITE	RANN	RWETM	RDRYM	RCVAR	RWETQ	RDRYQ	RCLQ	RWMQ
YP1	808	177	7	93.3	469	30	362	34
YP2	809	176	7	92.9	468	30	363	34
TD1	796	173	7	92.6	456	29	456	37
TD2 1995	798	173	7	92.5	457	29	357	37
TD2 1996	798	173	7	92.5	457	29	357	37
TD4 1995	798	173	7	92.5	457	29	357	37
TD4 1996	798	173	7	92.5	457	29	357	37
BP1 1993	774	171	7	93.1	444	29	344	36
BP1 1996	787	173	7	92.9	451	29	350	37
BP5 1993	793	174	7	92.7	454	30	353	37
BP5 1996	794	174	7	92.7	455	28	455	38
MC1	774	171	7	93	444	29	345	37
MC2	774	171	7	93	444	29	345	37
WP1	800	179	7	94.6	463	27	462	35
WP2	800	179	7	94.6	463	27	462	35
WP3	800	179	7	94.6	463	27	462	35
WP4	800	179	7	94.6	463	27	462	35
HH1	817	176	7	92.1	468	30	366	37
HH2	817	176	7	92.1	468	30	366	37
HH3	817	176	7	92.1	468	30	366	37
HH4	820	177	7	92	469	30	368	37
WR1	830	178	7	91.7	473	30	373	37
WR2	823	176	7	91.8	470	30	470	37
TH2	848	179	8	91.3	481	31	481	38
TH1	857	181	8	91.3	486	31	386	38
BP4	798	175	7	92.6	457	29	356	37
BP3	814	178	7	92.4	465	30	363	38
MH1	868	188	8	92.4	497	31	497	40
MH2	868	188	8	92.4	497	31	497	40
LS1	850	181	8	91.4	484	31	383	37
MR1	846	180	8	91.5	482	31	380	37
MR2	846	180	8	91.5	482	31	380	37
JK2	879	193	8	93	505	30	505	38
JK1	883	194	8	93	507	30	507	38

SITE	RANN	RWETM	RDRYM	RCVAR	RWETQ	RDRYQ	RCLQ	RWMQ
PA5	877	194	7	92.9	506	30	506	30
PA6	877	194	7	92.9	506	30	506	30
PA7	880	194	7	92.9	507	30	507	30
PA8	880	194	7	92.9	507	30	507	30
TR1	899	193	8	91.9	516	31	516	31
TR2	899	193	8	91.9	516	31	516	31
TR3	896	193	8	91.9	515	31	515	31
TR4	896	193	8	91.9	515	31	515	31

APPENDIX C: PHYSICAL ENVIRONMENTAL VARIABLES FOR THE REMNANT BUSHLAND AREAS SURVEYED ON THE QUINDALUP DUNE SYSTEM 1993-1997.

Data obtained from the Bureau of Meteorology (rainfall total, and average values for humidity, temperature, cloud cover and sunlight for the sample period).

DATE CODE	ALTITUDE (metres)	SAMPLING TIME (days)	RAINFALL TOTAL (mm)	TEMP-DAY (°C)	TEMP-NIGHT (°C)	REL. HUMITY 9am %	REL. HUMIDITY 3pm %	CLOUD COVER HI (Oktas)	CLOUD COVER LO (Oktas)	SUNLIGHT (hrs)
BP1B	20	67	241.9	3.61	4.8	19.29	2.85	6.5	1.46	7.09
BP1C	20	56	68.8	1.21	3.14	22.62	3.87	6.46	1.51	8.24
BP1D	20	50	0.4	0.01	0.06	29.52	5.27	6.28	0.38	11.97
BP1E	20	73	1.2	0.02	0.1	31.04	4.41	3.32	0.58	11.27
BP1F	20	62	18	0.29	1.18	26.88	3.31	4.08	0.98	8.71
BP1R	20	43	124.8	20.96	10.2	72.47	61.83	6.25	1.7	7.99
BP1S	20	43	98.5	26.02	13.48	62.22	55.36	4.46	0.95	9.72
BP1T	20	42	6	28.22	16.11	59.41	52.08	4.02	0.6	11.77
BP1U	20	41	1.5	32.98	19.08	59.37	49.28	3.41	0.36	12.05
BP1V	20	46	61.4	29.51	17.76	73.54	59.98	4.4	0.94	9.29
BP1W	20	39	32.8	25.72	13.95	89.08	68.78	5.54	1.38	7.21
BP1X	20	40	196.2	20.72	12.25	86.02	69.61	6.78	2.22	5.25
BP1Y	20	42	104.4	19.67	6.89	89.3	61.36	5.71	1.11	6.89
BP3B	50	67	241.9	3.61	4.8	19.29	2.85	6.5	1.46	7.09
BP3C	50	56	68.8	1.21	3.14	22.62	3.87	6.46	1.51	8.24
BP3D	50	50	0.4	0.01	0.06	29.52	5.27	6.28	0.38	11.97
BP3F	50	62	18	0.29	1.18	26.88	3.31	4.08	0.98	8.71
BP4A	45	62	238.3	3.91	8.88	18.45	1.75	6	1.37	5.99
BP4B	45	67	241.9	3.61	4.8	19.29	2.85	6.5	1.46	7.09
BP4C	45	56	68.8	1.21	3.14	22.62	3.87	6.46	1.51	8.24
BP4D	45	50	0.4	0.01	0.06	29.52	5.27	6.28	0.38	11.97
BP5A	55	62	238.3	3.91	8.88	18.45	1.75	6	1.37	5.99
BP5B	55	67	241.9	3.61	4.8	19.29	2.85	6.5	1.46	7.09
BP5C	55	56	68.8	1.21	3.14	22.62	3.87	6.46	1.51	8.24
BP5D	55	50	0.4	0.01	0.06	29.52	5.27	6.28	0.38	11.97

DATE CODE	ALTITUDE (metres)	SAMPLING TIME (days)	RAINFALL TOTAL (mm)	TEMP-DAY (°C)	TEMP-NIGHT (°C)	REL. HUMITY 9am %	REL. HUMIDITY 3pm %	CLOUD COVER HI (Oktas)	CLOUD COVER LO (Oktas)	SUNLIGHT (hrs)
BP5E	55	73	1.2	0.02	0.1	31.04	4.41	3.32	0.58	11.27
BP5R	55	43	124.8	20.96	10.2	72.47	61.83	6.25	1.7	7.99
BP5S	55	43	98.5	26.02	13.48	62.22	55.36	4.46	0.95	9.72
BP5T	55	42	6	28.22	16.11	59.41	52.08	4.02	0.6	11.77
BP5U	55	41	1.5	32.98	19.08	59.37	49.28	3.41	0.36	12.05
BP5V	55	46	61.4	29.51	17.76	73.54	59.98	4.4	0.94	9.29
BP5W	55	39	32.8	25.72	13.95	89.08	68.78	5.54	1.38	7.21
BP5X	55	40	196.2	20.72	12.25	86.02	69.61	6.78	2.22	5.25
BP5Y	55	42	104.4	19.67	6.89	89.3	61.36	5.71	1.11	6.89
MC1H	20	70	382.1	5.46	11.12	19.61	2.18	6.07	1.13	6.62
MC1I	20	65	93.7	1.44	6	22.24	3.36	5.51	0.86	9.17
MC1J	20	77	6.6	0.09	0.4	29.17	4.11	4.32	0.55	11.73
MC1K	20	63	1.4	0.02	0.14	32.3	4.5	2.88	0.4	11.04
MC1L	20	63	1.4	0.02	0.14	32.3	4.5	2.88	0.4	11.04
MC1M	20	64	253.9	0.52	1.13	27.14	4.19	6.35	1.41	6.43
MC2I	20	65	93.7	1.44	6	22.24	3.36	5.51	0.86	9.17
MC2J	20	77	6.6	0.09	0.4	29.17	4.11	4.32	0.55	11.73
MC2K	20	63	1.4	0.02	0.14	32.3	4.5	2.88	0.4	11.04
MC2L	20	45	23.6	0.52	1.13	27.14	4.19	5.24	0.8	8.28
MC2M	20	64	253.9	3.97	7.68	19.79	2.89	6.35	1.41	6.43
TD1N	5	75	379.6	4.63	7.22	19.88	1.92	6.39	1.56	6.75
TD1O	5	55	113.2	1.74	7.71	24.15	3.35	5.25	1.05	9.83
TD1P	5	62	6.2	0.1	0.29	29.85	4.67	4.06	0.62	11.37
TD2N	25	75	379.6	4.63	7.22	19.88	1.92	6.39	1.56	6.75
TD2O	25	55	113.2	1.74	7.71	24.15	3.35	5.25	1.05	9.83
TD2P	25	62	6.2	0.1	0.29	29.85	4.67	4.06	0.62	11.37
TD2Q	25	59	17.8	0.3	1.32	31.65	4.77	4.28	0.68	10.17
TD2S	25	43	98.5	26.02	13.48	62.22	55.36	4.47	0.95	9.72
TD2T	25	42	6	28.22	16.11	59.41	52.08	4.02	0.6	11.77
TD2V	25	46	61.4	29.51	17.76	73.54	59.98	4.4	0.94	9.29
TD2W	25	39	32.8	25.72	13.95	89.08	68.78	5.54	1.38	7.21
TD2X	25	40	196.2	20.72	12.25	86.02	69.61	6.78	2.22	5.25
TD2Y	25	42	104.4	19.67	6.89	89.3	61.36	5.71	1.11	6.89

DATE CODE	ALTITUDE (metres)	SAMPLING TIME (days)	RAINFALL TOTAL (mm)	TEMP-DAY (°C)	TEMP-NIGHT (°C)	REL. HUMITY 9am %	REL. HUMIDITY 3pm %	CLOUD COVER HI (Oktas)	CLOUD COVER LO (Oktas)	SUNLIGHT (hrs)
TD4N	5	75	379.6	4.63	7.22	19.88	1.92	6.39	1.56	6.75
TD4O	5	55	113.2	1.74	7.71	24.15	3.35	5.25	1.05	9.83
TD4P	5	62	6.2	0.1	0.29	29.85	4.67	4.06	0.62	11.37
TD4Q	5	59	17.8	0.3	1.32	31.65	4.77	4.28	0.68	10.17
TD4S	5	43	98.5	26.02	13.48	62.22	55.36	4.47	0.95	9.72
TD4T	5	42	6	28.22	16.11	59.41	52.08	4.02	0.6	11.77
TD4U	5	41	1.5	32.98	19.08	59.37	49.28	3.41	0.36	12.05
TD4W	5	39	32.8	25.72	13.95	89.08	68.78	5.54	1.38	7.21
TD4X	5	40	196.2	20.72	12.25	86.02	69.61	6.78	2.22	5.25
TD4Y	5	42	104.4	19.67	6.89	89.3	61.36	5.71	1.11	6.89
WP1H	0	70	333.7	5.96	13.74	19.61	2.18	6.07	1.13	6.62
WP1I	0	65	76.1	1.27	4.51	22.24	3.36	5.51	0.86	9.17
WP1J	0	77	5.3	0.07	0.38	29.17	4.11	4.32	0.55	11.73
WP1K	0	63	2.7	0.04	0.33	31.82	4.45	2.88	0.4	11.04
WP1L	0	45	20.6	0.54	1.47	27.25	4.18	5.24	0.8	8.28
WP1M	0	64	255.4	5.01	8.11	20.05	2.84	6.35	1.41	6.43
WP2H	0	70	333.7	5.96	13.74	19.61	2.18	6.07	1.13	6.62
WP2I	0	65	76.1	1.27	4.51	22.24	3.36	5.51	0.86	9.17
WP2J	0	77	5.3	0.07	0.38	29.17	4.11	4.32	0.55	11.73
WP2K	0	63	2.7	0.04	0.33	31.82	4.45	2.88	0.4	11.04
WP2L	0	45	20.6	0.54	1.47	27.25	4.18	5.24	0.8	8.28
WP2M	0	64	255.4	5.01	8.11	20.05	2.84	6.35	1.41	6.43
WP3H	0	70	333.7	5.96	13.74	19.61	2.18	6.07	1.13	6.62
WP3I	0	65	76.1	1.27	4.51	22.24	3.36	5.51	0.86	9.17
WP3J	0	77	5.3	0.07	0.38	29.17	4.11	4.32	0.55	11.73
WP3L	0	45	20.6	0.54	1.47	27.25	4.18	5.24	0.8	8.28
WP3M	0	64	255.4	5.01	8.11	20.05	2.84	6.35	1.41	6.43
WP4H	0	70	333.7	5.96	13.74	19.61	2.18	6.07	1.13	6.62
WP4I	0	65	76.1	1.27	4.51	22.24	3.36	5.51	0.86	9.17
WP4J	0	77	5.3	0.07	0.38	29.17	4.11	4.32	0.55	11.73
WP4K	0	63	2.7	0.04	0.33	31.82	4.45	2.88	0.4	11.04
WP4L	0	45	20.6	0.54	1.47	27.25	4.18	5.24	0.8	8.28
WP4M	0	64	255.4	5.01	8.11	20.05	2.84	6.35	1.41	6.43

DATE CODE	ALTITUDE (metres)	SAMPLING TIME (days)	RAINFALL TOTAL (mm)	TEMP-DAY (°C)	TEMP-NIGHT (°C)	REL. HUMITY 9am %	REL. HUMIDITY 3pm %	CLOUD COVER HI (Oktas)	CLOUD COVER LO (Oktas)	SUNLIGHT (hrs)
YP1R	40	43	162.9	20.96	10.2	72.47	61.83	6.26	1.7	7.99
YP1S	40	43	99.2	26.02	13.48	62.22	55.36	4.47	0.95	9.72
YP1U	40	41	0	32.98	19.08	59.37	49.28	3.41	0.36	12.05
YP1V	40	46	44.1	29.51	17.76	73.54	59.98	4.4	0.94	9.29
YP1Y	40	42	113.7	19.67	6.89	89.3	61.36	5.71	1.11	6.89
YP2R	30	43	162.9	20.96	10.2	72.47	61.83	6.26	1.7	7.99
YP2S	30	43	99.2	26.02	13.48	62.22	55.36	4.47	0.95	9.72
YP2T	30	42	25.8	28.22	16.11	59.41	52.08	4.02	0.6	11.77
YP2V	30	46	44.1	29.51	17.76	73.54	59.98	4.4	0.94	9.29
YP2W	30	39	60.8	25.72	13.95	89.08	68.78	5.54	1.38	7.21
YP2X	30	40	184.7	20.72	12.25	86.02	69.61	6.78	2.22	5.25
YP2Y	30	42	113.7	19.67	6.89	89.3	61.36	5.71	1.11	6.89

APPENDIX D: VEGETATIVE ENVIRONMENTAL VARIABLES FOR THE REMNANT BUSHLAND AREAS SURVEYED ON THE QUINDALUP DUNE SYSTEM 1993- 1997.

DATE CODE	STRATUM 1 HT	STRATUM 1 % COVER	STRATUM 2 HT	STRATUM 2 % COVER	STRATUM 3 HT	STRATUM 3 % COVER	STRATUM 4 HT	STRATUM 4 % COVER	LEAF LITTER % COVER	LEAF LITTER DEPTH
BP1B	1	5	1	1	1	1	1	1	4	5
BP1C	1	5	1	1	1	1	1	1	4	5
BP1D	1	5	1	1	1	1	1	1	4	5
BP1E	1	5	1	1	1	1	1	1	4	5
BP1F	1	5	1	1	1	1	1	1	4	5
BP1R	5	2	6	4	4	2	3	4	5	3
BP1S	5	2	6	4	4	2	3	4	5	3
BP1T	5	2	6	4	4	2	3	4	5	3
BP1U	5	2	6	4	4	2	3	4	5	3
BP1V	5	2	6	4	4	2	3	4	5	3
BP1W	5	2	6	4	4	2	3	4	5	3
BP1X	5	2	6	4	4	2	3	4	5	3
BP1Y	5	2	6	4	4	2	3	4	5	3
BP3B	4	3	4	4	2	5	1	1	5	5
BP3C	4	3	4	4	2	5	1	1	5	5
BP3D	4	3	4	4	2	5	1	1	5	5
BP3F	4	3	4	4	2	5	1	1	5	5
BP4A	7	3	6	3	4	2	2	4	6	4
BP4B	7	3	6	3	4	2	2	4	6	4
BP4C	7	3	6	3	4	2	2	4	6	4
BP4D	7	3	6	3	4	2	2	4	6	4
BP5A	2	5	1	1	1	1	1	1	6	4
BP5B	2	5	1	1	1	1	1	1	6	4
BP5C	2	5	1	1	1	1	1	1	6	4
BP5D	2	5	1	1	1	1	1	1	6	4
BP5E	2	5	1	1	1	1	1	1	6	4
BP5R	4	2	5	3	3	4	1	1	5	3
BP5S	4	2	5	3	3	5	1	1	5	3
BP5T	4	2	5	3	3	5	1	1	5	3
BP5U	4	2	5	3	3	4	1	1	3	2
BP5V	4	2	5	3	2	4	1	1	3	2
BP5W	4	2	5	3	2	4	1	1	3	2

DATE CODE	STRATUM 1 HT	STRATUM 1 % COVER	STRATUM 2 HT	STRATUM 2 % COVER	STRATUM 3 HT	STRATUM 3 % COVER	STRATUM 4 HT	STRATUM 4 % COVER	LEAF LITTER % COVER	LEAF LITTER DEPTH
BP5X	4	2	5	3	2	5	1	1	5	3
BP5Y	4	2	5	3	2	5	1	1	5	3
MC1H	3	4	2	6	1	1	1	1	1	1
MC1I	3	4	2	6	1	1	1	1	1	1
MC1J	3	4	2	6	1	1	1	1	1	1
MC1K	3	4	2	6	1	1	1	1	1	1
MC1L	3	4	2	6	1	1	1	1	1	1
MC1M	3	4	2	6	1	1	1	1	1	1
MC2I	3	4	5	5	2	5	1	1	6	5
MC2J	3	4	5	5	2	5	1	1	6	5
MC2K	3	4	5	5	2	5	1	1	6	5
MC2L	3	4	5	5	2	5	1	1	6	5
MC2M	3	4	5	5	2	5	1	1	6	5
TD1N	3	2	4	5	2	4	1	1	5	5
TD1O	3	2	4	5	2	4	1	1	5	5
TD1P	3	2	4	5	2	4	1	1	5	5
TD2N	1	5	1	1	1	1	1	1	5	5
TD2O	1	5	1	1	1	1	1	1	5	5
TD2P	1	5	1	1	1	1	1	1	5	5
TD2Q	1	5	1	1	1	1	1	1	5	5
TD2S	6	2	5	5	3	2	2	2	5	2
TD2T	6	2	5	5	3	2	2	2	5	2
TD2V	6	2	5	5	3	2	2	2	5	2
TD2W	6	2	5	5	3	2	2	2	5	2
TD2X	6	2	5	5	3	2	2	2	5	2
TD2Y	6	2	5	5	3	2	2	2	5	2
TD4N	2	5	1	1	1	1	1	1	5	5
TD4O	2	5	1	1	1	1	1	1	5	5
TD4P	2	5	1	1	1	1	1	1	5	5
TD4Q	2	5	1	1	1	1	1	1	5	5
TD4S	3	5	1	1	1	1	3	5	5	5
TD4T	3	5	1	1	1	1	3	5	5	5
TD4U	2	2	1	1	1	1	1	1	1	1
TD4W	2	2	1	1	1	1	2	2	1	1
TD4X	2	2	1	1	1	1	2	2	1	1
TD4Y	2	2	1	1	1	1	2	2	1	1
WP1H	3	4	2	5	1	1	1	1	5	5

DATE CODE	STRATUM 1 HT	STRATUM 1 % COVER	STRATUM 2 HT	STRATUM 2 % COVER	STRATUM 3 HT	STRATUM 3 % COVER	STRATUM 4 HT	STRATUM 4 % COVER	LEAF LITTER % COVER	LEAF LITTER DEPTH
WP1I	3	4	2	5	1	1	1	1	5	5
WP1J	3	4	2	5	1	1	1	1	5	5
WP1K	3	4	2	5	1	1	1	1	5	5
WP1L	3	4	2	5	1	1	1	1	5	5
WP1M	3	4	2	5	1	1	1	1	5	5
WP2H	3	4	5	5	3	5	1	1	5	5
WP2I	3	4	5	5	3	5	1	1	5	5
WP2J	3	4	5	5	3	5	1	1	5	5
WP2K	3	4	5	5	3	5	1	1	5	5
WP2L	3	4	5	5	3	5	1	1	5	5
WP2M	3	4	5	5	3	5	1	1	5	5
WP3H	5	4	6	4	5	3	2	5	5	5
WP3I	5	4	6	4	5	3	2	5	5	5
WP3J	5	4	6	4	5	3	2	5	5	5
WP3L	5	4	6	4	5	3	2	5	5	5
WP3M	5	4	6	4	5	3	2	5	5	5
WP4H	5	4	6	4	5	3	2	5	5	5
WP4I	5	4	6	4	5	3	2	5	5	5
WP4J	5	4	6	4	5	3	2	5	5	5
WP4K	5	4	6	4	5	3	2	5	5	5
WP4L	5	4	6	4	5	3	2	5	5	5
WP4M	5	4	6	4	5	3	2	5	5	5
YP1R	1	2	1	1	2	4	1	1	5	2
YP1S	1	2	1	1	2	4	1	1	5	2
YP1U	1	2	1	1	2	4	1	1	5	2
YP1V	1	2	1	1	2	4	1	1	5	2
YP1Y	1	2	1	1	2	4	1	1	5	2
YP2R	2	2	2	5	1	1	1	1	5	2
YP2S	2	2	2	5	1	1	1	1	5	2
YP2T	2	2	2	5	1	1	1	1	5	2
YP2V	2	2	2	5	1	1	1	1	5	2
YP2W	2	3	3	5	1	1	1	1	5	2
YP2X	2	3	3	5	1	1	1	1	5	2
YP2Y	2	3	3	5	1	1	1	1	5	2

APPENDIX E: CORRELATION MATRIX OF BIOCLIM SYNTHETIC CLIMATE VARIABLES AND SELECTED SPIECIES FOR ALL SITES ON THE SWAN COASTAL PLAIN.

	Correlations (synthetic climatic variables)															
	TANN	**TMNCM**	**TMXWM**	**TSPAN**	**TCLQ**	**TWMQ**	**TWETQ**	**TDRYQ**	**RANN**	**RWETM**	**RDRYM**	**RCVAR**	**RWETQ**	**RDRYQ**	**RCLQ**	**RWMQ**
TANN	1.000	0.465	0.062	-0.211	0.626	0.502	-0.107	0.399	-0.299	-0.449	-0.351	-0.392	-0.320	0.244	-0.546	0.094
TMNCM	0.465	1.000	-0.783	-0.946	0.958	-0.500	0.552	-0.604	-0.690	-0.773	-0.347	-0.062	-0.716	-0.147	-0.877	0.618
TMXWM	0.062	-0.783	1.000	0.939	-0.697	0.849	-0.756	0.875	0.746	0.680	0.389	-0.376	0.753	0.540	0.639	-0.694
TSPAN	-0.211	-0.946	0.939	1.000	-0.874	0.719	-0.695	0.787	0.758	0.767	0.394	-0.164	0.775	0.362	0.802	-0.683
TCLQ	0.626	0.958	-0.697	-0.874	1.000	-0.308	0.482	-0.413	-0.717	-0.808	-0.402	-0.086	-0.743	-0.121	-0.887	0.623
TWMQ	0.502	-0.500	0.849	0.719	-0.308	1.000	-0.652	0.967	0.457	0.357	0.136	-0.403	0.457	0.488	0.353	-0.475
TWETQ	-0.107	0.552	-0.756	-0.695	0.482	-0.652	1.000	-0.632	-0.664	-0.559	-0.442	0.622	-0.628	-0.720	-0.397	0.310
TDRYQ	0.399	-0.604	0.875	0.787	-0.413	0.967	-0.632	1.000	0.434	0.368	0.097	-0.307	0.442	0.375	0.404	-0.552
RANN	-0.299	-0.690	0.746	0.758	-0.717	0.457	-0.664	0.434	1.000	0.944	0.712	-0.386	0.994	0.678	0.756	-0.483
RWETM	-0.449	-0.773	0.680	0.767	-0.808	0.357	-0.559	0.368	0.944	1.000	0.556	-0.081	0.968	0.453	0.844	-0.596
RDRYM	-0.351	-0.347	0.389	0.394	-0.402	0.136	-0.442	0.097	0.712	0.556	1.000	-0.498	0.666	0.664	0.447	0.056
RCVAR	-0.392	-0.062	-0.376	-0.164	-0.086	-0.403	0.622	-0.307	-0.386	-0.081	-0.498	1.000	-0.293	-0.845	0.120	-0.154
RWETQ	-0.320	-0.716	0.753	0.775	-0.743	0.457	-0.628	0.442	0.994	0.968	0.666	-0.293	1.000	0.618	0.789	-0.545
RDRYQ	0.244	-0.147	0.540	0.362	-0.121	0.488	-0.720	0.375	0.678	0.453	0.664	-0.845	0.618	1.000	0.152	-0.073
RCLQ	-0.546	-0.877	0.639	0.802	-0.887	0.353	-0.397	0.404	0.756	0.844	0.447	0.120	0.789	0.152	1.000	-0.491
RWMQ	0.094	0.618	-0.694	-0.683	0.623	-0.475	0.310	-0.552	-0.483	-0.596	0.056	-0.154	-0.545	-0.073	-0.491	1.000
TOTAL	-0.145	-0.243	0.108	0.191	-0.252	0.041	0.099	0.100	-0.070	0.100	-0.242	0.494	-0.006	-0.382	0.213	-0.396
NONFLY	0.075	0.211	-0.304	-0.258	0.211	-0.208	0.414	-0.153	-0.545	-0.431	-0.448	0.499	-0.505	-0.596	-0.266	-0.005
VOLANT	-0.272	-0.493	0.396	0.467	-0.512	0.212	-0.210	0.230	0.384	0.522	0.042	0.250	0.439	-0.017	0.487	-0.575
G. crassipes	0.098	-0.092	0.020	0.068	-0.047	0.109	0.069	0.148	-0.109	-0.037	-0.276	0.225	-0.088	-0.228	0.000	-0.175
G. granularis	0.184	-0.048	0.309	0.194	-0.055	0.300	-0.123	0.267	0.200	0.167	0.148	-0.063	0.226	0.206	0.102	-0.334
L. verticalis	-0.320	-0.131	-0.060	0.041	-0.163	-0.160	-0.231	-0.138	0.296	0.374	0.263	0.065	0.302	0.070	0.305	0.096
***Notagonum* sp. 1**	-0.180	-0.307	0.396	0.349	-0.322	0.161	-0.235	0.193	0.332	0.308	0.282	-0.136	0.342	0.200	0.283	-0.348
N. mediosulcatus	0.000	-0.003	-0.035	-0.008	-0.010	0.015	-0.081	-0.028	0.027	-0.026	0.214	-0.125	-0.002	0.153	0.081	0.263
S. iriditinctus	-0.123	-0.157	0.219	0.213	-0.247	0.064	-0.240	0.045	0.311	0.290	0.259	-0.107	0.312	0.207	0.208	-0.216
S. lucidus	-0.028	0.348	-0.462	-0.429	0.288	-0.419	0.149	-0.404	-0.549	-0.475	-0.357	0.203	-0.553	-0.367	-0.430	0.232
S. silenus	0.071	-0.276	0.268	0.289	-0.218	0.292	-0.220	0.309	0.186	0.261	-0.141	0.059	0.208	0.048	0.226	-0.352
S. australis	-0.368	0.062	-0.383	-0.239	-0.035	-0.439	0.554	-0.393	-0.353	-0.209	-0.263	0.582	-0.315	-0.673	0.038	0.040
P. scauroides	0.030	0.021	-0.129	-0.077	0.050	-0.056	0.207	0.000	-0.346	-0.281	-0.310	0.297	-0.324	-0.469	-0.124	0.051

APPENDIX F: CORRELATION MATRIX FOR ENVIRONMENTAL PARAMETERS OF QUINDALUP DUNE SITES.

	REMNANT	TIME_TRA	FIRE_AGE	FRAGMENT	RAINFALL	TEMP_FRO	TEMP_TO	RELHUM9	RELHUM3	CLOUD_HI	CLOUD_LO	SUNLIGHT	STRATUM1H	STRATUM1C
REMNANT	1.000	0.165	-0.415	0.994	0.106	-0.039	-0.053	-0.024	-0.022	0.021	0.007	0.000	-0.740	-0.009
TIME_TRA	0.165	1.000	0.030	0.171	-0.070	0.233	0.185	-0.383	-0.387	-0.353	-0.330	0.335	-0.041	-0.041
FIRE_AGE	-0.415	0.030	1.000	-0.313	-0.061	0.046	0.056	-0.064	-0.038	-0.029	-0.015	0.055	0.542	-0.215
FRAGMENT	0.994	0.171	-0.313	1.000	0.104	-0.036	-0.050	-0.029	-0.025	0.020	0.008	0.004	-0.716	-0.044
RAINFALL	0.106	-0.070	-0.061	0.104	1.000	-0.813	-0.644	0.472	0.608	0.841	0.857	-0.782	-0.054	-0.041
TEMP_FRO	-0.039	0.233	0.046	-0.036	-0.813	1.000	0.942	-0.689	-0.649	-0.897	-0.750	0.831	0.007	0.012
TEMP_TO	-0.053	0.185	0.056	-0.050	-0.644	0.942	1.000	-0.626	-0.461	-0.728	-0.507	0.688	0.038	0.004
RELHUM9	-0.024	-0.383	-0.064	-0.029	0.472	-0.689	-0.626	1.000	0.884	0.785	0.662	-0.906	0.025	-0.120
RELHUM3	-0.022	-0.387	-0.038	-0.025	0.608	-0.649	-0.461	0.884	1.000	0.874	0.879	-0.933	0.054	-0.094
CLOUD_HI	0.021	-0.353	-0.029	0.020	0.841	-0.897	-0.728	0.785	0.874	1.000	0.949	-0.941	0.008	-0.078
CLOUD_LO	0.007	-0.330	-0.015	0.008	0.857	-0.750	-0.507	0.662	0.879	0.949	1.000	-0.890	0.027	-0.071
SUNLIGHT	0.000	0.335	0.055	0.004	-0.782	0.831	0.688	-0.906	-0.933	-0.941	-0.890	1.000	-0.020	0.094
STRATUM1H	-0.740	-0.041	0.542	-0.716	-0.054	0.007	0.038	0.025	0.054	0.008	0.027	-0.020	1.000	-0.166
STRATUM1C	-0.009	-0.041	-0.215	-0.044	-0.041	0.012	0.004	-0.120	-0.094	-0.078	-0.071	0.094	-0.166	1.000
STRATUM2H	-0.535	-0.042	0.810	-0.466	-0.014	-0.023	0.009	0.071	0.094	0.059	0.071	-0.064	0.879	-0.325
STRATUM2C	0.027	0.013	0.189	0.042	0.076	-0.084	-0.035	0.099	0.149	0.110	0.123	-0.110	0.558	-0.199
STRATUM3H	-0.474	0.052	0.717	-0.412	-0.080	0.067	0.065	-0.089	-0.074	-0.063	-0.051	0.082	0.765	-0.384
STRATUM3C	-0.024	0.113	0.503	0.035	-0.011	0.028	0.006	-0.072	-0.090	-0.050	-0.056	0.059	0.022	-0.334
STRATUM4H	-0.568	-0.056	0.283	-0.563	-0.049	-0.005	0.007	-0.020	0.002	-0.012	-0.002	0.013	0.563	0.238
STRATUM4C	-0.497	-0.019	0.314	-0.485	-0.078	0.036	0.039	-0.102	-0.072	-0.069	-0.054	0.084	0.461	0.403
LEAFLIT%	0.317	0.244	0.262	0.348	0.091	-0.077	-0.071	-0.164	-0.101	-0.011	-0.006	0.076	0.253	0.142
LEAFLITD	-0.249	0.126	0.502	-0.210	-0.049	0.027	0.022	-0.272	-0.206	-0.123	-0.105	0.194	0.296	0.619
DIST_BIT	0.547	0.186	0.108	0.585	0.014	0.043	0.005	-0.093	-0.116	-0.062	-0.074	0.080	-0.523	-0.220
NEAR_REM	-0.338	-0.014	0.713	-0.265	-0.045	0.030	0.036	-0.024	-0.013	-0.009	-0.001	0.024	0.215	-0.181
DIST_BEA	0.980	0.182	-0.391	0.976	0.090	-0.019	-0.044	-0.046	-0.054	-0.004	-0.019	0.024	-0.767	-0.037
SPRICH	-0.334	-0.052	0.292	-0.315	0.050	-0.065	-0.058	-0.194	-0.083	-0.030	0.012	0.063	0.277	0.282
C. scaritoides	0.076	0.052	-0.307	0.039	0.272	-0.234	-0.268	0.013	0.006	0.122	0.093	-0.119	-0.258	0.364
G. crassipes	-0.048	0.165	-0.004	-0.053	-0.441	0.495	0.510	-0.436	-0.416	-0.479	-0.408	0.506	-0.009	0.328
G. granularis	0.506	-0.130	-0.261	0.496	0.154	-0.050	-0.018	0.013	0.118	0.072	0.134	-0.108	-0.351	0.133
N. mediosulcatus	-0.086	-0.002	0.193	-0.065	0.057	-0.208	-0.282	0.194	0.034	0.095	-0.014	-0.131	0.140	-0.052
P. scauroides	-0.202	-0.035	-0.115	-0.227	0.190	-0.142	-0.151	-0.011	0.049	0.083	0.104	-0.103	-0.070	0.563
S. iriditinctus	0.243	-0.163	-0.125	0.238	0.266	-0.169	-0.053	0.151	0.233	0.257	0.315	-0.251	-0.145	0.180
S. lucidus	-0.252	0.185	0.414	-0.214	0.049	-0.031	-0.052	-0.330	-0.200	-0.066	-0.033	0.169	0.307	-0.024
S. silenus	0.206	0.112	0.022	0.218	0.047	-0.042	-0.090	-0.191	-0.158	-0.076	-0.076	0.099	-0.155	-0.105
S. australis	-0.377	-0.311	0.641	-0.316	0.167	-0.188	-0.069	0.136	0.233	0.270	0.307	-0.205	0.437	-0.197
L. verticalis	-0.073	-0.076	0.279	-0.042	-0.285	0.197	0.208	-0.273	-0.263	-0.234	-0.225	0.316	0.077	-0.057
Notagonum sp. 1	-0.253	-0.036	-0.241	-0.285	-0.213	0.290	0.230	-0.232	-0.276	-0.293	-0.267	0.262	-0.074	-0.059

APPENDIX F: Continued .....

	STRATUM2H	STRATUM2C	STRATUM3H	STRATUM3C	STRATUM4H	STRATUM4C	LEAFLIT%	LEAFLITD	DIST_BIT	NEAR_REM	DIST_BEA
REMNANT	-0.535	0.027	-0.474	-0.024	-0.568	-0.497	0.317	-0.249	0.547	-0.338	0.980
TIME_TRA	-0.042	0.013	0.052	0.113	-0.056	-0.019	0.244	0.126	0.186	-0.014	0.182
FIRE_AGE	0.810	0.189	0.717	0.503	0.283	0.314	0.262	0.502	0.108	0.713	-0.391
FRAGMENT	-0.466	0.042	-0.412	0.035	-0.563	-0.485	0.348	-0.210	0.585	-0.265	0.976
RAINFALL	-0.014	0.076	-0.080	-0.011	-0.049	-0.078	0.091	-0.049	0.014	-0.045	0.090
TEMP_FRO	-0.023	-0.084	0.067	0.028	-0.005	0.036	-0.077	0.027	0.043	0.030	-0.019
TEMP_TO	0.009	-0.035	0.065	0.006	0.007	0.039	-0.071	0.022	0.005	0.036	-0.044
RELHUM9	0.071	0.099	-0.089	-0.072	-0.020	-0.102	-0.164	-0.272	-0.093	-0.024	-0.046
RELHUM3	0.094	0.149	-0.074	-0.090	0.002	-0.072	-0.101	-0.206	-0.116	-0.013	-0.054
CLOUD_HI	0.059	0.110	-0.063	-0.050	-0.012	-0.069	-0.011	-0.123	-0.062	-0.009	-0.004
CLOUD_LO	0.071	0.123	-0.051	-0.056	-0.002	-0.054	-0.006	-0.105	-0.074	-0.001	-0.019
SUNLIGHT	-0.064	-0.110	0.082	0.059	0.013	0.084	0.076	0.194	0.080	0.024	0.024
STRATUM1H	0.879	0.558	0.765	0.022	0.563	0.461	0.253	0.296	-0.523	0.215	-0.767
STRATUM1C	-0.325	-0.199	-0.384	-0.334	0.238	0.403	0.142	0.619	-0.220	-0.181	-0.037
STRATUM2H	1.000	0.603	0.841	0.224	0.407	0.333	0.340	0.296	-0.262	0.435	-0.563
STRATUM2C	0.603	1.000	0.310	-0.307	0.100	0.020	0.482	-0.009	-0.442	-0.080	-0.121
STRATUM3H	0.841	0.310	1.000	0.278	0.572	0.494	0.371	0.314	-0.103	0.193	-0.413
STRATUM3C	0.224	-0.307	0.278	1.000	-0.414	-0.383	0.189	0.118	0.784	0.730	0.086
STRATUM4H	0.407	0.100	0.572	-0.414	1.000	0.971	0.093	0.493	-0.629	-0.309	-0.541
STRATUM4C	0.333	0.020	0.494	-0.383	0.971	1.000	0.157	0.649	-0.548	-0.262	-0.467
LEAFLIT%	0.340	0.482	0.371	0.189	0.093	0.157	1.000	0.560	0.196	-0.070	0.303
LEAFLITD	0.296	-0.009	0.314	0.118	0.493	0.649	0.560	1.000	-0.067	0.213	-0.231
DIST_BIT	-0.262	-0.442	-0.103	0.784	-0.629	-0.548	0.196	-0.067	1.000	0.353	0.656
NEAR_REM	0.435	-0.080	0.193	0.730	-0.309	-0.262	-0.070	0.213	0.353	1.000	-0.329
DIST_BEA	-0.563	-0.121	-0.413	0.086	-0.541	-0.467	0.303	-0.231	0.656	-0.329	1.000
SPRICH	0.252	0.000	0.253	-0.106	0.478	0.505	0.054	0.413	-0.250	0.064	-0.326
C. scaritoides	-0.414	-0.433	-0.215	0.001	0.063	0.120	-0.007	0.157	0.145	-0.229	0.145
G. crassipes	-0.098	-0.059	-0.032	-0.266	0.299	0.377	0.045	0.324	-0.195	-0.168	-0.053
G. granularis	-0.234	0.147	-0.318	-0.161	-0.289	-0.256	0.145	-0.146	0.130	-0.208	0.454
N. mediosulcatus	0.189	0.071	0.238	-0.049	0.244	0.237	0.070	0.117	-0.090	-0.031	-0.075
P. scauroides	-0.236	-0.261	-0.289	-0.141	0.162	0.249	-0.090	0.376	-0.180	0.024	-0.209
S. iriditinctus	-0.052	0.172	-0.188	-0.164	-0.139	-0.123	0.070	-0.070	-0.028	-0.100	0.189
S. lucidus	0.375	0.095	0.444	0.053	0.358	0.365	0.184	0.337	-0.117	0.135	-0.236
S. silenus	-0.082	-0.206	0.152	0.166	0.051	0.063	0.140	0.020	0.307	-0.142	0.286
S. australis	0.577	0.138	0.551	0.272	0.332	0.318	0.158	0.326	-0.067	0.372	-0.358
L. verticalis	0.191	0.043	0.169	0.249	-0.090	-0.071	0.063	0.120	0.103	0.330	-0.082
Notagonum sp. 1	-0.203	-0.267	-0.138	-0.228	-0.002	-0.019	-0.515	-0.276	-0.260	-0.149	-0.237

APPENDIX G: ABUNDANCE DATA FOR ALL SITES AND ALL SAMPLE PERIODS ON THE SWAN COASTAL PLAIN 1993-1997

Quindalup Dune System Sites

SITE	BP1					93-94	BP1								96-97
TAXON	20-Jul-93	24-Sep-93	18-Nov-93	6-Jan-94	18-Mar-94	TOTAL	29-Aug-96	10-Oct-96	21-Nov-96	2-Jan-97	14-Feb-97	1-Apr-97	9-May-97	18-Jun-97	TOTAL
Calosoma schayeri															
Carenum scaritoides															
Carenum sp. 1															
Catadromus lacordarei															
Cenogmus sp. 1															
Chlaenius greyanus															
Egadroma sp. 1															
Euthenaris sp. 1															
Euthenaris sp. 2															
Genus 1 sp. A															
Genus 1 sp. B															
Genus 1 sp. C															
Genus 1 sp. D															
Gnathoxys crassipes				1	1	**2**		1	3	2	1	1			**8**
Gnathoxys granularis															
Gnathoxys pannuceus															
Lecanomerus verticalis									4			1			**5**
Microlestes sp. 1															
Neocarenum sp. 1															
Notagonum sp. 1								2	1		1				**4**
Notagonum sp. 2															
Notagonum submetallicum															
Notonomus mediosulcatus														1	**1**
Notospeophonus sp. 1															
Phorticosomerus sp. 1															
Platycoelus sp. 1															
Promecoderus scauroides							2	1				3			**6**
Sarothrocrepis sp. 1															
Sarticus iriditinctus									1						**1**
Sarticus sp. 1															
Scaraphites lucidus	5	41	14	8	1	**69**	39	50	22	1	3				**115**
Scaraphites silenus							1	1	1						**3**
Scopodes boops															
Simodontus australis					1	**1**	40	16	29	10	3	40	63	12	**213**
Speotarus lucifugus								1							**1**
Teropha sp.															
Trigonothops sp. 1															
TOTAL	**5**	**41**	**14**	**9**	**3**	**72**	**82**	**72**	**61**	**13**	**8**	**45**	**63**	**13**	**357**

Appendix G continued….Quindalup Dunes

SITE	**BP5**						**93-94**	**BP5**								**96-97**
TAXON	20-May-93	20-Jul-93	24-Sep-93	18-Nov-93	6-Jan-94	18-Mar-94	**TOTAL**	29-Aug-96	10-Oct-96	21-Nov-96	2-Jan-97	14-Feb-97	1-Apr-97	9-May-97	18-Jun-97	**TOTAL**
Calosoma schayeri																
Carenum scaritoides																
Carenum sp. 1																
Catadromus lacordarei																
Cenogmus sp. 1																
Chlaenius greyanus																
Egadroma sp. 1																
Euthenaris sp. 1																
Euthenaris sp. 2																
Genus 1 sp. a																
Genus 1 sp. b																
Genus 1 sp. c																
Genus 1 sp. d																
Gnathoxys crassipes											1	1				**2**
Gnathoxys granularis																
Gnathoxys pannuceus																
Lecanomerus verticalis										10	3					**13**
Microlestes sp. 1																
Neocarenum sp. 1																
Notagonum sp. 1			1				**1**		1							**1**
Notagonum sp. 2																
Notagonum submetallicum																
Notonomus mediosulcatus																
Notospeophonus sp. 1																
Phorticosomerus sp. 1																
Platycoelus sp. 1																
Promecoderus scauroides	1	1					**2**	8	13				14	19	5	**59**
Sarothrocrepis sp. 1																
Sarticus iriditinctus																
Sarticus sp. 1																
Scaraphites lucidus	1	4	13	1	1		**20**	19	21	7		1	1			**49**
Scaraphites silenus																
Scopodes boops																
Simodontus australis	2						**2**	4	9	53	12	5	15	39	19	**156**
Speotarus lucifugus																
Teropha sp.									1							**1**
Trigonothops sp. 1																
TOTAL	**4**	**5**	**14**	**1**	**1**	**0**	**25**	**31**	**45**	**70**	**16**	**7**	**30**	**58**	**24**	**281**

Appendix G continued…Quindalup Dune sites continued…

SITE	MC1							MC2					
TAXON	24-Jun-94	1-Sep-94	4-Nov-94	19-Jan-95	21-Mar-95	4-May-95	TOTAL	1-Sep-94	4-Nov-94	19-Jan-95	21-Mar-95	4-May-95	TOTAL
Calosoma schayeri													
Carenum scaritoides	4	9	2		1	9	**25**		2			1	**3**
Carenum sp. 1													
Catadromus lacordarei													
Cenogmus sp. 1													
Chlaenius greyanus													
Egadroma sp. 1													
Euthenaris sp. 1													
Euthenaris sp. 2													
Genus 1 sp. a													
Genus 1 sp. b													
Genus 1 sp. c													
Genus 1 sp. d													
Gnathoxys crassipes					2		**2**		2	1			**3**
Gnathoxys granularis													
Gnathoxys pannuceus													
Lecanomerus verticalis			1				**1**						
Microlestes sp. 1													
Neocarenum sp. 1													
Notagonum sp. 1													
Notagonum sp. 2													
Notagonum submetallicum													
Notonomus mediosulcatus													
Notospeophonus sp. 1													
Phorticosomerus sp. 1													
Platycoelus sp. 1													
Promecoderus scauroides	3	3	2		2	9	**19**	5	1		1	15	**22**
Sarothrocrepis sp. 1													
Sarticus iriditinctus													
Sarticus sp. 1													
Scaraphites lucidus	1	7	2	1		1	**12**	27	16	3		1	**47**
Scaraphites silenus													
Scopodes boops													
Simodontus australis						3	**3**				2	23	**25**
Speotarus lucifugus													
Terópha sp.													
Trigonothops sp. 1	1						**1**						
TOTAL	**9**	**19**	**7**	**1**	**5**	**22**	**63**	**32**	**21**	**4**	**3**	**40**	**100**

Appendix G continued…Quindalup Dune sites continued…

SITE	WP1							WP2						
TAXON	24-Jun-94	1-Sep-94	4-Nov-94	19-Jan-95	21-Mar-95	4-May-95	**TOTAL**	24-Jun-94	1-Sep-94	4-Nov-94	19-Jan-95	21-Mar-95	4-May-95	**TOTAL**
Calosoma schayeri														
Carenum scaritoides						1	**1**		1					**1**
Carenum sp. 1														
Catadromus lacordarei														
Cenogmus sp. 1														
Chlaenius greyanus														
Egadroma sp. 1														
Euthenaris sp. 1														
Euthenaris sp. 2														
Genus 1 sp. a														
Genus 1 sp. b														
Genus 1 sp. c														
Genus 1 sp. d														
Gnathoxys crassipes	1		2	1	1	1	**6**	1	1		2	2		**6**
Gnathoxys granularis														
Gnathoxys pannuceus										1				**1**
Lecanomerus verticalis														
Microlestes sp. 1														
Neocarenum sp. 1														
Notagonum sp. 1		1					**1**	1	14	3	1	1	2	**22**
Notagonum sp. 2														
Notagonum submetallicum										2				**2**
Notonomus mediosulcatus														
Notospeophonus sp. 1														
Phorticosomerus sp. 1														
Platycoelus sp. 1														
Promecoderus scauroides	3	11	22		3	12	**51**	4	13	19		4	11	**51**
Sarothrocrepis sp. 1									1		1			**2**
Sarticus iriditinctus														
Sarticus sp. 1														
Scaraphites lucidus		3	1		1		**5**		2	1		1	1	**5**
Scaraphites silenus														
Scopodes boops														
Simodontus australis	73	7	13	8	15	68	**184**	5	9	128	6	39	131	**318**
Speotarus lucifugus										1		1		**2**
Teropha sp.														
Trigonothops sp. 1								2				1		**3**
TOTAL	**77**	**22**	**38**	**9**	**20**	**82**	**248**	**13**	**41**	**155**	**10**	**49**	**145**	**413**

Appendix G continued…Quindalup Dune sites continued…

SITE	WP3						WP4						
TAXON	24-Jun-94	1-Sep-94	4-Nov-94	21-Mar-95	4-May-95	TOTAL	24-Jun-94	1-Sep-94	4-Nov-94	19-Jan-95	21-Mar-95	4-May-95	TOTAL
Calosoma schayeri		1				1							
Carenum scaritoides					3	3					1		1
Carenum sp. 1													
Catadromus lacordarei													
Cenogmus sp. 1													
Chlaenius greyanus													
Egadroma sp. 1													
Euthenaris sp. 1													
Euthenaris sp. 2													
Genus 1 sp. a													
Genus 1 sp. b													
Genus 1 sp. c													
Genus 1 sp. d													
Gnathoxys crassipes							1			1	1		3
Gnathoxys granularis													
Gnathoxys pannuceus													
Lecanomerus verticalis													
Microlestes sp. 1													
Neocarenum sp. 1													
Notagonum sp. 1					1	1			1				1
Notagonum sp. 2													
Notagonum submetallicum													
Notonomus mediosulcatus													
Notospeophonus sp. 1													
Phorticosomerus sp. 1													
Platycoelus sp. 1													
Promecoderus scauroides	1				1	2	1	9	1		1	3	15
Sarothrocrepis sp. 1													
Sarticus iriditinctus													
Sarticus sp. 1													
Scaraphites lucidus		12	5			17		9	2				11
Scaraphites silenus													
Scopodes boops													
Simodontus australis	12	1	3	1	51	68	13	4	5		2	49	73
Speotarus lucifugus													
Teropha sp.													
Trigonothops sp. 1								1					1
TOTAL	13	14	8	1	56	92	15	23	9	1	5	52	105

Appendix G continued…Quindalup Dune sites continued…

SITE **TAXON**	**TD1** 13-Jul-95	25-Sep-95	28-Nov-95	**TOTAL**	**TD2** 13-Jul-95	25-Sep-95	28-Nov-95	29-Jan-96	**95-96** **TOTAL**	**TD2** 10-Oct-96	21-Nov-96	14-Feb-97	1-Apr-97	9-May-97	18-Jun-97	**96-97** **TOTAL**
Calosoma schayeri																
Carenum scaritoides														1		**1**
Carenum sp. 1																
Catadromus lacordarei																
Cenogmus sp. 1																
Chlaenius greyanus																
Egadroma sp. 1																
Euthenaris sp. 1																
Euthenaris sp. 2																
Genus 1 sp. a																
Genus 1 sp. b																
Genus 1 sp. c																
Genus 1 sp. d																
Gnathoxys crassipes							1	3	**4**			1		1		**2**
Gnathoxys granularis																
Gnathoxys pannuceus																
Lecanomerus verticalis																
Microlestes sp. 1																
Neocarenum sp. 1																
Notagonum sp. 1										2		1	1			**4**
Notagonum sp. 2																
Notagonum submetallicum																
Notonomus mediosulcatus																
Notospeophonus sp. 1																
Phorticosomerus sp. 1																
Platycoelus sp. 1																
Promecoderus scauroides	1	9		**10**	13	4			**17**	6			6	2	7	**21**
Sarothrocrepis sp. 1																
Sarticus iriditinctus																
Sarticus sp. 1																
Scaraphites lucidus	1	1		**2**	17	9	4	1	**31**	14	2					**16**
Scaraphites silenus	7	4	3	**14**												
Scopodes boops				**0**												
Simodontus australis	1	1		**2**	13	1			**14**	1	1		10	23	5	**40**
Speotarus lucifugus																
Teropha sp.																
Trigonothops sp. 1																
TOTAL	**10**	**15**	**3**	**28**	**43**	**14**	**5**	**4**	**66**	**23**	**3**	**2**	**17**	**27**	**12**	**84**

Appendix G continued…Quindalup Dune sites continued…

SITE TAXON	TD4 13-Jul-95	25-Sep-95	28-Nov-95	29-Jan-96	95-96 TOTAL	TD4 10-Oct-96	21-Nov-96	2-Jan-97	14-Feb-97	1-Apr-97	9 May 97	18 Jun 97	96-97 TOTAL
Calosoma schayeri													
Carenum scaritoides		3			**3**	2						1	**3**
Carenum sp. 1													
Catadromus lacordarei													
Cenogmus sp. 1													
Chlaenius greyanus													
Egadroma sp. 1													
Euthenaris sp. 1													
Euthenaris sp. 2													
Genus 1 sp. a													
Genus 1 sp. b													
Genus 1 sp. c													
Genus 1 sp. d													
Gnathoxys crassipes			2	1	**3**		5	1			1		**7**
Gnathoxys granularis													
Gnathoxys pannuceus													
Lecanomerus verticalis													
Microlestes sp. 1													
Neocarenum sp. 1													
Notagonum sp. 1		2		1	**3**	1	10	1	1	2			**15**
Notagonum sp. 2													
Notagonum submetallicum													
Notonomus mediosulcatus													
Notospeophonus sp. 1													
Phorticosomerus sp. 1													
Platycoelus sp. 1													
Promecoderus scauroides	2	14			**16**	91	1			7	17	20	**136**
Sarothrocrepis sp. 1	1				**1**								
Sarticus iriditinctus													
Sarticus sp. 1													
Scaraphites lucidus		25	5		**30**	11	1						**12**
Scaraphites silenus													
Scopodes boops													
Simodontus australis	8				**8**	1	2			1	7	3	**14**
Speotarus lucifugus		1			**1**								
Teropha sp.													
Trigonothops sp. 1													
TOTAL	**11**	**45**	**7**	**2**	**65**	**106**	**19**	**2**	**1**	**10**	**25**	**24**	**187**

Appendix G continued…Quindalup Dune sites continued…

SITE TAXON	YP1 29-Aug-97	10-Oct-96	2-Jan-97	14-Feb-97	18 Jun 97	TOTAL	YP2 29-Aug-96	10-Oct-96	21-Nov-96	14-Feb-97	1-Apr-97	9-May-97	18-Jun-97	TOTAL
Calosoma schayeri														
Carenum scaritoides	1	1			1	3								
Carenum sp. 1														
Catadromus lacordarei														
Cenogmus sp. 1														
Chlaenius greyanus														
Egadroma sp. 1														
Euthenaris sp. 1								1						1
Euthenaris sp. 2														
Genus 1 sp. a														
Genus 1 sp. b														
Genus 1 sp. c														
Genus 1 sp. d														
Gnathoxys crassipes			1	1		2		1	2	2				5
Gnathoxys granularis		1				1		1			1	1		3
Gnathoxys pannuceus														
Lecanomerus verticalis									1			2		3
Microlestes sp. 1														
Neocarenum sp. 1														
Notagonum sp. 1		1				1								
Notagonum sp. 2														
Notagonum submetallicum														
Notonomus mediosulcatus														
Notospeophonus sp. 1														
Phorticosomerus sp. 1														
Platycoelus sp. 1														
Promecoderus scauroides							9	10	1		1	3	4	28
Sarothrocrepis sp. 1														
Sarticus iriditinctus												1		1
Sarticus sp. 1														
Scaraphites lucidus														
Scaraphites silenus		3			1	4								
Scopodes boops													1	1
Simodontus australis		1				1							1	1
Speotarus lucifugus														
Teropha sp.														
Trigonothops sp. 1													1	1
TOTAL	1	7	1	1	2	12	9	13	4	2	2	7	7	44

Appendix G continued...Spearwood Dune System (Cottesloe Sands) sites...

SITE TAXON	BP3 24-Sep-93	18-Nov-93	6-Jan-94	18-Mar-94	TOTAL	BP3 20-May-93	20-Jul-93	24-Sep-93	18-Nov-93	6-Jan-94	18-Mar-94	9-May-97	18-Jun-97	TOTAL
Calosoma schayeri														
Carenum scaritoides														
Carenum sp. 1														
Catadromus lacordarei														
Cenogmus sp. 1														
Chlaenius greyanus														
Egadroma sp. 1														
Euthenaris sp. 1														
Euthenaris sp. 2														
Genus 1 sp. a														
Genus 1 sp. b														
Genus 1 sp. c														
Genus 1 sp. d														
Gnathoxys crassipes														
Gnathoxys granularis														
Gnathoxys pannuceus														
Lecanomerus verticalis	1	6			7			1	16	4				21
Microlestes sp. 1														
Neocarenum sp. 1														
Notagonum sp. 1														
Notagonum sp. 2														
Notagonum submetallicum														
Notonomus mediosulcatus														
Notospeophonus sp. 1														
Phorticosomerus sp. 1														
Platycoelus sp. 1														
Promecoderus scauroides			1		1	6	2	3						11
Sarothrocrepis sp. 1														
Sarticus iriditinctus		1			1									
Sarticus sp. 1														
Scaraphites lucidus	24	18			42		5	18	10					33
Scaraphites silenus														
Scopodes boops														
Simodontus australis				3	3	7		1	1				2	11
Speotarus lucifugus		1			1									
Teropha sp.														
Trigonothops sp. 1														
TOTAL	25	26	1	3	55	13	7	23	27	4	0	0	2	76

Appendix G continued…Spearwood Dune System (Cottesloe Sands) sites continued...

SITE	HH1	HH2		HH3		HH4			
TAXON	13-Jul-95	13-Jul-95	25-Sep-95	13-Jul-95	25-Sep-95	13-Jul-95	25-Sep-95	28-Nov-95	**TOTAL**
Calosoma schayeri									
Carenum scaritoides									
Carenum sp. 1					1				**1**
Catadromus lacordarei									
Cenogmus sp. 1		1							**1**
Chlaenius greyanus									
Egadroma sp. 1									
Euthenaris sp. 1									
Euthenaris sp. 2									
Genus 1 sp. a									
Genus 1 sp. b									
Genus 1 sp. c									
Genus 1 sp. d									
Gnathoxys crassipes								5	**5**
Gnathoxys granularis									
Gnathoxys pannuceus									
Lecanomerus verticalis						1			**1**
Microlestes sp. 1									
Neocarenum sp. 1									
Notagonum sp. 1									
Notagonum sp. 2									
Notagonum submetallicum									
Notonomus mediosulcatus									
Notospeophonus sp. 1									
Phorticosomerus sp. 1									
Platycoelus sp. 1									
Promecoderus scauroides	2			1		4	1		**7**
Sarothrocrepis sp. 1									
Sarticus iriditinctus									
Sarticus sp. 1									
Scaraphites lucidus									
Scaraphites silenus			1	2					**3**
Scopodes boops									
Simodontus australis				2		6			**8**
Speotarus lucifugus									
Teropha sp.									
Trigonothops sp. 1									
TOTAL	**2**	**1**	**1**	**5**	**1**	**11**	**1**	**5**	**21**

Appendix G continued...Spearwood Dune System (Karrakatta Sands) sites continued...

SITE TAXON	MH1 4-Oct-94	4-Nov-94	19-Jan-95	21-Mar-95	4-May-95	TOTAL	MH2 4-Oct-94	4-Nov-94	19-Jan-95	21-Mar-95	4-May-95	TOTAL	TH1 24-Sep-93	6-Jan-94	21-Mar-94	TOTAL
Calosoma schayeri																
Carenum scaritoides																
Carenum sp. 1																
Catadromus lacordarei																
Cenogmus sp. 1																
Chlaenius greyanus																
Egadroma sp. 1																
Euthenaris sp. 1																
Euthenaris sp. 2																
Genus 1 sp. a																
Genus 1 sp. b																
Genus 1 sp. c																
Genus 1 sp. d		21				**21**										
Gnathoxys crassipes														1		**1**
Gnathoxys granularis																
Gnathoxys pannuceus																
Lecanomerus verticalis	8		6	1		**15**	1	3	2			**6**				
Microlestes sp. 1																
Neocarenum sp. 1																
Notagonum sp. 1									1	1		**2**				
Notagonum sp. 2																
Notagonum submetallicum																
Notonomus mediosulcatus																
Notospeophonus sp. 1										1		**1**				
Phorticosomerus sp. 1																
Platycoelus sp. 1																
Promecoderus scauroides					2	**2**	2			1	1	**4**				
Sarothrocrepis sp. 1																
Sarticus iriditinctus													2			**2**
Sarticus sp. 1															1	**1**
Scaraphites lucidus																
Scaraphites silenus																
Scopodes boops																
Simodontus australis																
Speotarus lucifugus																
Teropha sp.																
Trigonothops sp. 1																
TOTAL	8	21	6	1	2	38	3	3	3	3	1	13	2	1	1	4

Appendix G continued…Spearwood Dune System (Karrakatta Sands) sites continued…

SITE	TH2				TH3					WR1	WR2			WR
TAXON	10-May-93	18-Nov-93	21-Mar-94	TOTAL	10-May-93	18-Nov-93	6-Jan-94	21-Mar-94	TOTAL	28-Nov-95	13-Jul-95	25-Sep-95	29-Jan-96	TOTAL
Calosoma schayeri														
Carenum scaritoides														
Carenum sp. 1														
Catadromus lacordarei														
Cenogmus sp. 1														
Chlaenius greyanus														
Egadroma sp. 1														
Euthenaris sp. 1														
Euthenaris sp. 2														
Genus 1 sp. a														
Genus 1 sp. b														
Genus 1 sp. c							1	1	2					
Genus 1 sp. d									2					
Gnathoxys crassipes	2		1	3			1			1			2	3
Gnathoxys granularis									1					
Gnathoxys pannuceus														
Lecanomerus verticalis		1		1		1			1					
Microlestes sp. 1														
Neocarenum sp. 1														
Notagonum sp. 1														
Notagonum sp. 2														
Notagonum submetallicum														
Notonomus mediosulcatus			1	1										
Notospeophonus sp. 1														
Phorticosomerus sp. 1														
Platycoelus sp. 1														
Promecoderus scauroides											2	1		3
Sarothrocrepis sp. 1														
Sarticus iriditinctus														
Sarticus sp. 1	1	5	1	7		1			1					
Scaraphites lucidus														
Scaraphites silenus														
Scopodes boops														
Simodontus australis	1			1	1				1			2		2
Speotarus lucifugus														
Teropha sp.														
Trigonothops sp. 1														
TOTAL	4	6	3	13	1	2	2	1	8	1	2	3	2	8

Appendix G continued…Spearwood/Bassendean Dune junction and Bassendean Dunes sites…

SITE	LS1		LS1	MR1	MR2		MR	Jk1					JK2			
TAXON	13-Jul-95	25-Sep-95	TOTAL	13-Jul-95	13-Jul-95	25-Sep-95	TOTAL	16-Jul-94	1-Sep-94	4-Nov-94	4-May-95	TOTAL	4-Nov-94	19-Jan-95	4-May-95	TOTAL
Calosoma schayeri																
Carenum scaritoides																
Carenum sp. 1																
Catadromus lacordarei																
Cenogmus sp. 1																
Chlaenius greyanus																
Egadroma sp. 1																
Euthenaris sp. 1																
Euthenaris sp. 2																
Genus 1 sp. a																
Genus 1 sp. b																
Genus 1 sp. c																
Genus 1 sp. d																
Gnathoxys crassipes													1			1
Gnathoxys granularis																
Gnathoxys pannuceus																
Lecanomerus verticalis					1		1	8	5	45		58	3	13		16
Microlestes sp. 1																
Neocarenum sp. 1																
Notagonum sp. 1																
Notagonum sp. 2																
Notagonum submetallicum																
Notonomus mediosulcatus																
Notospeophonus sp. 1																
Phorticosomerus sp. 1										1		1				
Platycoelus sp. 1																
Promecoderus scauroides																
Sarothrocrepis sp. 1																
Sarticus iriditinctus															2	2
Sarticus sp. 1																
Scaraphites lucidus																
Scaraphites silenus	2	3	5	1			1				1	1	1			1
Scopodes boops																
Simodontus australis				1		1	2	3				3			2	2
Speotarus lucifugus																
Teropha sp.																
Trigonothops sp. 1																
TOTAL	2	3	5	2	1	1	3	11	5	46	1	63	5	13	4	22

Appendix G continued...Bassendean Dunes sites continued...

SITE	PA5							PA6					
TAXON	10-May-93	28-Jul-93	24-Sep-93	18-Nov-93	6-Jan-94	18-Mar-94	**TOTAL**	10-May-93	28-Jul-93	24-Sep-93	6-Jan-94	18-Mar-94	**TOTAL**
Calosoma schayeri													
Carenum scaritoides													
Carenum sp. 1													
Catadromus lacordarei										3			**3**
Cenogmus sp. 1													
Chlaenius greyanus		1					**1**						
Egadroma sp. 1													
Euthenaris sp. 1													
Euthenaris sp. 2										1			**1**
Genus 1 sp. a								2					**2**
Genus 1 sp. b													
Genus 1 sp. c								1					**1**
Genus 1 sp. d													
Gnathoxys crassipes													
Gnathoxys granularis													
Gnathoxys pannuceus													
Lecanomerus verticalis				5	5	2	**12**				1	1	**2**
Microlestes sp. 1					1		**1**						
Neocarenum sp. 1								1					**1**
Notagonum sp. 1	5		1				**6**			1		3	**4**
Notagonum sp. 2													
Notagonum submetallicum													
Notonomus mediosulcatus													
Notospeophonus sp. 1													
Phorticosomerus sp. 1													
Platycoelus sp. 1										1			**1**
Promecoderus scauroides	1	1	11			1	**14**		1	1			**2**
Sarothrocrepis sp. 1													
Sarticus iriditinctus													
Sarticus sp. 1													
Scaraphites lucidus													
Scaraphites silenus	1		24				**25**						
Scopodes boops													
Simodontus australis													
Speotarus lucifugus				1			**1**						
Teropha sp.													
Trigonothops sp. 1													
TOTAL	**7**	**2**	**36**	**6**	**6**	**3**	**60**	**4**	**1**	**7**	**1**	**4**	**17**

Appendix G continued…Bassendean Dunes sites continued…

SITE	PA7							PA8				
TAXON	10-May-93	28-Jul-93	24-Sep-93	18-Nov-93	6-Jan-94	18-Mar-94	**TOTAL**	24-Jun-93	28-Jul-93	24-Sep-93	18-Nov-93	**TOTAL**
Calosoma schayeri												
Carenum scaritoides												
Carenum sp. 1												
Catadromus lacordarei				1			**1**					
Cenogmus sp. 1												
Chlaenius greyanus												
Egadroma sp. 1						1	**1**					
Euthenaris sp. 1												
Euthenaris sp. 2												
Genus 1 sp. a												
Genus 1 sp. b			1				**1**					
Genus 1 sp. c												
Genus 1 sp. d												
Gnathoxys crassipes	1			4	4	5	**14**					
Gnathoxys granularis												
Gnathoxys pannuceus												
Lecanomerus verticalis		1					**1**					
Microlestes sp. 1												
Neocarenum sp. 1												
Notagonum sp. 1	1				1		**2**					
Notagonum sp. 2												
Notagonum submetallicum												
Notonomus mediosulcatus												
Notospeophonus sp. 1												
Phorticosomerus sp. 1												
Platycoelus sp. 1		2					**2**					
Promecoderus scauroides		1	2				3	2	1	5	1	**9**
Sarothrocrepis sp. 1												
Sarticus iriditinctus								1				**1**
Sarticus sp. 1												
Scaraphites lucidus												
Scaraphites silenus			1	2			3		2		4	**6**
Scopodes boops												
Simodontus australis												
Speotarus lucifugus										1		**1**
Teropha sp.												
Trigonothops sp. 1												
TOTAL	2	4	4	7	5	6	28	3	3	6	5	17

Appendix G continued…Bassendean Dunes sites continued…

SITE TAXON	TR1 10-May-93	24-Jun-93	28-Jul-93	24-Sep-93	18-Nov-93	18-Mar-94	TOTAL	TR2 10-May-93	24-Jun-93	28-Jul-93	24-Sep-93	18-Mar-94	TOTAL
Calosoma schayeri													
Carenum scaritoides													
Carenum sp. 1													
Catadromus lacordarei													
Cenogmus sp. 1													
Chlaenius greyanus													
Egadroma sp. 1													
Euthenaris sp. 1													
Euthenaris sp. 2													
Genus 1 sp. a													
Genus 1 sp. b	3						**3**						
Genus 1 sp. c													
Genus 1 sp. d													
Gnathoxys crassipes			1				**1**						
Gnathoxys granularis	2						**2**						
Gnathoxys pannuceus													
Lecanomerus verticalis	1			1	1	2	**5**						
Microlestes sp. 1													
Neocarenum sp. 1													
Notagonum sp. 1	1					7	**8**		1	1	2	39	**43**
Notagonum sp. 2											1		**1**
Notagonum submetallicum													
Notonomus mediosulcatus													
Notospeophonus sp. 1													
Phorticosomerus sp. 1													
Platycoelus sp. 1													
Promecoderus scauroides	3	4					**7**	1					**1**
Sarothrocrepis sp. 1													
Sarticus iriditinctus	1	4					**5**						
Sarticus sp. 1	6						**6**						
Scaraphites lucidus													
Scaraphites silenus													
Scopodes boops													
Simodontus australis	6	2					**8**						
Speotarus lucifugus	3						**3**						
Teropha sp.													
Trigonothops sp. 1													
TOTAL	26	10	1	1	1	9	48	1	1	1	3	39	45

Appendix G continued…Bassendean Dunes sites continued…

SITE TAXON	TR3 24-Jun-93	24-Sep-93	18-Nov-93	TOTAL	TR4 24-Jun-93	18-Nov-93	TOTAL
Calosoma schayeri							
Carenum scaritoides							
Carenum sp. 1							
Catadromus lacordarei							
Cenogmus sp. 1							
Chlaenius greyanus							
Egadroma sp. 1							
Euthenaris sp. 1							
Euthenaris sp. 2							
Genus 1 sp. a						1	**1**
Genus 1 sp. b							
Genus 1 sp. c							
Genus 1 sp. d							
Gnathoxys crassipes					1		**1**
Gnathoxys granularis							
Gnathoxys pannuceus							
Lecanomerus verticalis	2	1	3	**6**		1	**1**
Microlestes sp. 1			1	**1**			
Neocarenum sp. 1							
Notagonum sp. 1		4	199	**203**		34	**34**
Notagonum sp. 2							
Notagonum submetallicum							
Notonomus mediosulcatus							
Notospeophonus sp. 1							
Phorticosomerus sp. 1							
Platycoelus sp. 1							
Promecoderus scauroides		2		**2**	1		**1**
Sarothrocrepis sp. 1						1	**1**
Sarticus iriditinctus							
Sarticus sp. 1			1	**1**	5		**5**
Scaraphites lucidus							
Scaraphites silenus							
Scopodes boops					1		**1**
Simodontus australis							
Speotarus lucifugus			2	**2**			
Teropha sp.							
Trigonothops sp. 1							
TOTAL	**2**	**7**	**206**	**215**	**8**	**37**	**45**

APPENDIX H: CARABIDAE SPECIMENS COLLECTED IN VERTEBRATE PITFALL TRAPS DURING THE GROUND FAUNA OF URBAN BUSHLAND REMNANTS SURVEY.

The following specimens were collected from vertebrate pitfall traps open concurrently with the invertebrate pitfall traps (examined in this thesis) in the various remnants surveyed by How *et al.* (1996). This list is not complete or exhaustive due to inconsistencies between field workers keeping or releasing specimens. However this indicates that one or two years of pitfall trapping may not adequately document the entire carabid assemblage for these remnants.

Sites WP1 (& WP2) {& WP3):

TAXA	**14 Nov-11 Dec 1994**	**1-12 March 1994**	**Total**
Gnathoxys crassipes	1(2)		**1(2)**
Scaraphites lucidus	{6}	1{1}	**1{7}**
Simodontus australis	{1}		**{1}**
Total			

Site BP1:

TAXA	**24-29 Aug 1993**	**18-31 Oct 1993**	**23 Nov- 24 Dec 1993**	**24 Jan- 5 Feb 1994**	**5 Oct- 20 Nov 1995**	Total
Gnathoxys crassipes			1			1
Scaraphites lucidus	2	7	6	1	1	17
Total	**2**	**7**	**7**	**1**	**1**	18

Sites BP3 (& BP4):

TAXA	**18-31 Oct 1993**	**23 Nov- 24 Dec 1993**	**24 Jan- 5 Feb 1994**	**24-29 Aug 1994**	**5 Oct- 20 Nov 1995**	**Total**
Gnathoxys crassipes		(3)	4		(1)	4(4)
Hormacrus latus				(1)		(1)
Promecoderus scauroides	(1)					(1)
Scaraphites lucidus	2(5)	2(5)	1(2)		(2)	5(14)
Total	**2(6)**	**2(8)**	**5(2)**	**(1)**	**(3)**	**9(20)**

Sites BP5 (& BP6):

TAXA	**24-29 Aug 1993**	**18-31 Oct 1993**	**23 Nov- 24 Dec 1993**	**5 Oct- 20 Nov 1995**	**Total**
Gnathoxys crassipes				(2)	(2)
Scaraphites lucidus	3	6	2	2(6)	13 (6)
Total	**3**	**6**	**2**	**2(8)**	**13 (8)**

Site MC1 (& MC2):

TAXA	**11-31 Oct 1994**	**1 28 Nov 1994**	**1-12 Dec 1994**	**1-12 March 1995**	**Total**
Carenum scaritoides	3			1	4
Gnathoxys crassipes		1	4(3)		5(3)
Promecoderus scauroides		(1)			(1)
Scaraphites lucidus	3(1)		1(1)		4(2)
Total	**6(1)**	**1(1)**	**5(4)**	**1**	**13(6)**

Various Sites: **JK1 (& JK2) {MH1} LS1 (& LS2) {& WR2} HH3 (& HH4)**

TAXA	**14 Nov-11 Dec 1994**	**7-19 Nov 1995**	**5-18 Dec 1995**	**Total**
Genus 1 sp. C	1			**1**
Gnathoxys crassipes	1{1}	{1}	1(1)	**5**
Neocarenum sp. 2	(1)			**1**
Scaraphites silenus		1 (1)		**2**
Total	**2(1){1}**	**1(1){1}**	**1(1)**	**10**

Sites PA5 (& PA6):

TAXA	**24-29 Aug 1993**	**18-31 Oct 1993**	**23 Nov- 24 Dec 1993**	**24 Jan- 5 Feb 1994**	**14-24 March 1994**	**Total**
Gnathoxys crassipes				3(1)		**3(1)**
Neocarenum sp. 1					(1)	**(1)**
Neocarenum sp. 2	(1)	(1)				**(2)**
Scaraphites silenus		2(1)			1	**3(1)**
Total	**(1)**	**2(2)**		**3(1)**	**1**	**6(5)**

Sites PA7 (& PA8):

TAXA	**24-29 Aug 1993**	**18-31 Oct 1993**	**23 Nov- 24 Dec 1993**	**24 Jan- 5 Feb 1994**	**Total**
Catadromus lacordarei			1		**1**
Gnathoxys crassipes				1	**1**
Neocarenum sp. 1		(1)			**(1)**
Promecoderus scauroides			(1)		**(1)**
Scaraphites lucidus					
Scaraphites silenus	(1)	(7)	(16)		**(24)**
Total	**(1)**	**(8)**	**1(17)**	**1**	**2(26)**

Sites TR1 (& TR4):

TAXA	**24-29 Aug 1993**	**18-31 Oct 1993**	**23 Nov- 24 Dec 1993**	**24 Jan- 5 Feb 1994**	**5 Oct- 20 Nov 1995**	**Total**
Gnathoxys crassipes	1					**1**
Gnathoxys granularis			(2)			**(2)**
Scaraphites silenus		2(3)	1(3)			**3(6)**
Total	**1**	**2(3)**	**1(5)**			**4(8)**

APPENDIX I: RECORDS USED FOR DISTRIBUTION MAPS.

Specimen records were accessed from the Entomology Departments of the Western Australian Museum (WAM), Agriculture W.A. (Ag. Dept.) and the Australian National Insect Collection (ANIC- CSIRO). Most records lack detailed collection data information and/or a source code (Institution registration number). Exceptions to this are specimens from Agriculture W.A.

DATE	SOURCE	SOURCE CODE	*GENUS*	*SPECIES*	COLLECTOR	SITE	LATITUDE	LONGITUDE
29 Aug 1978	Ag. Dept.	5472	*Gnathoxys*	*granularis*	Richards, K.T.	Kalbarri	27.72	114.17
29 Aug 1978	Ag. Dept.	5473	*Gnathoxys*	*granularis*	Richards,K.T.	Kalbarri	27.72	114.17
30 May 1973	Ag. Dept.	5466	*Gnathoxys*	*granularis*	McFarland, N.	Drummond Cove	28.67	114.62
	Ag. Dept.	5463	*Gnathoxys*	*granularis*	Clark, J.	Eradu	28.7	115.03
	Ag. Dept.	5462	*Gnathoxys*	*granularis*	Clark, J.	Geraldton	28.77	114.62
02 Aug 1978	Ag. Dept.	5468	*Gnathoxys*	*granularis*	Davis, P.R.	Geraldton	28.77	114.62
	Ag. Dept.	5461	*Gnathoxys*	*granularis*	Newman, L.J.	Geraldton	28.77	114.62
1912	Ag. Dept.	5460	*Gnathoxys*	*granularis*	Clark, J.	Geraldton	28.77	114.62
15 Aug 1978	Ag. Dept.	5469	*Gnathoxys*	*granularis*	Richards,K.T.	Badgingarra	30.38	115.5
15 Aug 1978	Ag. Dept.	5470	*Gnathoxys*	*granularis*	Richards,K.T.	Badgingarra	30.38	115.5
15 Aug 1978	Ag. Dept.	5471	*Gnathoxys*	*granularis*	Richards,K.T.	Badgingarra	30.38	115.5
28 Jul 1978	Ag. Dept.	5467	*Gnathoxys*	*granularis*	Solomon, G.	Moora	30.65	116
20 Aug 1971	Ag. Dept.	5465	*Gnathoxys*	*granularis*	Richards,K.T.	Guilderton	31.35	115.5
04 Nov 1903	Ag. Dept.	5459	*Gnathoxys*	*granularis*	Giles, H.M.	Kings Park	31.97	115.87
	Ag. Dept.	13727	*Notonomus*	*mediosulcatus*	Newman, L.J.	Albany	35	117.87
	Ag. Dept.	13728	*Notonomus*	*mediosulcatus*	Newman, L.J.	Albany	35	117.87
	Ag. Dept.	5551	*Promecoderus*	*scauroides*	Clark, J.	Swan River	31.97	115.93
	Ag. Dept.	5552	*Promecoderus*	*scauroides*	Clark, J.	Swan River	31.97	115.93
	Ag. Dept.	5553	*Promecoderus*	*scauroides*	Newman, L.J.	Swan River	31.97	115.93
	Ag. Dept.	5556	*Promecoderus*	*scauroides*	Bessen, M.	Dawesville	32.63	115.63
	Ag. Dept.	5554	*Promecoderus*	*scauroides*	Newman, L.J.	Bridgetown	33.97	116.13
	Ag. Dept.	6440	*Sarticus*	*iriditinctus*	Clark, J.	Swan River	31.87	116
	Ag. Dept.	6441	*Sarticus*	*iriditinctus*	Clark, J.	Swan River	31.87	116
	Ag. Dept.	6442	*Sarticus*	*iriditinctus*	Lea, A.M.	Swan River	31.87	116
21 Aug 1951	Ag. Dept.	5375	*Scaraphites*	*lucidus*		North Beach	31.87	115.75
01 Feb 1947	Ag. Dept.	5373	*Scaraphites*	*lucidus*		City Beach	31.93	115.75
13 Sep 1948	Ag. Dept.	5374	*Scaraphites*	*lucidus*	Davenport, N.	Perth	31.97	115.87
	Ag. Dept.	5371	*Scaraphites*	*lucidus*	Newman, L.J.	Swan River	31.97	115.93
13 Dec 1910	Ag. Dept.	5366	*Scaraphites*	*lucidus*	Giles, H.M.	Cottesloe	31.98	115.75
07 May 1910	Ag. Dept.	5365	*Scaraphites*	*lucidus*	Giles, H.M.	Rottnest Island 34	32	115.52
	Ag. Dept.	5368	*Scaraphites*	*lucidus*	Clark, J.	Ludlow	33.6	115.48

DATE	SOURCE	SOURCE CODE	*GENUS*	*SPECIES*	COLLECTOR	SITE	LATITUDE	LONGITUDE
	Ag. Dept.	5369	*Scaraphites*	*lucidus*	Clark, J.	Ludlow	33.6	115.48
	Ag. Dept.	5370	*Scaraphites*	*lucidus*	Clark, J.	Ludlow	33.6	115.48
Nov 1972	Ag. Dept.	5380	*Scaraphites*	*lucidus*		Ludlow	33.6	115.48
14 Jun 1959	Ag. Dept.	5376	*Scaraphites*	*lucidus*	Snell, A.	Busselton	33.65	115.33
05 May 1962	Ag. Dept.	5377	*Scaraphites*	*lucidus*	O'Halloran, L.M.	Deep Dene	34.27	115.05
23 Nov 1963	Ag. Dept.	5378	*Scaraphites*	*lucidus*	O'Halloran, L.M.	Deep Dene	34.27	115.05
	Ag. Dept.	5372	*Scaraphites*	*lucidus*		Big Brook	34.4	116
10 Feb 1972	Ag. Dept.	5379	*Scaraphites*	*lucidus*	Curry, S.J.	Pemberton	34.45	116.03
	Ag. Dept.	5411	*Scaraphites*	*silenus*	O'Halloran, L.M.	Dandaragan	30.68	115.7
	Ag. Dept.	5395	*Scaraphites*	*silenus*	Mitchell, C.E.	Mogumber	31.05	116.33
27 Jan 1971	Ag. Dept.	5413	*Scaraphites*	*silenus*	Richards,K.T.	Woolgangie	31.17	120.55
23 Sep 1941	Ag. Dept.	5406	*Scaraphites*	*silenus*	Forte, P.N.	Jennacubbine	31.43	116.72
05 Feb 1958	Ag. Dept.	5410	*Scaraphites*	*silenus*	Forte, P.N.	Yanchep	31.55	115.68
	Ag. Dept.	5397	*Scaraphites*	*silenus*	Crawshaw, W.	Kellerberrin	31.63	117.72
	Ag. Dept.	5405	*Scaraphites*	*silenus*		Wanneroo	31.75	115.8
18 Sep 1905	Ag. Dept.	5386	*Scaraphites*	*silenus*	Giles, H.M.	Wanneroo	31.75	115.8
	Ag. Dept.	5394	*Scaraphites*	*silenus*		Swan River, Gnangara	31.78	115.87
06 Oct 1978	Ag. Dept.	5415	*Scaraphites*	*silenus*	Davis, P.R.	Shenton Park	31.97	115.8
08 Nov 1951	Ag. Dept.	5408	*Scaraphites*	*silenus*	Edwards, B.A.B.	Shenton Park	31.97	115.8
04 Feb 1949	Ag. Dept.	5407	*Scaraphites*	*silenus*		Perth	31.97	115.87
	Ag. Dept.	5384	*Scaraphites*	*silenus*	Clark, J.	Swan River	31.97	115.93
	Ag. Dept.	5389	*Scaraphites*	*silenus*	Clark, J.	Swan River	31.97	115.93
	Ag. Dept.	5393	*Scaraphites*	*silenus*	Hamilton, C.	Swan River	31.97	115.93
	Ag. Dept.	5390	*Scaraphites*	*silenus*	Newman, L.J.	Swan River	31.97	115.93
	Ag. Dept.	5391	*Scaraphites*	*silenus*	Newman, L.J.	Swan River	31.97	115.93
	Ag. Dept.	5392	*Scaraphites*	*silenus*	Newman, L.J.	Swan River	31.97	115.93
08 Nov 1955	Ag. Dept.	5409	*Scaraphites*	*silenus*	Shedley, D.G.	Applecross	31.98	115.85
18 Dec 1934	Ag. Dept.	5396	*Scaraphites*	*silenus*	Casson, W.	South Perth	31.98	115.87
23 Apr 1906	Ag. Dept.	5387	*Scaraphites*	*silenus*	Giles, H.M.	South Perth	31.98	115.87
	Ag. Dept.	5388	*Scaraphites*	*silenus*	Giles, H.M.	South Perth	31.98	115.87
19 Feb 1970	Ag. Dept.	5412	*Scaraphites*	*silenus*	Richards,K.T.	Lake Cronin	32.38	119.75
Nov 1972	Ag. Dept.	5414	*Scaraphites*	*silenus*		Ludlow	33.6	115.48
	Ag. Dept.	5403	*Scaraphites*	*silenus*		Big Brook	34.4	116
	Ag. Dept.	5404	*Scaraphites*	*silenus*		Big Brook	34.4	116
	Ag. Dept.	5416	*Scaraphites*	*sp.*	Crawshaw, W.	Wyndham	15.48	128.12
04 Jul 1989	Ag. Dept.	6470	*Simodontus*	*australis*	Heterick, B.E.	Mount Willoughby, 17km Nth Northampton	28.2	114.58
04 Jul 1989	Ag. Dept.	6471	*Simodontus*	*australis*	Heterick, B.E.	Mount Willoughby, 17km Nth Northampton	28.2	114.58
	Ag. Dept.	6467	*Simodontus*	*australis*	Crawshaw, W.	Kellerberrin	31.63	117.72
	Ag. Dept.	6468	*Simodontus*	*australis*	Crawshaw, W.	Kellerberrin	31.63	117.72
23 Nov 1935	CSIRO		*Carenum*	*scaritoides*		Yanchep, 32 miles N of Perth	31.55	115.68
	CSIRO		*Gnathoxys*	*crassipes*		Rottnest Island	32	115.52
30 Dec 1936	CSIRO		*Gnathoxys*	*crassipes*		Fremantle, Coogee	32.05	115.73
14 Feb 1977	CSIRO		*Gnathoxys*	*crassipes*		Dwellingup (Curara Block)	32.72	116.07

DATE	SOURCE	SOURCE CODE	*GENUS*	*SPECIES*	COLLECTOR	SITE	LATITUDE	LONGITUDE
Aug 1926	CSIRO		*Promecoderus*	*scauroides*		Perth	31.97	115.87
	CSIRO		*Promecoderus*	*scauroides*		Rottnest Island	32	115.52
	CSIRO		*Promecoderus*	*scauroides*		Pinjarra	32.63	115.87
12 Dec 1913	CSIRO		*Scaraphites*	*lucidus*		Yallingup	32.65	115.02
07 Jan 1914	CSIRO		*Scaraphites*	*lucidus*		Bunbury	33.32	115.63
Sept 1926	CSIRO		*Scaraphites*	*silenus*		Kojerina	28.72	114.87
19 Dec 1983	CSIRO		*Scaraphites*	*silenus*		Moore River National Park	31.17	115.67
	CSIRO		*Scaraphites*	*silenus*		Swan River	31.87	116
08 Sep 1906	CSIRO		*Scaraphites*	*silenus*		Claremont	31.98	115.78
01 Jul 1934	CSIRO		*Scaraphites*	*silenus*		Applecross	31.98	115.85
June 1940	CSIRO		*Scaraphites*	*silenus*		Fremantle	32.05	115.73
	CSIRO		*Scaraphites*	*silenus*		Pinjarra	32.63	115.87
16 Jul 1934	CSIRO		*Scaraphites*	*silenus*		Lake Grace	33.1	118.47
22 Jul 1975	CSIRO		*Scaraphites*	*silenus*		Duggin	33.15	118.13
	CSIRO		*Scaraphites*	*silenus*		Bunbury	33.32	115.63
24 Sep 1983	CSIRO		*Scaraphites*	*silenus*		Lake Bryde	33.35	118.82
24 Aug 1981	CSIRO		*Scaraphites*	*silenus*		60 km NE of Wagin	33.53	117.55
25 Jul 1970	CSIRO		*Scaraphites*	*silenus*		Wilga	33.7	116.23
Aug 1926	CSIRO		*Simodontus*	*australis*		Perth	31.97	115.87
30 Dec 1913	CSIRO		*Simodontus*	*australis*		Manjimup	34.25	116.15
31 Jan 1968	WAM		*Carenum*	*scaritoides*	A. M. Douglas, L. E. Koch	Fields Find	29.03	117.25
30 Aug 1982	WAM		*Carenum*	*scaritoides*	R. P. McMillan	2 km E of Greenhead	30.07	114.97
30 Aug 1982	WAM		*Carenum*	*scaritoides*	R. P. McMillan	2 km E of Greenhead	30.07	114.97
30 Aug 1982	WAM		*Carenum*	*scaritoides*	R. P. McMillan	2 km E of Greenhead	30.07	114.97
30 Aug 1982	WAM		*Carenum*	*scaritoides*	R. P. McMillan	2 km E of Greenhead	30.07	114.97
30 Aug 1982	WAM		*Carenum*	*scaritoides*	R. P. McMillan	2 km E of Greenhead	30.07	114.97
21 Oct 1978	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Moorine Rock	31.3	119.13
23 Jun 1983	WAM		*Carenum*	*scaritoides*	W. F. Humphreys	14.5 km SE of Marvel Loch	31.5	119.22
08 Jun 1919	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Gibbs Property, Wanneroo	31.75	115.8
08 Jun 1919	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Gibbs Property, Wanneroo	31.75	115.8
08 Jun 1969	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Gibbs Property, Wanneroo	31.75	115.8
08 May 1966	WAM		*Carenum*	*scaritoides*	R. Humphries	Wembley	31.93	115.8
June 1915	WAM	1915-608	*Carenum*	*scaritoides*		Perth	31.97	115.87
26 Sep 1978	WAM	202	*Carenum*	*scaritoides*	T. F. Houston et al	0.6 km W of Lake Cronin	32.38	119.77
26 Sep 1986	WAM		*Carenum*	*scaritoides*	L. N. McKenna	Hopetown	33.97	120.12
04 Mar 1988	WAM		*Carenum*	*scaritoides*	B. Y. Main	West Cape Howe	34.13	117.6
26 Dec 1987	WAM		*Carenum*	*scaritoides*	B. Y. Main	West Cape Howe	34.13	117.6
17 Sep 1978	WAM		*Carenum*	*scaritoides*	A. Chapman; R How	Ocean Reef-Heathridge,	31.733	115.717
17 Sep 1978	WAM		*Carenum*	*scaritoides*	A. Chapman; R How	Ocean Reef-Heathridge,	31.733	115.717
24 Sep 1983	WAM	559-19	*Gnathoxys*	*crassipes*	T. F. Houston	East Yuna Reserve 34km WNW of Mullewa	28.33	115
26 Oct 1993	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Eneabba	29.82	115.27
28 Nov 1991	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Eneabba	29.82	115.27
28 Nov 1991	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Eneabba	29.82	115.27

DATE	SOURCE	SOURCE CODE	*GENUS*	*SPECIES*	COLLECTOR	SITE	LATITUDE	LONGITUDE
05 Nov 1992	WAM	797-8	*Gnathoxys*	*crassipes*	T. F. Houston	North Eneabba Nature Reserve 30km N Eneabba	29.82	115.27
05 Nov 1992	WAM	797-8	*Gnathoxys*	*crassipes*	T. F. Houston	North Eneabba Nature Reserve 30km N Eneabba	29.82	115.27
01 Sep 1972	WAM		*Gnathoxys*	*crassipes*	A. Baynes; N. T. Allen	Buntine Rock Area	29.97	116.58
1922	WAM	1922-215	*Gnathoxys*	*crassipes*		Moora	30.65	116
31 Dec 1989	WAM	739-99	*Gnathoxys*	*crassipes*	T. F. Houston	Moore River National Park	31.17	115.67
Sept 1937	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Spencer's Brook	31.72	116.63
Sept 1937	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Spencer's Brook	31.72	116.63
15 Dec 1950	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	North Beach	31.87	115.75
April 1977	WAM		*Gnathoxys*	*crassipes*	G. H. Lowe	Darlington, Perth	31.92	116.07
21 Jan 1988	WAM		*Gnathoxys*	*crassipes*	J. Dell	north end of Perth airport	31.93	115.97
March 1914	WAM	1914-476	*Gnathoxys*	*crassipes*		South Perth	31.98	115.87
1931	WAM	1931-1020	*Gnathoxys*	*crassipes*		Rottnest	32	115.52
1930	WAM	1930-42	*Gnathoxys*	*crassipes*		Rottnest	32	115.52
1932	WAM	1932-127	*Gnathoxys*	*crassipes*		Rottnest	32	115.52
1931	WAM	1931-1789	*Gnathoxys*	*crassipes*		Rottnest	32	115.52
1932	WAM	1932-128	*Gnathoxys*	*crassipes*		Rottnest	32	115.52
1932	WAM	1932-487	*Gnathoxys*	*crassipes*		Rottnest	32	115.52
1933	WAM	1933-906	*Gnathoxys*	*crassipes*		Forrestdale	32.17	115.97
1932	WAM	1932-2408	*Gnathoxys*	*crassipes*		Forrestdale	32.17	115.97
1932	WAM	1932-1708	*Gnathoxys*	*crassipes*		Forrestdale	32.17	115.97
19 Dec 1950	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Bejoording	32.28	116.78
25 Jul 1959	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Bejoording	32.28	116.78
1950	WAM	1950-5167	*Gnathoxys*	*crassipes*		Bejoording	32.28	116.78
1937	WAM	1937-4039	*Gnathoxys*	*crassipes*		Narrogin	32.93	117.18
1942	WAM	1942-327	*Gnathoxys*	*crassipes*		Wellington Mills	33.45	115.9
18 Nov 1985	WAM	639-23	*Gnathoxys*	*crassipes*	T. F. Houston	Cape Freycinet	34.1	114.98
07 Jan 1992	WAM		*Gnathoxys*	*crassipes*	R. P. McMillan	Denmark	34.97	117.35
1944	WAM	1944-651	*Gnathoxys*	*crassipes*		Youngs	35.03	117.87
25 Apr 1969	WAM		*Gnathoxys*	*crassipes*	P. G. Kendrick	2.5 miles W of Mundaring Weir		116.28
Sept 1956	WAM		*Gnathoxys*	*granularis*		Murchison River	26.6	116.38
10 Aug 1970	WAM		*Gnathoxys*	*granularis*	K. Youngson; R. Johnstone	Kalbarri National Park	27.72	114.17
25 May 1987	WAM		*Gnathoxys*	*granularis*	M. Peterson	19.5km N of Yuna on Dartmoor Road	28.33	115
26 Aug 1985	WAM	617-6	*Gnathoxys*	*granularis*	T. F. Houston	East Yuna Reserve, 34 km WNW of Mullewa	28.33	115
21 Sep 1915	WAM	1916-7246	*Gnathoxys*	*granularis*		Geraldton	28.77	114.62
12 Sep 1987	WAM	852-13	*Gnathoxys*	*granularis*	T. Houston	15km N Eneabba	29.82	115.27
12 Sep 1987	WAM	652-13	*Gnathoxys*	*granularis*	T. F. Houston	15km NW Eneabba	29.82	115.27
29 May 1995	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
30 May 1995	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
05 Jun 1992	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
02 Jun 1992	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
18 Oct 1994	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
02 Jun 1992	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
05 Jun 1992	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27

DATE	**SOURCE**	**SOURCE CODE**	***GENUS***	***SPECIES***	**COLLECTOR**	**SITE**	**LATITUDE**	**LONGITUDE**
17 Oct 1994	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
12 Oct 1980	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
10 Sep 1992	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Eneabba	29.82	115.27
31 Aug 1982	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	10km E Greenhead	30.07	115.97
17 Sep 1945	WAM	1946-1585	*Gnathoxys*	*granularis*		East Fremantle	32.05	115.8
1928	WAM	1928-772	*Gnathoxys*	*granularis*		East Fremantle	32.05	115.8
1927	WAM	1927-1563	*Gnathoxys*	*granularis*		Tambellup	34.03	117.63
15 Sep 1986	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Burma Rd Reserve 30km E of Walkaway	28.967	115.033
15 Sep 1986	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Burma Rd Reserve 30km E Walkaway	28.967	115.033
16 Oct 1979	WAM		*Gnathoxys*	*granularis*	R. P. McMillan	Mt. Walker	32.067	118.75
17 Sep 1978	WAM		*Gnathoxys*	*granularis*	A. Chapman; R How	Ocean Reef-Heathridge,	31.733	115.717
06 Aug 1950	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Carnamah	29.68	115.55
Dec 1989	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Eneabba	29.82	115.27
21 Jun 1979	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Bencubbin	30.82	117.85
Oct 1981	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Southern Cross	31.22	119.33
04 Apr 1969	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Sunday Hill- Strathalbyn, 1 mile N of Gingin	31.35	115.9
04 Apr 1969	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Sunday Hill- Strathalbyn, 1 mile N of Gingin	31.35	115.9
04 Apr 1969	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Sunday Hill- Strathalbyn, 1 mile N of Gingin	31.35	115.9
04 Apr 1969	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Sunday Hill- Strathalbyn, 1 mile N of Gingin	31.35	115.9
04 Apr 1969	WAM		*Carenum*	*scaritoides*	M. Archer; E. Jeffery etal	Sunday Hill- Strathalbyn, 1 mile N of Gingin	31.35	115.9
06 Jan 1978	WAM		*Carenum*	*scaritoides*	P. G. Kendrick	Ellenbrook near Margret River	31.55	115.97
05 Jul 1946	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Spencer's Brook	31.72	116.63
Sept 1946	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Spencer's Brook	31.72	116.63
May 1945	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Spencer's Brook	31.72	116.63
18 Jun 1946	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Spencer's Brook	31.72	116.63
Oct 1945	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Spencer's Brook	31.72	116.63
July 1947	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Spencer's Brook	31.72	116.63
05 Apr 1987	WAM		*Carenum*	*scaritoides*	J. M. Waldock	Glenbourne Farm, 10 km W Wooroloo	31.83	115.5
Sept 1978	WAM		*Carenum*	*scaritoides*	G. H. Lowe	Darlington, Perth	31.92	116.07
16 Apr 1985	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cottesloe	31.93	115.75
08 May 1969	WAM		*Carenum*	*scaritoides*	D. D. Giuliani	Rottnest	32	115.52
04 May 1969	WAM		*Carenum*	*scaritoides*	D. D. Giuliani	Rottnest	32	115.52
Sept 1939	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Rottnest	32	115.52
1932	WAM	32-126	*Carenum*	*scaritoides*		Rottnest	32	115.52
1934	WAM	34-3498	*Carenum*	*scaritoides*		Rottnest	32	115.52
1939	WAM	39-2387	*Carenum*	*scaritoides*		Rottnest	32	115.52
1931	WAM	31-1399	*Carenum*	*scaritoides*		Rottnest	32	115.52
1931	WAM	31-14	*Carenum*	*scaritoides*		Rottnest	32	115.52
	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Riverton, swamp	32.03	115.88
10 Jun 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
17 Jun 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
27 Apr 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95

DATE	SOURCE	SOURCE CODE	*GENUS*	*SPECIES*	COLLECTOR	SITE	LATITUDE	LONGITUDE
05 Nov 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
27 Aug 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
14 Sep 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
09 Jul 1953	WAM	53-1606	*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
July 1950	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
02 Aug 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
02 Aug 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
24 Sep 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
10 Apr 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
04 May 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
24 May 1953	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Cannington	32.03	115.95
July 1949	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Bejoording	32.28	116.78
July 1950	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Bejoording	32.28	116.78
19 May 1985	WAM		*Carenum*	*scaritoides*	F. H. Uther- Baker	Furnissdale, SE Mandurah	32.53	115.72
31-May 1969	WAM		*Carenum*	*scaritoides*	P. M. William	Pinjarra	32.63	115.87
March 1951	WAM		*Carenum*	*scaritoides*	R. P. McMillan	Albany	35.03	117.88
30 Apr 1990	WAM		*Carenum*	*scaritoides*	M. S. Harvey; J. M. Waldock	3 km N of Dog Pool	35.75	116.22
04 Mar 1968	WAM		*Carenum*	*scaritoides*	L. E. Koch; L. N. McKenna	Aralewn	32.117	116.1
15 Sep 1985	WAM		*Carenum*	*scaritoides*	D. Mueller	Lane Pool Reserve 14km S of Dwellingup	32.767	116.05
15 Sep 1985	WAM		*Carenum*	*scaritoides*	D. Mueller	Lane Pool Reserve 14km S of Dwellingup	32.767	116.05
15 Sep 1985	WAM		*Carenum*	*scaritoides*	D. Mueller	Lane Pool Reserve 14km S of Dwellingup	32.767	116.05
15 Sep 1985	WAM		*Carenum*	*scaritoides*	D. Mueller	Lane Pool Reserve 14km S of Dwellingup	32.767	116.05
26 May 1991	WAM		*Carenum*	*scaritoides*	D. Mueller	Lane Pool Reserve 14km S of Dwellingup	32.767	116.05
10 Oct 1974	WAM		*Scaraphites*	*lucidus*	P. Kane	Kallaroo	30.5	116.13
03 Sep 1963	WAM		*Scaraphites*	*lucidus*	R. P. McMillan	Culham	31.42	116.47
21 Aug 1961	WAM		*Scaraphites*	*lucidus*	R. P. McMillan	Culham	31.42	116.47
05 Sep 1977	WAM		*Scaraphites*	*lucidus*	P. G. & G. W. Kendrick	Ellenbrook near Margret River	31.55	115.97
20 Jun 1979	WAM		*Scaraphites*	*lucidus*	D. Moon	Karrinyup	31.87	115.75
27 Oct 1950	WAM		*Scaraphites*	*lucidus*	R. P. McMillan	Wembley	31.93	115.8
25 Nov 1989	WAM		*Scaraphites*	*lucidus*	R. P. McMillan	Bold Park	31.97	115.75
25 Nov 1989	WAM		*Scaraphites*	*lucidus*	R. P. McMillan	Bold Park	31.97	115.75
17 Jan 1971	WAM		*Scaraphites*	*lucidus*	B. Hanich	Garden Island	32.2	115.67
16 Jul 1969	WAM		*Scaraphites*	*lucidus*	D. S. Adair	Garden Island	32.2	115.67
04 Sep 1969	WAM		*Scaraphites*	*lucidus*	D. S. Adair	Garden Island	32.2	115.67
1942	WAM	1942-675	*Scaraphites*	*lucidus*		Yallingup	32.65	115.02
1942	WAM	1942-201	*Scaraphites*	*lucidus*		Dunsborough	33.6	115.1
22 Nov 1963	WAM		*Scaraphites*	*lucidus*	E. M. I. Ride	Busselton	33.65	115.33
22 Nov 1961	WAM		*Scaraphites*	*lucidus*	E. M. I. Ride	Busselton	33.65	115.33
22 Nov 1961	WAM		*Scaraphites*	*lucidus*	E. M. I. Ride	Busselton	33.65	115.33
Oct 1912	WAM	1912-6528	*Scaraphites*	*lucidus*		Margret River District	33.97	115.07
1942	WAM	1942-942	*Scaraphites*	*lucidus*		Lake Cave	34.08	115.03
18 Nov 1986	WAM	6398-23	*Scaraphites*	*lucidus*	T. F. Houston	Cape Freycinet	34.1	114.98

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18 Nov 1986	WAM	639-18	*Scaraphites*	*lucidus*	T. F. Houston	Cape Freycinet	34.1	114.98
Jan 1965	WAM		*Scaraphites*	*lucidus*	R. P. McMillan	Denmark	34.97	115.35
01 Jan 1965	WAM		*Scaraphites*	*lucidus*	R. P. McMillan	Denmark	34.97	115.35
31 May 1975	WAM		*Scaraphites*	*silenus*	A. M. & M. J. Douglas	Yuin Station	27.98	116.03
08 Jun 1993	WAM		*Scaraphites*	*silenus*	K. Aplin	4 km NNE of Arrowsmith	29.55	115.08
12 Sep 1987	WAM	652-14	*Scaraphites*	*silenus*	T. F. Houston	16km NW Eneabba	29.82	115.25
25 Oct 1993	WAM		*Scaraphites*	*silenus*	N. Todd	Eneabba	29.82	115.27
12 Sep 1980	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Eneabba	29.82	115.27
18 Oct 1994	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Eneabba	29.82	115.27
17 Oct 1994	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Eneabba	29.82	115.27
17 Oct 1994	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Eneabba	29.82	115.27
17 Oct 1994	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Eneabba	29.82	115.27
09 Sep 1973	WAM		*Scaraphites*	*silenus*	N. T. Allen; P. Thompson	Track on W side of 1st lake N of Lake Logue, Eneabba	29.82	115.27
03 Nov 1980	WAM	368-20	*Scaraphites*	*silenus*	T. F. Houston	Tutanning Reserve, 18- 25 km E of Pingelly	29.82	115.27
03 Nov 1980	WAM	368-27	*Scaraphites*	*silenus*	T. F. Houston	Tutanning Reserve, 18- 25 km E of Pingelly, Eneabba	29.82	115.27
18 Sep 1979	WAM	274	*Scaraphites*	*silenus*	T. F. Houston	12 km NNE of Bungalbin Hill	30.4	119.63
18 Sep 1979	WAM	274	*Scaraphites*	*silenus*	T. F. Houston	12 km NNE of Bungalbin Hill	30.4	119.63
03 Nov 1973	WAM		*Scaraphites*	*silenus*	A. Baynes	2 miles E of Jurien No 1 Oil Well	30.5	115
1923	WAM	1923-161	*Scaraphites*	*silenus*		Dandarragan	30.68	115.7
25 May 1952	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Regans Ford	30.98	115.7
1952	WAM	1952-18	*Scaraphites*	*silenus*		Bannister	31.68	116.55
1952	WAM	1952-19	*Scaraphites*	*silenus*		Bannister	31.68	116.55
July 1967	WAM		*Scaraphites*	*silenus*	L. K. Negas	Wanneroo	31.75	115.8
20 Jul 1969	WAM		*Scaraphites*	*silenus*	M. Archer; E. Jeffery etal	Wanneroo	31.75	115.8
20 Nov 1974	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Wanneroo	31.75	115.8
15 Oct 1971	WAM		*Scaraphites*	*silenus*		Gnangara Rd Caravan Park	31.78	115.87
22 Nov 1972	WAM		*Scaraphites*	*silenus*	D. G. & A. J. Kendrick	8 Dempster Rd Sorrento	31.82	115.73
22 Aug 1963	WAM		*Scaraphites*	*silenus*	A. E. Boyd	Sorrento	31.82	115.73
07 Apr 1964	WAM		*Scaraphites*	*silenus*	P. Pollitt	Wooroloo	31.83	115.5
14 Nov 1962	WAM		*Scaraphites*	*silenus*	F. N. O' Donnell	Tuart Hill	31.88	115.83
01 Nov 1965	WAM		*Scaraphites*	*silenus*	J. Shneider	Morley	31.88	115.87
03 Sep 1968	WAM		*Scaraphites*	*silenus*	P. Irwin	Morley	31.88	115.87
16 Oct 1973	WAM		*Scaraphites*	*silenus*	L. Fitzpatric	Scarborough	31.9	115.75
1942	WAM	1942-244	*Scaraphites*	*silenus*		Inglewood	31.92	115.87
1929	WAM	1929-1458	*Scaraphites*	*silenus*		Bayswater	31.92	115.9
1924	WAM	1924-243	*Scaraphites*	*silenus*		Bayswater	31.92	115.9
1940	WAM	1940-2069	*Scaraphites*	*silenus*		Cottesloe	31.93	115.75
Oct 1913	WAM	1913-8361	*Scaraphites*	*silenus*		Cottesloe	31.93	115.75
	WAM		*Scaraphites*	*silenus*	A. Douglas	Wembley	31.93	115.8
1931	WAM	1931-709	*Scaraphites*	*silenus*		Wembley	31.93	115.8
07 May 1966	WAM		*Scaraphites*	*silenus*	P. Humphries	Wembley Downs	31.93	115.8
13 Apr 1965	WAM		*Scaraphites*	*silenus*	R. Humphries	Wembley Downs	31.93	115.8
14 Oct 1971	WAM		*Scaraphites*	*silenus*	A. Dartnell	Mt Lawley	31.93	115.87

DATE	SOURCE	SOURCE CODE	*GENUS*	*SPECIES*	COLLECTOR	SITE	LATITUDE	LONGITUDE
1934	WAM	1934-3520	*Scaraphites*	*silenus*		Mt Lawley	31.93	115.87
1946	WAM	1946-2510	*Scaraphites*	*silenus*		Mt Lawley	31.93	115.87
1940	WAM	1940-1168	*Scaraphites*	*silenus*		Maylands	31.93	115.88
1945	WAM	1945-291	*Scaraphites*	*silenus*		Belmont	31.93	115.93
1930	WAM	1930-796	*Scaraphites*	*silenus*		Daglish	31.97	115.82
1930	WAM	1930-556	*Scaraphites*	*silenus*		Subiaco	31.97	115.82
01 Jul 1937	WAM		*Scaraphites*	*silenus*	R. P. McMillan	West Perth	31.97	115.85
01 Jul 1937	WAM		*Scaraphites*	*silenus*	R. P. McMillan	West Perth	31.97	115.85
1930	WAM	1930-838	*Scaraphites*	*silenus*		Perth	31.97	115.87
1920	WAM	1920-112	*Scaraphites*	*silenus*		Perth	31.97	115.87
1939	WAM	1939-1158	*Scaraphites*	*silenus*		Victoria Park	31.97	115.9
03 Dec 1967	WAM		*Scaraphites*	*silenus*	P. Yewers	Swanbourne	31.98	115.77
02 Jul 1958	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Swanbourne	31.98	115.77
1934	WAM	1934-2912	*Scaraphites*	*silenus*		Nedlands	31.98	115.8
1933	WAM	1933-2955	*Scaraphites*	*silenus*		Applecross	31.98	115.85
1938	WAM	1938-2503	*Scaraphites*	*silenus*		South Perth	31.98	115.87
1930	WAM	1930-450	*Scaraphites*	*silenus*		North Quairading	32.02	117.4
17 May 1953	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Riverton, swamp	32.03	115.88
	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Cannington	32.03	115.95
10 Jun 1953	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Cannington	32.03	115.95
10 Oct 1954	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Cannington	32.03	115.95
10 Jun 1953	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Cannington	32.03	115.95
04 Jul 1953	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Cannington	32.03	115.95
1933	WAM	1933-905	*Scaraphites*	*silenus*		Forrestdale	32.17	115.97
1939	WAM	1939-23	*Scaraphites*	*silenus*		Canning River	32.2	116.23
04 Oct 1970	WAM		*Scaraphites*	*silenus*	L. E. Koch; A. M. Douglas	Pt. Malcome	32.23	122.83
1939	WAM	1939-2198	*Scaraphites*	*silenus*		Peel Estate	32.6	115.72
1924	WAM	1924-93	*Scaraphites*	*silenus*		Peel Estate	32.6	115.72
19 Apr 1985	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Drynadra State Forest, 12.8 km SE of Caballing	32.78	116.97
1936	WAM	1936-3565	*Scaraphites*	*silenus*		Narrogin	32.93	117.18
1949	WAM	1949-1728	*Scaraphites*	*silenus*		Yarloop	32.97	115.9
1939	WAM	1939-2289	*Scaraphites*	*silenus*		Yarloop	32.97	115.9
1950	WAM	1950-48	*Scaraphites*	*silenus*		Yarloop	32.97	115.9
10 Apr 1966	WAM		*Scaraphites*	*silenus*	R. B. Humphries	Bunbury	33.32	115.63
04 Apr 1971	WAM		*Scaraphites*	*silenus*	L. A. Smith; D. J. Kitchener	Greenshields Soak, 17 miles E of Pingrup, Lake Magenta Reserve	33.5	118.88
16 Jul 1970	WAM		*Scaraphites*	*silenus*	A. G. Matthews	Coolinup Island, Yunderup Delta	33.67	115.33
08 Oct 1972	WAM		*Scaraphites*	*silenus*	D. L. Serventy	Culleenup Island, Yunderup Delta	33.67	115.33
1948	WAM	1948-1942	*Scaraphites*	*silenus*		Katanning	33.68	117.55
1937	WAM	1937-2185	*Scaraphites*	*silenus*		Keninup, Blackwood	33.92	116.57
1929	WAM	1929-1511	*Scaraphites*	*silenus*		Tambellup	34.03	117.63
1922	WAM	1922-3	*Scaraphites*	*silenus*		Tambellup	34.03	117.63
1935	WAM	1935-1279	*Scaraphites*	*silenus*		Tambellup	34.03	117.63
11 Apr 1982	WAM	444	*Scaraphites*	*silenus*	T. F. Houston	Fitzgerald River National Park (NW section)	34.13	119.55

DATE	SOURCE	SOURCE CODE	*GENUS*	*SPECIES*	COLLECTOR	SITE	LATITUDE	LONGITUDE
21 Oct 1987	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Mt. Observation	34.9	116.55
1932	WAM	1932-1736	*Scaraphites*	*silenus*		Yoting		117.97
24 Jun 1974	WAM		*Scaraphites*	*silenus*	M. Holland	Attadale	32.017	115.8
1932	WAM	1932-1416	*Scaraphites*	*silenus*		Bassendean	31.9	115.95
1936	WAM	1936-126	*Scaraphites*	*silenus*		Boscabel	33.65	117.1
29 Sep 1987	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Burma Rd Reserve, 30 km E of Walkaway	28.967	115.033
17 Sep 1956	WAM		*Scaraphites*	*silenus*	R. P. McMillan	Burma Rd Reserve, 30 km E Walkaway	28.967	115.033
1933	WAM	1933-1227	*Scaraphites*	*silenus*		Midland	31.9	116

APPENDIX J: GLOSSARY OF TERMS

Terms presented here are cited from Matthews (1980), Nichols (1989) and Lawrence and Britton (1994)

Abdominal tergite, a dorsal sclerite of the abdomen (posterior division of the insect body, with no wings) (T-B).

Aedeagus, the male copulatory organ, consisting of: the basal tegmen, which is composed of the basal piece or phallobase; and paired parameres; the penis or median lobe; and the internal sac or endophallus (L & B).

Antennal groove, one of a pair of grooves on the facial plate in which the antennae lie (T-B).

Apical declivity, downward sloping toward the apex (adapted from T-B).

Apical, at, near or pertaining to the apex of any structure (T-B).

Basal border, a border at or pertaining to the point of attachment or nearest the main body (T-B).

Bifid, bifidus (Latin), cleft or divided into 2 parts, forked (T-B).

Bilobed, divided into 2 lobes (T-B).

Bisetose, bisetosus, bisetous, bearing 2 setae (T-B).

Carina, (pl., carinae), an elevated ridge or keel, not necessarily high or acute (T-B).

Cleaning organ, an excavation with a comb-like setal fringe positioned near the apex of the fore tibia (L & B).

Clypeus, the part of the insect head below the frons, to which the labrum is attached anteriorly (T-B).

Coxa, (pl., coxae), the basal segment of the leg, by which it articulates with the body (T-B).

Dentate, dentatus (Latin), toothed (T-B); with toothlike prominences(T-B); with acute teeth, the sides of which are equal and the tip is above the middle of base (T-B).

Elytron, (pl., elytra), the leathery (or hardened) forewing of beetles, serving as a covering for the hind wings, usually meeting opposite elytron in a straight line down the middle of the dorsum in repose (T-B).

Epipleuron, (pl., epipleura), the adult Coleoptera, the deflexed or inflexed portion of the elytron, laterally when the elytra are closed (T-B).

Filiform, threadlike, slender and of equal diameter, commonly applied to antennae (T-B).

Fore coxal cavity, the opening or space in which the fore or anterior coxa articulates (after T-B).

Forespur, thick cuticular appendage or spine connected by a joint to near the end of the foretibia (after T-B).

Fossorial, formed for or with the habit of digging or burrowing (T-B).

Foveate, foveatus (Latin), pitted with numerous, regular, depressions or pits (foveae) (T-B).

Genital ring, the phallobase or basal piece (L & B); tegmen, ring (S & M).

Granulate, granulatus (Latin), covered with very small grains or granules (T-B).

Hind angle, anal angle, q. v. (T-B); posterior angle.

Humeral angle, the angle at the base of the costal margin of the wing (T-B); in adult Coleoptera, the basal exterior angle of the elytra (T-B).

Humeral prominence, projection, tooth or other extension of the elytral epipleuron at the humeral angle.

Labrum, the upper lip, abutting the clypeus in front of the mouth (T-B).

Lacinia(e), a blade; the inner lobe of the maxilla, articulated to the stipes and bearing brushes of hairs or spines (T-B); sensory in function.

Mandibular scrobe, a broad deep groove on the outer side of the mandible (first pair of jaws) in some Coleoptera (T-B).

Maxilla, (pl., maxillae), second pair of jaws in insects with chewing mouthparts (T-B).

Mentum, (pl., menta), distal subdivision of postmentum

Mesepimeron, (pl., mesepimera), the epimeron of the mesothorax (T-B).

Mesosternum, sternum of the mesothorax (T-B).

Metasternum, sternum of the metathorax (T-B).

Midcoxa, coxa of the midleg (T-B).

Moniliform, beaded like a necklace, possessing distinct neck-like constrictions between successive segments (T-B).

Palmate, palmated, palmatus (Latin), like the palm of a hand, with fingerlike processes (T-B).

Palp, (pl., palpi), tactile, usually segmented (fingerlike) structures borne by the maxillae (maxillary palpi) and labium (labial palpi) (T-B).

Paramere, in male insects, lateral phallomeres when primary phallic lobes are secondarily divided, the median ones being mesomeres (T-B).

Peduncle, pedunculus(Latin) (pl., pedunculi), a stalk or petiole (T-B).

Peduculated body, corpora pedunculata, q.v. (T-B).

Penis (pl., penes), male intromittent organ which is nonhomologous in insects (T-B); in Coleoptera, apical (distal), unpaired part of the copulatory apparatus, containing terminal portion and orifice of ductus ejaculatorius (T-B); the terminating median lobe of the aedeagus (adapted from L & B).

Proepimeron tubercle, a small knoblike or rounded protuberance on the epimeron of the prothorax (adapted from T-B).

Pronotum, the upper and dorsal part of the prothorax (T-B).

Prosternum, sternum of the prothorax (T-B).

Prothorax, the first thoracic ring or segment, bearing the anterior legs but no wings (T-B).

Puncture, small impression on the cuticle, like that made by a needle (T-B).

Scape, scapus (Latin), the first or basal segment of the antennae (T-B).

Scutellary striole, a fine longitudinal impressed line, often punctured, on the triangular plate at the base and between the elytra (adapted from T-B).

Securiform, hatchet shaped, usually describing the terminal segment of palpi (T-B).

Seta (pl., setae), a sclerotized hairlike projection of cuticula arising from a single trichogen cell and surrounded at the base by a small cuticular ring (T-B).

Setigerous, set with or bearing setae (T-B).

Sinuate, sinuated, sinuatus (Latin), cut into sinuses; wavy, applying specifically to edges and margins (T-B).

Sternite, a subdivision of a sternum, or any one of the sclerotic components of a definite sternum (T-B).

Stria (pl., striae), a longitudinal line or furrow, usually punctured, extending from the base to the apex of the elytra (T-B).

Stylus (pl., styli), a small, pointed, nonarticulated process, attached to the coxite (which is part of the female ovipositor) (adapted from L & B).

Submentum, the proximal division of the postmentum, by means of which the labium is attached to the head (T-B).

Subquadrate, not quite a square (T-B).

Sulcate, sulcated, sulcatus (Latin), deeply furrowed or grooved (T-B).

Sulcus (pl., sulci), groove with a purely functional origin (T-B).

Supraorbital bristle, bristle or seta situated above the eye (T-B).

Tarsal segment, tarsomere, subdivision or article of the tarsus, usually numbering from 2-5 (T-B).

Tarsus (pl., tarsi), the leg segment attached to the apex of the tibia, bearing the pretarsus and consisting of from one to 5 tarsomeres (T-B).

Tergite, a dorsal sclerite or part of a segment, especially when such consists of a single sclerite (T-B).

Tibial tooth, an acute angulation; short pointed process; or very stout heavy spicule with a blunt apex found on the fourth segment of the leg, between the femur and tarsus (tibia) (adapted from T-B).

Trochanter, a segment of the insect leg between the coxa and femur, sometimes divided or fused with the femur (T-B).

Truncate, truncatus (Latin), cut off squarely at the tip (T-B).