Eskom Holdings Limited

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED NUCLEAR POWER STATION ('NUCLEAR-1') AND ASSOCIATED INFRASTRUCTURE

Terrestrial Invertebrate Assessment

Ecocheck

February 2014

EXECUTIVE SUMMARY

During the two field surveys of August – September 2012 and December 2013, 605 invertebrate species were collected at the 51 sample points at Duynefontein, Bantamsklip and Thyspunt. Of the 605 species, 138 species were only found at Duynefontein, 205 species only at Bantamsklip and 166 species were only sampled at Thyspunt. Twenty-seven species were only found within the Western Strandveld area (including Duynefontein and Bantamsklip only), and 69 eurytopic species (wide geographic distribution) were sampled. The invertebrates found during the two field investigations included snails, centipedes, millipedes, amphipods, ticks, scorpions, spiders and insects. Most of the species were identified to family level; 133 species were identified to genus or species level.

A Wishbone Trapdoor Spider of the genus *Spiroctenus* Simon, 1889 was collected at the Bantamsklip site during the December 2013 field investigation. A very good series of live specimens were sent to specialist Ian Engelbrecht, including several sub-adult males. The species is likely to be an undescribed species of *Spiroctenus* Simon, 1889 (it is impossible to be certain until the sub-adult males have reached maturity); the same species was misidentified during the first survey as a species of *Ancylotrypa* Simon, 1889 (Wafer-lid Trapdoor Spider).

A species of Common Baboon Spider of the genus *Harpactira* Ausserer, 1871 was also collected at the Bantamsklip site. The specimen collected is designated as *Harpactira* cf. *cafreriana* (Walckenaer, 1837), the Cape Orange Baboon Spider, but positive identification is not possible until adult males of the population at Bantamsklip are collected (only a female was collected during the December 2013 field investigation). The specimen collected looks quite different to typical *H. cafreriana*.

In order to be able to compare the three sites in terms of Red Data species, all species listed for the Western and Eastern Cape Provinces of South Africa are included in this assessment.

A total of 47 threatened (VU, EN and CR listed) invertebrate species are listed for the two provinces (Onychophora, Gastropoda, Diplopoda, Odonata and Lepidoptera). The following conservation categories are included:

- Nineteen species are listed as Vulnerable;
- Fourteen species are listed as Endangered; and
- Fourteen species are listed as Critically Endangered

Forty-one of the forty-seven species have not been recorded from the regions in which the study sites are located (they are known from elsewhere within the Eastern and Western Cape provinces) and six of the species are known from the regions in which the study area is located. None of the these six species are considered likely to occur within any of the study sites – a combination of known local distribution and specific habitat requirements of these species are not met within the study sites.

Based on the results obtained during this study it is evident that the Bantamsklip study site has a high invertebrate sensitivity and is deemed unsuitable for the proposed Nuclear Power Station. None of the results indicate the unsuitability of the Duynefontein and Thyspunt study sites regarding the proposed Nuclear Power Station.

It is recommended that the Bantamsklip study site is excluded a potential site for the proposed Nuclear Power Station.

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED NUCLEAR POWER STATION ('NUCLEAR-1') AND ASSOCIATED INFRASTRUCTURE

CONTENTS

Chapter	Description		Page
1	**INTRODUCTION**		**7**
	1.1	Background	7
	1.1.1	Proposed Nuclear 1 Power Station	7
	1.1.2	Alternatives	7
	1.1.3	EIA process	7
	1.2	Study Approach	8
	1.2.1	Study Philosophy	8
	1.2.2	Experimental Design	9
	1.2.3	August – September 2012 and December 2013 surveys	10
	1.2.4	Statistical analyses	16
2	**DESCRIPTION OF AFFECTED ENVIRONMENT**		**17**
	2.1	Invertebrate habitats of the study sites	17
	2.1.1	Duynefontein	17
	2.1.2	Bantamsklip	17
	2.1.3	Thyspunt	18
	2.2	Invertebrate diversity of the study sites	18
	2.2.1	Duynefontein invertebrates	40
	2.2.2	Bantamsklip invertebrates	40
	2.2.3	Thyspunt invertebrates	41
	2.2.4	Noteworthy invertebrate inhabitants of the study area	41
	2.3	Invertebrate red data assessment	42
3	**IMPACT IDENTIFICATION AND ASSESSMENT**		**45**
	3.1	Identification of impacts	45
	3.2	Nature of impacts	46
	3.2.1	Habitat loss of conservation important species	46
	3.2.2	Loss and degradation of sensitive invertebrate habitat	46
	3.2.3	Displacement of invertebrate species, human-animal conflicts and interactions	47
	3.2.4	Loss of ecological connectivity and ecosystem functioning	47
	3.2.5	Degradation of surrounding habitat – indirect impact	47
	3.2.6	Conservation of sensitive invertebrate habitat	48
	3.3	Causative Activities	48

3.4 Assessment of impacts 49

4 ENVIRONMENTAL ASSESSMENT 53

4.1 Duynefontein 54
4.1.1 Habitat sensitivity 54

4.2 Bantamsklip 54
4.2.1 Habitat sensitivity 54

4.3 Thyspunt 54
4.3.1 Habitat sensitivity 54

5 MITIGATION MEASURES 55

5.1 Recommended mitigation measures 55
5.1.1 Site-specific mitigation measures 55
5.1.2 General aspects 55
5.1.3 Environmental Control Officer 55
5.1.4 Fences and demarcation 55
5.1.5 Fire 56
5.1.6 Workers and personnel 56
5.1.7 Waste 56
5.1.8 Invertebrates 56

6 CONCLUSIONS AND RECOMMENDATIONS 57

6.1 Conclusions 57

6.2 Recommendations 57

7 PROPOSED INVERTEBRATE MONITORING PROGRAM 58

7.1 Aims 58

7.2 Target Invertebrate Groups 58
7.2.1 Proposed Invertebrate Groups for Monitoring 58

7.3 Collection methods 59

7.4 Experimental Design 59
7.4.1 Seasonal Field Investigation Timing 59
7.4.2 Status Quo Sampling 60
7.4.3 Reference collection 60

8 REFERENCES 61

8.1 Bibliography 61

9 APPENDICES 65

TABLES

Table 1:	Wet season pitfall sampling – Duynefontein
Table 2:	Duynefontein sampling points
Table 3:	Wet season pitfall sampling – Bantamsklip
Table 4:	Bantamsklip sampling points
Table 5:	Wet season pitfall sampling – Thyspunt
Table 6:	Thyspunt sampling points
Table 7:	Invertebrate species confirmed and identified
Table 8:	Red Data fauna assessments for the study sites
Table 9:	Impact Assessment for the Duynefontein site
Table 10:	Impact Assessment for the Bantamsklip site
Table 11:	Impact Assessment for the Thyspunt site

FIGURES

Figure 1:	Google Earth image of the Duynefontein study site
Figure 2:	Google Earth image of the Bantamsklip study site
Figure 3:	Google Earth image of the Thyspunt study site

APPENDICES

Appendix 1:	Photographic records of species confirmed

ABBREVIATIONS

AEM	**Agri-environmental Management**
CR	**Critically Endangered**
DD	**Data Deficient**
DEA	**Department of Environmental Affairs**
EAP	**Environmental Assessment Practitioner**
ECO	**Environmental Control Officer**
EIA	**Environmental Impact Assessment**
EMP	**Environmental Management Program**
EN	**Endangered**
FMP	**Fire Management Plan**
FPA	**Fire Protection Association**
Ha	**Hectares**
IUCN	**International Union for Conservation of Nature**
IR	**Irreplaceable Resource**
LT	**Least Threatened**
MMASL	**Mean Metres Above Sea-level**
MW	**Mega Watt**
NT	**Near Threatened**
NPS	**Nuclear Power Station**
PoC	**Probability of Occurrence**
PWR	**Pressurised Water Reactor**
RoD	**Record of Decision**
SABCA	**South African Butterfly Conservation Assessment**
VU	**Vulnerable**

GLOSSARY

Biodiversity	**Diversity among and within plant and animal species in an environment**
Eurytopic	**Able to adapt to a wide range of environmental conditions; widely distributed (used for an animal or plant)**
Invertebrate	**An animal, such as an insect or mollusc that lacks a backbone or spinal column**

1 INTRODUCTION

1.1 Background

1.1.1 Proposed Nuclear 1 Power Station

Eskom proposed the construction of a Nuclear Power Station (NPS) with a power generation capacity of up to 4 000 MW, using Pressurised Water Reactor (PWR) technology. It is estimated that the entire development of the NPS will require approximately up to 280 hectares (ha), including all auxiliary infrastructure. The proposed NPS will include nuclear reactors, turbine complex, spent fuel and nuclear fuel storage facilities, waste handling facilities, cooling water intake and outfall structures, a desalination plant and various other elements of auxiliary service infrastructure.

1.1.2 Alternatives

No specific design has been selected for the proposed NPS. All design alternatives will require additional infrastructure. However, the varying details of main construction and associated infrastructure are not expected to be significant in terms of impacts on the invertebrate communities of the study areas. As a result, different technology options are not considered viable EIA alternatives for the proposed NPS.

The three proposed site alternatives are located on the South African coastline. Duynefontein is found in the Western Cape Province between Melkbosstrand in the south and Grotto Bay in the north at 33.644569°S and 18.417700°E (approximate centre point). Bantamsklip is found in the Western Cape Province between Pearly Beach in the northwest and Suiderstrand in the southeast at 34.708726°S and 19.565514°E (approximate centre point). Thyspunt is found in the Eastern Cape Province between Oyster Bay in the west and Cape St Francis in the east at 34.185474°S and 24.711337°E (approximate centre point).

The precise placement of the NPS and associated infrastructure within each of the three alternative EIA corridor sites proposed is considered relevant and practical alternatives. Finally, the no-development (so-called “no-go”) option is also an alternative to the above discussed alternative EIA corridor sites.

1.1.3 EIA process

GIBB (Pty) Ltd was appointed by Eskom Holdings Limited (Eskom) to undertake an Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) for the proposed construction of a NPS called “Nuclear-1” and associated infrastructure on five alternative sites that are located in the Northern, Eastern and Western Cape Provinces. The Scoping Phase of this EIA process has resulted in the two sites in the Northern Cape being excluded from further investigation as potential sites for Nuclear-1.

For the initial EIA specialist studies, GIBB appointed AfriBugs CC in August 2008 to undertake a specialist study of the potential impacts of Nuclear-1 on the terrestrial invertebrates of the three remaining sites (as discussed above). Subsequently, GIBB appointed Ecocheck Environmental Services and Art CC (Ecocheck) to augment the initial invertebrate assessment by AfriBugs to provide a greater level of certainty to the prediction of impacts on invertebrates.

1.2 Study Approach

1.2.1 Study Philosophy

Most animals on the planet are invertebrates (about 97% of animal life); insects are probably the most hyper diverse and economically important metazoans on the planet (Finlay *et al* 2006). Despite the prevalence of invertebrates, very little is known about a significant number of these animals. A large number of species are yet to be named; no information exists on the ecology, distribution and conservation status of most species. On-going studies in the fields of invertebrate ecology and arthropod diversity reveal new trends and add to the information databases continuously. For instance, recent community-level studies have acknowledged that generalist species are more widespread than previously thought (Fontaine *et al* 2012) and recent downward revisions of extremely high estimates of tropical species richness suggests that tropical ecosystems may not be as biodiverse as previously thought (Novotny & Basset 2005).

The ecological relationship between invertebrate assemblages and vegetation community structure has been well documented and is continually investigated. These complex interactions have been observed for both terrestrial and aquatic ecosystems. Of wetlands, it has been noted that extensive reed beds serve as refuges for many groups of aquatic macroinvertebrates within lowland fishpond ecosystems (Sychra *et al* 2012). Also, the structure and age of the vegetal formation of ponds play a significant role in selecting species traits related to the population dynamics and feeding habits of invertebrates (Céréghinoa *et al* 2008). The many studies focusing on plant-invertebrate interactions have revealed the complex and intricate nature of the relationship between the different trophic levels of terrestrial ecosystems. Examples include the source-sink relationships between mixed genotype plants and aphids (Utsumi *et al* 2011), the positive effects of plant diversity on aphids in the presence of mutualistic ants (Moreira *et al* 2012) and the close relationship between range size and structural complexity of host plans and the diversity of plant-feeding insects and other host specific taxa (Joy and Crispi 2012). Despite the complex nature of these ecological interactions and the significant information gaps that still exist, some general ecological patterns have been observed. Such patterns include parallel rank-abundance distributions, flatter species-area curves found for smaller insects (indicating their wider geographic distributions), the recurrence of the same species-rich family in the same body-size class at all spatial scales and the discovery that with decreasing mean body-size class at all spatial scales. Further patterns that have been discovered include that with decreasing mean body size class at all spatial scales, local species richness represents an increasing fraction of global species richness (Finlay *et al* 2006).

Invertebrate diversity is influenced by ecological factors on various scales within the study areas. Regional scale diversity patterns may be dictated by general climatic conditions such as rainfall, humidity and temperature as well as general vegetation community diversity within the study area as well as region. It has been predicted that the 4°C rise in temperature expected by the end of the century has the potential to alter the structure and functioning of aquatic ecosystems profoundly, as well as the intimate linkages between these levels of ecological organization (Dossena *et al*

2012). As a result of the small size of invertebrates, diversity and richness of invertebrate assemblages and communities are also a result of the number and diversity of microhabitats present (habitats such as rock fissures and leaf-littered forest floors provide additional habitats to invertebrates that are not directly relevant to larger vertebrates). Different invertebrate trophic levels also react to different ecological processes and on different scales. Studies on arthropod species richness have shown that for spiders (i.e. predators) local processes are important, with assemblages in a particular patch being constrained by habitat structure; in contrast, for sucking insects (i.e. primary consumers), local processes may be insignificant in structuring communities (Borgesa and Browna 2004).

There are many ways to approach invertebrate assessments. Assessments aimed at finding as many "new" species as possible have the final goal of adding to the taxonomical databases by describing "new" species and increasing our understanding of specific invertebrate groups. Unfortunately, such study approaches have little ecological value and cannot increase our understanding with regards to the comparative sensitivities between and within study sites.

This invertebrate study has focused on the current strengths of invertebrate ecology and on finding answers that can provide an ecological understanding of the three study sites as well as providing information that can assist the EAP to compare the invertebrate impacts of each study site (within and between sites).

1.2.2 Experimental Design

The main aim of this invertebrate study was to assess the three study sites in terms of invertebrate diversity and, finally, be able to compare the invertebrate habitats of the study sites in terms of biodiversity value, red data hosting ability and general sensitivity (environmental sensitivity with regards to the proposed project and anticipated impacts).

With the aim discussed above, the experimental design was concluded before the wet season field investigation (end of wet season – August to September 2012) commenced. The same experimental design (sampling methods, materials, periods and sequences) was applied to all three study sites:

- Six fixed sampling plots capturing the diversity of the natural invertebrate habitats of the sites, were allocated within each of the three study sites;
- Ten active sampling plots were included in each of the study sites; these were spaced more or less evenly throughout each study site within the natural invertebrate habitat areas;
- One two-hour light trapping session at each study site; and
- Four ten-minute UV-light scorpion collection periods in each study site.

At each of the six fixed sampling points five, baited pitfalls were used – four baited with fresh cattle dung and one with carrion (chicken livers). The cattle dung-baited pitfalls were re-baited three times with fresh cattle dung at twelve hour intervals – to complete a forty-eight hour sampling period. One two-hundred-step sweep-net sampling effort and one one-hundred-point beating sampling effort were also included at each of the six fixed sampling points. The active sampling point effort included a thirty-minute active search of specific invertebrate microhabitats such as under logs and rocks as well as on plants; also active sampling of flying insects using a handheld net.

Nighttime sampling included a two-hour light-trap sampling period during which all invertebrates attracted to the artificial light (spotlight shining on a white sheet) were collected. In addition, four ten-minute search periods with a UV-light were included to search for scorpions (scorpions reflect UV-light brightly) in each of the study sites.

The experimental design included various sampling methods targeting a variety of invertebrate groups. Sampling periods were concluded within five days (at each of the study sites) – extra time was allotted to each of the sampling periods to allow for unfavourable weather conditions.

After consultation with local invertebrate specialists, it was decided to include two different, but optimal seasonal surveys: end of wet season 2012 (August – September) and height-of-summer season (December 2013).

1.2.3 August – September 2012 and December 2013 surveys

Duynefontein

The 2012 investigation for Duynefontein was completed between 27 and 31 August 2012. The forty-eight hour pitfall sampling period started on 28 August and ended on 30 August 2012. The 2013 investigation was completed between 2 and 6 December 2013. The forty-eight hour pitfall sampling period started on 3 December and ended on 5 December 2013.

Table 1. Duynefontein sampling points				
Sampling point	**Latitude (°S)**	**Longitude (°E)**	**Elevation (mmasl)**	**Vegetation community (Low 2009)**
Fixed sampling point 1	33.640571	18.422528	54	Unvegetated to poorly vegetated transverse dunes
Fixed sampling point 2	33.643578	18.418443	41	Unvegetated to poorly vegetated transverse dunes
Fixed sampling point 3	33.633303	18.416654	41	Tall to dwarf thicket on high parabolic dunes
Fixed sampling point 4	33.641588	18.411172	28	Tall to dwarf thicket on high parabolic dunes
Fixed sampling point 5	33.664224	18.424649	9	Dune thicket on transverse dunes
Fixed sampling point 6	33.654268	18.431185	31	Dune thicket on transverse dunes
Active sampling point 1	33.644186	18.421503	40	Unvegetated to poorly vegetated transverse dunes
Active sampling point 2	33.625743	18.412988	51	Tall to dwarf thicket on high parabolic dunes
Active sampling point 3	33.629564	18.401718	39	Dwarf thicket on deflated parabolic dunes
Active sampling point 4	33.637481	18.406958	33	Dwarf thicket on deflated parabolic dunes
Active sampling point 5	33.639251	18.413508	46	Tall to dwarf thicket on high parabolic dunes
Active sampling point 6	33.646742	18.415762	22	Unvegetated to poorly vegetated transverse dunes
Active sampling point 7	33.652698	18.417454	10	Unvegetated to poorly vegetated transverse dunes
Active sampling point 8	33.659642	18.422252	8	Embryo and foredunes
Active sampling point 9	33.656953	18.426001	19	Dune thicket on transverse dunes
Active sampling point 10	33.660259	18.433671	24	Dune thicket on transverse dunes
Light-trap sampling point	33.638649	18.41381	30	Tall to dwarf thicket on high parabolic dunes
UV-light sampling point	33.657572	18.421144	12	Unvegetated to poorly vegetated transverse dunes

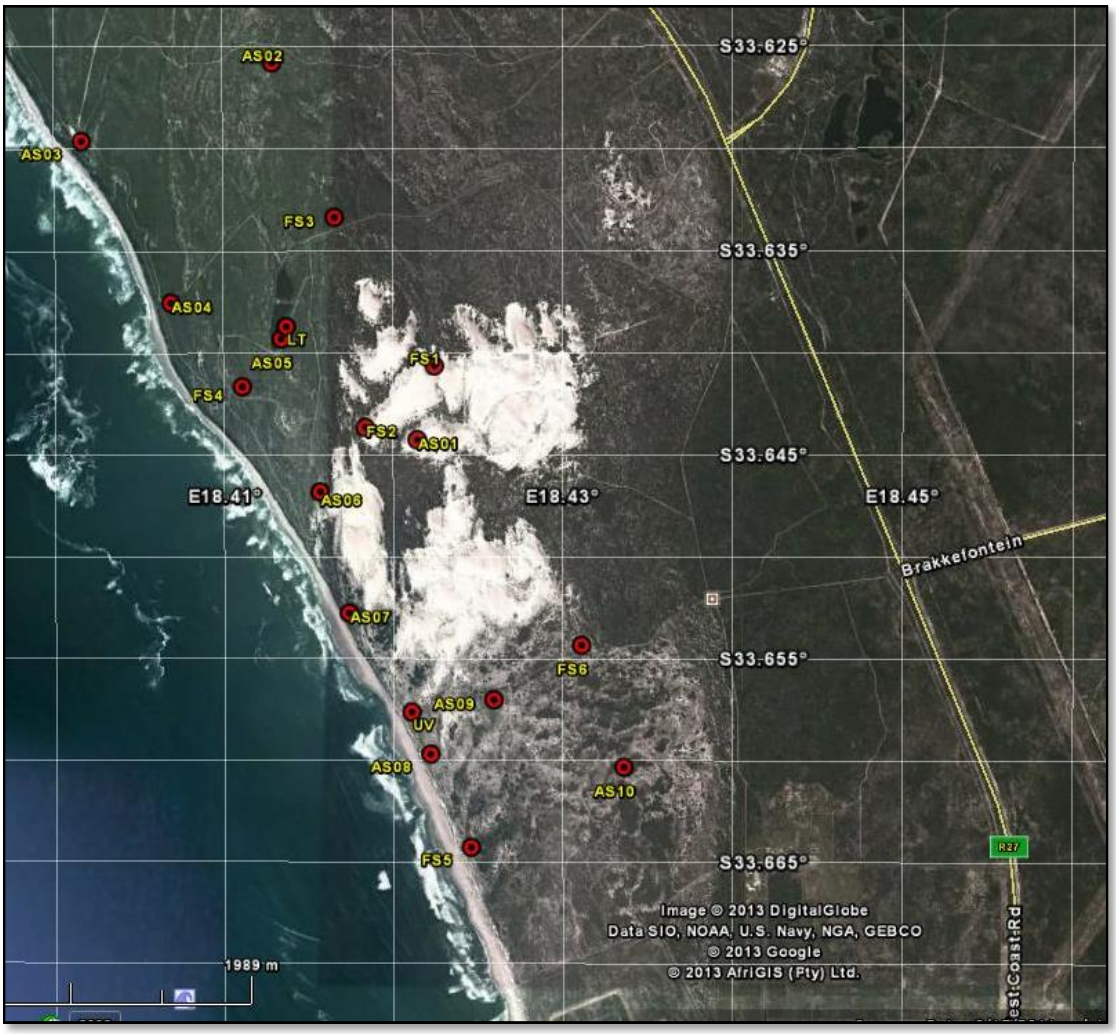


Figure 1. Google Earth image of the Duynefontein study site, showing the six fixed sampling points (FS1 – FS6), ten active sampling points (AS01 – AS10), UV sampling point (UV) and light-trap sampling point (LT).

<u>Bantamsklip</u>

The 2012 field investigation for Bantamsklip was completed between 4 and 9 September 2012. The forty-eight hour pitfall sampling period started on 5 September and ended on 7 September 2012. The 2013 field investigation for Bantamsklip was completed between 9 and 12 December 2013. The forty-eight hour pitfall sampling period started on 10 December and ended on 12 December 2013.

Table 2. Bantamsklip sampling points				
Sampling point	**Latitude (°S)**	**Longitude (°E)**	**Elevation (mmasl)**	**Vegetation community (Low 2009)**
Fixed sampling point 1	34.705169	19.566857	25	Dune fynbos on deep sand over limestone
Fixed sampling point 2	34.707747	19.562753	15	Fynbos on coastal limestone
Fixed sampling point 3	34.712091	19.575383	27	Dune fynbos on deep sand over limestone
Fixed sampling point 4	34.713358	19.571627	12	Dune thicket on transverse dunes
Fixed sampling point 5	34.707802	19.554561	15	Fynbos on coastal limestone
Fixed sampling point 6	34.718177	19.574704	13	Dune thicket on transverse dunes
Active sampling point 1	34.713267	19.575079	32	Dune fynbos on deep sand over limestone
Active sampling point 2	34.710938	19.567993	26	Dune fynbos on deep sand over limestone
Active sampling point 3	34.710316	19.563623	25	Dune fynbos on deep sand over limestone
Active sampling point 4	34.708704	19.560501	19	Fynbos on coastal limestone
Active sampling point 5	34.702718	19.563463	35	Dune thicket on transverse dunes
Active sampling point 6	34.705971	19.556954	23	Fynbos on coastal limestone
Active sampling point 7	34.709374	19.554331	11	Dwarf coastal dune thicket
Active sampling point 8	34.711792	19.562463	11	Dune thicket on primary and foredunes
Active sampling point 9	34.707296	19.565248	26	Dune fynbos on deep sand over limestone
Active sampling point 10	34.704277	19.565943	41	Dune fynbos on deep sand over limestone
Light-trap sampling point	34.70585	19.563938	33	Dune thicket on transverse dunes
UV-light sampling point	34.702301	19.564506	30	Dune thicket on transverse dunes

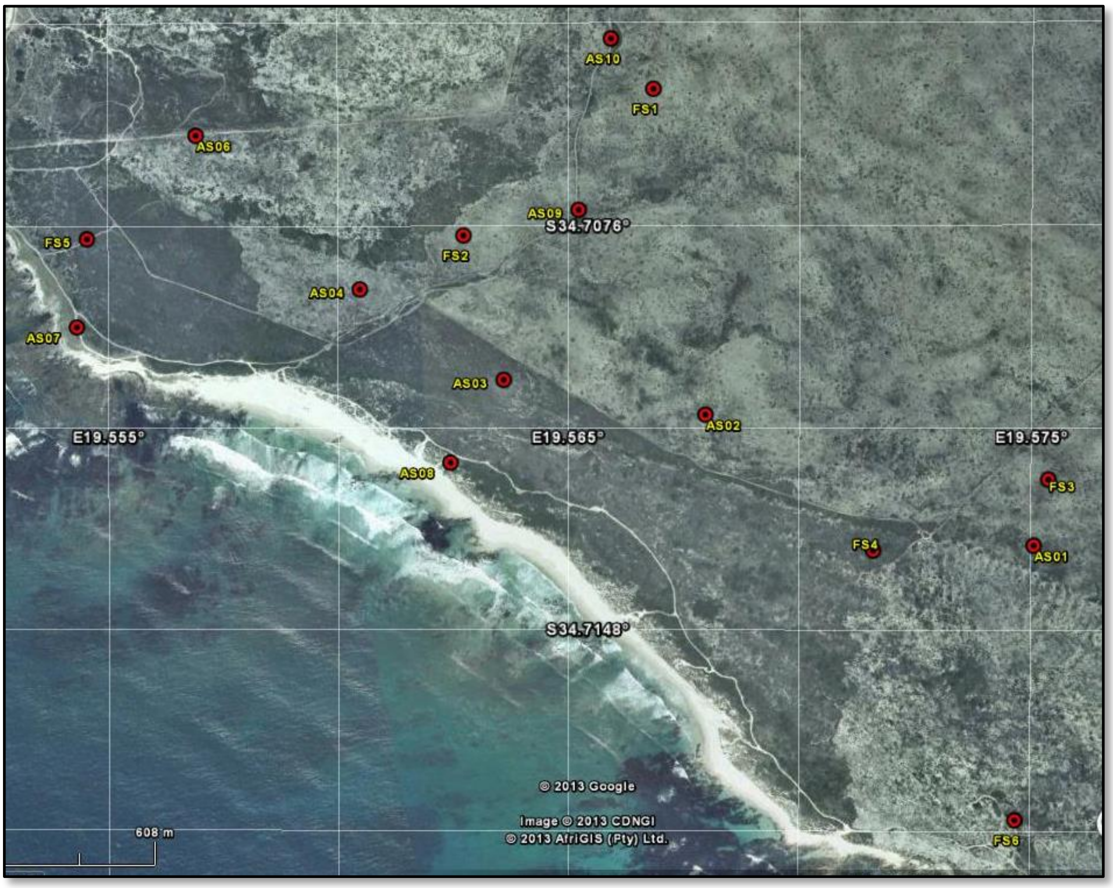


Figure 2. Google Earth image of the Bantamsklip study site, showing the six fixed sampling points (FS1 – FS6), ten active sampling points (AS01 – AS10), UV sampling point (UV) and light-trap sampling point (LT).

<u>Thyspunt</u>

The 2012 field investigation for Thyspunt was completed between 10 and 14 September 2012. The forty-eight hour pitfall sampling period started on 11 September and ended on 13 September 2012. The 2013 field investigation for Thyspunt was completed between 16 and 19 December 2013. The forty-eight hour pitfall sampling period started on 16 December and ended on 18 December 2013.

Table 3. Thyspunt sampling points				
Sampling point	**Latitude (°S)**	**Longitude (°E)**	**Elevation (mmasl)**	**Vegetation community (Low 2009)**
Fixed sampling point 1	34.187709	24.698969	10	Dwarf thicket - partially stable dunes
Fixed sampling point 2	34.191521	24.713031	18	Dwarf dune thicket near coast
Fixed sampling point 3	34.187199	24.716319	19	Dwarf thicket - partially stable dunes
Fixed sampling point 4	34.183733	24.722351	21	Dwarf dune thicket near coast
Fixed sampling point 5	34.183811	24.708898	51	Dune fynbos - various
Fixed sampling point 6	34.180291	24.705547	49	Dune fynbos - various
Active sampling point 1	34.188521	24.697654	10	Dwarf thicket - partially stable dunes
Active sampling point 2	34.188266	24.703822	30	Dwarf thicket - partially stable dunes
Active sampling point 3	34.186941	24.708865	33	Dwarf thicket - partially stable dunes
Active sampling point 4	34.188138	24.713151	25	Dwarf thicket - partially stable dunes
Active sampling point 5	34.185162	24.718443	20	Dune fynbos - various
Active sampling point 6	34.183778	24.725598	21	Dune fynbos - various
Active sampling point 7	34.183797	24.715565	28	Dwarf dune thicket near coast
Active sampling point 8	34.185873	24.709466	16	Dune fynbos - various
Active sampling point 9	34.184841	24.708634	53	Dune fynbos - various
Active sampling point 10	34.181221	24.706705	54	Dune fynbos - various
Light-trap sampling point	34.183779	24.721805	16	Dwarf dune thicket near coast
UV-light sampling point	34.183979	24.725997	25	Dune fynbos - various

Figure 3. Google Earth image of the Thyspunt study site, showing the six fixed sampling points (FS1 – FS6), ten active sampling points (AS01 – AS10), UV sampling point (UV) and light-trap sampling point (LT).

1.2.4 Statistical analyses

Although this study is mostly of a descriptive nature, the methods of data collection allowed for some statistical analyses.

<u>Simpson's Index (D)</u>
Simpson (1949) gave the probability of any two individuals drawn at random from an infinitely large community belonging to the same species as:
$D = \sum p_i^2$

Where p_i = the proportion of individuals in the *i*th species. The form of the index appropriate for a finite community is:
$D = \sum (n_i[n_i-1]/N[N-1])$

Where n_i = the number of individuals on the *i*th species, and N = the total number of individuals. As D increases, diversity decreases. Simpson's Index is therefore usually expressed as 1-D or 1/D. Simpson's Index is heavily weighted towards the most abundant species in the sample, while being less sensitive to species richness. Simpson's Index is one of the most meaningful and robust diversity measures available. In essence, it captures the variance of the species abundance distribution. A separate measure of evenness can, however, be calculated by dividing the reciprocal form of the Simpson's Index by the number of species in the sample:
$E_{1/D} = (1/D)/S$

The measure ranges from 0 to 1 and is not sensitive to species richness. It is usually termed $E_{1/D}$ to denote the use of the reciprocal form of the index (Magurran 2004).

2 DESCRIPTION OF AFFECTED ENVIRONMENT

2.1 Invertebrate habitats of the study sites

For a detailed and complete discussion of the vegetation of the study area, please refer to the vegetation section of this document. Below follows a summary of the regional vegetation communities of the study sites (Mucina & Rutherford 2006), as well as site-specific habitats within each site.

2.1.1 Duynefontein

The Duynefontein region includes three regional vegetation communities from three bioregions and two biomes: Cape Seashore Vegetation (Azonal Vegetation Biome, Seashore Vegetation Bioregion), Cape Flats Dune Strandveld (Fynbos Biome, West Strandveld Bioregion) and Atlantis Sand Fynbos (Fynbos Biome, Southwest Fynbos Bioregion). Two of these regional vegetation communities are considered to be threatened: Atlantis Sand Fynbos is listed as Vulnerable (only 60.3% remains untransformed) and Cape Flats Dune Strandveld is listed as Endangered (only 61.8% remains untransformed). Within the Duynefontein site, the following vegetation communities were identified (after Low 2009):

- Dwarf Dune Thicket;
- Tall-Dwarf Dune Thicket;
- Dune Thicket – Transverse Dunes;
- Transition;
- Low-Dwarf Dune Thicket;
- Unvegetated Dunes;
- Wetlands;
- Primary Dunes;
- Dune Thicket – Sand Plain Fynbos; and
- Transformed.

2.1.2 Bantamsklip

The Bantamsklip region includes three regional vegetation communities from three bioregions and one biome: Overberg Dune Strandveld (Fynbos Biome, South Strandveld Bioregion), Agulhas Limestone Fynbos (Fynbos Biome, South Coast Fynbos Bioregion) and Overberg Sandstone Fynbos (Fynbos Biome, Southwest Fynbos Bioregion). None of these regional vegetation communities are considered to be threatened. Within the Bantamsklip site, the following vegetation communities were identified (after Low 2009):

- Dwarf Dune Thicket;
- Limestone Fynbos;
- Dune Thicket;
- Dune Fynbos;
- Proteoid Fynbos;
- Proteoid Fynbos – sandstone;
- Proteoid Fynbos – acid sand;
- Seep Fynbos;
- Wetlands;

- Dune Thicket – primary dines; and
- Transformed.

2.1.3 Thyspunt

The Thyspunt region includes three regional vegetation communities from three bioregions and two biomes: Cape Seashore Vegetation (Azonal Vegetation Biome, Seashore Vegetation Bioregion), Algoa Dune Strandveld (Azonal Vegetation Biome, Eastern Strandveld Bioregion) and Southern Cape Dune Fynbos (Fynbos Biome, South Strandveld Bioregion). None of these regional vegetation communities are considered to be threatened. Within the Thyspunt site, the following vegetation communities were identified (after Low 2009):

- Cropland;
- Dune Fynbos;
- Dwarf Dune Thicket;
- Partially Bare Dwarf Dune Thicket;
- Limestone Fynbos;
- Primary Dunes;
- Rocky Shore Vegetation;
- Sandstone Fynbos;
- Tall Thicket;
- Unvegetated Dunes; and
- Wetlands.

2.2 Invertebrate diversity of the study sites

During the two field surveys of August – September 2012 and December 2013, 605 invertebrate species were collected at the 51 sample points at Duynefontein, Bantamsklip and Thyspunt. Of the 605 species, 138 species were only found at Duynefontein, 205 species only at Bantamsklip and 166 species were only sampled at Thyspunt (Table 4). Twenty-seven species were only found within the Western Strandveld area (including Duynefontein and Bantamsklip only), and 69 eurytopic species (wide geographic distribution) were sampled. The invertebrates found during the two field investigations included snails, centipedes, millipedes, amphipods, ticks, scorpions, spiders and insects (Tables 4 and 5). Most of the species were identified to family level (except for most of the spiders); 133 species were identified to genus or species level (Table 5).

Table 4. Invertebrate community table of the study area

Groups	Morphospecies	Sample plots																				
		DAS	DPF 1	DPF 2	DPF 3	DPF 4	DPF 5	DPF 6	BAS	BPF 1	BPF 2	BPF 3	BPF 4	BPF 5	BPF 6	TAS	TPF 1	TPF 2	TPF 3	TPF 4	TPF 5	TPF 6
Duynefontein	Acrididae 21	+																				
	Apidae 12	+																				
	Apidae 2	+																				
	Araneae 17	+																				
	Araneae 18	+																				
	Buprestidae 3	+																				
	cf. *Microdon testaceus*	+																				
	Cicadidae 1	+																				
	Curculionidae 23	+																				
	Eurychora species 2	+																				
	Formicidae 9	+																				
	Harpactira atra	+																				
	Hopliini 8	+																				
	Hoplolopha species	+																				
	Lycidae 1	+																				
	Lygaeidae 3	+																				
	Mantidae 1	+																				
	Muscidae 3	+																				
	Myrmeleontidae 4	+																				
	Reduviidae 4	+																				
	Reduviidae 5	+																				
	Sphecidae 1	+																				
	Sphecidae 2	+																				
	Sphecidae 3	+																				
	Sphecidae 4	+																				
	Tenebrionidae 13	+																				
	Tenebrionidae 18	+																				
	Tenebrionidae 19	+																				
	Tettigoniidae 1	+																				
	Orthetrum trinacria	+																				
	Anthene definita definita	+																				
	Chrysoritis chrysaor	+																				

Chrysoritis thysbe osbecki	+						
Utetheisa pulchella	+						
Acrididae 31	+						
Hopliini 9	+	1					
Allodapula species 2	+		1				
Lygaeidae 1	+		1				
Melolonthinae 4	+		1				
Aphodius species 7	+	1		1			
Formicidae 7	+			+	+		
Acrididae 30	+					1	
Apidae 1	+					1	
Xylocopa caffra	+					1	
Curculionidae 15	+						1
Curculionidae 18	+			1			1
Noctuidae 2	+						
Noctuidae 3	+						
Noctuidae 4	+						
Aphodius species 6	+						12
Formicidae 4		+					
Apidae 3		1					
Bembix species		1					
Braconidae 1		1					
Buprestidae 4		1					
Chrysomelidae 16		1					
Gonia species		1					
Mutilidae 2		1					
Sphecidae 16		1					
Tenebrionidae 20		1					
Anax imperator		1					
Hopliini 10		2					
Tenebrionidae 15		1		4	1		
Chrysomelidae 19		1	1			2	
Sphecidae 15		1	3			1	
Tenebrionidae 21		1					1
Odontoloma species		1	2	30	14	2	2
Araneae 27			1				
Araneae 28			1				

Cerambycidae 5	1				
Chrysomelidae 30	1				
Curculionidae 14	1				
Elateridae 3	1				
Spirostreptidae 2	1				
Chrysomelidae 15	2				
Hippodamia variegata	1		1		
Tenebrionidae 17	1		1		
cf. *Platychila pallida*	2			2	
Epirinus species	7	4	4	2	
Pentatomidae 3	1				1
Acanthosomatidae 1		1			
Acrididae 26		1			
Araneae 16		1			
Araneae 34		1			
Araneae 35		1			
Araneae 36		1			
Carabidae 5		1			
Muscidae 5		1			
Sphecidae 18		1			
Hopliini 12		2			
Macroderes greeni		4			
cf. *Chrysomya chloropyga*		1	1		
Gryllidae 1		1	1		
Rhipicephalus species 1		1	1		
Aphodius species 9		3	2		
Scarabaeus rugosus		1		1	
Araneae 25		1	1	1	
Psammodes species 2		2	12	1	10
Anthicidae 2			1		
Apidae 10			1		
Apidae 4			1		
Araneae 19			1		
Araneae 20			1		
Araneae 21			1		
Araneae 22			1		
Araneae 23			1		

	Araneae 24	1			
	Araneae 26	1			
	Cerambycidae 8	1			
	Curculionidae 21	1			
	Curculionidae 22	1			
	Dictyopharidae 1	1			
	Epilachna species	1			
	Histeridae 5	1			
	Mantidae 2	1			
	Tenebrionidae 12	1			
	Tenebrionidae 22	1			
	Araneae 15	1	1	1	
	Aphodius species 10		1		
	Araneae 33		1		
	Cerambycidae 1		1		
	Chrysomelidae 17		1		
	Curculionidae 20		1		
	Lepismatidae 1		1		
	Nitidulidae 1		1		
	Tenebrionidae 23		6		
	Acrididae 15		1	1	
	Elateridae 2		1	2	
	Pentatomidae 4		4	1	
	Araneae 29			1	
	Araneae 30			1	
	Araneae 31			1	
	Araneae 32			1	
	Blatellidae 6			1	
	Curculionidae 19			1	
	Curculionidae 24			1	
	Myrmeleontidae 5			1	
	Vespidae 4			1	
	Acrididae 27				+
	Apidae 5				+
Bantamsklip	Araneae 39				+
	Araneae 40				+
	Araneae 41				+

Araneae 42		+			
Araneae 43		+			
Araneae 64		+			
Araneae 65		+			
Araneae 66		+			
Blaberidae 1		+			
Blaberidae 7		+			
Blatellidae 7		+			
Buprestidae 1		+			
Buprestidae 8		+			
Carabidae 8		+			
Cerambycidae 2		+			
cf. *Aptera fusca*		+			
Chrysomelidae 1		+			
Chrysomelidae 22		+			
Elateridae 4		+			
Forficulidae 1		+			
Hopliini 1		+			
Hopliini 13		+			
Hopliini 2		+			
Hopliini 3		+			
Hopliini 5		+			
Meloidae 1		+			
Mydidae 1		+			
Mygalomorphae 1		+			
Pentatomidae 5		+			
Reduviidae 1		+			
Sphecidae 7		+			
Sphecidae 8		+			
Tabanidae 3		+			
Tettigoniidae 4		+			
Vespidae 2		+			
Spialia sataspes		+			
Tarucus thespis		+			
Palpares species		+			
Noctuidae 1		+			
Harpactira cf. *cafrariana*		+			
Spiroctenus species		+			
Curculionidae 26		+	1		
Acrididae 28		+		1	

Melolonthinae 2	+			1			
Veterna species	+			1			
Chrysomelidae 11	+				1		
Cormocephalus species	+	1				1	
Acrididae 29	+				2	1	
Gryllidae 3	+	2	1			3	
Spirostreptidae 3	+	4	1	1		2	
Tenebrionidae 24	+	8		3	1	3	
Chrysoritis zeuxo zeuxo	+						1
Acrididae 12	+						2
Chrysomelidae 5	+						13
Blaberidae 4	+				1		1
Acrididae 19	+			2			1
Araneae 37	+						
cf *Bullacris intermedia*	+						
Myrmeleontidae 3	+						
cf. *Sia pallidus*	+	1			1		
Anoplocheilus germari		1					
Anthicidae 4		1					
Araneae 53		1					
Araneae 54		1					
Araneae 55		1					
Araneae 56		1					
Araneae 57		1					
Araneae 58		1					
Araneae 6		1					
Araneae 75		1					
Araneae 76		1					
Araneae 77		1					
Araneae 78		1					
Araneae 79		1					
Araneae 80		1					
Araneae 81		1					
Araneae 82		1					
Araneae 83		1					
Curculionidae 13		1					
Curculionidae 28		1					
Curculionidae 5		1					
Oniticellus pictus		1					
Rhipicephalus species 2		1					

cf. *Psammodes striatus*	1	1				
Curculionidae 27	1	1				
Dermestidae 2	1		1	2	5	3
Araneae 61	1		1			
Cicadidae 3	1		1			
Curculionidae 25	1		1			
Cicadellidae 2	1		2	1		
Acrididae 34	1			1		
Staphilinidae 3	1			1		
Chrysomelidae 20	1				1	
Mantophasmatodea 1	1				1	
Eurychora species 1	1				2	3
Carabidae 6	1					1
Lagria species 1	2					
Melyridae 3	2					
Oniticellus africanus	2					
Pulmonata 6	8					
Lygaeidae 2	5					
Tettigoniidae 2	2	1				
Acrididae 32	2		1			
Euoniticellus africanus	3		4		1	
Pulmonata 5	6		1	3	1	
Staphilinidae 5	6	2			1	
Formicidae 2	+	+	+			+
Formicidae 1	+	+		+		+
Euoniticellus triangulatus	5	3		1		3
Chrysomelidae 10	12	17	5	1		9
Araneae 46		1				
Araneae 47		1				
Araneae 48		1				
Araneae 49		1				
Araneae 50		1				
Araneae 51		1				
Araneae 52		1				
Araneae 84		1				
Araneae 85		1				
Araneae 86		1				
Onthophagus africanus		1				
Reduviidae 6		1				
Vespidae 1		1				

Araneae 45	2				
Tenebrionidae 3	2				
Acrididae 22	1	1			
Carabidae 2	1				2
Apidae 8		1			
Araneae 38		1			
Araneae 5		1			
Blatellidae 2		1			
Cartarsius tricornutus		1			
Chrysomelidae 31		1			
Curculionidae 4		1			
Psychidae 1		1			
Tiphiidae 1		1			
Lagria species 2		2			
Trichostetha capensis		3			
Curculionidae 12		5	2		
Scarabaeus convexus		2	1	1	
Histeridae 4		5	1	5	7
Acrididae 2			1		
Araneae 1			1		
Araneae 4			1		
Araneae 44			1		
Araneae 62			1		
Araneae 63			1		
Araneae 71			1		
Araneae 72			1		
Araneae 73			1		
Chrysomelidae 23			1		
Coreidae 3			1		
Elateridae 1			1		
Ichneumonidae 1			1		
Ichneumonidae 2			1		
Scutigeromorpha 1			1		
Talitroides species			1		
Tettigoniidae 3			1		
Coreidae 1			2		
Diplopoda 2			2		
Cerambycidae 4			3		
Sphecidae 6			9		
Pentatomidae 1			1		1

Lentulidae 2	1		3
Tenebrionidae 25	3	2	1
Formicidae 12		+	
Araneae 2		1	
Araneae 3		1	
Araneae 59		1	
Araneae 60		1	
Araneae 88		1	
Araneae 89		1	
Araneae 90		1	
Araneae 91		1	
Araneae 92		1	
Cercopidae 3		1	
Chrysomelidae 25		1	
Megachilidae 1		1	
Mutilidae 1		1	
Myrmeleontidae 1		1	
Onitis aygulus		1	
Pulmonata 4		1	
Trombidae 1		1	
Onthophagus binodus		2	
Curculionidae 2		3	
Curculionidae 29		3	
Tenebrionidae 11		3	
Araneae 87		6	
Devylderia species		1	2
Trox capensis		2	1
Acrididae 14			1
Acrididae 6			1
Araneae 74			1
Carabidae 1			1
Carabidae 3			1
cf. *Anubis scalaris*			1
Chrysomelidae 21			1
Curculionidae 1			1
Curculionidae 3			1
Hymenopodidae 1			1
Lepismatidae 3			1
Scarabaeus satyrus			1
Sphenoptera species 1			1

	Phasis thero thero	+							+							
	Odontopygidae 1	+	2	1	1	2			+							
	Sphecidae 5	+								1						
	Tabanidae 2	+			2					1						
	Anthicidae 1	+					1			1						
	Asilidae 1	+			1		1	1	+		1					
	Muscidae 1	+											1			
	Blaberidae 8	+						1	+		1		1			
	Tenebrionidae 1	+					7	7	+	3	6			5		
	Parabuthus capensis	+									1				1	
	Pulmonata 2	+								6	8	4	2	35	1	
	Chrysomelidae 18	+					1		+			1	2		3	
W. Strandveld	*Aphodius* species 1	+	32	12	1	1	6	11		1	8	29	2	2	8	
	Uroplectes lineatus	+							+							
	Acrididae 33	+				1			+							
	Curculionidae 16		2				3			1						
	Scarabaeus intricatus		1	11	207	42	190	96		1			1	3		
	Aphodius species 2		2		1						2	7	5		1	
	Pentatomidae 2			4		1						1				
	Formicidae 6				+	+	+	+		+	+		+			
	Tenebrionidae 5					1	1			1				4		
	Forficulidae 4					1									1	
	Poophilus species					1	1		+	1	1		2		9	
	Armadillidae 1						1		+							
	Melolonthinae 5						1		+							
	Formicidae 3						+			+						
	Anthicidae 3						2	1							2	
	Acrididae 7															+
	Acrididae 9															+
	Anoplocheilius variabilis															+
	Apidae 6															+
Thyspunt	Apidae 7															+
	Asilidae 4															+
	Asilidae 5															+
	Buprestidae 5															+
	cf. *Ectrichodia crux*															+
	cf. *Holopterna alata*															+

Chrysomelidae 2			+				
Curculionidae 10			+				
Curculionidae 9			+				
Exosprosopa species			+				
Formicidae 8			+				
Hopliini 6			+				
Melolonthinae 7			+				
Membracidae 1			+				
Polistes species 1			+				
Polistes species 2			+				
Polistes species 3			+				
Solifugae 1			+				
Sphecidae 10			+				
Sphecidae 11			+				
Sphecidae 12			+				
Sphecidae 13			+				
Sphecidae 14			+				
Staphilinidae 4			+				
Tenebrionidae 8			+				
Tenebrionidae 9			+				
Africallagma glaucum			+				
Gegenes niso niso			+				
Orthetrum chrysostigma			+				
Araneae 120			+				
Papilio demodocus			+				
Pentatomidae 6			+				
Sphecidae 17			+	1			
cf. *Rhinaulax analis*			+		1		
Coreidae 2			+		1		
Acrididae 25			+		3		
Acrididae 18			+			1	
Buprestidae 6			+			1	
Curculionidae 8			+			1	
Leptotes pirithous			+			1	
Mordellidae 1			+			3	
Apidae 9			+				1
Pulmonata 7			+				1
Tenebrionidae 27			+				1
Lophyra species 2			+				2
Sceliages species			+	1			1

Buprestidae 2	+			1	2		
Hopliini 7	+	6		5	13		
Pontia helice helice	+					1	
Acrididae 10	+		1			1	
cf. *Archibracon servillei*	+				2	2	
Tenebrionidae 26	+	2	1	3		1	
Allodapula species 1	+		1	1	2	2	
Sceliages adamastor	+						1
Sphaerotherium species	+	8	4	1	4	2	2
Garreta unicolor	+	13	37	66	21	52	39
Cerambycidae 10	+						
Lampyridae 2	+						
Lampyridae 1	+	2					
Termitidae 1	+		+				
Araneae 95		1					
Cassidinae 1		1					
Cydnidae 1		1					
Lygaeidae 4		1					
Onitis species		1					
Sphecidae 19		1					
Tenebrionidae 28		1					
Trombidae 2		1					
Vespidae 5		2					
Blatellidae 1		3					
Blatellidae 8		2	2				
Neosisyphus species		2		1			
Araneae 96		1			1		
Nitidulidae 3		1			1		
Rhipicephalus species 3		1			2		
Carabidae 9		1		1	2		
Tettigoniidae 5		1				1	
Chrysomelidae 26		1				4	
Araneae 97		1	1		1	2	
Araneae 98		1	1		1	2	
Scutigeromorpha 2		3	1	1		2	
Hydrophilidae 1		2					1
Melyridae 2		5					1
Araneae 14		1		1			1
Trox rhyparoides		2				1	3
Formicidae 14		+		+		+	+

Sphenoptera species 2	1		1		1	1
Copris fidius	4	4	1	4		5
Epirinus flagellatus	1	3	24	57	36	23
Aphodius species 8	130		329	1270	790	451
Acrididae 4		1				
Araneae 10		1				
Araneae 109		1				
Araneae 110		1				
Araneae 8		1				
Forficulidae 7		1				
Meloidae 2		1				
Reduviidae 2		1				
Scaritinae 1		1				
Sphenoptera species 3		1				
Araneae 108		2				
Araneae 9		1	1			
Acrididae 5		1	5			
Odontoloma pygidiale		2		1		
Oniticellus planatus		2		1		
Metacatharsius tricornutus		1		1	1	
Cercopidae 6		6	2		3	
Acrididae 23		1				1
Cercopidae 4		3	2			3
Acrididae 1			1			
Araneae 7			1			
Buprestidae 7			1			
Chrysomelidae 28			1			
Cydnidae 2			1			
Lygaeidae 5			1			
Sagra species			1			
Tenebrionidae 31			1			
Tettigoniidae 6			1			
Curculionidae 7			2			
Trox nanniscus			2			
Acrididae 20			2		1	
Apionidae 1			1	1	1	
Forficulidae 6			1	2	1	
Elateridae 5			1	1		1
Apidae 11				1		
Araneae 103				1		

	Araneae 105				1		
	Araneae 106				1		
	Araneae 107				1		
	Carabidae 4				1		
	Cercopidae 1				1		
	Sisyphus species				1		
	Araneae 104				2		
	Araneae 13				2		
	Cercopidae 2				3		
	Mordellidae 2				1	2	
	Blatellidae 3				1	7	
	Tenebrionidae 30				1	11	
	Onthophagus sugillatus				1		1
	Araneae 12				2		1
	Coccinellidae 2				1	2	1
	Cerambycidae 3					1	
	Cercopidae 5					1	
	cf. *Cyphononyx flavicornis*					1	
	Chrysomelidae 9					1	
	Cleridae 1					1	
	Forficulidae 3					1	
	Pentatomidae 7					1	
	Pentatomidae 8					1	
	Reduviidae 3					1	
	Forficulidae 5					2	
	Mantidae 3					2	
	Lepismatidae 2					7	
	Curculionidae 31					8	
	Pulmonata 8					9	
	Myrmeleontidae 2					10	3
	Araneae 11						1
	Araneae 111						1
	Araneae 112						1
	Araneae 113						1
	Cerambycidae 7						1
	Coccinellidae 3						1
Eurytopic	*Cassionympha cassius*	+		+			
	Ischnura senegalensis	+		+			
	Vanessa cardui	+	1	+			

Acrididae 16	+				2										+						
Sympetrum fonscolombii	+	1						+							+						
Apis mellifera capensis	+							+		1					+						
Cicadidae 2	+						1	+							+						
Acrididae 11	+	1			1	2									+						
Acrididae 24	+		1		1	2		+		2		3		2				1			
Lygaeidae 6	+				5	13			1					3				2			
Exochomus flavipes	+		3		1							1				2		1			
Forficulidae 2	+											1					2		1		
cf. *Promeces longipes*	+			1															2		
Pulmonata 1	+	5		2	40	14			18	12	9		10	25			2	1	5		
Curculionidae 6	+	5	1													5	1	2	1	6	1
Crocothemis erythraea		1													+						
Tenebrionidae 2		1		2		7		+	13	26	11	5	6	9	+						
Cheilomenes lunata		3	1	2	2	2	1	+				1			+		2				
Epirinus aeneus		2	1	24	10	6	23		3		2	4	2					2			
Trox sulcatus		4	7	3	4		6		25	2	3		2			2	1			1	
Lophyra species 1		2																			2
Aphodius species 4		2	20		1										+					1	2
Copris anceus		1	1	1		8	6		1		1	1	2	2						1	1
Melyridae 4			3					+			4			2		1					
Aphodius species 5			5	2			11					1				2					
Histeridae 1			1	3	2	6	5		1	6	4	2	3	12						3	1
Hyalomma species				1											+						
Crematogaster peringueyi				+				+	+			+	+	+	+	+		+			
Melolonthinae 3				3																	1
Epirinus minimus				1													2	11	11	3	6
Formicidae 5				+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+
Chrysomelidae 29				1								18	3			1	1			4	
Hopliini 11					1										+						
Onthophagus minutus					3	1	2		10	10	6	4	3	8		1	1			1	
Histeridae 3					1				10	15	7	3	1	1			2				1
Acrididae 8						2		+			+				+			1			
Onthophagus giraffa						1			18	27	5	13	5	14		6	6	7	5	2	6
Blaberidae 2							1								+						
Melolonthinae 1							3		3		1						1				

Odontoloma pussilum							6					1						1			
Acrididae 17								+							+						
Dermestidae 1								+			1				+						
Hopliini 4								+								1					
Tabanidae 1								+							+	1					
Blatellidae 5								+		5				2		1					
Phasmatidae 1								+				1	1					1			
Formicidae 13								+	+										+		
Opistophthalmus macer								+													1
Acrididae 3								+			2		1	2							2
Spirostreptidae 1								+							+	1	1		1	5	1
Pulmonata 3								+	2	2	1		2		+	2			2		1
Formicidae 11								+						+				+	+	+	
Staphilinidae 1									5	20	1	23	45	49	+						
Myrmeleontidae 6									1							2					
Aphodius species 3									9	1	5	1		2					1		
Carabidae 7									5	1										1	
Blatellidae 4									5	5	1	5		3							1
Coccinellidae 1									1		2		2			8			1	3	1
Thanatophilus species									12	5	15	18	68	29			1			9	3
Histeridae 2									15	1	4	5	13	18			1	1		2	6
Scarabaeus spretus									3	1	8	1	2			2	51	36	23	52	38
Melolonthinae 6										1					+						
Staphilinidae 2										2		2	1	1			1				
Acrididae 13										1			1		+		2	2			
Nitidulidae 2										7		1		2		1			1		
Alticinae 1												1		1		1					
Epirinus comosus												3							4		1
Psammodes species 1													2		+		2	1	2		1
Cicadellidae 3														1			1				

Table 5. Invertebrates identified to genus or species level				
Class	**Order**	**Family**	**Biological Name**	**English Name**
Arachnida	Araneae	Nemesiidae	*Spiroctenus* species	Wishbone Trapdoor Spider
		Theraphosidae	*Harpactira atra*	Baboon Spider
			Harpactira cf. *cafrariana*	Baboon Spider
	Ixodida	Ixodidae	*Hyalomma* species	Striped-legged Tick
			Rhipicephalus species 1	Brown Tick
			Rhipicephalus species 2	Brown Tick
			Rhipicephalus species 3	Brown Tick
	Scorpiones	Buthidae	*Uroplectes lineatus*	Lesser-thicktail Scorpion
		Scorpionidae	*Opistophthalmus macer* (Thorell, 1876)	Fynbos Burrower
Chilopoda	Scolopendromorpha	Scolopendridae	*Cormocephalus* species	Common Centipede
Crustacaea	Amphipoda	Talitridae	*Talitroides* species	Terrestrial Amphipod
Diplopoda	Sphaerotheriida	Sphaerotheriidae	*Sphaerotherium* species	Pill Millipede
Insecta	Blattodea	Blaberidae	cf. *Aptera fusca* (Thunberg, 1784)	Table Mountain Cockroach
	Coleoptera	Buprestidae	*Sphenoptera* species 1	Jewel Beetle
			Sphenoptera species 2	Jewel Beetle
			Sphenoptera species 3	Jewel Beetle
		Cerambycidae	cf. *Anubis scalaris* (Pascoe, 1863)	Skunk Longhorn
			cf. *Promeces longipes* (Olivier, 1795)	Common Metallic Longhorn
		Chrysomelidae	*Sagra* species	Swollen-legged Leaf Beetle
		Cicindelidae	cf. *Platychila pallida*	Night Tiger Beetle
			Lophyra species 1	Common Tiger Beetle
			Lophyra species 2	Common Tiger Beetle
		Coccinellidae	*Cheilomenes lunata*	Lunate Ladybird
			Epilachna species	Herbivorous Ladybird
			Exochomus flavipes (Thunberg, 1781)	Black Mealy Bug Predator
			Hippodamia variegata	Spotted Amber Ladybird
		Scarabaeidae	*Anoplocheilius variabilis* (Gory & Percheron, 1833)	Fruit Chafer
			Anoplocheilus germari (Wiedemann, 1818)	Fruit Chafer
			Aphodius species 1	Miniature Dung Chafer
			Aphodius species 10	Miniature Dung Chafer
			Aphodius species 2	Miniature Dung Chafer
			Aphodius species 3	Miniature Dung Chafer
			Aphodius species 4	Miniature Dung Chafer
			Aphodius species 5	Miniature Dung Chafer
			Aphodius species 6	Miniature Dung Chafer
			Aphodius species 7	Miniature Dung Chafer
			Aphodius species 8	Miniature Dung Chafer
			Aphodius species 9	Miniature Dung Chafer
			Cartarsius tricornutus	Dung Beetle
			Copris anceus (Olivier, 1789)	Dung Beetle
			Copris fidius (Olivier, 1789)	Dung Beetle
			Epirinus aeneus (Wiedemann, 1823)	Dung Beetle
			Epirinus comosus Péringueyi, 1901	Dung Beetle
			Epirinus flagellatus (Fabricius, 1775)	Dung Beetle
			Epirinus minimus Medina & Scholtz, 2005	Dung Beetle
			Epirinus species	Dung Beetle
			Euoniticellus africanus (Harold, 1873)	Dung Beetle
			Euoniticellus triangulatus (Harold, 1873)	Dung Beetle
			Garreta unicolor	Dung Beetle
			Macroderes greeni (Kirby, 1818)	Dung Beetle

			Metacatharsius tricornutus	Dung Beetle
			Neosisyphus species	Dung Beetle
			Odontoloma pusillum Howden & Scholtz, 1987	Dung Beetle
			Odontoloma pygidiale	Dung Beetle
			Odontoloma species	Dung Beetle
			Oniticellus africanus	Dung Beetle
			Oniticellus pictus	Dung Beetle
			Oniticellus planatus	Dung Beetle
			Onitis aygulus	Dung Beetle
			Onitis species	Dung Beetle
			Onthophagus africanus	Dung Beetle
			Onthophagus binodus	Dung Beetle
			Onthophagus giraffa Hausmann, 1807	Dung Beetle
			Onthophagus minutus (Hausmann, 1807)	Dung Beetle
			Onthophagus sugillatus	Dung Beetle
			Scarabaeus convexus	Dung Beetle
			Scarabaeus intricatus (Fabricius, 1801)	Dung Beetle
			Scarabaeus rugosus	dung Beetle
			Scarabaeus satyrus	Dung Beetle
			Scarabaeus spretus Zur Strassen, 1962	Dung Beetle
			Sceliages adamastor	Dung Beetle
			Sceliages species	Dung Beetle
			Sisyphus species	Dung Beetle
			Trichostetha capensis	Fruit Chafer
		Silphidae	*Thanatophilus* species	Carrion Beetle
		Tenebrionidae	cf. *Psammodes striatus*	Striped Toktokkie
			Eurychora species 1	Mouldy Beetle
			Eurychora species 2	Mouldy Beetle
			Lagria species 1	Hairy Darkling Beetle
			Lagria species 2	Hairy Darkling Beetle
			Psammodes species 1	Toktokkie
			Psammodes species 2	Toktokkie
		Trogidae	*Trox capensis*	Carcass Beetle
			Trox nanniscus	Carcass Beetle
			Trox rhyparoides	Carcass Beetle
			Trox sulcatus Thunberg, 1787	Carcass Beetle
	Diptera	Bombyliidae	*Exosprosopa* species	Bee Fly
		Calliphoridae	cf. *Chrysomya chloropyga* (Wiedemann, 1818)	Copper-tailed Blowfly
		Syrphidae	cf. *Microdon testaceus* Walker, 1857	Coastal Hover Fly
		Tachinidae	*Gonia* species	Tachinid Fly
	Hemiptera	Cercopidae	cf. *Rhinaulax analis* (Fabricius, 1794)	Spittle Bug
			Poophilus species	Spittle Bug
		Coreidae	cf. *Holopterna alata*	Twig Wilter
		Pentatomidae	*Veterna* species	Grass Stink Bug
		Reduviidae	cf. *Ectrichodia crux*	Millipede Assassin
	Hymenoptera	Apidae	*Allodapula* species 1	Bee
			Allodapula species 2	Bee
			Apis mellifera capensis	Cape Honey Bee
			Xylocopa caffra	Carpenter Bee
		Braconidae	cf. *Archibracon servillei* (Brulle, 1846)	Braconid Wasp
		Formicidae	*Crematogaster peringueyi* Emery, 1895	Cocktail Ant
		Pompilidae	cf. *Cyphononyx flavicornis* (Fabricius, 1781)	Spider-hunting Wasp

		Sphecidae	*Bembix* species	Sand Wasp
		Vespidae	*Polistes* species 1	Paper Wasp
			Polistes species 2	Paper Wasp
			Polistes species 3	Paper Wasp
	Lepidoptera	Arctiidae	*Utetheisa pulchella* (Linnaeus, 1758)	Crimson-speckled Footman
		Hesperiidae	*Gegenes niso niso* (Linnaeus, 1764)	Common Hottentot Skipper
			Spialia sataspes (Trimen, 1864)	Boland Sandman
		Lycaenidae	*Anthene definita definita* (Butler, 1899b)	Common Hairtail
			Chrysoritis chrysaor (Trimen, 1864)	Burnished Opal
			Chrysoritis thysbe osbecki (Aurivillius, 1882)	Melkbosstrand Common Opal
			Chrysoritis zeuxo zeuxo (Linnaeus, 1764)	Jitterbug Opal
			Leptotes pirithous pirithous (Linnaeus, 1767)	Common Zebra Blue
			Phasis thero thero (Linnaeus, 1764)	Arrowhead
			Tarucus thespis (Linnaeus, 1764)	Vivid Dotted Blue
			Cassionympha cassius (Godart, [1824])	Rainforest Brown
		Nymphalidae	*Vanessa cardui* (Linnaeus, 1758)	Painted Lady
			Papilio demodocus demodocus Esper [1798]	Citrus Swallowtail
		Papilionidae	*Pontia helice helice* (Linnaeus, 1764)	Common Meadow White
		Pieridae	*Palpares* species	Veld Antlion
	Neuroptera	Myrmeleontidae	*Anax imperator* Leach, 1815	Blue Emperor
	Odonata	Aeshnidae	*Africallagma glaucum* Burmeister, 1839	Swamp Bluet
		Coenagrionidae	*Ischnura senegalensis* Rambur, 1842	Common Bluetail
			Crocothemis erythraea Brullé, 1832	Broad Scarlet
		Libellulidae	*Orthetrum chrysostigma*	Epaulet Skimmer
			Orthetrum trinacria Selys, 1841	Long Skimmer
			Sympetrum fonscolombii	Nomad
			Devylderia species	Apterous Grasshopper
	Orthoptera	Lentulidae	*Hoplolopha* species	Saw-backed Locust
		Pamphagidae	cf *Bullacris intermedia* (Péringuey, 1916)	Bladder Grasshopper
		Pneumoridae	cf. *Sia pallidus* (Walker, F., 1869)	Jerusalem Cricket
		Stenopelmatidae		

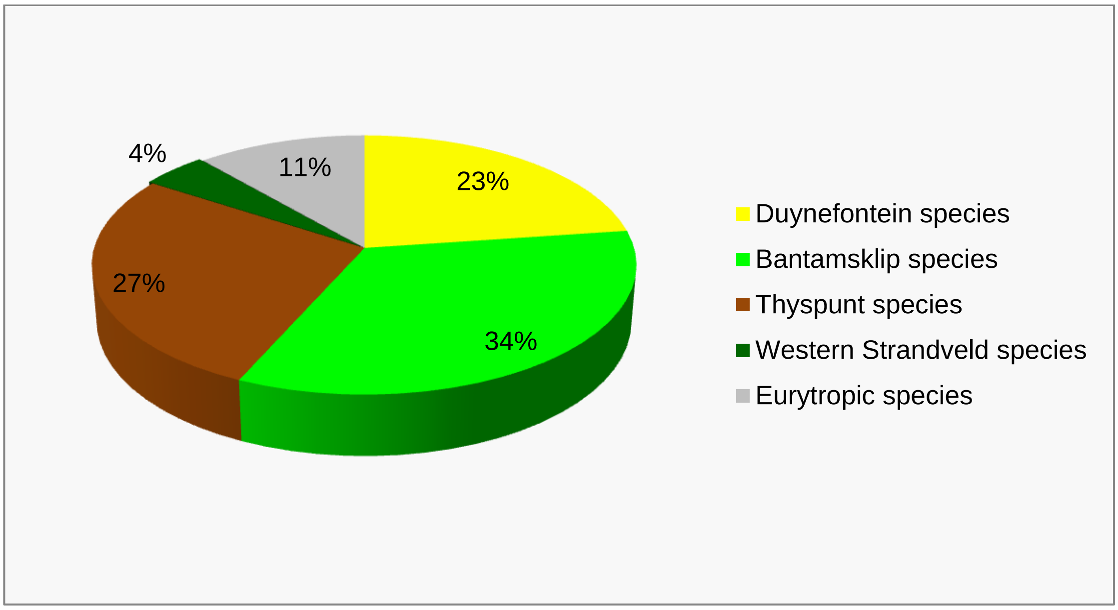


Figure 4. More than a third of the species sampled, were only found at Bantamsklip (light green). Only 15% of the species encountered were observed at more than one of the three sites (dark green and grey).

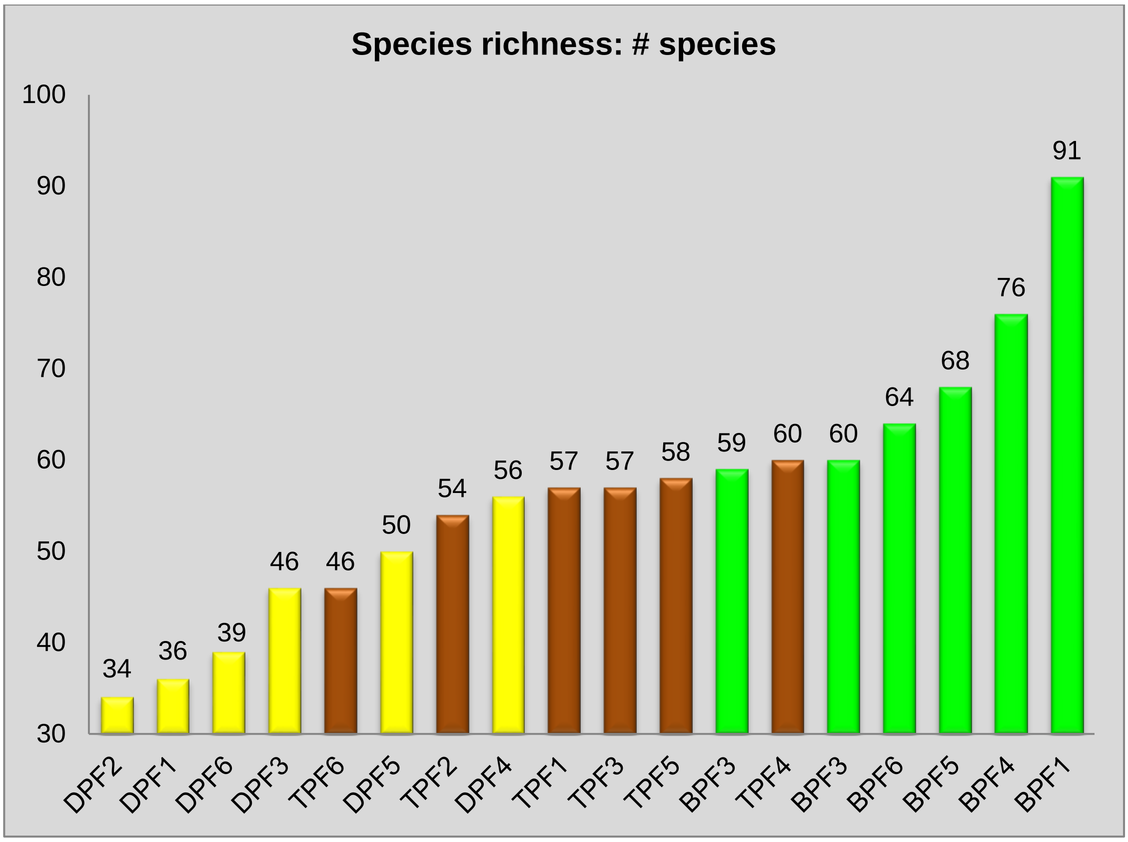


Figure 5. On average, the sample plots of Duynefontein (yellow) were the least species rich and the sample plots of Bantamsklip (green) were the most species rich.

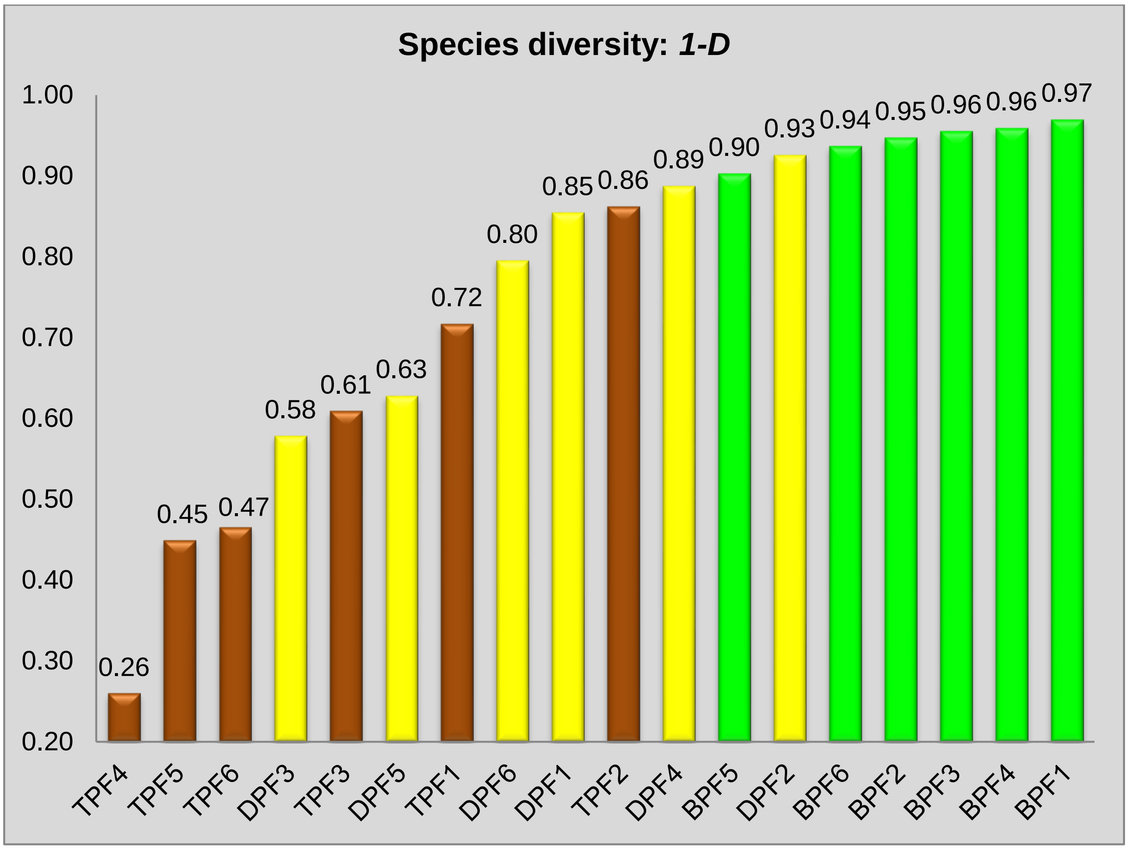


Figure 6. On average, the sample plots of Thyspunt (brown) were the least species diverse and the sample plots of Bantamsklip (green) were the most species diverse.

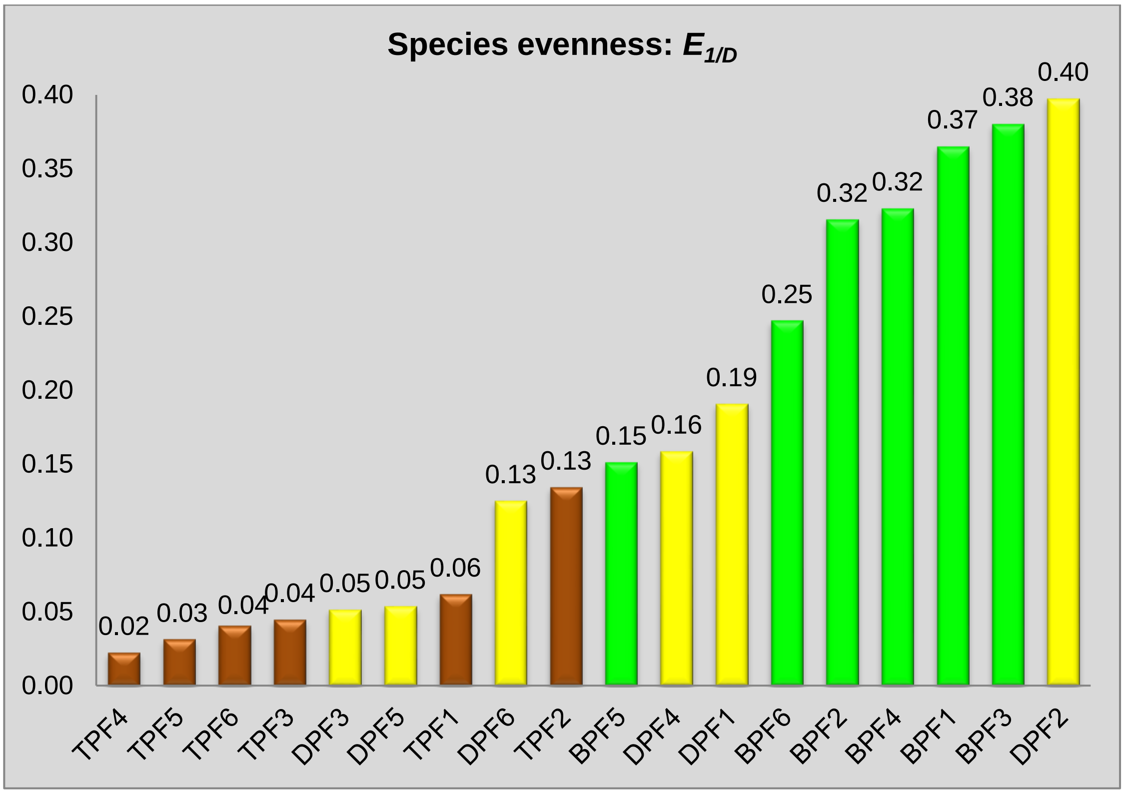


Figure 7. On average, the sample plots of Thyspunt (brown) were the least species even and the sample plots of Bantamsklip (green) were the most species even.

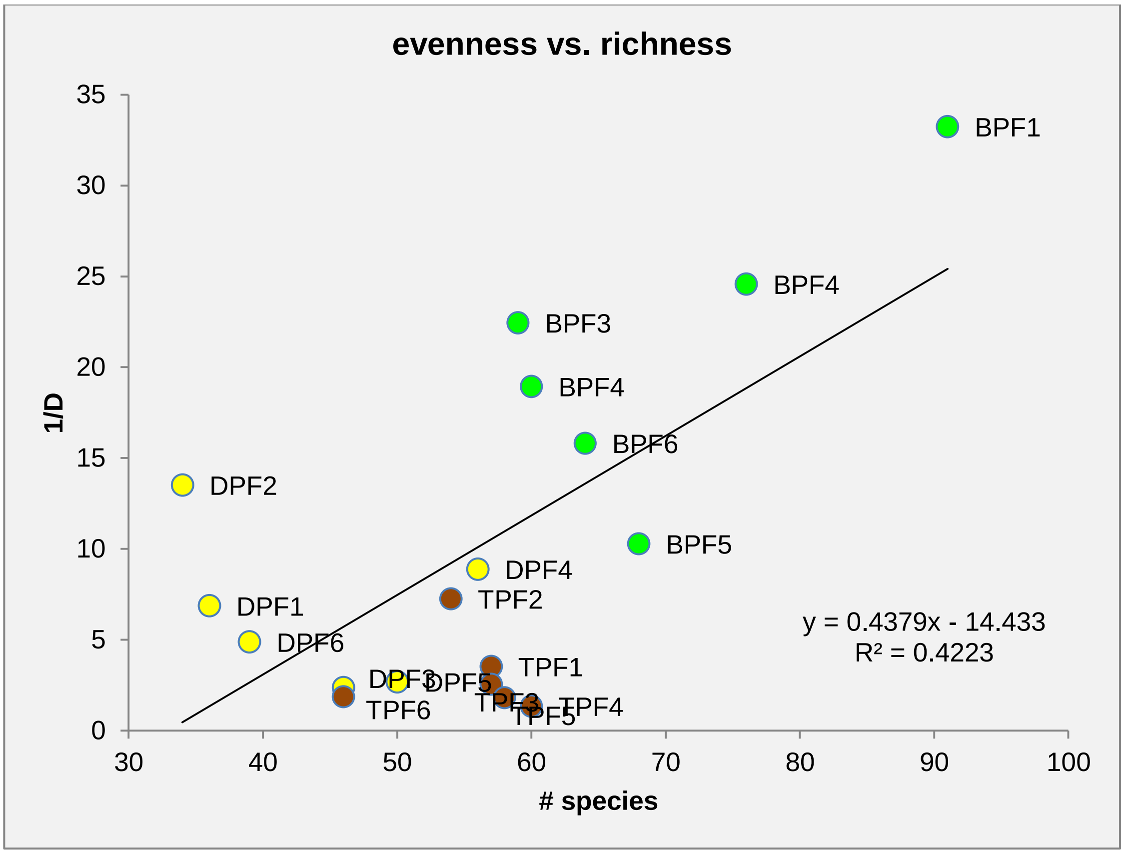


Figure 8. The linear relationship between the species evenness and species richness of the pitfall sample plots is insignificant ($R^2 = 0.4223$).

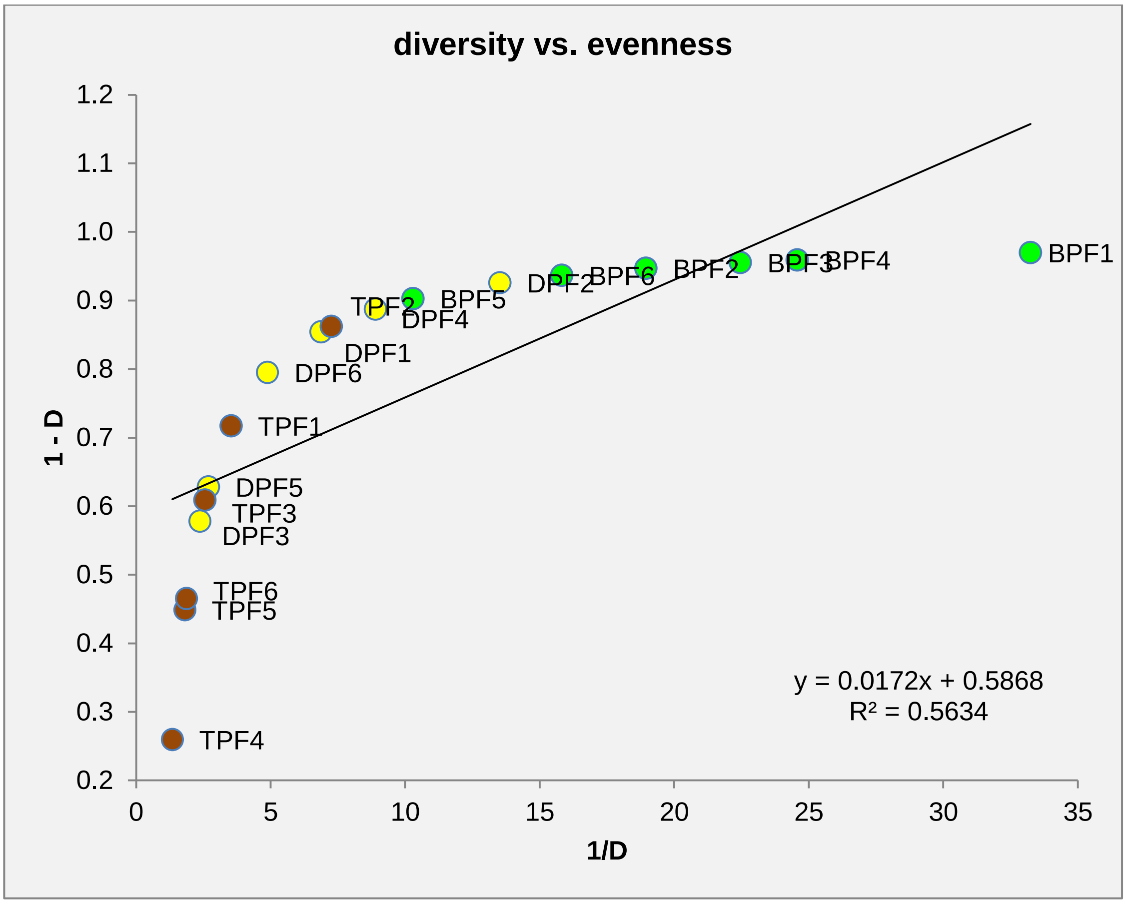


Figure 9. The linear relationship between the species diversity and species evenness of the pitfall sample plots is also of poor significance ($R^2 = 0.5634$).

2.2.1 Duynefontein invertebrates

One hundred and ninety-three invertebrate species were found at the seventeen sample plots of Duynefontein; one hundred and thirty-eight species were only found at Duynefontein. The invertebrate communities of Duynefontein was dominated by the eurytopic species of *Epirinus aeneus* (Dung Beetle), Pulmonata 1 (Land Snail), *Cheilomenes lunata* (Lunate Ladybird), *Trox sulcatus* (Carcass Beetle), the Western Strandveld species of *Scarabaeus intricatus* (Dung Beetle), *Aphodius* species 1 (Miniature Dung Chafer) and the Duynefontein 'endemics' of *Odontoloma* species (Dung Beetle), *Epirinus* species (Dung Beetle) and *Psammodes* species 2 (Toktokkie). The species richness of the Duynefontein pitfall sample plots varied between 34 and 56 species (average 43.5±7.8 species); Duynefontein was found to be the least species rich of the three study sites. The species diversity of the Duynefontein pitfall sample plots varied between 0.58 and 0.93 (average: *1-D* = 0.78±0.13); Duynefontein was found to be more species diverse than Thyspunt but less diverse than Bantamsklip. The species evenness of the Duynefontein pitfall sample plots varied between 0.05 and 0.40 (average: $E_{1/D}$ = 0.16±0.12); Duynefontein was found to be more species even than Thyspunt but less species even than Bantamsklip.

2.2.2 Bantamsklip invertebrates

Three hundred and one invertebrate species were found at the seventeen sample plots of Bantamsklip; two hundred and five species were only found at Bantamsklip.

The invertebrate communities of Bantamsklip was dominated by the eurytopic species of *Onthophagus minutus* (Dung Beetle), Pulmonata 1 (Land Snail), *Thanatophilus* species (Carrion Beetle), Tenebrionidae 2 (Darkling Beetle), Histeridae 3 (Steel Beetle), *Onthophagus giraffa* (Dung Beetle), the Western Strandveld species of Pulmonata 2 (Land Snail), *Aphodius* species 1 (Miniature Dung Chafer) and the Bantamsklip 'endemics' of Chrysomelidae 10 (Leaf Beetle), *Euoniticellus triangulatus* (Dung Beetle) and Tenebrionidae 24 (Toktokkie). The species richness of the Bantamsklip pitfall sample plots varied between 59 and 91 species (average 69.7±11.09 species); Bantamsklip was found to be the most species rich of the three study sites. The species diversity of the Bantamsklip pitfall sample plots varied between 0.90 and 0.97 (average: *1-D* = 0.95±0.02); Bantamsklip was found to be the most species of the three sites. The species evenness of the Bantamsklip pitfall sample plots varied between 0.15 and 0.38 (average: $E_{1/D}$ = 0.30±0.0.08); Bantamsklip was found to be the most species even of the three sites.

2.2.3 Thyspunt invertebrates

Two hundred and thirty-five invertebrate species were found at the seventeen sample plots of Thyspunt; one hundred and sixty-six species were only found at Thyspunt. The invertebrate communities of Thyspunt was dominated by the eurytopic species of *Scarabaeus spretus* (Dung Beetle), *Onthophagus giraffa* (Dung Beetle), *Epirinus* minimus (Dung Beetle), Curculionidae 9 (Weevil), and the Thyspunt 'endemics' of *Aphodius* species 8 (Miniature Dung Chafer), *Epirinus flagellatus* (Dung Beetle) and *Garreta unicolor* (Dung Beetle). The species richness of the Thyspunt pitfall sample plots varied between 46 and 60 species (average 55.3±4.5 species); Thyspunt was found to be more species rich than Duynefontein but less species diverse than Bantamsklip. The species diversity of the Thyspunt pitfall sample plots varied between 0.26 and 0.86 (average: *1-D* = 0.56±0.0.20); Thyspunt was found to be the least species diverse of the three sites. The species evenness of the Thyspunt pitfall sample plots varied between 0.02 and 0.13 (average: $E_{1/D}$ = 0.06±0.04); Thyspunt was found to be the least species even of the three sites.

2.2.4 Noteworthy invertebrate inhabitants of the study area

It is likely than a significant number of the 605 invertebrate species found during this study is unknown to science and is yet to be described. It is not, however, within the scope of this study to ascertain the taxonomic status of each morphospecies collected. However, some of the higher taxonomic groups are relatively well known and species of these groups were sent to the various specialists for positive identification.

A Wishbone Trapdoor Spider of the genus *Spiroctenus* Simon, 1889 was collected at the Bantamsklip site during the December 2013 field investigation. A very good series of live specimens were sent to specialist Ian Engelbrecht, including several sub-adult males. The species is likely to be an undescribed species of *Spiroctenus* Simon, 1889 (it is impossible to be certain until the sub-adult males have reached maturity); the same species was misidentified during the first survey as a species of *Ancylotrypa* Simon, 1889 (Wafer-lid Trapdoor Spider).

A species of Common Baboon Spider of the genus *Harpactira* Ausserer, 1871 was also collected at the Bantamsklip site. The specimen collected is designated as *Harpactira* cf. *cafreriana* (Walckenaer, 1837), the Cape Orange Baboon Spider, but positive identification is not possible until adult males of the population at Bantamsklip are collected (only a female was collected during the December 2013 field investigation). The specimen collected looks quite different to typical *H. cafreriana* (Ian Engelbrecht, pers. comm.).

Thirty-five dung beetle species were collected during the field investigation. This included three west and south coast endemics, *Copris anceus* (Olivier, 1789), *Onthophagus minutus* (Hausmann, 1807) and *Onthophagus giraffa* (Hausmann, 1807). All three species were encountered in all three study sites. One flightless species of dung beetle, *Macroderes greeni* (Kirby, 1818) is very localized and rare; it was found at the Duynefontein study site and could warrant future red data status as more data on the species becomes available (C.M. Deschodt, pers. comm.).

Three species of Fruit Chafer, *Anoplocheilus variabilis* (Gory & Percheron, 1833), *Anoplocheilus germari* (Wiedemann, 1818) and *Trichostetha capensis* (Linnaeus, 1767) was found during the field investigations. *A. germari* was found at Bantamsklip; the species is strictly limited to coastal dunes (Holm & Marais 1992). *A. variabilis* is found in high densities under vegetation on coastal dunes from November to February and the distribution is distinctly coastal (Holm & Marais 1992); a single specimen was collected at Thyspunt.

Fourteen butterflies were collected during the two field investigations. *Chrysoritis thysbe osbecki* (Aurivillius, 1882), the Melkbosstrand Common Opal, is endemic to the Western Cape and is found from the Bloubergstrand in the south to Lamberts Bay in the north. The species was collected at the Duynefontein site. The endemic Arrowhead, *Phasis thero thero* (Linnaeus, 1764), was collected at the Duynefontein and Bantamsklip sites.

2.3 Invertebrate red data assessment

In order to be able to compare the three sites in terms of Red Data species, all species listed for the Western and Eastern Cape Provinces of South Africa are included in this assessment.

A total of 47 threatened (VU, EN and CR listed) invertebrate species are listed for the two provinces (Onychophora, Gastropoda, Diplopoda, Odonata and Lepidoptera). The following conservation categories are included:

- Nineteen species are listed as Vulnerable;
- Fourteen species are listed as Endangered; and
- Fourteen species are listed as Critically Endangered

Forty-one of the forty-seven species have not been recorded from the regions in which the study sites are located (they are known from elsewhere within the Eastern and Western Cape provinces) and six of the species are known from the regions in which the study area is located (Table 6).

The Cape Thorntail, *Ceratogomphus triceratus* Balinsky, 1963, is restricted to the southern Cape region of South Africa, from Malmesbury area to Cradock; the type was described from the Berg River at Franschoek in 1962. It is a rare and little-known species that frequents fast-flowing, rocky streams (Tarboton & Tarboton 2002). The species is deemed unlikely to be present in any of the study sites – although it is known from the region in which Duynefontein and Bantamsklip is located, none of these two areas include fast-flowing, rocky streams.

The Rock Malachite, *Ecchlorolestes peringueyi* Ris, 1921, is endemic to South Africa and restricted to the mountains of the southwestern Cape, with a recorded range that extends from Cedarberg in the north to Kogelberg in the south; it is uncommon and localised in occurrence, and found mainly in the headwater streams of the Breede, Molenaar's, Witte and Hex rivers where it frequents sections of open river with extensive granite or sandstone outcrop; the type specimen is from Ceres in 1913 (Tarboton & Tarboton 2005). Although the species is known from areas close to the Bantamsklip site, the species seems to have a montane distribution and is deemed an unlikely inhabitant of the Bantamsklip site.

The Yellow Presba, *Syncordulia gracilis* Burmeister, 1839, is endemic to South Africa, most records are from the southwestern Cape; the type was described from Groot Drakenstein in 1932. The species is rare everywhere and no longer present at many sites where it was historically recorded. It frequents clear, fast-flowing streams in open country (Tarboton & Tarboton 2002). The Bantamsklip study site does not include clear, fast-flowing streams and the species in not deemed a likely inhabitant of this study site.

The Chestnut Presba, *Syncordulia venator* Barnard, 1933, is endemic to the southwestern Cape, originally ranging from the Cape Peninsula to Garcia Pass (near Riversdale). The species' present range has been significantly reduced; it is most likely no largely restricted to the Hawekwas Mountains. The type specimen is from Franschoek in 1932. The species frequents rocky streams in mountainous wooded country (Tarboton & Tarboton 2002). The species is historically known from the region of the Duynefontein and Bantamsklip study sites; however, these study sites do not include the Chestnut Presba's typical habitat and is most likely currently absent from the region of the study sites.

The Red Hill Copper, *Aloeides egerides* (Riley, 1938), is found from Red Hill in Simonstown on the Cape Peninsula in the west to Struisbaai in the east and Pella mission near Mamre in the north. It prefers flat sandy open ground in fynbos, occurring from just above sea-level to about 500 m. The species is known from Peninsula Sandstone Fynbos, Atlantis Sand Fynbos, De Hoop Limestone Fynbos, Agulhas Sand Fynbos and Cape Flats Sand Fynbos (Mecenero *et al* 2013). Although the species is not known from Cape Flats Dune Strandveld (Duynefontein) and Overberg Dune Strandveld (Bantamsklip), the potential present of the species in these two study sites cannot be wholly discounted. The species is deemed to have a moderate-low probability of occurring in both the Duynefontein and Bantamsklip study sites.

The Cape Flats Unique Ranger, *Kedestes lenis lenis* Riley, 1932a, is endemic to the southwestern Cape; it is found from Strandfontein east of Muizenberg and near Retreat in the south, and recorded from a locality near Worchester in the north. The species frequents grassy areas in Fynbos and is known from Cape Flats Dune Strandveld and Breede Shale Fynbos (Mecenero *et al* 2013). Most of the species habitat north of Table Mountain has been destroyed by housing development and alien invasive vegetation and it is unlikely that the species is still present in the Cape Flats Dune Strandveld of the Duynefontein study site.

Table 6. Red data invertebrates of the Eastern and Western Cape provinces			
Genus species	**English name**	**Status**	**Study region**
Onychophora			
Peripatopsis clavigera Purcel, 1899	Knysna Velvet Worm	VU	not recorded
Gastropoda			
Gulella aprosdoketa Connolly, 1939	Eastern Cape Land Snail	EN	not recorded
Gulella claustralis Connolly, 1939	Wild Coast Land Snail	EN	not recorded
Gulella puzeyi Connolly, 1939	Port St Johns Land Snail	CR	not recorded
Natalina beyrichi (Von Martens, 1890)	Pondoland Cannibal Snail	CR	not recorded
Sheldonia puzeyi Connolly, 1939	Port St Johns Sheldonid Land Snail	VU	not recorded
Odonata			
Ceratogomphus triceratus Balinsky, 1963	Cape Thorntail	VU	present
Chlorolestes apricans Wilmot, 1975	Amatola Malachite	EN	not recorded
Ecchlorolestes peringueyi Ris, 1921	Rock Malachite	VU	present
Metacnemis angusta Selys,1863	Ceres Stream-damsel	VU	not recorded
Metacnemis valida Hagen in Selys, 1863	Kubusi Stream-damsel	EN	not recorded
Orthetrum rubens Barnard, 1937	Ruby Skimmer	CR	not recorded
Proischnura polychromaticum (Barnard, 1937)	Cape Bluet	CR	not recorded
Syncordulia gracilis Burmeister, 1839	Yellow Presba	VU	present
Syncordulia venator Barnard, 1933	Chestnut Presba	VU	present
Lepidoptera			
Aloeides carolynnae carolynnae Dickson, 1983	Carolynn's Copper	EN	not recorded
Aloeides clarki Tite & Dickson, 1968	Coega Copper	EN	not recorded
Aloeides egerides (Riley, 1938)	Red Hill Copper	VU	present
Aloeides lutescens Tite & Dickson, 1968	Worcester Copper	EN	not recorded
Aloeides thyra orientis Pringle, 1994c	Red Copper	EN	not recorded
Aloeides trimeni southeyae Tite & Dickson, 1973	Trimen's Copper	EN	not recorded
Chrysoritis brooksi tearei (Dickson, 1966d)	Brook's Opal	VU	not recorded
Chrysoritis dicksoni (Gabriel, 1947)	Dickson's Strandveld Copper	CR	not recorded
Chrysoritis lyncurium (Trimen, 1868)	Tsomo River Opal	VU	not recorded
Chrysoritis penningtoni (Riley, 1938)	Pennington's Opal	VU	not recorded
Chrysoritis pyroeis hersaleki (Dickson, 1970b)	Sand-dune Opal	VU	not recorded
Chrysoritis rileyi (Dickson, 1966e)	Riley's Opal	CR	not recorded
Chrysoritis thysbe schloszae (Dickson, 1994a)	Moorreesburg Common Opal	CR	not recorded
Chrysoritis thysbe whitei (Dickson, 1994b)	Algoa Common Opal	EN	not recorded
Cymothoe alcimeda clarki Stevenson, 1940	Battling Glider	VU	not recorded
Durbania amakosa albescens Quickelberge, 1981	Amakosa Rocksitter	VU	not recorded
Durbaniella clarki belladonna Ball, 1994b	Clark's Rocksitter	VU	not recorded
Kedestes barbarae bunta Evans, 1956	Barber's Cape Flats Ranger	CR	not recorded
Kedestes lenis lenis Riley, 1932a	False Bay Unique Ranger	EN	present
Kedestes niveostriga schloszi Pringle & Schlosz, 1997	Greyton Dark Ranger	EN	not recorded
Lepidochrysops ketsi leucomacula Henning & Henning, 1994	Ketsi Blue	EN	not recorded
Lepidochrysops victori Pringle, 1984	Victor's Blue	VU	not recorded
Orachrysops niobe (Trimen, 1862a)	Brenton Blue	CR	not recorded
Stygionympha dicksoni (Riley, 1938)	Dickson's Hillside Brown	CR	not recorded
Thestor brachycerus brachycerus (Trimen, 1883)	Seaside Skolly	CR	not recorded
Thestor claassensi Heath & Pringle, 2004	Claassens' Skolly	VU	not recorded
Thestor dicksoni malagas Dickson & Wykeham, 1994d	Atlantic Skolly	VU	not recorded
Thestor kaplani Dickson & Stephen, 1971b	Kaplan's Skolly	EN	not recorded
Trimenia malagrida malagrida (Wallengren, 1857)	Scarce Mountain Copper	CR	not recorded
Trimenia malagrida paarlensis Dickson, 1967d	Scarce Mountain Copper	CR	Not recorded
Trimenia wallengrenii gonnemoi Ball, 1994f	Wallengren's Silver-spotted Copper	VU	not recorded
Trimenia wallengrenii wallengrenii (Trimen, 1887b)	Wallengren's Silver-spotted Copper	CR	not recorded

3 IMPACT IDENTIFICATION AND ASSESSMENT

3.1 Identification of impacts

The impact assessment is aimed at presenting a description of the nature, extent, significance and potential mitigation of identified impacts on the ecological environment. Direct or primary impacts can result from any activity that involves land clearance (such as access road construction, topsoil stripping etc.) or direct discharges into water bodies or the air. Direct impacts are usually readily identifiable, while indirect impacts or secondary impacts can result from social or environmental changes induced by mining operations and are often harder to identify and assess. Cumulative impacts occur where a number of projects are developed in environments that are influenced by other projects both power generation and other projects.

Only one impact that could lead to a beneficial impact on the ecological environment of the study sites was identified – the conservation of natural invertebrate habitat as a result of the construction and operation of the NPS (as is the case with conservation area next to the current Koeberg Nuclear Power Station). However, most impacts identified are of a negative nature since the proposed development is largely destructive, involving the alteration of natural habitat or degradation of habitat that is currently in a (mostly) climax status.

Impacts resulting from the proposed construction and operation of a NPS on the invertebrates of the study sites are largely restricted to the physical effects of habitat clearance and the establishment of artificial habitat. Direct impacts include any effects on populations of individual species of conservation importance and on overall species richness. This includes impacts on genetic variability, population dynamics, overall species existence or health and on habitats important for species of concern. On addition, impacts on sensitive or protected habitat are included in this category, but only on a local scale. These impacts are mostly measurable and easy to assess, as the effects thereof are immediately visible and can be determined to an acceptable level of certainty.

In contrast, indirect impacts are not immediately evident and can consequently not be measured at a moment in time. In addition, the extent of the effects is frequently at a scale that is larger than the actual site of impact. A measure of estimation is therefore necessary in order to evaluate the significance of these impacts. Lastly, impacts of a cumulative nature place direct and indirect impacts of this proposed project into a regional and national context, particularly in view of similar or resultant developments and activities. The following impacts on the invertebrates of the three study sites were therefore identified as relevant to the proposed project:

- Habitat loss of conservation important species;
- Loss and degradation of sensitive invertebrate habitat;
- Displacement of invertebrates and human-animal conflicts;
- Loss of ecological connectivity and ecosystem functioning;
- Degradation of surrounding habitat – indirect impact; and
- Conservation of sensitive invertebrate habitat (beneficial impact).

3.2 Nature of impacts

Generic impacts that are likely to result from the construction and operation of the proposed NPS at any of the three alternative sites are described briefly below. The list of impacts was compiled from a generic list of possible impacts derived from previous projects and from a literature review of the potential impacts of this type of development on the ecological environment.

3.2.1 Habitat loss of conservation important species

Invertebrate taxa of conservation importance generally do not contribute significantly to the species richness of a region, but do contribute significantly to the ecological diversity of a region as their presence usually provides an indication of a relatively pristine environment. Significant impacts result from losses and degradation of suitable habitat that is available to these species. This represents a significant direct impact on these animals. Additional aspects that will be affected include migration patterns and suitable habitat for breeding and foraging purposes. Habitat requirements and preferences of conservation important species are much stricter than for common or generalist species and a higher conservation obligation is placed on such areas. Even slight changes to habitat in which these species persist are therefore likely to have significant effects on the presence and status of these taxa within the immediate region.

The presence of Red Data invertebrate species has not been confirmed for any of the three study sites. However, the study has not been completed and this scenario might change. Should any conservation important species be confirmed for any of study sites, the exclusion of the habitat of these species is the only sensible manner in which this impact can be mitigated to some extent.

3.2.2 Loss and degradation of sensitive invertebrate habitat

The loss and/or degradation of natural vegetation or habitat that are regarded sensitive as a result of restricted presence in the larger region, represents a potential loss of habitat and biodiversity on a local and regional scale. Sensitive habitat types might include mountains, ridges, koppies, wetlands, rivers, streams, pans and localised habitat types of significant physiognomic variation and unique species composition. These areas represent centres of atypical habitat and contain biological attributes that are not frequently encountered in the greater surrounds. A high conservation value is generally ascribed to the invertebrate habitats that occupy these areas as they contribute significantly to the biodiversity of a region.

Natural invertebrate habitat of the study sites will be affected adversely by direct impacts resulting from construction and operational activities. Particular reference is made to the loss of habitat resulting from surface clearing activities, the construction of infrastructure and contamination of natural habitat through the leaching of chemicals into the groundwater and surface water and generation of dust and spillages. Also of importance is the loss of habitat that are not necessarily considered suitable for Red Data species, but where high endemic species richness is likely to be recorded.

This impact also includes adverse effects on any processes or factors that maintain ecosystem health and character, including the following:

- Disruption of nutrient-flow dynamics;
- Impedance of movement of material or water;
- Habitat fragmentation;
- Changes to abiotic environmental conditions;
- Changes to disturbance regimes, e.g. increased/decreased incidence of fire;
- Changes to successional processes;
- Effects on pollinators; and
- Increased invasion by plants and animals not endemic to the area.

Changes to the natural habitat may lead to a reduction in the resilience of ecological communities and ecosystems and changes in ecosystem function. Furthermore, regional ecological processes, particularly aquatic processes that is dependent on the status and proper functioning of the wetland habitat types, is particularly important. A high conservation value is generally ascribed to invertebrate assemblages that persist in these areas as they contribute significantly to the biodiversity of a region.

3.2.3 Displacement of invertebrate species, human-animal conflicts and interactions

Activities that are known to transpire from human-animal conflicts are likely to affect animals that utilise surrounding areas. Unwanted activities might include the killing by accidental contact, death of individuals as a result of attraction to artificial lights at night and the purposeful killing of species that might be considered as a threat (especially scorpions and spiders). While the tolerance levels of common species is generally of such a nature that surrounding areas will suffice in habitat requirements of the species forced to move from the area of impact, some species would not be able to relocate, such as ground living, sedentary species (trapdoor spiders and baboon spiders are good examples).

The presence of personnel within the development area during construction and operational phases will inevitably result in some contact with invertebrates. It is also highly likely that the natural invertebrate species will be attracted to the artificial lights of the proposed NPS; a lack of knowledge and understanding of the personnel frequently results in the unnecessary deaths of some invertebrates.

3.2.4 Loss of ecological connectivity and ecosystem functioning

The larger regions of all three study sites is characterised by matrixes of transformed and natural invertebrate habitat. Therefore, the ecological connectivity that natural habitat provides within this regional setting of habitat fragmentation and isolation, is therefore particularly important in the effective functioning of the regional and local processes. In order to ensure the persistence of the invertebrates of the study sites and surrounding areas within these ecological systems on both local and regional scales, it is critical that the basic characteristics of the system, such as a natural species composition, physiognomy, aquatic principles, contributions from surrounding habitat types, etc. are preserved.

Natural invertebrate habitat of the study sites will be affected adversely by direct impacts resulting from construction and operational activities. Particular reference is made to the disruption of migration patterns of flightless invertebrates.

3.2.5 Degradation of surrounding habitat – indirect impact

Surrounding areas and species present in the direct vicinity of the study sites will likely be affected adversely by indirect impacts resulting from construction and operation. These indirect impacts also include adverse effects on any processes or factors that maintain ecosystem health and character, including the following:

- Disruption of nutrient-flow dynamics;
- Impedance of movement of material or water;
- Habitat fragmentation;
- Changes to abiotic environmental conditions;
- Changes to disturbance regimes, e.g. increased/decreased incidence of fire;
- Changes to successional processes;
- Effects on pollinators; and
- Increased invasion by plants and animals not endemic to the area.

These impacts lead to initial, incremental or augmentation of existing types of environmental degradation, including impacts on the air, soil and water present within available habitat. Pollution of these elements might not always be immediately visible or readily quantifiable, but incremental or fractional increases might arise to levels where biological attributes could be affected adversely on a local or regional scale. In most cases, these effects are not bound to the geographic boundaries of the footprint area of the proposed project itself and are dispersed, or diluted over an area that is much larger than the actual footprint of the casual factor. The nature of a NPS is such that pollution and degradation of the surrounding areas is unlikely but cannot be discounted totally.

These impacts lead to a reduction in the resilience of peripheral ecological communities and ecosystems or loss or changes in ecosystem function. Furthermore, regional ecological processes, particularly aquatic processes dependent on the status and proper functioning of drainage lines, are important.

3.2.6 Conservation of sensitive invertebrate habitat

The only beneficial (positive) impact of the proposed project is the conservation of sensitive invertebrate habitat by the creation of de facto conservation areas proclamation of a conservation area as a result of the construction of the NPS (i.e. without the realisation of the proposed project no conservation area would result). Examples of the value of such conservation areas are found at Ingula Pumped Storage Scheme and Koeberg NPS itself. To assess the true impact of the proposed project, the resultant conservation area must be measured in terms of biodiversity and conservation value against the loss of these ecological attributes within the footprint area of the proposed NPS. The resultant conservation area has the potential to negate most of the negative ecological impacts if planned and managed optimally.

3.3 Causative Activities

The following activities, related to the construction, operation and decommissioning phases of the proposed development, are expected to result in adverse impacts on the ecological environment:

- Clearing of land for construction purposes;
- Construction of required infrastructure (roads, offices, storage areas, etc.);
- Presence of construction and operational personnel within a natural environment (ablution, fires, damage to vegetation, etc.);
- Chemical contamination by construction vehicles and machinery;
- Hydrocarbon spillages;

- Generation and handling of waste;
- Operational activities;
- Removal and dismantling of infrastructure during decommissioning; and
- Rehabilitation activities (introduction of species).

3.4 Assessment of impacts

Assessments of above-mentioned impacts for each of the three study sites, based on criteria specified to specialists, are presented here (Tables 7-9).

Table 7: Impact Assessment for the Duynefontein site

Impact		**Intensity**	**Extent**	**Duration**	**IR**	**Prob.**	**SIGNIFICANCE**
1. Habitat loss of conservation important species	Unmitigated	Medium	Medium	High	Medium	Medium	**Medium**
Mitigated	Mitigated	Medium	High	High	Low	Low	**Low**
2. Loss and degradation of sensitive invertebrate habitat	Unmitigated	Medium	Medium	High	High	High	**Medium**
Mitigated	Mitigated	Medium	Low	High	Low	Low	**Low - Medium**
3. Displacement of invertebrates & human-animal conflicts	Unmitigated	Medium	Medium	High	Low	Medium	**Medium**
Mitigated	Mitigated	Low	Low	High	Low	Low	**Low**
4. Loss of ecological connectivity & ecosystem functioning	Unmitigated	Low	Medium	Medium	Medium	High	**Low - Medium**
Mitigated	Mitigated	Low	Low	Medium	Low	Low	**Low**
5. Degradation of surrounding habitat (indirect impact)	Unmitigated	Medium	Low	High	Medium	High	**Medium**
Mitigated	Mitigated	Low	Low	Medium	Low	Low	**Low**

Table 8: Impact Assessment for the Bantamsklip site

<u>**Impact**</u>		**Intensity**	**Extent**	**Duration**	**IR**	**Prob.**	**SIGNIFICANCE**
1. Habitat loss of conservation important species	Unmitigated	Medium	High	High	Medium	High	**High**
Mitigated	Mitigated	Medium	High	High	Low	Medium	**Medium**
2. Loss and degradation of sensitive invertebrate habitat	Unmitigated	Medium	Medium	High	High	High	**Medium**
Mitigated	Mitigated	Medium	High	High	Medium	High	**High**
3. Displacement of invertebrates & human-animal conflicts	Unmitigated	Medium	Medium	High	Low	Medium	**Medium**
Mitigated	Mitigated	Low	Low	High	Low	Low	**Low**
4. Loss of ecological connectivity & ecosystem functioning	Unmitigated	Medium	Medium	High	Medium	High	**Medium**
Mitigated	Mitigated	Medium	Medium	High	Low	Low	**Low - Medium**
5. Degradation of surrounding habitat (indirect impact)	Unmitigated	Medium	Low	High	Medium	High	**Medium**
Mitigated	Mitigated	Low	Low	Medium	Low	Low	**Low**
6. Conservation of sensitive invertebrate habitat	Unmitigated	Medium	Medium	High	Medium	Medium	**Medium**
Mitigated	Mitigated	High	High	High	High	High	**High**

Table 9: Impact Assessment for the Thyspunt site

Impact		**Intensity**	**Extent**	**Duration**	**IR**	**Prob.**	**SIGNIFICANCE**
1. Habitat loss of conservation important species	Unmitigated	Medium	Medium	High	Medium	Medium	**Medium**
Mitigated	Mitigated	Medium	High	High	Low	Low	**Low**
2. Loss and degradation of sensitive invertebrate habitat	Unmitigated	Medium	Medium	High	High	High	**Medium**
Mitigated	Mitigated	Medium	Low	High	Low	Low	**Low - Medium**
3. Displacement of invertebrates & human-animal conflicts	Unmitigated	Medium	Medium	High	Low	Medium	**Medium**
Mitigated	Mitigated	Low	Low	High	Low	Low	**Low**
4. Loss of ecological connectivity & ecosystem functioning	Unmitigated	Medium	Medium	High	Medium	High	**Medium**
Mitigated	Mitigated	Medium	Medium	High	Low	Low	**Low - Medium**
5. Degradation of surrounding habitat (indirect impact)	Unmitigated	Medium	Low	High	Medium	High	**Medium**
Mitigated	Mitigated	Low	Low	Medium	Low	Low	**Low**
6. Conservation of sensitive invertebrate habitat	Unmitigated	Medium	Medium	High	Medium	Medium	**Medium**
Mitigated	Mitigated	High	High	High	High	High	**High**

4 ENVIRONMENTAL ASSESSMENT

The results obtained from the 2012 and 2013 field investigations and the desktop study of the red data invertebrates of the Eastern and Western Cape provinces were incorporated into the environmental assessment and habitat sensitivity analyses of the Duynefontein, Bantamsklip and Thyspunt study sites.

Five ecological criteria were used to calculate the relative and inherent sensitivity of each study site. Each criterion was scored out of 10 (qualitative scoring, 10 being the maximum) for each study site. During the qualitative scoring of each criterion, the study sites were compared to each other and to other natural invertebrate habitats found in the general regions of the study sites.

The five criteria scored are:

- Habitat status (level of habitat transformation and degradation evident);
- Habitat diversity (number of different invertebrate habitats present);
- Habitat linkage (degree to which the study site is ecologically connected);
- Ecological ability to host threatened taxa (Red Data species); and
- Inherent ecological sensitivity (presence of sensitive habitat types).

A summation of the five criteria listed above provided a comparative percentage sensitivity score for each of the three study sites. The following sensitivity classes apply to the total percentage sensitivity scores:

- Low sensitivity = 0-19%;
- Medium-low sensitivity = 20-39%;
- Medium sensitivity = 40-59%;
- Medium-high sensitivity = 60-79%; and
- High sensitivity = 80-99%.

Results of the invertebrate study (species richness, species diversity and species evenness) are incorporated into the habitat status and habitat diversity scores (diversity and natural status of the habitats are reflected in the species richness, diversity and evenness of the invertebrates found to be present).

Based on the above mentioned analyses of the five criteria, it is estimated that the Duynefontein and Thyspunt study sites have medium invertebrate sensitivities and Bantamsklip has a high invertebrate sensitivity.

Table 10. Sensitivities of the three study sites

Study Site	Status	Diversity	Linkage	RD	Sens	Total	Class
Duynefontein	7	7	5	5	5	58%	medium
Bantamsklip	9	9	9	5	8	80%	high
Thyspunt	6	6	6	2	6	52%	medium

4.1 Duynefontein

4.1.1 Habitat sensitivity

The Duynefontein study site has an estimated medium invertebrate sensitivity. It does not include any significant habitat variation such as large wetlands or significant surface rock and is characterised by significant levels of habitat transformation (in certain areas within the study site) as a result of alien invasive vegetation. None of the invertebrates found during the two field investigations at Duynefontein are known to be threatened or otherwise limited in distribution or scarce; the invertebrate communities of the Duynefontein study site is characterised by moderate species richness, species diversity and species evenness. It is unlikely that the Duynefontein study site will host any listed Red Data invertebrate of the Western Cape Province.

4.2 Bantamsklip

4.2.1 Habitat sensitivity

The Bantamsklip study site is deemed to have a high invertebrate sensitivity. It was the most species rich, species diverse and species even of the three study sites. More than a third of the total number of species collected during this study was only found at Bantamsklip. Bantamsklip include significant areas of sensitive invertebrate habitat – significant areas of surface rock are present within the study site. Only very small fragments of alien invasive vegetation are found within the Bantamsklip study site; the natural invertebrate habitat of this study site is largely intact and ecologically well connected to large areas of similar habitat. The Bantamsklip study site is also host to two potentially 'new' species of Mygalomorph spiders – a species of *Spiroctenus* (Wishbone Trapdoor Spider) and a species of *Harpactira* (Common Baboon Spider).

4.3 Thyspunt

4.3.1 Habitat sensitivity

The Thyspunt study site has an estimated medium invertebrate sensitivity. It does not include any significant habitat variation such as large wetlands or significant surface rock and is characterised by significant levels of habitat transformation (in certain areas within the study site) as a result of alien invasive vegetation. None of the invertebrates found during the two field investigations at Thyspunt are known to be threatened or otherwise limited in distribution or scarce; the invertebrate communities of the Thyspunt study site is characterised by moderate species richness, species diversity and species evenness. It is unlikely that the Thyspunt study site will host any listed Red Data invertebrate of the Eastern Cape Province.

5 MITIGATION MEASURES

The mitigation measures described below are the same for the three proposed alternatives; therefore they are not discussed individually for each of the alternative sites proposed. Obviously, if the 'no-go' alternative realises, al the mitigation measures described below are irrelevant (none of the impacts related to the proposed project will occur and mitigation is unnecessary).

5.1 Recommended mitigation measures

5.1.1 Site-specific mitigation measures

- Exclude all areas of high ecological sensitivity from the proposed development;
- Prevent all and any effluent from all construction and operational activities from entering wetland systems; and
- Prevent contamination of natural terrestrial and wetland habitats from any source of pollution.

These mitigation measures aim to be effective at the **REDUCTION** level within the mitigation hierarchy.

5.1.2 General aspects

- Appoint an Environmental Control Officer (ECO) prior to commencement of the construction phase. Responsibilities should include, but not necessarily be limited to, ensuring adherence to the Environmental Management Program (EMP) guidelines, guidance of activities, planning and reporting; and
- Compile and implement environmental monitoring program, the aim of which should be ensuring long-term success of rehabilitation and prevention of environmental degradation. Biodiversity monitoring should be conducted at least twice per year (summer and winter) in order to assess the status of the natural habitat and effects of the development on the natural environment.

Depending on the specific nature, timing and duration of an impact within the above-mentioned spheres of impact mitigation, these mitigation measures may be effective at the **AVOIDANCE, REDUCTION** or **RECTIFICATION** levels within the mitigation hierarchy.

5.1.3 Environmental Control Officer

It is important that strict control measures are in place during especially the construction phase of the project. The Environmental Control Officer (ECO) must ensure that these control measures are adhered to at all times. The control measures relating to the ECO as found in the EMP are supported.

5.1.4 Fences and demarcation

- Demarcate construction areas by semi-permanent means and materials, in order to control movement of personnel and vehicles, and providing boundaries for construction and operational sites; and

This mitigation measure aims to be effective at the **REDUCTION** level within the mitigation hierarchy.

5.1.5 Fire

- The project team will compile a Fire Management Plan (FMP) and contractors directed by the ECO will submit a FMP; the project FMP shall be approved by the local Fire Protection Association (FPA), and shall include *inter alia* aspects such as relevant training, equipment on site, prevention, response, rehabilitation and compliance to the National Veld and Forest Fire Act, Act No. of 1998;
- Prevent all open fires;
- Provide demarcated fire-safe zones, facilities and suitable fire control measures; and
- The use of branches of trees, shrubs or any vegetation for fire making purposes is strictly prohibited.

These mitigation measures aim to be effective at the **AVOIDANCE** level within the mitigation hierarchy.

5.1.6 Workers and personnel

- Provide sufficient on-site ablution, sanitation, litter and waste management and hazardous materials management facilities; and
- Ablution anywhere other than in provided toilets shall not be permitted - under no circumstances shall use of the veld be permitted.

These mitigation measures aim to be effective at the **AVOIDANCE** level within the mitigation hierarchy.

5.1.7 Waste

Waste needs to be strictly controlled and to this end, the mitigation measures regarding waste as found in the EMP are supported.

5.1.8 Invertebrates

- No invertebrates may killed, captured or trapped for any purpose whatsoever – fences and boundaries should be patrolled weekly in order to locate and remove traps;
- Vehicular traffic should be limited after dark in order to limit accidental killing of nocturnal invertebrates such as scorpions;
- Dangerous invertebrates (specifically scorpions and spiders) should be handled by a competent person only;
- Compile a graphic list of potentially dangerous invertebrates and present this to all workers as part of the site induction;
- Sensitize all personnel to the presence, characteristics and behaviour of invertebrate on the site;
- Include suitable procedures in the event of encountering potentially dangerous invertebrates on the site; and
- No domestic pets should be allowed on the site.

These mitigation measures aim to be effective at the **REDUCTION** level within the mitigation hierarchy.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the results obtained during this study it is evident that the Bantamsklip study site has a high invertebrate sensitivity and is deemed unsuitable for the proposed Nuclear Power Station. None of the results indicate the unsuitability of the Duynefontein and Thyspunt study sites regarding the proposed Nuclear Power Station.

6.2 Recommendations

It is recommended that the Bantamsklip study site is excluded a potential site for the proposed Nuclear Power Station.

7 PROPOSED INVERTEBRATE MONITORING PROGRAM

7.1 Aims

The main aim of an effective invertebrate monitoring program should be twofold: to monitor invertebrate numbers and assemblage composition over time and to relate any significant changes to the impacts associated with the particular project. Secondly, to use the monitoring program as a tool to mitigate impacts on the natural invertebrate habitats by diverting impacts from sensitive habitats and species.

The difficulty is to distinguish between ‘natural’ changes invertebrate numbers and assemblage composition and changes caused by the impacts of the project. Cause-effect can easily be mistakenly assumed unless the monitoring program is carefully planned.

7.2 Target Invertebrate Groups

It is not practical to include all invertebrates groups into a monitoring program. Despite the prevalence of invertebrates, very little is known about a significant number of these animals. Most invertebrate groups are poorly known ecologically; many species remain unnamed. Consequently, it is important to select specific target groups that will fulfil the aims of the monitoring program designed for the project. Such invertebrate groups should have as many of the following characteristics as possible:

- Be easily identifiable;
- Its ecology well known;
- Should be represented by significant numbers in the study area;
- Should be species rich;
- Should be sensitive to changes in its habitat and environmental conditions; and
- Target invertebrate groups must be easy to collect consistently with repeatable, scientific collection methods.

The assemblage of target invertebrate groups should include species that are taxonomically diverse, from all trophic levels in the ecosystem and representative of the keystone species of all the invertebrate habitats of the project area to be monitored.

7.2.1 Proposed Invertebrate Groups for Monitoring

Based on the results obtained during this invertebrate study, as well as personal invertebrate monitoring experience, the following invertebrate groups are proposed to be included in the monitoring program:

- Baboon spiders and trapdoor spiders (Arachnida: Mygalomorphae);
- Scorpions (Arachnida: Scorpiones)
- Damselflies and Dragonflies (Insecta: Odonata)
- Beetles (Insecta: Coleoptera);
- Antlions and relatives (Insecta: Neuroptera);

- Butterflies (Lepidoptera: Hesperiidae, Lycaenidae, Pieridae, Papilionidae and Nymphalidae); and
- Ants (Hymenoptera: Formicidae)

7.3 Collection methods

The invertebrate groups proposed for inclusion in the monitoring program (1.2.1, above), are ecologically, morphologically and taxonomically diverse. As such, a diverse number of collection methods are necessary in order to successfully monitor their numbers and assemblage structures over time. These collection methods include the following:

- Pitfall trapping (both baited and un-baited);
- Sweep netting;
- Handheld netting;
- Light trapping;
- UV light searches;
- Active searches of group specific niches; and
- Yellow tray trapping.

Each of the above listed collection methods are chosen for their repeatability, effectiveness in targeting one or more of the target invertebrate groups and cost effective, practical application in the field.

7.4 Experimental Design

To effectively design the long-term invertebrate monitoring program, a final layout of the project's infrastructure and areas of habitat destruction is needed. There is no sense in having long-term monitoring points in areas that are designated for project infrastructure and consequently destruction of the invertebrate habitats of that area. However, a few general experimental design objectives are essential and not bound to specific layout plans.

7.4.1 Seasonal Field Investigation Timing

The effectiveness of the invertebrate monitoring program will depend greatly on the timing of the field investigation period. The best period for invertebrate sampling in the study area region is during the summer months – invertebrates are mostly active when heat and moisture is present in their environment. The field investigation for the invertebrate monitoring program is therefore proposed for a two-week period during the early to mid-summer period; the first two weeks in December are ideal. It is important that the field investigation be completed during the same time each year; it eliminates some of the seasonal variation that confounds results of ill-timed field surveys.

7.4.2 Status Quo Sampling

Once the final layout of the project has been approved, the experimental design can be finalised and the first phase invertebrate sampling can be executed. It is imperative that the status quo of the invertebrates is sampled **before any construction activities commence**. The most important component of an effective invertebrate monitoring program is the sampling of the area before any of the impacts associated with the project influences the invertebrates of the project area. The data collected during this first sampling period acts as a benchmark against which all changes can be measured during subsequent yearly sampling bouts. Without this benchmark dataset, it becomes increasingly difficult to discern natural changes in invertebrate numbers and assemblage structures from changes resulting directly or indirectly from impacts caused by the project.

7.4.3 Reference collection

It is necessary to build up a reference collection of the invertebrates sampled during the monitoring program. It will ensure that species identifications are refined over time and that fewer identification anomalies are included in the final datasets used during the monitoring of invertebrates. Such a reference collection may be housed on sight or at an appropriate alternative; curation of the collection needs to be under the auspices of a trained entomologist or experienced museum official. The reference collection will have significant value as a training tool and as baseline scientific dataset.

8 REFERENCES

8.1 Bibliography

Balmford, A., Green, R. and Phalan, B. (2012) 'What conservationists need to know about farming', *Proceedings of the Royal Society. B,* vol. 279. No. 1739, July, pp. 2714-2724.

Batary, P., Baldi, A., Kleijn, D. and Tscharntke, T. (2011) 'Landscape-moderated biodiversity effects of agri-environmental management: a meta-analysis', *Proceedings of the Royal Society B,* vol. 278 no. 1713, June, pp. 1894-1902.

Begon, M., Harper, J.L. and Townsend, C.R. (1990) *Ecology. Individuals, Populations and Communities.* Blackwell Scientific Publications, USA.

Borgesa, P.A.V. and Browna, V.K. (2004) 'Arthropod community structure in pastures of an island archipelago (Azores): looking for local-regional species richness patterns at fine-scales', *Bulletin of Entomological Research*, 94, pp. 111-121.

Braack, L. (1991) *Field Guide to Insects of the Kruger National Park*. Struik Publishers, Cape Town.

Brackenbury, J. (1995) *Insects and Flowers. A Biological Partnership*. Wellington House, London, UK.

Carruthers, V. (ed.) (2000) *The Wildlife of Southern Africa. A Field Guide to the Animals and Plants of the Region.* Struik Publishers, Cape Town.

Cereghinoa, R., Ruggieroa, A., Martya, P. and Angeliberta, S. (2008) 'Influence of vegetation cover on the biological traits of pond invertebrate communities', *Annales de Limnologie – International Journal of Limnology,* vol. 44, pp. 267-274.

De Villiers, D. and Costello, J. (2006) *Mkambati and the Wild Coast. South Africa and Pondoland's Unique Heritage*. Wilderness Safaris, Cape Town.

Dippenaar-Schoeman, A.S. (2002) *Baboon and Trapdoor Spiders of Southern Africa: An Identification Manual.* ARC – Plant Protection Research Institute, Pretoria.

Dippenaar-Schoeman, A.S., Foord, S. and Haddad, C. (2013) *Spiders of the Savanna Biome*. University of Venda, Thohoyandou, and Agricultural Research Council, Pretoria, South Africa.

Dippenaar-Schoeman, A.S. and Jocqué, R. (1997) *African Spiders: An Identification Manual.* Agricultural Research Council – Plant Protection Institute, Biosystematics Division, National Collection of Arachnida, Pretoria.

Dippenaar-Schoeman, A.S. and Van den Berg, A. (2010) *Spiders of the Kalahari*. Plant Protection Research Institute Handbook No. 18. Agricultural Research Council, Pretoria.

Deguine, J.-P., Atiarna-Nurbel, T., Douraguia, E., Chiroleu, F. and Quilici, S. (2012) 'Species diversity within a community of the curcubit fruit flies *Bactrocera cucurbitae, Dacus ciliatus* and *Dacus demmerez* roosting in corn borders near cucurbit production areas of Reunion Island', *Journal of Insect Science,* 12:32 available online: insectscience.org/12:32.

Dossena, M., Yvon-Durocher, G., Grey, J., Montoya, J.M., Perkins, D.M., Trimmer, M. and Woodward, G. (2012) 'Warming alters community size structure and ecosystem functioning', *Proceedings of the Royal Society B,* vol. 279 no. 1740, August, pp. 3011-3019.

Duncan, A. (2005) 'Farm Animals and Biodiversity', *Animal Science*, vol. 81, pp. 187-188.

Evans, H.E. (1984) *Insect Biology: A Textbook of Entomology.* Addison-Wesley Publishing Company, USA.

Filmer, M.R. (1991) *Southern African Spiders. An identification guide.* Struik Publishers, Cape Town.

Finlay, B.J., Thomas, J.A., McGavin, G.C., Fenchel, T. and Clarke, R.T. (2006) 'Self-similar patterns of nature: insect diversity at local to global scales', *Proceedings of the Royal Society B,* vol. 273 no. 1596, August pp. 1935-1941.

Fletcher, R.J., Orrock, J.L. and Robertson, B.A. (2012) 'How the type of anthropogenic change alters the consequences of ecological traps', *Proceedings of the Royal Society B*, vol. 279 no. 1738, July, pp. 2546-2552.

Fontaine, C., Thebault, E. and Dajozi I. (2009) 'Are insect pollinators more generalist than insect herbivores?', *Proceedings of the Royal Society B,* vol. 276 no. 1669, August, pp. 3027-3033.

Forsman, A., Wennersten, L., Karlsson, M. and Caesar, S. (2012) 'Variation in founder groups promotes establishment success in the wild', *Proceedings of the Royal Society,* vol. 279 no. 1739, July, pp. 2800-2806.

Gerber, A. and Gabriel, M.J.M. (2002) *Aquatic Invertebrates of South African Rivers. Field Guide*. Institute for Water Quality Studies, DWAF, Pretoria.

Grove, A.J. and Newell, G.E. (1962) *Animal Biology, 6th edition, revised.* University Tutorial Press, London.

Holm, E. (2008) *Inseklopedie van Suider-Afrika.* Lapa Uitgewers, Pretoria.

Holm, E. (1986) *Insekgedrag Menslik Betrag*. Ekogilde cc, Pretoria.

Holm, E. and Dippenaar-Schoeman, A.S. (2010) *Goggagids. Die Geleedpotiges van Suider-Afrika.* Lapa Uitgewers, Pretoria.

Holm, E. and Marais, E. (1992) *Fruit Chafers of Southern Africa (Scarabaeidae: Cetoniini)*. Ekogilde cc, Pretoria.

Joy, J.B. and Crespi, B.J. (2012) 'Island phytophagy: explaining the remarkable diversity of plant-feeding insects', *Proceedings of the Royal Society B,* vol. 279 no. 174, August, pp. 3250-3255.

Kamffer, D. (2004) *Community-level effects of fragmentation of the afromontane grassland in the escarpment region of Mpumalanga, South Africa.* MSc. Thesis, University of Pretoria, Pretoria.

Leeming, L. (2003) *Scorpions of Southern Africa.* Struik Publishers, Cape Town.

Leroy, A. and Leroy, J. (2003) *Spiders of Southern Africa.* Struik Publishers, Cape Town.

Mecenero, S., Ball, J.B., Edge, D.A., Hamer, M.L., Henning, G.A., Krüger, M., Pringle, E.L., Terblanche, R.F. and Williams, M.C. (eds.) (2013) *Conservation assessment of butterflies of South Africa, Lesotho and Swaziland: Red list and atlas*. Saftronics (Pty) Ltd., Johannesburg and Animal Demography Unit, Cape Town.

Modlmeier, A.P., Liebmann, J.E. and Foitzik, S. (2012) 'Diverse societies are more productive: a lesson from ants', *Proceedings of the Royal Society B,* vol. 279 no. 1736, June, pp. 2142-2150.

Moreira, X., Mooney, K.A., Zas, R. and Sampedro, L. (2012) 'Bottom-up effects of host-plant species diversity and top-down effects of ants interactively increase plant performance', *Proceedings of the Royal Society B,* vol. 279 no. 1746, November, pp. 4464-4472.

Novotny, V. and Basset, Y. (2005) 'Host specificity of insect herbivores in tropical forests', *Proceedings of the Royal Society B,* vol. 272 no. 1568, June, pp. 1083-1090.

Picker, M. and Griffiths, C. (2011) *Alien & Invasive Animals. a South African Perspective.* Struik Publishers, Cape Town.

Picker, M., Griffiths, C. and Weaving, A. (2002) *Field Guide to the Insects of South Africa.* Struik Publishers, Cape Town.

Pringle, E.L.L., Henning, G.A. and Ball, J.B. (eds.) (1994) *Pennington's Butterflies of Southern Africa, 2nd edition*. Struik Publishers, Cape Town.

Scholtz, C.H. and Holm, E. (1989) *Insects of Southern Africa.* Butterworths, Durban.

Spector, S. (2002) 'Biogeographic crossroads as priority areas for biodiversity conservation', *Conservation Biology,* 16(6): 1480-1487.

Sutherland, W.J. (ed.) (2006) *Ecological Census Techniques, 2nd edition.* Cambridge University Press, UK.

Svensson, J.R., Lindegarth, M., Jonsson, P.R. & Pavia H. (2012) 'Disturbance-diversity models: what do they really predict and how are they tested?', *Proceedings of the Royal Society B,* vol. 279 no. 1736, June, pp. 2163-2170.

Swanepoel, D.A. (1953) *Butterflies of South Africa*. Maskew Miller Limited, Cape Town.

Sychra, J., Adamek, Z. & Petrivalska. (2010) 'Distribution and diversity of littoral macroinvertebrates within extensive reed beds of a lowland pool', *Annales de Limnologie – International Journal of Limnology*, vol. 46, pp. 281-289.

Tallowina, J.R.B., Rooka, A.J. and Ruttera, S.M. (2005) 'Impact of grazing management on biodiversity of grasslands', *Animal Science,* vol. 81 pp. 193-198.

Tarboton, W. and Tarboton M. (2002) *A Fieldguide to the Damselflies of South Africa*. Privately Published: Authors.

Tarboton, W. and Tarboton M. (2002) *A Fieldguide to the Dragonflies of South Africa*. Privately Published: Authors.

Utsumi, S., Ando, Y., Craig, T.P. & Ohqushi, T. (2011) 'Plant genotypic diversity increase population size of a herbivorous insect', *Proceedings of the Royal Society B,* vol. 278 no. 1721, October, pp. 3108-3155.

Wanger, T.C., Wielgoss, A.C., Motzke, I., Clough, Y., Brook, B.W., Sodhi, N.S. & Tscharntke, T. (2011) 'Endemic predators, invasive prey and native diversity', *Proceedings of the Royal Society B,* vol. 278 no. 1706, March, pp. 690-694.

Wiegand, T., Huth, A., Getzin, S., Wang, X., Hao, Z., Gunatilleke, C.V.S. and Gunatilleke, I.U.A.N. (2012) 'Testing the independent species' arrangement assertion made by theories of stochastic geometry of biodiversity', *Proceedings of the Royal Society B,* vol. 279 no. 1741, August, pp. 3313-3320.

Woodhall, S. (2005) *Field Guide to the Butterflies of South Africa.* Struik Publishers, Cape Town.

Web Pages:

http://www.sanbi.org/

http://www.iucnredlist.org/

http://www.catalogueoflife.org/

http://sabca.adu.org.za/

http://animaldiversity.ummz.umich.edu/

http://www.africanmoths.com/

9 APPENDICES

APPENDIX 1: PHOTOGRAPHIC RECORDS OF SPECIFIC SPECIES CONFIRMED

Cassionympha cassius (Godart [1824])

Chrysoritis thysbe osbecki (Aurivillius, 1882)

Copris anceus (Olivier, 1789)

Epirinus aeneus (Wiedemann, 1823)

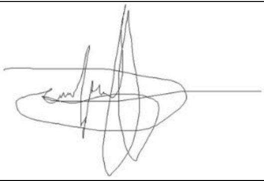
Ischnura senegalensis Rambur 1842

Opistophthalmus macer (Thorell, 1876)

Papilio demodocus demodocus Esper [1798]

Phasis thero thero (Linnaeus, 1764)

Pontia helice helice (Linnaeus, 1758)

Company name	Ecocheck Environmental Services and Art CC
Specialist signature	
Date	2014/02/28