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

Terrestrial Invertebrate Fauna Assessment

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- Specialist invertebrate studies
- EIA / biodiversity surveys
- Rehabilitation monitoring

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DECLARATION OF INDEPENDENCE

I, Peter Geoffrey Hawkes, as duly authorised representative of Afribugs, hereby confirm my independence (as well as that of Afribugs) as a specialist and declare that neither I nor Afribugs have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Arcus GIBB was appointed as environmental assessment practitioner in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), other than fair remuneration for worked performed, specifically in connection with the Environmental Impact Assessment for the proposed conventional nuclear power station ('Nuclear 1'). I further declare that I am confident in the results of the studies undertaken and conclusions drawn as a result of it, subject only to declared limitations – as is described in my attached report.

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Sensitivity analysis

Conclusions regarding both the relative sensitivity of the sites from a terrestrial invertebrate conservation perspective, as well as the optimal positioning of the proposed NPS within sites, must be regarded as tentative due to the inappropriate timing of field surveys as well as their extremely short duration and restricted taxon coverage.

The results of the field surveys and butterfly desktop assessment suggest that in contrast to the predictions of the terrestrial invertebrates scoping report, the Thyspunt site probably supports the most species-rich invertebrate community. However, due to the larger diversity of rare and relictual species predicted at the Bantamsklip site, and the discovery of a population of an undescribed and potentially restricted ant species as well as a probably undescribed trapdoor spider species here, the latter is considered to have the most valuable invertebrate community from a conservation perspective, and is considered the most sensitive of the three sites. Duynefontein had the lowest butterfly diversity, but ant diversity slightly greater than that of Thyspunt, and probably has an intermediate overall invertebrate diversity; with very few rare or relictual species observed or predicted, this site was considered the least sensitive.

The additional site inspections carried out in December 2009 / January 2010 confirmed that, in the case of Bantamsklip and Thyspunt, whatever the sensitivity of the habitats within the proposed footprint areas, there is sufficient scope for protecting adequate amounts of similar habitat elsewhere on the site. At Duynefontein, while similar habitat outside the proposed footprint area is very limited, we are confident that the majority of invertebrate species within the proposed footprint will be adequately represented in other habitat types on the site. For all three sites, the recommendations made here regarding preferred footprints are however made on the express understanding that thorough invertebrate surveys of the site(s) selected for NPS construction will be carried out prior to commencement of any construction activities to confirm that no unique species or communities will be threatened.

Impact identification and recommended mitigation

The most important potential **negative** impacts of the proposed NPS development on the terrestrial invertebrate communities of the three sites and the basic recommended mitigation measures are indicated in Table A.

Table A: Most significant potential negative impacts and recommended mitigation measures

Impact	Outline of basic mitigation recommendations
Direct habitat destruction	1. Carry out more detailed invertebrate surveys of all three sites to enable sound recommendations to be made regarding the most suitable portions of the sites for development; 2. Minimise development footprint and restrict all development activities to the recommended areas; and 3. Dispose of spoil off-site and keep temporary stockpiles as small as possible.
Reduction in populations of rare / threatened / protected species	1. Minimise development footprint and restrict all development activities to the recommended areas; 2. implement all measures required to minimise impacts of road mortality and light pollution.
Light pollution	1. Externally visible lighting should be kept to an absolute minimum and 2. wherever possible long-wavelength light sources should be used.
Spread of alien invasive invertebrate species	1. Institute strict control over materials brought onto site; 2. Rehabilitate disturbed areas as quickly as possible; and 3. Institute monitoring and eradication programmes to detect and control alien invasive species.

The most important potential **positive** impact of the proposed NPS development on the terrestrial invertebrate communities of the three sites will be enhanced protection and conservation-oriented management of the sites by Eskom. Evaluation of the negative and positive impacts of the proposed development suggests that for Bantamsklip and Thyspunt a net positive impact is achievable. It could further be argued that construction of one NPS at each of these sites would result in a greater net positive impact at a national level than would construction of one or more at only one site.

Recommended monitoring programmes

Outlines of the monitoring programmes recommended for evaluating the effectiveness of and aiding in the implementation of important mitigation measures are presented in Table B.

Table B: Summary of recommended invertebrate monitoring programmes

Monitoring programme	Duration of monitoring	Reporting	Management objectives
1. Invertebrate mortality caused by external lighting	Life of project: commence prior to construction to obtain baseline, continue throughout construction and operational phases.	3-monthly until target reached, annually thereafter	Reduction of light-induced mortality to insignificant levels; no measurable impact of light pollution on surrounding invertebrate populations.
2. Invasion by alien invertebrate species	Life of project: commence prior to construction to obtain baseline, continue throughout construction and operational phases.	Annual	Detection of establishment of alien species to allow early intervention in terms of eradication / control.
3. Diversity and community structure of selected indicator groups such as ants and leafhoppers	Commence prior to construction to obtain baseline values and continue throughout construction (including post-construction rehabilitation of disturbed areas) and decommissioning phases.	Annual	Diversity and species composition of selected indicator taxa return to baseline values after successful rehabilitation.

Environmental assessment

Assessment of the unmitigated and mitigated expected impacts indicated that at all three sites the significance of most impacts could be reduced by mitigation to low or medium, but for direct habitat destruction and reduction in populations of rare / threatened / protected species this was not possible and an offset may be required to alleviate this. Such an offset is readily identifiable in mitigation of the potential positive impact described above, if conservation-oriented management is enhanced, possibly by additional properties being incorporated into the reserve areas.

Conclusions and Recommendations

While every effort was made to provide as complete an assessment as possible, the limitations resulting from the inadequate duration and inappropriate timing of the invertebrate assessment surveys must be seen as a major impediment. A thorough objective assessment of such a large area (5 885 ha in total) is not possible under such circumstances and in order to increase confidence in the sensitivity ranking, identify specific impacts in more detail, and provide more valid input into the selection of least sensitive areas within sites, it is strongly recommended that additional surveys of the invertebrate fauna of the three sites be carried out. Such studies should cover a broad spectrum of taxonomic groups with differing ecological roles and ideally be carried out over at least a full active season, allowing field surveys to be carried out at least during spring/early summer, mid/late summer and late summer / early autumn, with butterfly surveys covering the months of October, November and February as a minimum. These surveys should include a component specifically aimed at finding male specimens of the probable new trapdoor spider species (*Spiroctenus* sp.) found at Bantamsklip so that its identity can be confirmed, as well as determining its distribution on the site and in surrounding areas to aid in selecting preferred locations for NPS development while ensuring conservation of the species. Full surveys of the ant fauna of the site(s) selected for development should be carried out prior to construction to provide a baseline for monitoring both of rehabilitation (especially of spoil stockpile areas) and potential invasion by alien ant species, as well as providing input to detailed sensitivity assessments and assessing the conservation status of the new species identified from each site.

While we do not view any of the sites as fatally flawed, we believe that, from the perspective of the terrestrial invertebrate groups investigated, development of the Duynefontein site would have the least negative impact and of Bantamsklip the most. Conversely, due to the currently conserved status of the Duynefontein property, this site would also have the least to gain from positive impacts in terms of site protection and management, and both Bantamsklip and Thyspunt stand to gain far more from continued or enhanced management as conservation areas under Eskom stewardship. Although further studies may yield findings that increase the sensitivity assessments of all of the sites, with more significant negative impacts as a result, there would most likely be a concomitant increase in positive impacts which would more than offset the negative aspects.

It should however be borne in mind that the above assessment is based on the assumption that a nuclear accident resulting in significant radioactive contamination of the environment will never occur. The risk of potentially disastrous negative impacts on the surrounding invertebrate communities would need to be balanced against the positive impacts described above. Although the reactor designs under consideration should be able to ensure that there is virtually zero risk of major radioactive release, if an accident risk assessment concludes that such an event does have a significant probability of occurrence, the sensitivity assessment of the sites would probably change and from the perspective of invertebrate conservation the consequences of such an event would be expected to be least significant at Duynefontein and most significant at Bantamsklip.

We feel that an NPS development at Bantamsklip would probably have the least impact on terrestrial invertebrate communities if it is positioned as far to the north-east of the EIA corridor as possible, at Duynefontein as far south as possible in the EIA corridor (adjacent to the existing Koeberg Power Station) and at Thyspunt we recommend NPS placement roughly in the centre of the EIA corridor.

NUCLEAR 1 ENVIRONMENTAL IMPACT ASSESSMENT AND ENVIRONMENTAL MANAGEMENT PROGRAMME

SPECIALIST STUDY FOR ENVIRONMENTAL IMPACT REPORT

SPECIALIST STUDY: TERRESTRIAL INVERTEBRATES

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ABBREVIATIONS

ADS	Algoa Dune Strandveld
ALF	Agulhas Limestone Fynbos
ALL Protocol	Ants of the Leaf Litter Protocol
ASF	Atlantis Strand Fynbos
ATBI	All-Taxa Biodiversity Inventory
CBD	Convention on Biological Diversity
CFDS	Cape Flats Dune Fynbos
CR	Critically Endangered
DD	Data Deficient
DDT	Dwarf Dune Thicket
DEAT	Department of Environmental Affairs and Tourism (part of which now constitutes the Department of Environmental Affairs)
Decon	Decontamination
DTT	Dune Thicket on Transverse dunes
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EN	Endangered
EPR	European Pressurised Reactor
HV	High Voltage
IUCN	International Union for Conservation of Nature
IUCN SSC	IUCN Species Survival Commission
IUCN SSC ISSG	IUCN SSC Invasive Species Specialist Group
KPS	Koeberg Power Station
kV	Kilovolt
LC	Least Concern
LED	Light Emitting Diode
LDT	Low to Dwarf Dune Thicket
MM	Michaelis-Menten
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998)
NKPA	National Key Points ACT 1980 (Act No. 102 of 1980)
NPS	Nuclear Power Station
NT	Near-Threatened
ODS	Overberg Dune Strandveld
OSF	Overberg Sandstone Fynbos
PBMR	Pebble Bed Modular Reactor
PWR	Pressurised Water Reactor

RD	Red Data
SA	South Africa
SAM	South African Museum, Cape Town
SCDF	Southern Cape Dune Fynbos
TDT	Tall to dwarf dune Thicket on high parabolic dunes
TR	Transition between transverse & parabolic dunes
TSF	Tsitsikama Sandstone Fynbos
UV	Ultraviolet
VU	Vulnerable

GLOSSARY

Arboreal	Living in trees.
Invasive species	A species often associated with humans and human-induced disturbance, but also able to colonise undisturbed natural habitats outside of its natural range, usually with severe negative consequences for indigenous populations.
Monotypic	A genus represented by only a single described species.
Morphospecies	A temporary grouping created to distinguish morphologically distinct clusters of specimens from one another prior to rigorous identification.
New species	A species that has not yet been formally described and which appears never to have been collected previously.
Tramp species	An invasive species associated with humans and human-induced disturbance, but not normally able to colonise undisturbed natural habitats outside of its natural range, and hence less threatening to indigenous populations than an invasive species.
Undescribed species	A species that has not been formally described but which may have previously been collected and specimens deposited in a recognised collection.

1 INTRODUCTION

1.1 Background

1.1.1 Proposed Nuclear 1 Power Station

Eskom proposes to construct 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 in the order of 60 hectares (ha), including all auxiliary infrastructure, although this will be confirmed during the detailed design phase of the project. The proposed NPS will include a nuclear reactor, turbine complex, spent fuel and nuclear fuel storage facilities, waste handling facilities, intake and outfall structures, desalination plant and various auxiliary service infrastructures. Additional areas will also be disturbed by the construction of soil and rock spoil stockpiles; the combined area of these has been estimated at approximately 54-91 ha but will depend on the site selected and the positioning of the NPS within the site.

In the event that the proposed project is authorised, it is estimated that the construction of the NPS could commence in 2011 with commissioning of the first unit in 2017.

1.1.2 Pressurised Water Reactor Design and alternatives

At present, no specific design has been selected for the proposed plants at the three sites. Any selected plant type will require additional infrastructure:, but although details of the main construction and associated infrastructure would likely differ slightly between alternative designs, the area required is expected to be similar and thus there is no need to consider the alternatives separately in terms of potential impacts on the invertebrate communities. Anticipated infrastructure requirements were provided in the Nuclear 1 NPP Consistent Dataset (Eskom 2009) for consideration during the assessment process.

The development alternatives considered for the purposes of this study were thus the no-development ("no-go") option, the three site alternatives and the precise positioning of the NPS units within each of the three proposed EIA corridors.

1.1.3 EIA process

Arcus GIBB (Pty) Ltd (ARCUS GIBB) was appointed by Eskom Holdings Limited (Eskom) to undertake an Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) for the proposed construction of Nuclear Power Stations (NPS) 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 the Nuclear 1 NPS.

AfriBugs CC (AfriBugs) was appointed by Arcus GIBB in August 2008 to undertake a specialist study of the potential impacts of the proposed NPS on the terrestrial invertebrate fauna of the three remaining sites: Duynefontein (adjacent to the existing Koeberg NPS), Bantamsklip (east of Pearly Beach) and Thyspunt (between Oyster Bay and St, Francis Bay). Dr Dave Edge (of Dave Edge & Associates) and Dr Alan Gardiner (an independent consultant) were subcontracted by AfriBugs to contribute to the butterfly component of this study.

1.1.4 Background to the invertebrate studies for the Nuclear 1 EIA & EMP

Invertebrates include the arthropods, which constitute the majority (over 75%) of all described species of living organisms on earth, and make up over 95% of all known animal species (see e.g. May 1988) and the lack of attention paid to this group in most biodiversity studies is a significant impediment to managing our biodiversity. As signatory to the Convention on Biological Diversity (CBD), South Africa has an obligation to conserve biodiversity as a whole and not only the groups that previous conservation efforts have tended to concentrate on. The South African Government has recognised that invertebrates and other poorly known groups have been neglected in past approaches to conservation and is committed to taking appropriate action to conserve such groups (DEAT, 1998). Invertebrate studies are therefore playing an ever-increasing role in conservation and environmental management decision-making processes in South Africa.

Insects and other invertebrates are vital to the functioning of the earth's ecosystems in their present form and help to maintain the balance that allows the vast diversity of life to coexist; for example some invertebrates assist plant species to reproduce and disperse, while others feed on the same plants and keep them in check, allowing room for other species. Other insects turn the soil or feed on decomposing matter, thus playing important roles in nutrient cycling; virtually every aspect of ecosystem functioning is dependant in some way on insects, which are the main non-plant drivers of ecosystem dynamics.

"*So important are insects and other land-dwelling arthropods that if all were to disappear, humanity probably could not last more than a few months. Most of the amphibians, reptiles, birds, and mammals would crash to extinction about the same time. Next would go the bulk of the flowering plants and with them the physical structure of most forests and other terrestrial habitats of the world. The land surface would literally rot*." (Wilson, 1999)

However, the very diversity that makes the invertebrates so important is also a significant impediment to their evaluation and conservation: With invertebrates constituting more than half of the close to two million described species of living organisms on earth, and estimates ranging from about 15-100 million (mostly invertebrates) still to be discovered, it is not feasible to carry out comprehensive biodiversity surveys of all species at a site (the cost of such All Taxa Biodiversity Inventories - ATBIs - has been estimated at around $100 million per site and each survey would tie up the majority of the world's taxonomic expertise for years). The only practical solution is to survey a subset of the overall biodiversity and either to extrapolate from the results to obtain an overall estimate, or to base evaluations or between-site comparisons on the chosen subset alone. Specific surveys for species known to be rare or threatened may also be used to supplement these data.

A specialist study covering the terrestrial invertebrates was produced by Dr Mike Picker (Picker, 2007) for the Nuclear 1 scoping report. In his report five potential sites for the proposed NPS were assessed and ranked according to predicted species richness in 14 invertebrate taxa considered to be of value as surrogates for species richness, endemicity and rarity. A limitation of such a desktop assessment is that differing amounts of historical data may exist for different sites, leading to the possibility of over or underestimation of their relative sensitivity. It is essential therefore to carry out comparable on-site assessments using the same methodology throughout to eliminate the confounding effect of previous over or under-collecting. Two of the proposed sites considered by Picker (2007) were subsequently excluded from further investigation for the proposed Nuclear 1 NPS, and the present study represents a further assessment of the remaining three sites on the basis of field surveys of certain of the surrogate taxa he used, with some additional taxa also being investigated.

The protocol normally followed by AfriBugs addresses the major inadequacies commonly encountered in EIA specialist studies (DEAT, 2002) by providing quantified baseline data at the species level for certain priority and indicator groups. This facilitates proper evaluation of the conservation value of a site and allows definite predictions regarding potential impacts to be drawn, thus forming a sound and statistically testable basis for monitoring of impacts during and after project development, as well as for evaluating success of rehabilitation programmes. Time constraints on the initial part of this study did not allow this approach to be used and so the alternative described in section 1.2 was followed instead. An opportunity for additional survey work arose during late March 2009 and a quantified survey of butterflies was then carried out at each of the three sites. It was apparent that even with the inclusion of the quantified butterfly data, there was insufficient detail on the invertebrate fauna of the sites to provide definite conclusions regarding preferred siting of the NPS. Additional detailed inspections of the areas indicated as most suitable by consensus of the majority of biophysical specialists were therefore carried out during December 2009 – January 2010.

1.2 Study Approach

Since a fairly thorough desktop assessment of the invertebrate diversity of the alternative sites, from the viewpoint of endemicity and rarity as well as species richness of selected taxa, has already been carried out (Picker 2007) there is little point in repeating such an exercise here, although we have extended the set of diversity surrogates to include butterflies; these were used only as rarity indicators by Picker (2007). The main thrust of the present study was to carry out comparable surveys of invertebrate diversity associated with the three sites, with equal search effort by the same collectors to minimise the effect of collector bias, as probable relative over-collecting at Duynefontein had been noted by Picker (2007). A secondary aim was to attempt to confirm the presence/absence of those species or groups of conservation concern identified as potentially occurring on each site. Both of these approaches contribute to an evaluation of the relative sensitivity of the three sites, thus allowing informed decisions to be made regarding siting of the proposed NPS.

1.2.1 Rationale for selection of the focus groups for this study

- Butterfly surveys have become a frequently used tool to gauge the invertebrate biodiversity of proposed development sites. This is particularly necessary in the southern Cape region, where there are many endemic and threatened butterfly taxa (Edge 2005).

- Ants are commonly used as biodiversity and ecological indicators and a standard protocol (the ALL protocol, Agosti *et al*. 2000) has been formulated to allow valid comparisons to be made between geographically removed sites. While this group was not considered in the specialist study by Picker (2008), they were included in the present study as, being present year-round, they represent one of very few insect taxa that could be reasonably effectively surveyed at the time of the field visits, which had to be carried out very early in the season before most invertebrates had become active. Although time constraints precluded a sufficiently in-depth survey and analysis to allow an evaluation of the sites in terms of community composition and rare or restricted ant species, estimates of the relative total ant diversity at each site could be obtained to allow a comparative indication of invertebrate diversity and contribute to an assessment of the relative importance of the invertebrate communities at the three sites.

- Mygalomorph spiders (trapdoor and baboon spiders) include many protected species in South Africa (e.g. several baboon spider genera) and are thus of conservation concern. Relatively complete information on their taxonomy and distribution is also available, which enhances their value as an indicator group.

- The groups selected by Picker (2007) for the initial assessment were considered, where feasible (for some, e.g. termites and grasshoppers, both sampling and identification even to morphospecies were impractical within the timeframe of this study), in order to provide continuity in the assessment process. In addition to butterflies, ants and mygalomorph spiders, searches during the brief August-September 2008 field survey were thus aimed at locating specimens of the following groups, bearing in mind that there were serious constraints in terms of both the duration and timing of the survey:

  1. Soldier flies (Mydaidae)
  2. Heelwalkers (Mantophasmatodea)
  3. Monkey beetles (Hopliini)
  4. Millipedes (Myriapoda)
  5. Scorpions (Arachnida: Scorpiones)
  6. Jewel beetles (Buprestidae)
  7. Spoonwing lacewings (Nemopteridae)
  8. Horseflies (Tabanidae)
  9. Velvet worms (Onchyophora)

1.2.2 Stratification of sampling

Sampling for the initial survey was stratified according to vegetation mapping in Mucina and Rutherford (2006) and inspection of satellite images of the sites. More detailed vegetation mapping later became available from the Botany specialist study (Low 2009) well after the initial surveys had been carried out, and this was used both in stratifying sampling for the 2009 butterfly surveys and for mapping of survey results and sensitivity assessments.

1.2.3 Butterfly surveys

(a) 2008 surveys

The normal method used by Dave Edge and Associates in carrying out a full butterfly survey is to systematically search a site on at least six occasions spread through the spring, summer and autumn months. For this project very limited time was available, thus this method could not be used. Initially only one late winter / very early spring visit was possible for each site and these were accomplished on the dates indicated in Table 1.1, with weather conditions as described.

At each site the position and disturbance footprint of three options for positioning the nuclear power station and its ancillary facilities had been demarcated on site plans provided, and the butterfly surveys concentrated on these areas. From review of the botany specialist study for the Nuclear 1 Scoping Report (Low and Desmet 2007), a general impression of the vegetation and habitat types was obtained. Stratification of sampling during the initial survey was based on vegetation mapping in Mucina & Rutherford (2006) and the scoping report assessment of the vegetation and habitats, but when the additional butterfly surveys were carried out, more detailed site-specific information had become available from the Botany specialist report (Low 2009), and this was used in planning the later surveys

During the surveys, all butterflies observed and any potential larval food plants found were recorded, and notes were made on the dominant and important plants at each site.

To supplement these observations, reference was made to publications recording the habits and distribution of South African butterflies (Pringle *et al*., 1994; Woodhall, 2005).

A spreadsheet was developed listing all the potential butterflies for the three sites, with their preferred habitat types, known food plants occurring in the area (Vári & Kroon, 1986; Goldblatt & Manning 2000), and assessed probability of butterfly occurrence. Red Listed butterfly taxa were highlighted in accordance with Henning *et al*., (2008), and any regional endemics were noted.

Probable total species counts were calculated by summing the estimated probabilities of all species predicted as potentially occurring on each site. Due to the limited survey carried out this is not directly comparable to similar estimates from other sites studies previously, but as the same method was applied at all three sites in the present survey, it does provide a relative measure for comparison of expected butterfly diversity at the three sites. Estimates of the probability of occurrence of Red Data butterfly species were similarly calculated by summing estimated probabilities of all RD species predicted for each site; again caution must be applied in comparing this to other sites where more detailed surveys have been carried out, but comparisons between the three sites surveyed are valid. Within-site comparisons of habitat sensitivity could not be carried out using the limited data obtained from these brief surveys, and these results were thus applicable only to between-site comparisons.

(b) 2009 surveys

In order to provide more detailed information to allow within-site sensitivity mapping, quantified butterfly surveys were carried out at all the three sites during a 2-week period in late March 2009 (see Table 1.1). While many more species would be expected to be observed at these sites at a more appropriate time of year, it was expected that the data would at least provide some indication of the relative sensitivity of the various habitats within each site. Between-site comparisons would be less reliable, as due to the large distances between sites, seasonal influences on butterfly activity would be expected to differ (see climate summaries in Figures 1, 7 and 11) and hence confound interpretation of observed differences in abundance and diversity, but as the main focus of the later surveys was on within-site variation, this was not considered a major impediment.

A sampling protocol was established (Appendix 2) to ensure that comparable surveys were carried out at the three sites despite one researcher (Dave Edge) being responsible for one of the three sites (Thyspunt) and a different researcher (Alan Gardiner) for the other two (Duynefontein and Bantamsklip). Each half hour period was considered one sampling unit. Where a site was very heterogeneous and the vegetation types fragmented (e.g. Thyspunt), time was often lost in walking or driving between vegetation patches because of the discontinuities in the vegetation. The time within the 30-minute period that was actually spent observing within the target vegetation type was thus recorded and this was sometimes significantly less than 30 minutes. When this occurred samples were combined so the total sampling time for combined samples was approximately 30 minutes. Due to differences in the extent of vegetation types, it was not possible to complete the same number of sampling periods in each habitat type as this would have meant covering the same area several times in areas of limited coverage. The use of EstimateS software (Colwell 2005) to generate smoothed species accumulation curves and estimates of overall diversity (see section 1.2.2 for further detail) compensated both for the slight differences in length of sampling periods and for the differing numbers of samples per habitat type.

At Thyspunt a full day was devoted to each vegetation type surveyed. At Bantamsklip and Duynefontein, one vegetation type was sampled in one day where feasible. Where this was not logistically possible, a survey of a vegetation type was split over more than one day. During each half hour period, all the butterflies observed were identified (or voucher specimens were taken if identity was uncertain) and recorded.

Table 1.1: Dates and weather conditions during August / September 2008 and March 2009 butterfly surveys

Site	**Dates**	**Weather**
Duynefontein	8 August 2008	Fine, warm
	25-30 March 2009	Assessed adequate according to criteria in Appendix 2
Bantamsklip	29 August 2008	Partly cloudy, cool
	18-23 March 2009	Assessed adequate according to criteria in Appendix 2
Thyspunt	1 September 2008 2 September 2008	Fine, strong cool wind Partly cloudy, mild
	19 - 30 March 2009	Assessed adequate according to criteria in Appendix 2

1.2.4 Ant surveys

A survey of the ant fauna should ideally include at least the basic survey methods outlined in the ALL protocol (Agosti *et al*. 2000), i.e. pitfall trapping and Winkler extraction of leaf litter samples, but as this protocol requires a minimum of three days fieldwork and an additional three to four weeks sample processing per site, it was not possible to carry out this protocol. Instead a limited survey was performed by structured hand-collecting; 20 samples, each comprising representatives of all ant species encountered during a 15-minute period, were collected at each site. Although this technique carries a high risk of results being influenced by operator bias, this was minimised by all 60 samples from the three sites being collected by a single experienced collector. The twenty ant samples collected at each site were divided equally between the five main habitat types identified by inspection of satellite images and available vegetation maps; while four hand-collected samples per habitat is far from adequate (about 10% of the sampling effort considered sufficient for reliable between-habitat comparisons), this was done to provide at least some habitat-specific information on ants.

Ant collections were carried out at the three sites on the dates indicated in Table 1.2. All samples were initially checked for the presence of the invasive Argentine Ant (*Linepithema humile*) as there are concerns that development of the NPS could assist in the spread of this highly destructive species. The samples were then sorted and representatives of each morphospecies mounted and identified using available literature, as far as possible to species level. Where necessary, assistance with identifications was provided by Dr Barry Bolton (pers. comm.). The number of specimens of each worker species was recorded for each sample to allow construction of a species x sample matrix from which species accumulation curves and estimates of species richness for each site were calculated using EstimateS (Colwell 2005). Species accumulation curves were constructed by randomising the sample order 100 times and plotting the mean number of previously unrecorded species in the sample series against the number of samples. EstimateS calculates a number of estimates of total species richness from both the individual randomised runs and averaged accumulation curves; we selected the Michaelis-Menten Means estimate (based on the averaged curve) for comparisons in this study as it generally provides more consistent estimates that are less sensitive than other alternatives to sampling effort. The averaged species accumulation curves and Michaelis-Menten richness estimates for each site are shown in Appendix 5 and a list of ant species recorded at each site is presented in Appendix 6.

Table 1.2: Dates and weather conditions during ant surveys

Site	**Dates**	**Weather**
Duynefontein	27 August 2008	Fine, mild
Bantamsklip	29 August 2008 30 August 2008	Partly cloudy, cool Clear to partly cloudy with strong winds and intermittent rain, cold
Thyspunt	1 September 2008 2 September 2008	Fine, strong cool wind Partly cloudy, mild

Of the 40 ant species collected during the survey, 26 could be fairly confidently identified as known species and five were confirmed as new or very probably new species, with nine remaining species belonging to genera for which no identification keys are currently available and for which further identification may not be possible at this stage. The new and potentially new species, as well as those not yet identified were further studied during November 2009 at the South African Museum.

1.2.5 Other invertebrates

No formal or detailed surveys for other taxonomic groups could be accommodated in the limited time available, so only unstructured searches were carried out during the site inspections in August/September 2008, with particular emphasis being placed on searching likely habitats of those groups identified in the scoping report as potentially being represented by rare or unique species (see section 1.1.5). Habitat assessments and searches were carried out on the following dates:

Table 1.3: Dates and weather conditions during surveys for other invertebrates

Site	**Dates**	**Weather**
Duynefontein	25 August 2008 27 August 2008	Partly cloudy with moderate wind and intermittent rain, cool Fine, mild
Bantamsklip	29 August 2008 30 August 2008	Partly cloudy, cool Clear to partly cloudy with strong winds and intermittent rain, cold
Thyspunt	1 September 2008 2 September 2008	Fine, strong cool wind Partly cloudy, mild

1.2.6 Additional habitat assessments

At each of the three sites one day was spent, by a field team of two invertebrate specialists, inspecting the area identified by the majority of biophysical specialists as most suitable for location of an NPS, in order to become thoroughly acquainted with all habitats that would be impacted on by development within this area. A second day was then spent on each site surveying other similar areas to confirm whether or not all habitat types identified within the potential footprint area were adequately represented elsewhere on the site, and whether protection of these areas could be reasonably expected to result in on-site conservation of all invertebrate communities and species that would be impacted on by construction of the NPS. Attempts to confirm the presence, outside the potential footprint areas, of important invertebrate species previously identified from each site were also made. In addition, specimens of other potentially significant invertebrate species were collected.

They Thyspunt site was inspected from 21-23 December 2009, Duynefontein from 12-13 January 2010 and Bantamsklip fro 15-16 January 2010.

1.2.7 Sensitivity assessment

Comment on terminology

It should be noted that "sensitivity" as used in this report does not conform to the correct meaning of the term, but has been retained here for purposes of consistency with other biophysical specialist reports constituting the Nuclear 1 EIA studies. Correctly used, habitat sensitivity refers to the ability (or rather lack thereof) of a habitat to tolerate a given impact without suffering degradation or loss of biodiversity, but as used here indicates conservation value / importance. In the context of a development which will involve the complete transformation of a substantial area of natural habitat, "sensitivity" in itself is meaningless: no natural habitat can be to any degree insensitive to being covered by a thick concrete slab. In this context the conservation value / importance of the habitat becomes the only criterion on which preferred layouts and / or "no-go" areas can be based. Thus, although the terminology used may be incorrect, the appropriate criterion has been used to assess potential impacts of the proposed NPS.

Sensitivity ranking procedures

Only during the second field surveys, carried out during late March 2009, was data suitable for carrying out a formal sensitivity assessment collected so that the approach outlined below could be followed. These surveys could only be carried out on a single taxonomic group (butterflies).

Butterfly species identified during the field surveys were assigned a value from 1 to 5 based on their importance assessment from "very low" to "very high" according to Table 1.4.

Table 1.4: Species sensitivity scoring criteria

Red Data Status	Protected				Non-Protected			
	Local Endemic	Regional Endemic	National Endemic	Continent / Global	Local Endemic	Regional Endemic	National Endemic	Continent / Global
CR, EN	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
VU, NT	Very High	Very High	High	High	High	High	High	High
DD	High	High	Medium	Medium	Medium	Medium	Medium	Medium
LC, None	High	Medium	Medium	Medium	Medium	Low	Very Low	Very Low

The individual species scores for all species recorded within each area were summed to give a total endemicity score; a summed habitat sensitivity score was then calculated by adding the estimated species richness to the endemicity score (see Table 1.5).

Table 1.5: Habitat sensitivity scoring criteria

Rank	Sensitivity	Summed sensitivity score range
0	Developed / transformed (none)	0
1	very low	1-5
2	low	6-15
3	medium	16-25
4	high	26-35
5	very high	35 +

The resulting score thus gives equal weighting to the degree of endemicity of the butterfly community (a measure of the taxon-specific conservation value of the habitat) and to the overall diversity (a surrogate measure of the species richness of the entire invertebrate community). However, the use of a single taxon to provide both of these measures is risky and the sensitivity rankings obtained could differ substantially if a more thorough invertebrate survey is undertaken.

An alternative sensitivity ranking procedure, modified from that used in the Terrestrial Vertebrate Fauna Impact Study (Harrison *et al.* 2009) was therefore also carried out. This procedure gives a base ranking of medium sensitivity to all undisturbed natural habitats and low or very low to disturbed habitats. The ranking is then increased from its basic level for each area in which species of conservation importance have been recorded. Thus any undisturbed natural habitat in which conservation-important species have been recorded will receive a High sensitivity ranking. The method yields a rather coarse and possibly over-conservative scoring, but in doing so compensates for a lack of detailed information (see section 1.2.8 below) in line with the NEMA precautionary principle.

1.2.8 Limitations of the study

This study was commissioned at a very late stage during the EIA process, allowing only three weeks to complete the initial field surveys, analyses, impact assessments and reporting. Only a very superficial survey was thus possible in early spring 2008, with approximately two days being available to inspect each site; this translates to approximately one person-day per 1000 ha, which is roughly 1/30 of the survey effort that we would normally consider appropriate. The limitations resulting from the short duration of the field survey were further exacerbated by inappropriate timing (the majority of the field visits being between 25 August and 2 September), as the majority of invertebrate species present exhibit very low levels of activity at this time of year. It must therefore be borne in mind that failure to detect a given species during these surveys cannot be taken as a strong indication of its absence.

An important aim of the study was to determine the *relative* sensitivity of the sites, and such an assessment might be expected to be less influenced by inappropriate timing as long as all sites were assessed at approximately the same time under similar weather conditions. However it must be borne in mind that:

- different species have different seasonal activity periods;
- the potential species of concern at the three sites were not the same; and
- one of the sites (Thyspunt) falls within a different bioregion and experiences a different climate (with higher and less seasonally restricted rainfall) than the other two

It is therefore to be expected that the influence of the inappropriate timing of the survey on the results obtained would differ between sites. Thus it is quite possible that both the overall sensitivity ratings and the relative ranking of the sites may have been influenced by the timing of the survey.

The potential impact of any large-scale development such as the proposed NPS on the invertebrate fauna can only properly be assessed by carrying out extensive field surveys covering the appropriate seasonal activity periods for all taxa of conservation concern as well as for any diversity surrogates used. Such a study should ideally be carried out over a full year, allowing field surveys to be carried out at least during spring/early summer, mid/late summer and late summer/autumn, with sufficient time prior to the spring surveys to allow proper planning.

The initial surveys carried out were concentrated, due to time constraints, in the areas covered by the three proposed development footprints on each site; as a result it was not possible to use this information to identify preferred development areas and no-go areas within each site. Although the additional butterfly surveys carried out in March 2009 went some way toward rectifying this, both the taxonomic and seasonal scope of these surveys were also limited. Further more detailed and taxonomically comprehensive surveys of the invertebrate fauna of the site will be required to refine the within-site sensitivity assessments and enable layouts to be adjusted where necessary to minimise impacts.

The additional inspections carried out during December 2009 / January 2010 were considered sufficient to allow assessment of whether or not development of the preferred footprint areas (as determined by majority agreement of other biophysical specialist studies) would be likely to impact on invertebrate species or communities that are not elsewhere adequately represented on the site within areas to be conserved. Confirmation of the conclusions drawn from these studies should however still be confirmed by full seasonal surveys (as described above) of the site selected for development of Nuclear 1, since invertebrate community composition often varies over shorter distances and hence at a much finer scale than do vegetation communities. A risk therefore remains that conclusions based on these habitat inspections may not truly reflect the situation from an invertebrate community perspective. In order to mitigate these limitations, Eskom has committed to ensuring that such surveys will be carried out.

2 DESCRIPTION OF AFFECTED ENVIRONMENT

2.1 Site 1: Duynefontein

2.1.1 Habitats

The predominant vegetation types on the Duynefontein site are defined by Mucina & Rutherford (2006) as Atlantis Sand Fynbos (ASF) in the south-eastern portion and Cape Flats Dune Strandveld (CFDS) over most of the remainder of the site, with a small strip of Cape Seashore Vegetation along the beachfront. However, while the majority of the Duynefontein site portions on which construction of the NPS is proposed fall within the CFDS, this is locally quite varied and comprises a mix of unvegetated or partially vegetated (both natural and heavily infested by alien species) shifting dune systems, as well as completely stabilised sand flats in the more inland parts. An initial visual inspection suggested that at least five distinct vegetation zones could be identified within the CFDS on the Duynefontein site:

A. Largely unvegetated dunes with small patches of vegetation especially in the dune slacks, where some seasonal wetlands were also found;
B. Moderately vegetated mobile transverse dunes;
C. Heavily alien-infested dunes;
D. Well-established and stable sand flats vegetation; and
E. Previously disturbed but quite well-rehabilitated vegetation transitional between the mobile transverse dunes and the stable sand flats form.

The vegetation mapping shown in Figure 1, which is based on information (Low 2009) made available to AfriBugs subsequent to the initial survey, delimits these and other distinct habitats in more detail, but initial description of the butterfly communities of the site was based on the preliminary assessment outlined above.

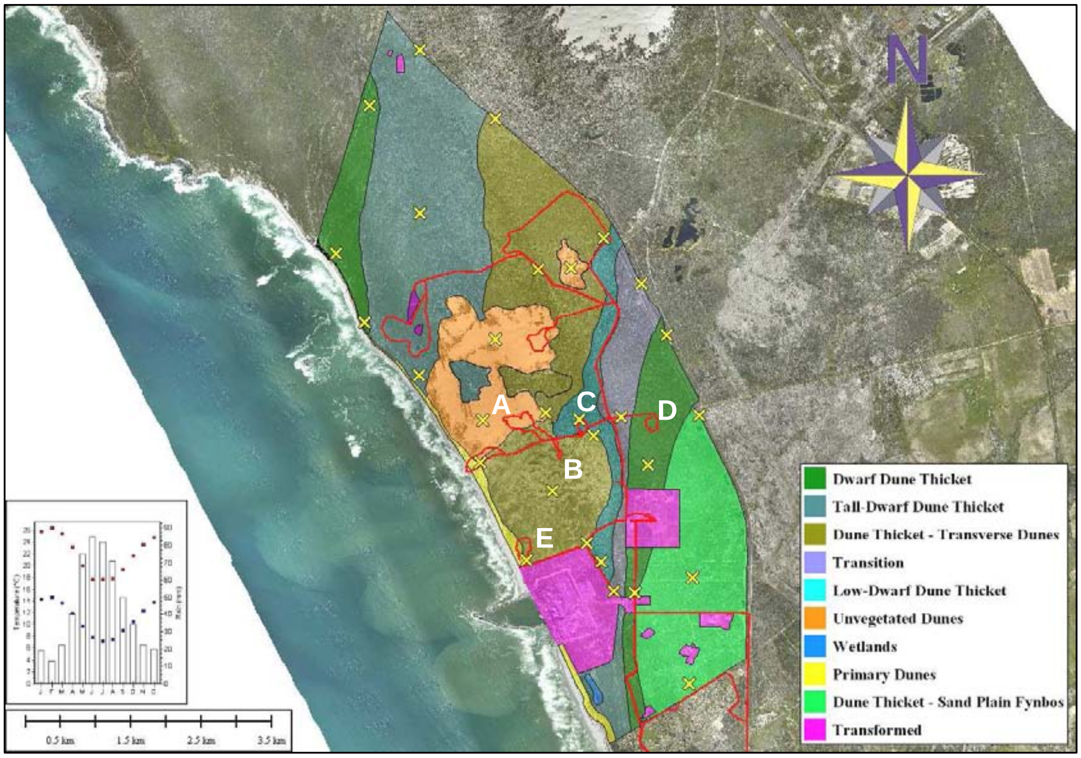

Figure 1: Duynefontein invertebrate surveys. Vegetation types (after Low 2009) and routes followed during the non-butterfly components of the invertebrate survey (red) are indicated; butterfly transects followed different routes (yellow crosses indicate butterfly survey targets for March 2009 survey). Climate summary shows monthly minimum/maximum temperatures and rainfall. (Note: semitransparent vegetation overlays mean colours are less intense than in the key)

2.1.2 Ant diversity

The 20 ant samples collected were equally distributed between the areas indicated A-E in Figure 1. Twenty-two species were collected (see Appendix 6), with an estimated total diversity of approximately 27 species (Michaelis-Menten estimate); see Appendix 5. No Argentine Ant (*Linepithema humile*) specimens were found, but these may prove to occur on the site closer to the existing developments, where no surveys were carried out during the present survey. Another widespread tramp species, *Hypoponera eduardi*, was found near the edge of the non-vegetated dunes in area A, but this species is not yet considered of major conservation concern.

Two ant species of special interest were collected at Duynefontein. These were:

- *Tetramorium* sp. AFRC-WCA-01 (an undescribed species related to *T. flaviceps*) found in the Dune Thicket on Transverse Dunes (area E, Figure 1); and
- *Monomorium* sp. AFRC-WCA-01 (an undescribed species related to *M. damarense*) found in the Dwarf Dune Thicket (area D, Figure 1).

These species are illustrated in Figures 2 and 3. There is also some uncertainly about the identity of the *Ocymyrmex* specimens collected in the Dwarf Dune Thicket. These are still being investigated.

Figure 2: New species of *Tetramorium* found in Dune Thicket on Transverse Dunes at Duynefontein

Figure 3: Undescribed species of *Monomorium* found in Dwarf Dune Thicket at Duynefontein

2.1.3 Butterfly diversity

- **Predicted diversity:** Potential butterfly species and their probability of occurrence at the Duynefontein site are listed in Appendix 1. The summed probable total species count for this site is low at 23.1 with a very low Red List species probability of 0.01, but it must be borne in mind that these figures can be compared directly only to the other sites surveyed during this study (see Section 1.2.1).

- **Habitat assessment:** There are three main vegetation types of relevance to butterflies at the site – Atlantis Sand Fynbos (ASF) in the south-eastern corner of the site and Cape Flats Dune Strandveld (CFDS) over most of the rest of the site with a transitional zone between. No detailed botanical survey was available at the time of writing this report. Important butterfly food plants seen were *Chrysanthemoides incana, Rhus* spp. and *Zygophyllum* spp. The southern portions of this site are in good condition, with hardly any alien vegetation, while in the north extensive invasion by invasive species such as *Acacia cyclops* is evident.

- **Observed diversity - survey 1:** Because it was so early in the butterfly season (which according to Woodhall 2005 is mainly spring-early summer with a second peak in late summer-autumn in the winter rainfall region of South Africa), when fewer than 5% of the predicted butterfly species would be expected to be active, hardly any butterflies were seen during the initial survey. On the crest of the dunes trending north-south in the middle of the site *Chrysoritis osbecki* males were observed hill-topping. A partial search of the ASF area in the eastern part of the site did not reveal any of the Red-listed *Chrysoritis dicksoni*, which used to occur in similar habitat at Melkbosstrand (Woodhall 2005) 5 km to the south. It has not been seen here since the late 1950's / early 1960's, nor in the Mamre area some 15-20 km to the north-east, where it was last recorded in the early 1980's (Henning & Henning 1989).

- **Observed diversity - survey 2** (Refer to species accumulation curves in Appendix 4 and summary in Table 2.1): No butterflies could be found during three transect searches in the unvegetated dunes. The Dune Thicket on Transverse Dunes (DTT) had an extremely low number of individuals and species .

  The Dwarf Dune Thicket (DDT) and the Low to Dwarf Thicket (LDT) had the same and highest number of species (7). The species observed curves are similar for the two vegetation types although the extrapolated curves suggest DDT has a higher species number than the LDT. The MM curves differ for the two vegetation types. The DDT curve appears to have flattened out, at 12 species, and is higher than the LDT curve, however the LDT curve, at 8 species, is still on the increase (although suggesting a lower species richness).

  The Dwarf Dune Thicket, unlike the other vegetation types, was dominated by *Chrysoritis pyroeis pyroeis* (41%) (this species was only observed in DDT and the neighbouring Tall to Dwarf Dune Thicket on high parabolic dunes TDT2). Most vegetation types were dominated By *Chrysoritis thysbe thysbe f. osbecki* (except for TDT and DDT). The dominant species in LDT was *Chrysoritis thysbe thysbe f. osbecki* (51%) followed by *C. f.felthami* (36%). Although a large area of DTT2 is infested with exotic Acacia the northern part of it, which had been cleared, had the same number of species (6) as TDT2 and the transitional area between the transverse and parabolic dunes (TR). The extrapolated observed species curve suggests DTT2 has similar species richness to DDT and a higher diversity than the other vegetation types. (The observed species curve and the MM species richness curve for DTT2 are not flattening as is the case for the other two vegetation types.) The MM estimator also suggests higher species richness for DTT2 than TDT2 and TR. The dominant species in DTT2 was *C. thysbe thysbe f. osbecki* (53%). The Tall to Dwarf Dune Thicket on high parabolic dunes (TDT2) had a similar observed species and MM curve to the Transitional area (at about 8 species), the MM curves suggesting adequate sampling for these two areas.

  All six species found in the TDT2 have a distribution restricted to the Cape. The Transitional area had the highest species abundance with *C. thysbe thysbe f. osbecki* (56%) as the dominant species followed by *C. f. felthami* (26%). *Aloeides thyra thyra* (10%) were also in relatively high numbers in the TR. The vegetation of the Tall to Dwarf Dune Thicket (TDT1) was very similar to the Low to Dwarf Thicket (LDT) and the samples from these two types were grouped, the dominant species were *C. thysbe thysbe f. osbecki* (50%) and *C. f. felthami* (39%). The MM curve suggests these two areas (combined) may have similar species richness to TDT2 and TR.

Table 2.1: Results of March 2009 butterfly survey at Duynefontein

Vegetation type	Dwarf Dune Thicket	Tall Dune Thicket 2	Transition	Dune Thicket-Transverse Dunes	Dune Thicket-Transverse Dunes 2	Tall Dune Thicket 1 + Low-Dwarf Dune Thicket	Unvegetated Dunes	All combined
Samples*	11(13)	11	11	11	11	15	(3)***	73
No. of individuals	29	41	72	4	17	54	0	271
No. of species	7	6	6	2	6	7	0	12
Estimated richness	11.89	8.70	7.97	5.60	10.49	7.66	0	14.39
Local endemics	0	0	0	0	0	0	0	0
Regional endemics	4	6	4	2	4	3	0	6
SA endemics	1	0	1	0	1	1	0	2
Widespread species	2	0	1	0	1	3	0	4
Endemicity Score	11	12	10	4	10	10	0	18
Summed sensitivity score**	22.89	20.7	17.97	9.6	20.49	17.66	0	32.39
Within-site sensitivity rank	1	2	4	6	3	5	7	n/a

* adjusted where necessary to give 30-minute samples; unadjusted sample numbers given in brackets.
** Sum of estimated species richness and endemicity score.
*** No butterflies seen, so data from this habitat was excluded from analysis.

A brief search in the Dune Thicket - Sand Plain Fynbos (which was not formally surveyed) indicated that similar species to LDT, TR and DDT2 would be present. The species observed were *C. thysbe thysbe f. Osbecki*, *T. thespis*, *A. thyra* and the widespread *Vanessa cardui*.

2.1.4 Other invertebrates

1. **Velvet worms** (Onchyophora): none found.
2. **Mygalomorph spiders:** One specimen of *Harpactira atra* (Theraphosidae), a protected baboon spider species common in the south-western Cape (Dippenaar-Schoeman 2002), was observed during the survey; another was also seen by the terrestrial vertebrate fauna investigation team.
3. **Scorpions** (Arachnida: Scorpiones): no scorpions were encountered during the survey, but conditions were poor and no night searches were carried out as the probability of scorpion activity was very low.
4. **Soldier flies** (Mydaidae): none found.
5. **Heelwalkers** (Mantophasmatodea): none found.
6. **Monkey beetles** (Hopliini): several specimens of 1 species found; most were inactive and hiding under rocks.
7. **Millipedes** (Myriapoda): - 3 species were found.
8. **Jewel beetles** (Buprestidae): none found.
9. **Spoonwing lacewings** (Nemopteridae): none found.
10. **Horseflies** (Tabanidae): none found. The only long-tongued flies observed were *Australoechus hirtus* (Bombyliidae).

In addition to the above observations, specimens of one terrestrial gastropod species were also noted on the dunes.

2.1.5 Additional Duynefontein site survey – January 2010

The vegetation within the consensus preferred footprint area (the southernmost portion of the EIA corridor as indicated in Figure 4) was all classified by the Botany specialist (Low 2009) as Dune Thicket on Transverse Dunes (DTT), but within this type we noted several differing formations of significance from an invertebrate perspective:

- Bare-partially vegetated areas with low vegetation (mostly less than 0.5 m) and a significant percentage of open sandy soil.
- Moderately to completely vegetated areas with low to medium height (0.5-2 m) vegetation.
- Densely vegetated areas of medium height thicket (1-3 m), mainly in the dune slacks.

Different plant species were predominant in each of these habitat types, adding another dimension of diversity to the already complex array of insolation and temperature microhabitats maintained by the different degrees of vegetation cover. Such a mosaic of differing habitats would be expected to harbour a greater diversity of invertebrate species than would an extensive area of a single habitat type. Some exotic vegetation was present (grasses that had been planted to stabilise the dunes as well as *Acacia cyclops* which had mainly been cleared), but indigenous species appeared to predominate.

At least four additional ant species (not found during the 2008 survey) and several monkey beetle species were collected during the January 2010 visit. A West Coast endemic scorpion species, *Uroplectes variegates*, was also found to be abundant in the proposed footprint area (it is likely to be found over the entire site). A find of potentially more significance was a trapdoor spider (see Figure 5), probably of the Nemesiid genus *Pionothele* (Ian Engebrecht, pers. comm.). *Pionothele* is a monotypic genus previously recorded from only two localities, so whether the Duynefontein is the same as the previously described species, or a new species (this has not yet been determined), this is a rare discovery and further research is warranted. However, attempts to locate another invertebrate species of significance identified in earlier surveys within the footprint area (an undescribed *Tetramorium* ant species) were not successful during this survey. It is possible that the drought conditions being experienced in the region at the time had reduced activity of these species, or (less likely) that this was a naturally low activity season.

We were also unsuccessful in attempts to locate other areas on the Duynefontein site that matched the proposed footprint in terms of dune and vegetation structure and composition. Other areas to the far north on the site also classified by Low (2009) as DTT were clearly much more established (and included slow-growing plant species such as some succulent *Euphorbia* species that were suggestive of a long period of dune stability), included a different mix of plant species and a much lower overall percentage of bare soil. Areas of DTT lying between the proposed footprint area and the DTT area in the north of the site are heavily infested with *Acacia cyclops*. An area nearby that appears likely to be similar to the proposed footprint is the Atlantis dune field to the north of Duynefontein. However, according to Gert Greet (Manager, Environmental & Land Management, Eskom Nuclear Sites), this area is heavily disturbed by recreational use.

The area within which the proposed NPS footprint lies thus appears to be quite significant in terms of the invertebrate diversity it is expected to maintain, and this is supported by the fact that the only known specimen of an undescribed ant species(*Tetramorium* sp.) was previously collected in this area.

However, during discussions with Gert Greef, it was indicated that prior to construction of the Koeberg Power Station (KPS), this area was an entirely unvegetated dune field. Stabilisation of the dunes by planting of grass and invasion by *Acacia cyclops*, in combination with the KPS preventing natural inflow of sand from the south, have resulted in the establishment of the plant communities now present. This in turn will have resulted in establishment of a very different invertebrate community from that which was present prior to construction of the KPS. Significant species such as the undescribed *Tetramorium* probably established themselves here subsequent to the development of at least partial vegetation cover; they would presumably have moved in from surrounding vegetated areas.

Thus, while the particular pattern of dune structure and vegetation within the proposed footprint area may be unique on the Duynefontein site and also not well-conserved in neighbouring areas, it is 1) not the natural state of the area and 2) most indigenous species present have presumably colonised from other natural areas nearby and should thus be represented in such areas.

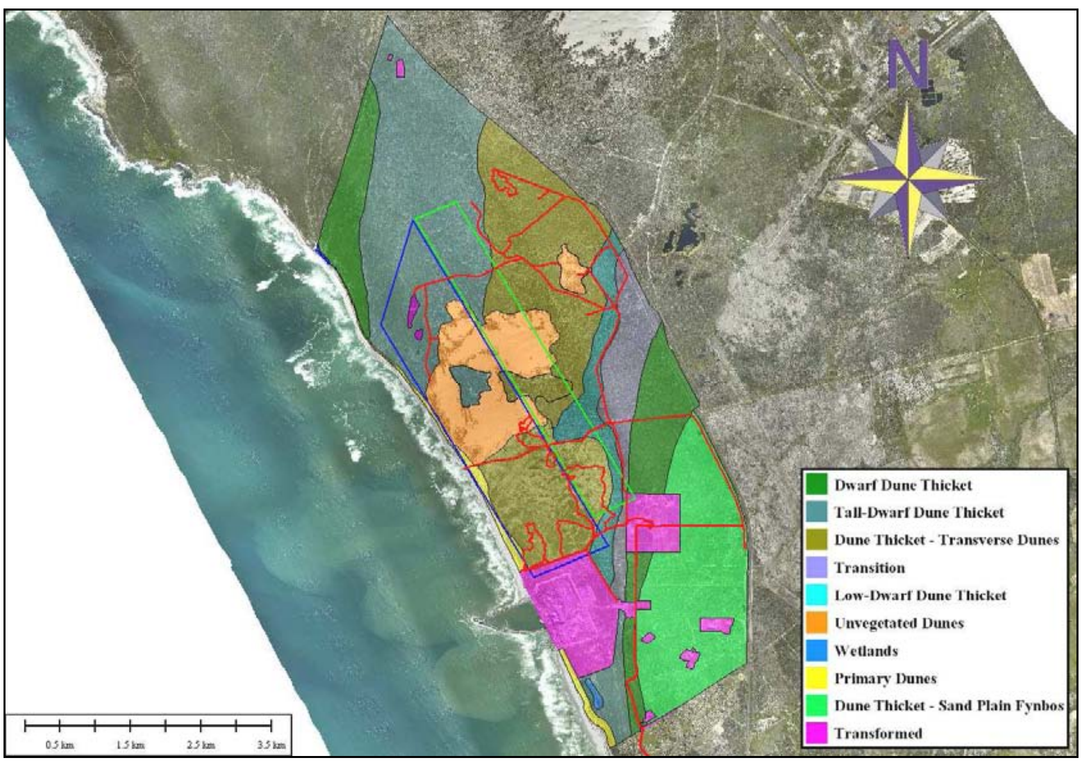

Figure 4: Additional invertebrate survey of Duynefontein site, January 2010. EIA corridor for NPS (blue outline) and HV yard (green outline) and routes followed (red lines) are indicated.

Figure 5: Probable *Pionothele* sp. trapdoor spider (left) and its burrow (right) found in Dune Thicket on Transverse Dunes in the north-eastern region of Duynefontein.

Figure 6: Koeberg viewed from the north at night. Extensive use of outward-directed lighting is apparent.

Observations of Koeberg Power station at night revealed that while the external lighting used is mainly of wavelengths that should be relatively unattractive to insects, the intensity is very high and much of the lighting is directed outwards into the surrounding natural environment. It is to be expected that despite the yellow lighting used (see Figure 6), there is a significant ongoing negative impact on invertebrate populations at this site.

2.2 Site 2: Bantamsklip

2.2.1 Habitats

The predominant vegetation types on the Bantamsklip site are defined by Mucina & Rutherford (2006) as Overberg Dune Strandveld (ODS), which covers almost the entire south-western portion of the site on which the NPS construction is proposed, while Agulhas Limestone Fynbos (ALF) and Overberg Sandstone Fynbos (OSF) predominate on the north-eastern portion. The latter portion, which also has significant wetland areas and some Agulhas Sand Fynbos, was not investigated during this study due both to time constraints and the fact that no part of the NPS development itself is proposed in this area. However, if the NPS is approved at Bantamsklip the main transmission line may pass over it. The transmission lines outside the WIA corridor are subject to a separate EIA process.

Within the south-eastern portion of the site a narrow strip of ALF is present, and the layout plans provided indicated that the proposed NPS might just touch on this area, but that the NPS development would otherwise be contained entirely in the ODS area. Once again, a number of subtypes were evident in the ODS vegetation on the site, but these were present as a mosaic over the whole site rather than in distinct areas as was seen at Duynefontein. Distinct vegetation types & subtypes noted were:

A. Agulhas Limestone Fynbos
B. Mixed ODS / ALF vegetation with the latter on scattered limestone outcrops
C. "Pure" ODS with bushes up to 2 m in height
D. Very low (c. 30 cm) ODS vegetation with many *Erica* species predominating toward the western end of the development area
E. Partially to completely vegetated dunes (with some alien invasion) toward the coastline.

The vegetation mapping shown in Figure 7, which is based on information (Low 2009) made available to AfriBugs subsequent to the initial survey, delimits these and other distinct habitats in more detail. However, stratification of sampling during the initial survey and the initial description of the butterfly communities of the site were based on the preliminary assessment outlined above.

Alien eradication at Bantamsklip appears to have been extremely effective in many parts, though there are still areas with substantial infestations of exotic *Acacia* species. In comparison to other areas along the road from Pearly Beach to the Bantamsklip site and beyond, the latter is by far the closest to its natural state and the positive impact of Eskom's management is very apparent. However, substantial evidence of poaching of perlemoen and harvesting of pincushion proteas was observed in the vicinity of area "A" indicated in Figure 7.

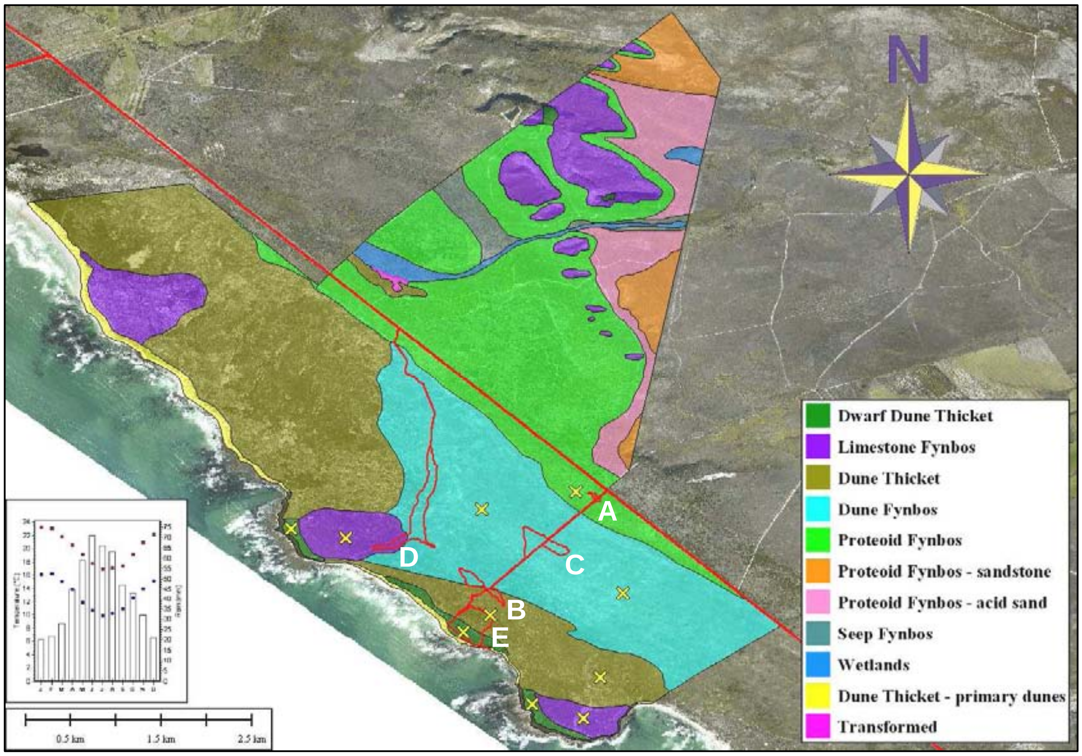

Figure 7: Bantamsklip invertebrate surveys. Vegetation types (after Low 2009) and routes followed during the non-butterfly components of the invertebrate survey (red) are indicated; butterfly transects followed different routes (yellow crosses indicate butterfly survey targets for March 2009 survey). Climate summary shows monthly minimum/maximum temperatures and rainfall. (Note: semitransparent vegetation overlays mean colours are less intense than in the key)

2.2.2 Ant diversity

The twenty ant samples collected at Bantamsklip were equally distributed between the areas indicated as A-E in Figure 7. Eighteen species were collected in total (see Appendix 6) with an estimated diversity of approximately 21 species (Michaelis-Menten estimate); see Appendix 5. No Argentine Ant (*Linepithema humile*) specimens were found and it is considered unlikely that this species is currently present on the site.

Leptogenys sp. AFRC-WCA-01 was identified from the samples collected in areas D (Limestone Fynbos) and E (Dune Thicket / Dwarf Dune Thicket) and is illustrated in Figure 8. Initially this was thought to be an undescribed species, but it now appears likely that these specimens simply represent an atypical form of *L. peringueyi;* further taxonomic investigation is required. Specimens from other localities matching those found at Bantamsklip were located in the South African Museum ant collection in Cape Town in November 2009, so even if this is eventually confirmed to be a species distinct from *L. peringueyi*, it is clearly not threatened by development at Bantamsklip. *Leptogenys* species are generally specialist predators, often preying on isopods or amphipods and are thus associated with moist/humid environments.

Figure 8: Atypical form of *Leptogenys peringueyi* found in Limestone Fynbos and Dune Thicket / Dwarf Dune Thicket at Bantamsklip

2.2.3 Butterfly diversity

- **Predicted diversity:** Potential butterfly species and their probability of occurrence at the Bantamsklip site are listed in Appendix 1; the summed probable total species count for this site is moderate at 28.2 with a significant Red List species probability of 0.15, but it must be borne in mind that these figures can be compared directly only to the other sites surveyed during this study (see Section 1.2.1).

- **Habitat assessment:** There are three main vegetation types on this site:
    - Overberg Dune Strandveld (ODS) broadly occurring in a strip about 2 km wide adjacent to the coast;
    - Agulhas Limestone Fynbos (ALF) further inland and on outcrops within the ODS; and
    - Overberg Sandstone Fynbos (OSF) in the north-eastern corner of the site. The western part of the ODS and the ALF site is quite heavily infested with alien vegetation.

  The central and eastern parts are in much better condition, and a praiseworthy effort has been made by Eskom to eliminate and control alien vegetation. Within this area there are many patches where there is no sand cover over the limestone and ALF vegetation occurs. Important butterfly food plants seen were *Chrysanthemoides monilifera, Iscyrolepis* spp., *Ehrharta* spp. and *Rhus* spp.

- **Observed diversity:** The weather during the initial site visit was not ideal and only one butterfly was seen (*Vanessa cardui*). However, much of the site, particularly the ALF, appears to have potential for many butterfly species including some regional endemics such as *Aloeides carolynnae aurata*, *Thestor rossouwi*, *Thestor overbergensis* and *Argyrocupha malagrida maryae.* The Red List species *Chrysoritis dicksoni* is known from strandveld similar to the ODS at Witsand 125 km to the east.

- **Observed diversity - survey 2** (Refer to species accumulation curves in Appendix 4): The Dune Fynbos and Proteoid Fynbos had the highest number of species (Table 2.2). The species richness indicator MM was highest for the Proteoid Fynbos although the Dune Fynbos has a curve with a steeper incline and hence with increased sampling may have produced a similar MM species richness to the Proteoid Fynbos. The Proteoid Fynbos had the highest number of range restricted species (seven). The species with the highest abundance in the Proteoid Fynbos was *Tarucus thespis* (31%) (this species was dominant in all the vegetation types) followed by *Chrysoritis thysbe thysbe* (29%). Although *T. thespis* (47%) was common in the Dune Fynbos the other two species with high abundance were *Torynesis mintha mintha* (24%) and Aloeides almeida (16%) (both range restricted species). The Dune Thicket (which also contained limestone fynbos and the thicket parts were mostly exotic Acacia) had the next highest species richness and the MM curve (although flattening out compared to the Limestone Fynbos) and the extrapolated observed species curve also suggests it had the next highest species richness. In the Dune thicket the species with the highest abundance, after *T. thespis* (48%), were *Chrysoritis felthami felthami* (26%) and then *Aloeides almeida* (13%) (Both the latter are range restricted species).The Dune Thicket had the highest abundance per average sampling unit being slightly greater than the Limestone Fynbos and Proteoid Fynbos. The Limestone Fynbos had a relatively low species richnesss although its MM and species observed curves do suggest inadequate sampling. The species with the next highest abundance in the Limestone Fynbos, after *T. thespis* (65%), was *A. almeida* (16%). The Limestone Fynbos and Dune Thicket both had five range restricted species. The vegetation type with the lowest number of species, indicated by both the actual number and the curves for the species observed and MM species richness indicator, was the Dwarf Dune Thicket which was dominated by *T. thespis* (72%). However, several *C. thysbe thysbe* (17%) were also found in this vegetation type. The Dwarf Dune thicket also had the lowest abundance per average sampling unit. Apart from *T. thespis* the vegetation types Proteiod fynbos, Dune Fynbos, Dune thicket and Limestone Fynbos were dominated by different species.

Table 2.2: Results of March 2009 butterfly survey at Bantamsklip

Vegetation type	Dwarf Dune Thicket	Dune Thicket	Dune Fynbos	Proteoid Fynbos	Limestone Fynbos	All combined
Samples	10	13	16	12	12	63
No. of individuals	36	61	62	55	55	269
No. of species	4	7	9	9	6	14
Estimated richness	4.6	9.35	10.6	11.58	6.89	14.93
Local endemics	0	0	0	0	0	0
Regional endemics	3	5	4	7	5	8
SA endemics	0	0	1	0	0	1
Widespread species	1	2	4	2	1	5
Endemicity Score	7	12	13	16	11	22
Summed sensitivity score*	11.6	21.35	23.6	27.58	17.89	36.93
Within-site sensitivity rank	5	3	2	1	4	n/a

* Sum of estimated species richness and endemicity score.

2.2.4 Other invertebrates

1. **Velvet worms** (Onchyophora): none found.
2. **Mygalomorph spiders:** one baboon spider species (a small *Harpactira* species was found. This genus is currently undergoing revision and so a definitive identification is not possible at this time. A more significant find was numerous specimens of a possibly undescribed trapdoor species of the genus *Spiroctenus* (Nemesiidae) (Figure 9). This species appeared fairly widely but very patchily distributed on the site (being extremely abundant in patches but absent from most areas), but was not seen in the Proteoid Fynbos along the north-eastern boundary, appearing to favour the more sandy soils closer to the coast. It was first incorrectly identified as an undescribed species of *Ancylotrypa* (Cyrtauchenidae) by Dr Ansie Dippenaar-Schoeman (pers. comm,) but has now been confirmed to belong to the genus *Spiroctenus* by Ian Engelbrecht (pers comm.).

   No *Spiroctenus* have previously been recorded from the Bantamsklip/Agulhas area according to Dippenaar-Schoeman (2002), and most species of this southern African endemic genus have very limited distributions and are known only from single localities. It is thus likely that the Bantamsklip specimens represent an undescribed species, but adult male specimens are needed to confirm this, and none were found during these brief surveys. An attempt is being made to rear adult males from immature specimens collected in January 2010, but if this is not successful, further surveys will be required. Adult male trapdoor spiders are often only present for a short season each year, and this varies from species to species, so several searches spread out through the year may be required. Although abundant on the Bantamsklip site, the possibility that this species has a limited distribution along the southern Cape coast must be considered and further surveys to determine its range are recommended.

The ease with which a fairly large apparently undescribed species was found in such a brief survey is an indication of how much remains to be learned about the invertebrate diversity at these sites. Mygalomorph spiders are a primitive group and this find may thus support Picker's (2007) suggestion that the Bantamsklip site was the most likely of the five he assessed to contain relictual species. While it is likely that this species has a distribution significantly larger than the proposed NPS site along the southern Cape coast, the precautionary principle[1] of the National Environmental Management Act (NEMA) requires that, until it is proven that there are sufficient other safe populations to ensure its survival, the known locality at the Bantamsklip site should be considered highly sensitive.

Figure 9: Left: *Spiroctenus* sp. from the Bantamsklip site; two burrow entrances are visible in the habitat photograph on the right, the inset shows a close-up of one burrow to illustrate the turret structure.

3. **Scorpions** (Arachnida: Scorpiones): two scorpion species (*Opistophthalmus macer* and *Uroplectes lineatus)* were found on the Bantamsklip site; both species are fairly common and widespread in the Western Cape.
4. **Soldier flies** (Mydaidae): none found.
5. **Heelwalkers** (Mantophasmatodea): none found.
6. **Monkey beetles** (Hopliini): none found.
7. **Millipedes** (Myriapoda): **-** 5 species were found.
8. **Jewel beetles** (Buprestidae): none found.
9. **Spoonwing lacewings** (Nemopteridae): none found.
10. **Horseflies** (Tabanidae): none found.

In addition to the above observations, specimens of six terrestrial gastropod species were noted on the site.

[1] Section 2 (4) (a) (vii) of the National Environmental Management Act 107 of 1998 (NEMA) requires that a risk-averse and cautious approach, which takes into account the limits of current knowledge about the consequences of decisions and actions, should be applied. This principle indicates that on the basis of current information, the Bantamsklip site must be considered as though it was the only locality at which populations of the potentially new trapdoor spider exist.

2.2.5 Additional Bantamsklip site survey – January 2010

The vegetation within the consensus preferred footprint area at Bantamsklip was classified by the Botany specialist (Low 2009) as:

- Dune Fynbos on deep sands,
- Dune Thicket on transverse dunes and
- Limestone Fynbos,

with the majority of the areas being comprised of the first two of these types. Within the Dune Thicket there is a mix of natural and heavily *Acacia cyclops*-infested areas, the latter being more evident closer to the coast.

Shortly before the site visit in January 2010, most of the Bantamsklip site was burnt by an extensive fire that covered approximately 40 000 ha. While this made evaluation of habitats based on vegetation type difficult, a positive effect was that is was very easy to search for the burrows of the potentially undescribed *Spiroctenus* species previously found on the site. It quickly became apparent that while occasional individuals of this species may be found quite widely distributed on the site, the distribution is extremely patchy, with very high densities in certain areas, and no burrows or very low densities elsewhere. The highest density observed (up to an estimated 25 burrows per m^2) was in an area of Limestone Fynbos on the western side of the EIA corridor. Apparently similar areas of Limestone Fynbos on the eastern side of the site (including a number of areas within the area classified as Dune Thicket to the north of the easternmost area indicated as Limestone Fynbos in Figure 10) had few or no *Spiroctenus* burrows. Of the two main concentrations of Limestone Fynbos patches on the site (there is a third large patch further west in State Forest land, but this could not be reached in the time available), high concentrations of *Spiroctenus* were found only in the western area and this area must therefore be considered a very important habitat area for this species. Areas of high and medium density of *Spiroctenus* are indicated in Figure 10; in all other areas covered during the survey, no or only very small numbers of *Spiroctenus* burrows were found.

The extreme patchiness, apparently not predictable from vegetation and soil type, of the distribution of the *Spiroctenus* species at Bantamsklip serves as confirmation of the view that assessments of invertebrate communities based on habitat/vegetation inspections must be treated with caution and should be backed up by detailed surveys.

Additional colonies of the atypical form of *Leptogenys peringueyi* were located in Limestone Fynbos areas on the east of the site, and it appears that this species is fairly widely distributed at least in the coastal portion of the site.

At least two additional ant species (not found at Bantamsklip during the 2008 survey) were collected during the January 2010 visit; these included *Dorylus helvolous* and *Tetramorium* cf *erectum*/*emeryi*. The latter was previously recorded from Thyspunt in 2008 and while it may prove to be an undescribed species distinct from *T. erectum* and *T. emeryi*, it is clearly widely distributed along the southern cape coast and would not be threatened by development of either site.

A male and a female specimen of an atypical form of the Almeida Copper Butterfly (*Aloeides almeida*) were collected at Bantamsklip during the January 2010 visit. While it has been confirmed that these specimens (as well as those observed earlier in the year by Alan Gardiner) display unusual patterning, it is not yet clear whether they are geographically isolated from other populations and differ sufficiently from the typical form for the Bantamsklip population to be considered a separate (and hence new) subspecies; further studies will be required to determine their status.

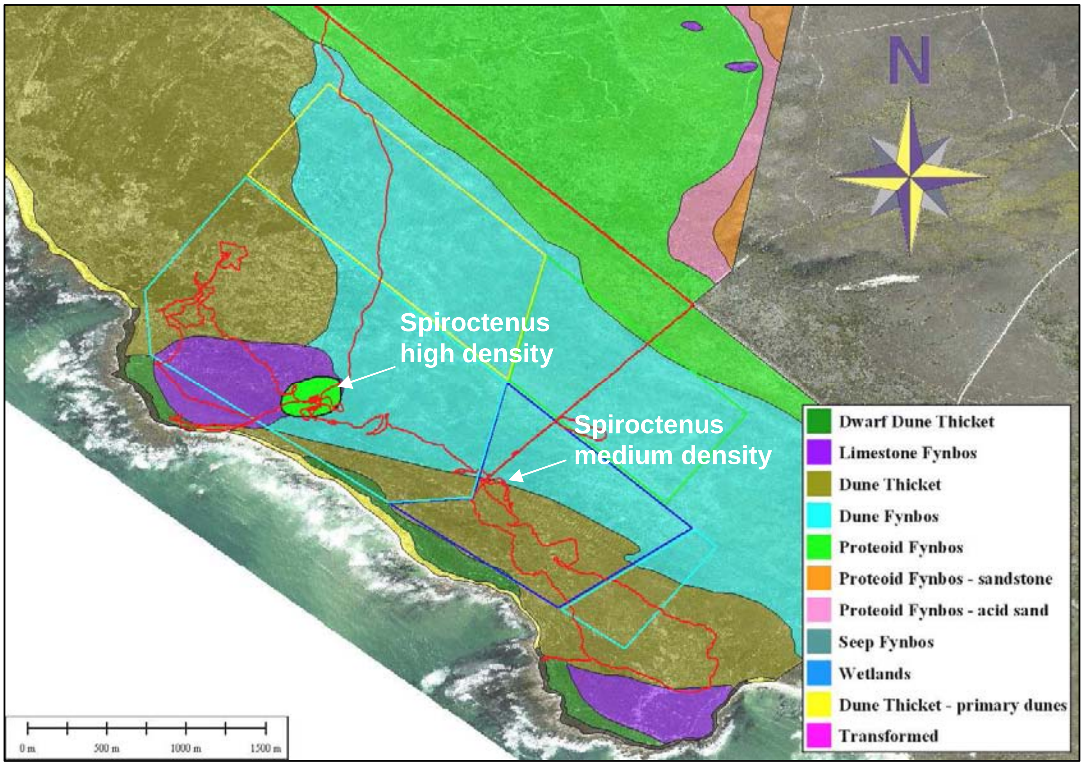

Figure 10: Additional invertebrate survey of the Bantamsklip site. EIA corridor for NPS (dark blue outline, with turquoise outline subject to purchase) and HV yard (green outline, with yellow outline subject to purchase) and routes followed (red lines) are indicated.

2.3 Site 3: Thyspunt

2.3.1 Habitats

The predominant vegetation types on the Thyspunt site are defined by Mucina & Rutherford (2006) as Algoa Dune Strandveld (ADS) and Southern Cape Dune Fynbos (SCDF). The SCDF is essentially a strip bounded on the north and south by bands of ADS. Further to the north the remainder of the site is dominated by Tsitsikama Sandstone Fynbos (TSF), but this has mostly been transformed for agricultural use, except where rocky outcrops have prevented ploughing. Both the ADS and SCDF areas have been substantially infested by alien *Acacia* species, but significant efforts have been made to eradicate these.

The area of Algoa Dune Strandveld within which construction of the NPS is proposed appears to comprise a linear patchwork of vegetation subtypes, with low shrubby vegetation along the ridges of the stabilised dunes running approximately parallel to the coastline, and significantly taller plant forms including small trees in the valleys between the dunes, where a dense and almost impenetrable thicket has formed in parts. This vegetation pattern appeared fairly constant throughout the currently proposed development area, but further to the west on the site there is considerable invasion by exotic *Acacias* which have formed dense thickets in places.

Habitats surveyed for ants and other non-butterfly invertebrate species were as follows:

A. Algoa Dune Strandveld – thicket in dune valleys;
B. Algoa Dune Strandveld – fynbos on dune ridges
C. Unvegetated dunes within ADS;
D. Limestone outcrop in SCDS; and
E. Dense thicket in ADS.

The vegetation mapping shown in Figure 11, which is based on information (Low 2009) made available to AfriBugs subsequent to the initial survey, delimits these and other distinct habitats in more detail. However, stratification of sampling during the initial survey and the initial description of the butterfly communities of the site were based on the preliminary assessment outlined above.

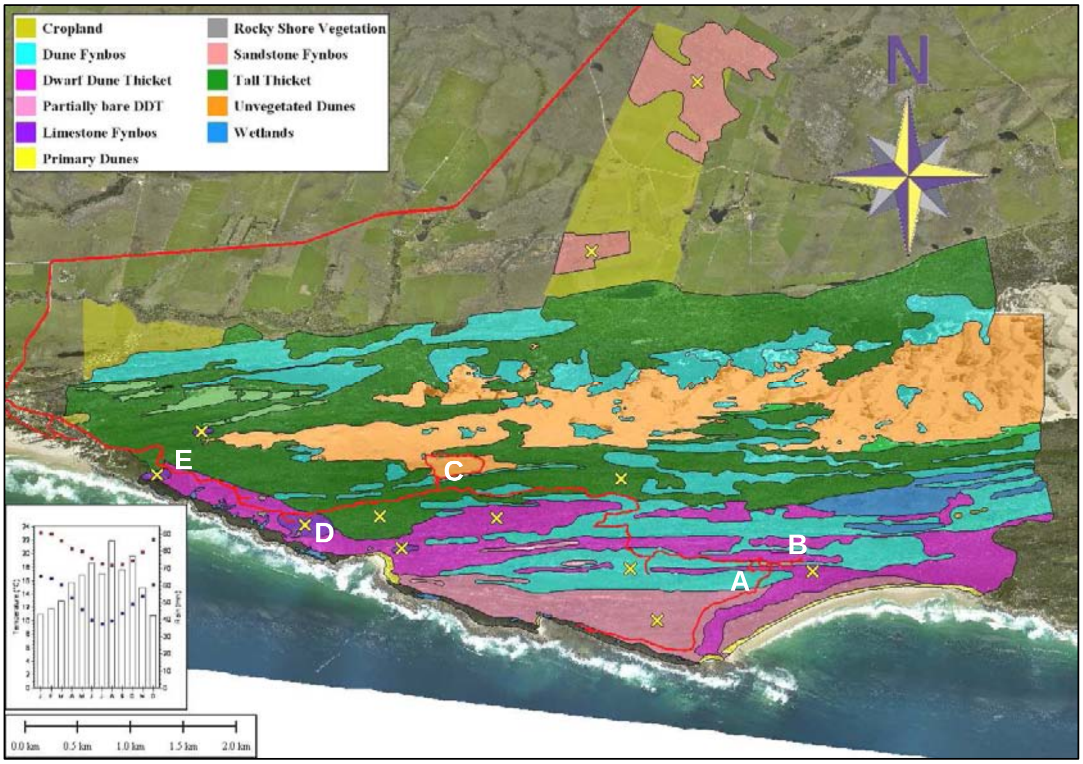

Figure 11: Thyspunt site invertebrate surveys. Routes followed during the non-butterfly components of the invertebrate survey are shown in red; butterfly transects followed different routes (yellow crosses indicate butterfly survey targets for March 2009 survey). Vegetation types follow Low (2009) Climate summary shows monthly minimum/maximum temperatures and rainfall. (Note: semitransparent vegetation overlays mean colours are less intense than in the key)

2.3.2 Ant diversity

The twenty ant samples from Thyspunt were collected within the areas indicated A-E in Figure 11. Twenty-one species were collected in total (see Appendix 6) with an estimated diversity of approximately 26 species (Michaelis-Menten estimate) - see Appendix 5. No Argentine Ant (*Linepithema humile*) specimens were found and it is considered unlikely that this species is present on the site.

Two undescribed ant species and one extremely rarely encountered ant species were identified from the samples collected at Thyspunt in 2008. These were

- *Tetramorium* sp. AFRC-ECA-01 (an undescribed species related to *T. emeryi* and *T. erectum*), found on the Unvegetated Dunes
- *Monomorium* sp. AFRC-ECA-01 (an undescribed species related to *M. disertum*); and
- *Diplomorium longipenne*. This is a monotypic genus which appears to be endemic to the Western / Eastern Cape border region of South Africa. It has to date only been recorded from George, Willowmore and Port Elizabeth.

These species are illustrated in Figures 12-14. Nothing is known about the biology of *Diplomorium* and its occurrence in three of the eight samples collected in the thicket/fynbos mosaic suggests local abundance high enough to provide a good opportunity to study this species further.

Figure 12: Potentially undescribed species of *Tetramorium* found on Unvegetated Dunes at Thyspunt

Figure 13: New species of *Monomorium* found in Dune Fynbos at Thyspunt

Figure 14: *Diplomorium longipenne*, an apparently rare and restricted ant species found in Tall Thicket and Dune Fynbos at Thyspunt

2.3.3 Butterfly diversity

- **Predicted diversity:** Potential butterfly species and their probability of occurrence at the Thyspunt site are listed in Appendix 1. The summed probable total species count for this site is high at 42.6 but the Red List species probability of 0.01 is very low; however it must be borne in mind that these figures can be compared directly only to the other sites surveyed during this study (see Section 1.2.1).

- **Habitat assessment:** This site has three main vegetation types – Algoa Dune Sandveld (ADS) adjacent to the coast; Southern Cape Dune Fynbos (SCDF) further inland; and Algoa Sandstone Fynbos (ASF) in the strip of land extending northwards (11). Most of the investigation concentrated on the ADS area. Efforts have clearly been made to remove alien vegetation, but much remains to be done. The eastern part of the site is in relatively better condition. A number of important butterfly larval food plants were recorded, including *Imperata cylindricla, Indigofera erecta, Rhus* spp., *Iscyrolepis* spp., *Osyris compressa, Ehrharta calycina, Grewia occidentalis* and *Chrysanthemoides monilifera.*

- **Observed diversity - survey 1:** The weather on the first day was unfavourable for butterflies, with a cool westerly wind blowing. The second day was much better, with partly cloudy sky clearing later on and no wind. This resulted in a larger number of butterflies being observed than at the other sites (seven species). One of these (*Antanartia hippomene hippomene*) is considered to be rare and localised, and infrequently encountered on the coast – it is more often found in Afromontane forests further inland. It was apparent that this was very early in the butterfly season and that the site could have lots of potential later in the year. Regional endemics that could occur here are *Aloeides pallida* ssp. nova (recorded from Oyster Bay) and *Chrysoritis whitei* (known from Humewood, P.E.). There is also a remote possibility that the site could harbour the Red-listed *Aslauga australis*, which is known only from coastal bush in the Eastern Cape.

- **Observed diversity - survey 2** (Refer to species accumulation curves in Appendix 4): The thicket vegetation had the highest species richness according to the actual number observed (Table 2.3), the extrapolated curve of the number of species observed and the MM species estimation. The extrapolated curves for the number of species observed were very similar for the two thicket types. Although the thicket vegetation had the most species these were mostly common widespread species (Appendix 3). The most dominant species in the Tall Dune Thicket was *Leptotes pirithous* (34% of total) followed by *Belenois gidica abyssinica* (17%), both widespread and common species. In the Dwarf Dune Thicket Chrysoritis chrysaor (30%) (restricted to South Africa) was the most dominant followed by *Leptotes pirithous* (20%). The extrapolated curve for the number of species observed in the Limestone Fynbos was between those of the two thicket types and the other fynbos types. The most dominant species in the Limestone Fynbos was the widespread and common *Papilio d. demodocus* (44%). The Dune Fynbos had the lowest number of species and the curve for the observed species richness was low although the MM estimate and the extrapolated observed species curve suggests the species richness may be slightly higher than the Sandstone Fynbos. *Leptotes pirithous* (64%) was the dominant species in the Dune Fynbos. The Sandstone Fynbos observed species curve indicates adequate sampling in this vegetation type. The Sandstone Fynbos had the highest individual abundance levels mainly due to the presence of the more range restricted *Pseudonympha magus* (35%) (recorded only in this vegetation type) but also due to some widespread and common species *Papilio d. demodocus* (19%) and *Belenois gidica abysssinica* (18%). *Pontia helice helice* (12%) another widespread species was also quite common in the sandstone fynbos. The Sandstone Fynbos had the highest number of range restricted species. However, due to its substantially lower overall species richness, it received a lower summed sensitivity score than either of the Dune Thicket sub-types on this site.

Table 2.3: Results of March 2009 butterfly survey at Thyspunt

Vegetation type	Tall Dune Thicket	Dwarf Dune Thicket	Dune Fynbos	Sandstone Fynbos	Limestone Fynbos	All combined
2.3.4 Samples*	11 (13)	10 (12)	11 (12)	11 (12)	6 (9)	49 (58)
No. of individuals	29	20	11	57	18	135
No. of species	10	9	5	8	7	22
Estimated richness	16.44	17.88	9.62	9.88	11.27	26.55
Local endemics	0	0	0	0	0	0
Regional endemics	1	1	0	3	1	3
SA endemics	2	2	0	0	0	3
Widespread species	7	6	5	5	5	16
Endemicity Score	11	10	5	11	7	25
Summed sensitivity score**	27.44	27.88	14.62	20.88	18.27	51.55
Within-site sensitivity rank	2	1	5	3	4	n/a

* adjusted where necessary to give 30-minute samples; unadjusted sample numbers given in brackets.
** Sum of estimated species richness and endemicity score.

Thyspunt has the highest overall butterfly diversity of the three sites, and also potentially the largest number of rare and/or endemic species. Without appropriate mitigation development of this site would have the highest probable impact on this important group. With appropriate mitigation including siting the infrastructure in the central to western portion of the site, continuing alien eradication operations and protection of the undisturbed portions of the site as a reserve, the potential negative impacts could be offset to the extent that a net positive impact is achieved.

2.3.5 Other invertebrates

1. **Velvet worms** (Onchyophora): one specimen of velvet worm (see Figure 15) was found by the terrestrial vertebrate fauna investigation team at the edge of a field on the inland (agriculturally transformed TSF) portion of the Thyspunt site. This was a particularly interesting find as, while Onchyophora were predicted for the Bantamsklip site by Picker (2007), they were not predicted for either Duynefontein or Thyspunt.

Figure 15: Onchyophoran found at the Thyspunt site (courtesy of James Harrison).

2. **Mygalomorph spiders (**(Arachnida: Araneae: Mygalomorphae): none found.
3. **Scorpions** (Arachnida: Scorpiones): no scorpions were encountered during the survey, but conditions were poor and night searches were not carried out as the probability of scorpion activity was very low.
4. **Soldier flies** (Mydaidae): none found.
5. **Heelwalkers** (Mantophasmatodea): none found.
6. **Monkey beetles** (Hopliini): none found.
7. **Millipedes** (Myriapoda): - 3 species found.
8. **Jewel beetles** (Buprestidae): none found.
9. **Spoonwing lacewings** (Nemopteridae): none found.
10. **Horseflies** (Tabanidae): none found.

In addition to the above observations, several specimens of one terrestrial gastropod species were noted on the site.

2.3.6 Additional Thyspunt site survey – December 2009

Habitats identified within the consensus preferred footprint area were mapped in the Botany and Dunes Impact Assessment (Low 2009) as a mixture of Dwarf Dune Thicket (with some partially bare patches) and Dune Fynbos, but close inspection revealed a much more complex situation and the following habitat types were recognised:

- Tall thicket: this was of two forms, with the vast majority being alien *Acacia cyclops* and only a few relatively small areas of indigenous thicket. The latter in places had a sufficiently developed canopy to be considered as forest. Tall Thicket was not indicated in the vegetation mapping of this portion of the site and these areas fell within portions mapped as Dwarf Dune Thicket by Low (2009).
- Dwarf Dune thicket.
- Dune Fynbos: again two forms were identifiable, but in this case both comprised natural vegetation. The forms were dominated by different plant

species and were classified as "short" (30-50 cm) and "tall" (80-150 cm) Dune Fynbos.
- Disturbed seasonal wetland from which dense *Acacia cyclops* growth had been cleared.
- Non-vegetated/Partially Vegetated (Dwarf Dune Thicket) dune habitat, but only a few small patches.

Even discounting the alien thicket areas, which would naturally have been covered by Dwarf Dune Thicket or one of the two Dune Fynbos subtypes, there were thus six distinct natural habitat types represented within the approximately 1 km^2 potential footprint area. This complex mosaic of habitats is expected to be of significance in maintaining a high diversity of invertebrate species.

Attempts to locate invertebrate species of significance identified in earlier surveys within the footprint area (two ant species - *Diplomorium longipenne* and an undescribed *Monomorium* species) were not successful during this survey. It is possible that the drought conditions being experienced in the region at the time had reduced activity of these species, or (less likely) that this was a naturally low activity season.

An additional six ant species (not recorded from Thyspunt during the 2008 survey) were found during the additional inspection of the Thyspunt site in December 2009. These included a probably new arboreal species of *Camponotus*, illustrated in Figure 17. Specimens of this species, which was first found in natural Tall Thicket / Forest within the potential NPS footprint area, but also subsequently located in similar habitat well to the west of the footprint area, were taken to the South African Museum in Cape Town in January 2010. No matching specimens could be found in the SAM collection, although the species appears closely related to two un-named species from Tanzania. It is very likely that the Thyspunt specimens represent an undescribed species, but this remains to be confirmed.

Inspection of the remainder of the site outside of the potential NPS footprint revealed that all of the habitats identified within the footprint area are represented by substantial areas that could potentially be protected by enforcement of an 800 m development exclusion zone around the NPS. Most significantly:

- Natural Tall Thicket / Forest habitat is far better represented (both in area and quality), in areas to the west and especially north of the potential footprint area, than it is within the footprint.
- Much larger and better condition wetlands exist to the north-east of the footprint area.
- Substantial areas of Dwarf Dune Thicket are located to the east and west and to a lesser extent to the south of the footprint area.
- Fairly substantial areas of both Dune Fynbos subtypes were located to the north, east and west of the footprint area.
- Non-vegetated/Partially Vegetated (Dwarf Dune Thicket) dune habitat is very well-represented to the south of the proposed footprint area.

There is thus significant potential for protection of the entire range of habitat types, in a similar mosaic pattern, on the remainder of the site if an NPS were constructed in the area proposed. That the majority of the Tall Thicket within the proposed footprint is represented by alien infestations is also motivation for considering this area of relatively low value. However, there is also substantial *Acacia cyclops* infestation on the remainder of the site, especially to the north and west of the proposed footprint. This poses a very significant threat to all of the habitat types and hence their invertebrate communities, as the dense alien infestations support an extremely depauperate invertebrate community. Eradication of *Acacia cyclops* on the site should be considered a priority, and it is clear that a more detailed mapping of vegetation, to provide clear distinction between alien and natural thicket areas, is required. This will entail a substantial survey effort.

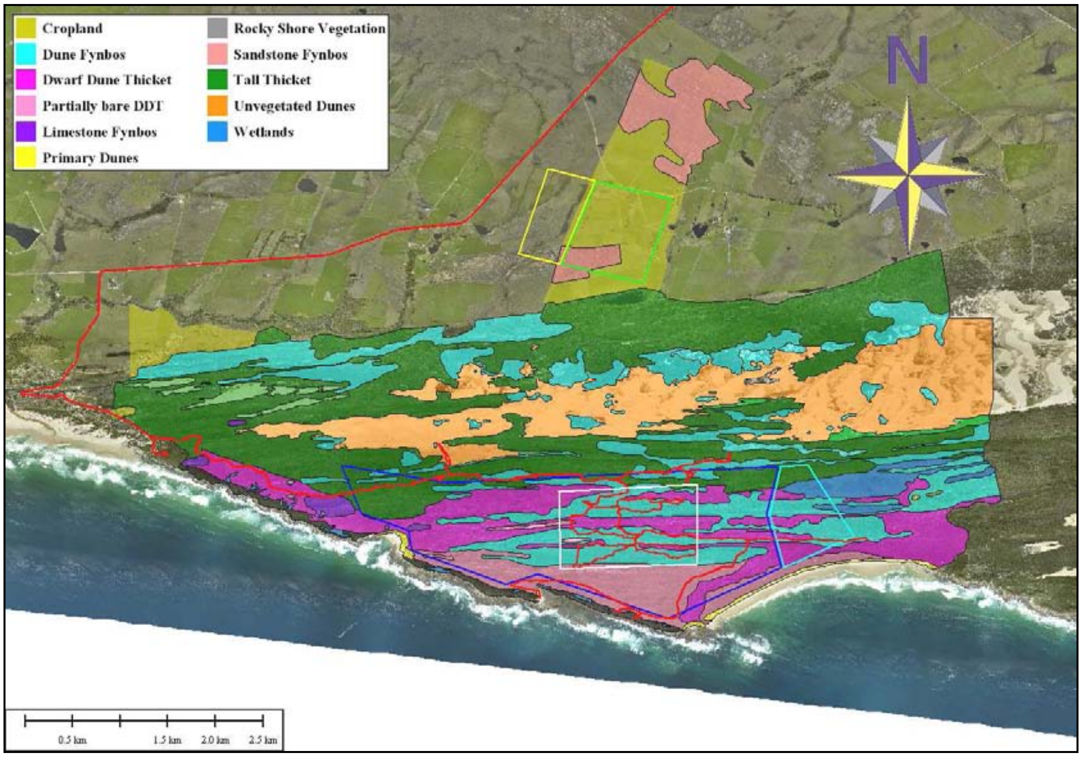

Figure 16: Additional invertebrate survey of Thyspunt site. Approximate consensus footprint area for NPS (white outline) within EIA corridor (dark blue outline, with turquoise outline subject to purchase); HV yard (green outline, with yellow outline subject to purchase) and routes followed (red lines) are also indicated.

Figure 17: Probably new species of *Camponotus* found in Tall Thicket / forest at Thyspunt

3 IMPACT IDENTIFICATION AND ASSESSMENT

The potential impacts of the proposed Nuclear 1 power station on the terrestrial invertebrate communities are described for the three sites below; most of the impacts are very similar for all three sites, so we have not provided a separate list for each site, but site-specific differences in significance or type are emphasised where applicable. **The phases during which specific impacts are considered to be important are indicated. Where a phase is not mentioned in respect of a particular impact, it is considered unlikely that the impact in question would occur at that time.**

3.1 Potential impacts of the proposed Nuclear 1 power station on the Duynefontein, Bantamsklip and Thyspunt sites

3.1.1 Direct habitat destruction

Construction phase

The impact of a large construction project such as the proposed NPS will result in significant loss of and damage to natural habitats, both in the areas permanently transformed, including the development footprint and permanent access roads, and in areas used for lay-down of machinery, materials and soil/rock removed during the construction process, and possible temporary access roads. Rehabilitation of some areas is possible, but despite this there is likely to be at least some long-term damage. Dumping of construction rubble and waste material may also cause long-term habitat degradation.

Decommissioning phase

Direct habitat destruction would be mainly limited to the construction phase, but could also occur during decommissioning, depending on what procedure is followed. However, the decommissioning process will be carried out so far in the future (*c*. approximately 60 years) that technology and methods are likely to have altered radically from what is currently available; in the absence of plans now (even for Koeberg, we do not know precisely what is to be done and much of the current decommissioning plan relates to development and design of aspects of the plan), we cannot at this stage properly assess the potential impacts and a full EIA process will be required closer to the time of decommissioning.

Decommissioning by immediate decontamination and dismantlement (the “Decon” option), as currently planned for Koeberg, would have impacts similar to construction in that areas of habitat beyond the immediate footprint of the reactor site would be severely degraded when used for stockpiling of rubble and other waste. However, if effective rehabilitation of these areas as well as the previously developed area is achieved, these impacts could be substantially mitigated and a net positive impact could result.

Decommissioning by entombment would have the advantage of not significantly adding to the environmental degradation of the site (small areas might be affected e.g. by the need for concrete preparation), but this needs to be weighed against the lack of improvement in the environmental status of the reactor site itself, as this would not be returned to a natural state.

3.1.2 Indirect habitat alteration / degradation by changes in groundwater regime

Construction phase

While most obviously impacting on wetland ecosystems, the terrestrial / wetland interface is an important ecosystem component for many species, thus we would like to emphasise the significance of impacts resulting from changes to the groundwater regime; these are covered in more detail in the Wetland Ecosystems specialist report (Day 2009). This impact is most likely to be of significance to invertebrate populations at Thyspunt, followed by Duynefontein, while at Bantamsklip there is relatively little likelihood of it being significant.

Decommissioning phase

This cannot be properly assessed at this stage - see section 3.1.1. If the Decon option is followed, further changes (either improvement, or further degradation) in the groundwater regime could result, while for the entombment option, no change from the operational phase would be expected.

3.1.3 Habitat fragmentation

Construction phase

The construction of buildings, fences and roads will inevitably result in natural movement patterns being disrupted and to a varying degree, depending on how different species react to these barriers, will result in the fragmentation of natural populations. Such impacts would be long-term or permanent, most likely the latter, depending on the procedure followed during eventual decommissioning.

Operational phase

All barriers remaining after construction will continue to impact at least for the life of the project and possibly permanently, depending on the decommissioning process followed.

Decommissioning phase

If decommissioning follows the Decon process, increased habitat fragmentation may occur during decommissioning, but following rehabilitation all barriers should be removed, resulting in a positive impact. If entombment is used for decommissioning, all barriers remaining during the operational phase would be expected to endure permanently.

3.1.4 Reduction in populations of rare / threatened / protected species

Construction phase

This impact would be localised and mainly limited to the direct construction area, access roads and materials / soil lay-down areas during the construction period (but see also under light pollution for more extensive and long-term potential impacts). Populations of non-flying invertebrates on the construction site will largely be destroyed, although some may escape into the surrounding areas. Their chance of survival here may be low due to difficulties in establishing in an area that may already be at or near carrying capacity. Adult stages of species that are able to fly may be able to escape, but their immature stages, which are often confined to the vegetation or are underground, will also be destroyed. The impact will be permanent in the transformed areas, but may be partially reversible in rehabilitated portions of the project area.

While several previously undescribed invertebrate species were collected during the very brief initial survey of the Duynefontein, Bantamsklip and Thyspunt sites, and many more undescribed species would be expected to be found if more detailed surveys were carried out, the significance of impacts on these species is difficult to estimate as nothing is currently known about their potential distribution beyond the site boundaries. At least some of the species probably have much wider distributions, but given the coastal location of the three sites, it is possible that some may be specific to coastal habitats and hence have limited distributions. Given the high development pressures on South Africa's coastline, species restricted to the coastal zone may be significantly threatened.

3.1.5 Soil and water pollution

Construction phase

Construction work of the magnitude contemplated for the proposed NPS will always carry a substantial risk of soil and water pollution, with large construction vehicles contributing substantially due to oil and fuel spillages. Building waste, batching plants, sewage and domestic waste are also potential contributors to this problem. If not promptly dealt with, spillages or accumulation of waste matter can contaminate the soil and surface or ground water, leading to potential medium/long-term impacts on invertebrates in the soil as well as aquatic species. Soil stockpiles may run off into streams and wetlands resulting in excessive sedimentation.

Operational phase

Sewage and domestic waste would be the main contributors to potential pollution problems during the operational phase, but this can very easily be managed effectively to avoid impacts.

Decommissioning phase

The impacts during this phase cannot be properly assessed at this stage - see section 3.1.1. If the Decon option is followed, soil and water pollution impacts could be similar to those experienced during construction, while for the entombment option, no further soil & water pollution would be expected.

3.1.6 Dust pollution

Construction phase

Excavation and movement of soil, as well as movement of heavy vehicles on dirt roads, has the potential to cause substantial dust pollution in the area surrounding the construction site and access roads. Accumulation of dust on plants can reduce their productivity, with knock-on effects on invertebrate herbivores and their predators as well as directly interfering with invertebrate species by *e.g*. physically impeding their movement on plants.

Decommissioning phase

Cannot be properly assessed at this stage - see section 3.1.1; if the Decon option is followed, dust pollution impacts could be similar to those experienced during construction, while for the entombment option, minimal dust pollution would be expected.

3.1.7 Light pollution

After habitat destruction, light pollution is probably the single most significant potential impact of a development of this nature, but, in the operational phase at least, it is also one of the most easily manageable. The impacts of artificial lighting on insect populations can be very significant, resulting in the deaths of many thousands of individuals every night, and causing a very substantial drain effect ("population sink") on surrounding populations. Other impacts may include interference with normal foraging and mating behaviours, resulting in less immediate but equally significant reductions in natural population levels. The consequent knock-on effects, given the vital role that invertebrates play in ecosystem functioning, may affect virtually every component of the surrounding ecosystem (Harrison *et al*. 2009, Rich & Longcore 2005).

Direct impacts of artificial lights such as high pressure mercury vapour streetlamps may extend up to 600 m or more from the source (Eisenbeis 2005), and the drain effect resulting from continual depletion of the populations within this zone will probably cause a significant decline in population density of affected species up to at least several times this distance. High level unshielded lighting at the NPS could thus extend the area of direct impact from the c. 80 ha of the construction footprint to over 360 ha, with lower intensity indirect impacts potentially being significant over an area of more than 3 000 ha (i.e. beyond the property boundary). These impacts would be continuous throughout the life of the project, and in our opinion, no justification can be made for allowing such easily controllable impacts to occur.

Construction phase

- Due to the changing "landscape" within the development footprint as well as the need for strong lighting if construction continues at night, light pollution is often particularly difficult to control during the construction phase, and this is where the greatest impacts are to be expected.

Operational phase

- Any external lighting used will continue to have an impact throughout the life of the project.

Decommissioning phase

Impacts of this phase will depend on the process followed and so this cannot be fully assessed at present. if the Decon option is followed, light pollution impacts could be similar to those experienced during construction, while for the entombment option, minimal light pollution in addition to that experienced during the operational phase would be expected.

Bantamsklip and Thyspunt are probably the most sensitive to this impact as their isolation means that at present there is very little impact of artificial lighting, while Duynefontein has probably already been significantly impacted; cumulative effects would be greatest at the latter site. However, the potential impact at all sites is sufficiently severe that the assessment criteria used do not allow a fine enough distinction for these differences in sensitivity to be apparent in the relative significance ratings of the three sites.

3.1.8 Increased radiation levels

Operational phase

The operation of a nuclear power plant utilising currently available technology inevitably leads to the emission of at least small amounts of radioactive material into the atmosphere, with a risk that this may result in accumulation of radioisotopes in the surrounding environment and the organisms inhabiting it. While the risk appears to be extremely small and easily managed judging by the historical data from Koeberg, it still needs to be considered, especially in the light of potential cumulative impacts of having as many as three (or even five in the case of Duynefontein) nuclear power stations at one site.

Assessment of the risk of a serious accident resulting in the release of substantial amounts of radioactivity is beyond the scope of this study; however it is understood that the designs of the reactors under consideration by Eskom are such that even in the extremely improbable (theoretically impossible) event of a reactor meltdown, all radioactivity would be contained and no release into the environment would occur.

Decommissioning phase

Cannot be properly assessed at this stage - see section 3.1.1; if the Decon option is followed, there may be a more significant risk of radioactive contamination than at any other stage during the life of the project, while for the entombment option, a risk equivalent to or lower than that during the operational phase would be expected.

3.1.9 Road mortality

All phases

Large numbers of invertebrates are killed either by being crushed under the tyres of vehicles in the case of crawling species, or by colliding with the vehicle itself in the case of flying species. While extremely difficult to quantify, Gepp (1973, in Eisenbeis 2005) estimated that approximately 116 insects were killed by the front of a car in Austria for every km travelled; this apparently did not take into account individuals crushed under the wheels.

It is thus difficult to predict the extent of such mortality, or to suggest whether the impact would be greater during the construction/decommissioning phases (with larger numbers of heavy, but perhaps slower-moving, vehicles) than during the operational phase (with few large but many small and probably faster-moving vehicles), but for all phases it is obvious that mortality would be increased by higher vehicle speeds and numbers.

3.1.10 Increased risk of fire

Construction phase

The presence of a large number of construction workers on site over a protracted period will result in a greatly increased risk of uncontrolled fires arising from cooking fires, improperly disposed cigarettes etc. This risk may be somewhat higher at Koeberg and Bantamsklip due to the more strongly seasonal rainfall at these sites.

Operational phase

The increased risk of fire would be expected to be smaller during the operational phase, but may still be significant due to the possibility of e.g. cigarette butts being thrown from vehicles transporting personnel to the site, or by accidental fires caused by visitors to the conservation area.

Decommissioning phase

Increased fire risk is possibly also important during the decommissioning phase, but the impact will be dependant on the means of decommissioning, which is so far in the future (approximately 60 years) that technology and methods may have altered radically from what is currently available, and thus no assessment can be made at present.

3.1.11 Spread of alien invasive invertebrate species

Along with light pollution, this is probably one of the most significant potential impacts from a terrestrial invertebrate perspective, and also may have very significant knock-on effects that could impact of virtually every aspect of the surrounding ecosystem.

Two destructive invertebrate species which have already invaded the Western Cape and are considered the most likely to be of significance to this project are the Argentine ant, *Linepithema humile*, and the alien land snail, *Thisbe pisana*. An additional tramp ant species (*Hypoponera eduardi*) was confirmed only at Duynefontein during the course of this study, supporting the view that construction of the proposed NPS would be likely to increase the risk of establishment of such species.

Invasive invertebrate species are commonly transported to new areas in construction materials and their establishment and spread is often enhanced by disturbance of natural ecosystems. The large volumes of materials that would be required to be transported to the site for construction of an NPS carry a very high risk that invasive species will be carried to the site in this way. The large areas that will be disturbed, as well as the long duration of construction-related disturbance, will provide ideal conditions and ample opportunity for establishment and spread of invasive species on site.

The impact of an invasive species such as the Argentine ant can be very severe, as it displaces many of the indigenous ant species and competes very strongly for resources such as nectar, thus potentially impacting on honeybee populations as well as any other insect species that utilise nectar as a food source. Ant reproductives ("flying ants") are an important food source for many organisms, particularly for birds, and since Argentine ant reproductives do not fly, this resource can be severely reduced if indigenous ant species are displaced by Argentine ants. Other impacts of this species include reduced pollination and seed set of indigenous plants, and interference with normal seed dispersal, which in the fynbos is carried out to a large extent by indigenous ant species. It is thus very important to prevent invasion by such species in sensitive habitats.

Construction phase

The construction phase almost certainly carries by far the greatest risk of alien invasive species being imported to the site, and the high levels of habitat disturbance also provide the greatest opportunities for such species to establish themselves, since most indigenous species are less tolerant of disturbance. The biggest risk is that colonies of species such as Argentine ants or individuals of exotic snails may be carried onto the site along with materials that have been stockpiled elsewhere at already invaded sites.

Operational phase

Continued movement of personnel and vehicles on and off the site, as well as occasional delivery of materials required for maintenance, will result in a lower-level risk of importation of alien species throughout the life of the project.

Decommissioning phase

Depending on the process followed, the decommissioning phase may carry risks of alien importation similar in level to those resulting from construction, so monitoring and control at this stage might be equally important as at any other stage; this cannot however be evaluated at this stage.

Bantamsklip is probably the most sensitive to this impact as its isolation renders it least likely to already have been invaded; in this respect it is followed by Thyspunt, and then Duynefontein, which may prove to have already been affected. However, the potential impact at all sites is sufficiently severe that the assessment criteria used do not allow a fine enough distinction for this to be apparent in the relative significance ratings of the three sites.

3.1.12 Invasion of land by employment seekers

Construction phase

Prior to and during construction, this could happen at any of the sites (see Dippenaar 2010) and would result in additional habitat destruction in the vicinity of the site, with both direct and indirect effects on invertebrate populations.

3.1.13 Cumulative impacts

All of the impacts identified above (3.1.1 - 3.1.12) would be exacerbated by the construction of additional nuclear power stations at any one of the sites considered. In addition, existing (including Koeberg) and planned (PBMR) developments at and near the Duynefontein site would further increase the cumulative effect of many impacts. The implications of these on the invertebrate populations are briefly described below.

Habitat destruction

- If PBMR construction at Koeberg is approved and this occurs concurrently with Nuclear 1 construction, the magnitude of construction-related impacts at Duynefontein would be significantly increased and more difficult to contain.
- If Nuclear 2 and Nuclear 3 projects also go ahead at any one of the sites, impacts of the combined construction (and decommissioning) phases of the three (or four in the case of Koeberg) projects would be similarly increased, and, depending on the degree of temporal overlap between projects, construction (and possibly decommissioning) impacts may occur over such a time period that they would need to be considered as **long-term impacts** (16-30 years), which would have a substantial effect on the consequence ratings of some construction-related impacts (*e.g.* dust pollution).

Cumulative impacts would be greatest at Duynefontein due to the presence of Koeberg and the PBMR, but may be most significant at Thyspunt due to the difficulties of avoiding impacts on wetlands; Bantamsklip would probably experience the lowest cumulative impact due to the relatively uniform mosaic of habitats.

Indirect habitat alteration / degradation by changes in groundwater regime

- Impact induced by changes in the groundwater flow patterns would be significantly increased by the addition of further NPS projects at any of the sites, with the significance probably being greatest at Thyspunt.

Habitat fragmentation

- Fragmentation of habitats would be significantly increased by the addition of further NPS projects at any of the sites.

Reduction in populations of rare/protected species

- Destruction of portions of local populations of rare or protected species would be significantly increased by the addition of further NPS projects at any of the sites, with the cumulative effect on invertebrate populations probably of greatest significance at Bantamsklip.

Soil and water pollution

- Risk of soil and water pollution would be significantly increased by the addition of further NPS projects at any of the sites.

Dust pollution

- The impact of dust pollution would be significantly increased by the addition of further NPS projects at any of the sites.

Light pollution

- The impact of light pollution would be significantly increased by the addition of further NPS projects at any of the sites, with the greatest cumulative effect at Duynefontein due to the already impacted nature of the environment.

Increased radiation levels

- While expected to be extremely small, this impact would be most important during the operational phase and possibly during decommissioning (but the latter we cannot assess at present - see 3.1.1). The cumulative effects of this impact would be greatest, but probably still insignificant, at Duynefontein, due to presence of the Koeberg NPS and possibly the PBMR to the south. At all sites the potential for impacts would be increased by the addition of Nuclear 2 and 3, effectively this would require that each plant keep its emissions to less than the current allowable maximum for Koeberg divided by the number of plants. At Duynefontein, should the PBMR and Nuclear 1, 2 and 3 be constructed, the allowable maximum emissions for each plant would thus be approximately 20% of the current levels specified for Koeberg. From Eskom's historical data this seems quite easily achievable, but the safety margin would be substantially reduced.

Road mortality

- The impact of road mortality would be significantly increased by the addition of further NPS projects at any of the sites.

Increased risk of fire

- The risk of accidental fires would be significantly increased by the addition of further NPS projects at any of the sites.

Spread of alien invasive species

- The risk of invasion by alien invasive invertebrate species would be significantly increased by the addition of further NPS projects at any of the sites.

Invasion of land by employment seekers

- The risk of land invasion would be significantly increased by the addition of further NPS projects at any of the sites, but the area surrounding Koeberg would be better able to absorb additional job-seekers than those surrounding Thyspunt and Bantamsklip, so cumulative impacts would potentially be greatest at the latter sites.

3.1.14 Climate change

Probable impacts of climate change on invertebrate populations at the proposed Nuclear 1 sites may be divided into three main categories:

- **Reduction in available habitat due to sea level rise resulting from increased global temperatures.** Given the fairly small predicted sea level rise over the next century, this impact is unlikely to be very large over the lifespan of the proposed NPS. It is likely however to be exacerbated by more frequent and severe storms and stronger average wind speed which would increase the amount of habitat lost by wave-mediated erosion, with the 100-year flood line predicted to extend as much as 100 m further inland by 2075 along parts of the shorelines of the proposed NPS sites (PDRW 2009). This impact would be more severe if the NPS was situated too close to the shoreline as this could interfere with natural movement of habitat boundaries as the mean sea level rises.
- **indirect effects via change in distribution of vegetation types due to** a) localised microclimatic changes due to altered shoreline caused by sea level rise and b) broader climatic changes (at all three sites involving increased temperature, decreased rainfall, changes in mean wind speed and direction), influencing habitat suitability for and hence distribution of various host or food plant species.
- **direct effects of** a) localised microclimatic changes due to altered shoreline caused by sea level rise and b) broader climatic changes (at all three sites involving increased temperature, decreased rainfall, changes in mean wind speed and direction), influencing habitat suitability for and hence distribution of various invertebrate species.

Precise impacts (especially for the latter two types of impact) are very difficult to predict given uncertainty about the degree of climatic change that is likely during the lifetime of the nuclear power stations, as well as very limited knowledge of habitat and climatic requirements of the majority of invertebrate species. The only communities for which some predictions may be possible are those which are associated with particular plant communities for which predicted influences of climate change are better-understood.

Note that in assessing the significance of climate change, while this is clearly an influence of global extent, only the on-site impacts are here considered, so it is treated as local in extent.

3.1.15 Positive contribution to conservation by protection of owner-controlled property and prevention of further development within an exclusion zone

The positive impact of continued stewardship by Eskom of the sites on which construction of the NPS is proposed must be emphasised/ On all sites a substantial, and in parts extremely effective, effort has been made to control and eradicate alien invasive plant species, with the result that (particularly at Bantamsklip) the Eskom-controlled areas appear in far better condition than their surroundings. Formal proclamation and management of the Bantamsklip or Thyspunt sites as conservation areas would be expected to further enhance these positive impacts, with controlled access hopefully leading to reduced poaching of marine resources and wildflowers. Continued and enhanced conservation-oriented management of these sites by Eskom must be seen as a significant positive impact of the proposed project.

However, it must also be borne in mind that:

- the positive impact may be significantly reduced during the construction and possibly decommissioning phases by increased unauthorised use of resources by the workforce

- the area benefiting from the positive impact will be substantially reduced if Nuclear 1, 2 and 3 go ahead on one site; and
- current progress in conservation of the Duynefontein site will be substantially reduced if any of Nuclear 1, 2, 3 or the PBMR proceed at this location.

The positive impact could be substantially enhanced if a large exclusion zone around nuclear developments is gazetted, but only if prevention of development is not allowed to result in neglect and further degradation of the surrounding properties. The best approach to prevent such degradation would probably be for all land within the exclusion zone to fall under the stewardship of Eskom so that it could be managed in a coordinated manner along with the Eskom-owned lands on which the NPS is situated.

3.2 Assessment of impacts

Assessment of identified impacts, carried out according to the criteria and rating scales provided to all specialists and presented in the Final Plan of Study for Environmental Impact Assessment for Eskom's Proposed Nuclear-1 – September 2009, are presented on the following pages in Tables 3.1-3.7.

Table 3.1: Assessment of unmitigated and mitigated on-site impacts of the proposed NPS on the terrestrial invertebrate fauna at Duynefontein

Description of impact (See section 3.1 for full descriptions)		Nature	Extent	Intensity	Duration	Probability	Reversibility	Impact on irreplaceable resources	Confidence	Consequence	Significance
1. Direct habitat destruction	Unmitigated	Negative	National *	High	Permanent	Definite	Low	Yes	High	High	High
	Mitigated	Negative	National *	Medium	Permanent	Definite	Medium	Yes	High	High	High
2. Indirect habitat alteration by groundwater disturbance	Unmitigated	Negative	Local	Medium	Permanent	Probable	Low	Yes	Low	Medium	Medium
	Mitigated	Negative	Local	Low	Permanent	Probable	Low	Yes	Low	Low	Low
3. Habitat fragmentation	Unmitigated	Negative	Local	Medium	Permanent	Highly Probable	Medium	No	High	Medium	Medium
	Mitigated	Negative	Local	Low	Permanent	Highly Probable	Medium	No	High	Low	Low
4. Reduction in populations of rare/protected species	Unmitigated	Negative	Regional *	Low	Permanent	Probable	Low	Yes	Medium	Medium	Medium
	Mitigated	Negative	Regional *	Low	Permanent	Probable	Low	Yes	Medium	Medium	Medium
5. Soil and water pollution	Unmitigated	Negative	Local	Medium	Medium-term	Highly probable	Medium	Yes	Medium	Medium	Medium
	Mitigated	Negative	Local	Low	Medium-term	Probable	High	Yes	Medium	Low	Low
6. Dust pollution	Unmitigated	Negative	Local *	Medium	Short-term	Highly probable	High	No	High	Low	Low
	Mitigated	Neutral	Local	Low	Short-term	Probable	High	No	High	Low	Low
7a. Light pollution - construction phase	Unmitigated	Negative	Local *	High	Medium-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Partly Mitigated**	Negative	Local *	Medium	Medium-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Fully Mitigated**	Neutral	Local	Low	Short-term	Highly Probable	High	Yes	High	Low	Low
7b. Light pollution - operational phase	Unmitigated	Negative	Local *	High	Long-term	Highly Probable	Low	Yes	High	High	High
	Partly Mitigated**	Negative	Local *	Medium	Long-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Fully Mitigated**	Neutral	Local	Low	Long-term	Highly Probable	High	Yes	High	Low	Low
8. Increased radiation levels	Unmitigated	Negative	Local	Low	Long-term	Possible	High	No	Medium	Low	Low
	Mitigated	Neutral	Local	Low	Long-term	Possible	High	No	Medium	Low	Low
9. Road mortality	Unmitigated	Negative	Local	Medium	Long-term	Highly Probable	High	No	High	Medium	Medium
	Mitigated	Negative	Local	Low	Long-term	Highly Probable	High	No	High	Low	Low
10. Increased risk of fire	Unmitigated	Negative	Local	High	Long-term	Highly Probable	High	No	High	High	High
	Mitigated	Negative	Local	Medium	Long-term	Probable	High	No	Medium	Medium	Medium
11. Spread of alien invasive invertebrate species	Unmitigated	Negative	Local *	High	Long-term	Highly Probable	Low	Yes	Medium	High	High
	Mitigated	Negative	Local *	Medium	Long-term	Probable	Low	Yes	Medium	Medium	Medium
12. Land invasion by employment seekers	Unmitigated	Negative	Local	Medium	Medium-term	Probable	Medium	Yes	Low	Medium	Medium
	Mitigated	Negative	Local	Low	Short-term	Probable	High	Yes	Low	Low	Low
13. Cumulative impacts	Unmitigated	Negative	Local	High	Long-term	Highly Probable	Low	Yes	High	High	High
	Mitigated	Negative	Local	Low	Long-term	Highly Probable	Medium	Yes	High	Low	Low
14. Climate change	Unmitigated	Negative	Local	Medium	Long-term/permanent	Highly Probable	Low	Yes	Medium	Medium	Medium
	Mitigated	Neutral	Local	Low	Long-term/permanent	Highly Probable	Low	Yes	Medium	Low	Low
15. Positive contribution to conservation	Unmitigated	Neutral	National	N/A	Long-term	Highly Probable	High	Yes	High	Low	Low
	Mitigated	Positive	National	Medium	Permanent	Definite	Low	Yes	High	High	High

* Significant potential contributors to cumulative impacts at regional / national level. ** See discussion in section 5.1.7

Table 3.2: Assessment of unmitigated and mitigated on-site impacts of the proposed NPS on the terrestrial invertebrate fauna at Bantamsklip

Description of impact (See section 3.1 for full descriptions)		Nature	Extent	Intensity	Duration	Probability	Reversibility	Impact on irreplaceable resources	Confidence	Consequence	Significance
1. Direct habitat destruction	Unmitigated	Negative	National *	High	Permanent	Definite	Low	Yes	High	High	High
	Mitigated	Negative	National *	Medium	Permanent	Definite	Medium	Yes	High	High	High
2. Indirect habitat alteration by groundwater disturbance	Unmitigated	Negative	Local	Medium	Permanent	Probable	Low	Yes	Low	Medium	Medium
	Mitigated	Negative	Local	Low	Permanent	Probable	Low	Yes	Low	Low	Low
3. Habitat fragmentation	Unmitigated	Negative	Local	Medium	Permanent	Highly Probable	Medium	No	High	Medium	Medium
	Mitigated	Negative	Local	Low	Permanent	Highly Probable	Medium	No	High	Low	Low
4. Reduction in populations of rare/protected species	Unmitigated	Negative	National *	Medium	Permanent	Highly Probable	Low	Yes	Medium	High	High
	Mitigated	Negative	National*	Low	Permanent	Highly Probable	Low	Yes	Medium	High	High
5. Soil and water pollution	Unmitigated	Negative	Local	Medium	Medium-term	Highly probable	Medium	Yes	Medium	Medium	Medium
	Mitigated	Negative	Local	Low	Medium-term	Probable	High	Yes	Medium	Low	Low
6. Dust pollution	Unmitigated	Negative	Local *	Medium	Short-term	Highly probable	High	No	High	Low	Low
	Mitigated	Neutral	Local	Low	Short-term	Probable	High	No	High	Low	Low
7a. Light pollution - construction phase	Unmitigated	Negative	Local *	High	Medium-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Partly Mitigated**	Negative	Local *	Medium	Medium-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Fully Mitigated**	Neutral	Local	Low	Short-term	Highly Probable	High	Yes	High	Low	Low
7b. Light pollution - operational phase	Unmitigated	Negative	Local *	High	Long-term	Highly Probable	Low	Yes	High	High	High
	Partly Mitigated**	Negative	Local *	Medium	Long-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Fully Mitigated**	Neutral	Local	Low	Long-term	Highly Probable	High	Yes	High	Low	Low
8. Increased radiation levels	Unmitigated	Negative	Local	Low	Long-term	Possible	High	No	Medium	Low	Low
	Mitigated	Neutral	Local	Low	Long-term	Possible	High	No	Medium	Low	Low
9. Road mortality	Unmitigated	Negative	Local	Medium	Long-term	Highly Probable	High	No	High	Medium	Medium
	Mitigated	Negative	Local	Low	Long-term	Highly Probable	High	No	High	Low	Low
10. Increased risk of fire	Unmitigated	Negative	Local	High	Long-term	Highly Probable	High	No	High	High	High
	Mitigated	Negative	Local	Medium	Long-term	Probable	High	No	Medium	Medium	Medium
11. Spread of alien invasive invertebrate species	Unmitigated	Negative	Local *	High	Long-term	Highly Probable	Low	Yes	Medium	High	High
	Mitigated	Negative	Local *	Medium	Long-term	Probable	Low	Yes	Medium	Medium	Medium
12. Land invasion by employment seekers	Unmitigated	Negative	Local	Medium	Medium-term	Probable	Medium	Yes	Low	Medium	Medium
	Mitigated	Negative	Local	Low	Short-term	Probable	High	Yes	Low	Low	Low
13. Cumulative impacts	Unmitigated	Negative	Local	High	Long-term	Highly Probable	Low	Yes	High	High	High
	Mitigated	Negative	Local	Low?	Long-term	Highly Probable	Medium	Yes	High	Low	Low
14. Climate change	Unmitigated	Negative	Local	Medium	Long-term/permanent	Highly Probable	Low	Yes	Medium	Medium	Medium
	Mitigated	Neutral	Local	Low	Long-term/permanent	Highly Probable	Low	Yes	Medium	Low	Low
15. Positive contribution to conservation	Unmitigated	Neutral	National	N/A	Long-term	Highly Probable	High	Yes	High	Low	Low
	Mitigated	Positive	National	Medium	Permanent	Definite	Low	Yes	High	High	High

* Significant potential contributors to cumulative impacts at regional / national level. ** See discussion in section 5.1.7

Table 3.3: Assessment of unmitigated and mitigated on-site impacts of the proposed NPS on the terrestrial invertebrate fauna at Thyspunt

Description of impact (See section 3.1 for full descriptions)		Nature	Extent	Intensity	Duration	Probability	Reversibility	Impact on irreplaceable resources	Confidence	Consequence	Significance
1. Direct habitat destruction	Unmitigated	Negative	National *	High	Permanent	Definite	Low	Yes	High	High	High
	Mitigated	Negative	National *	Medium	Permanent	Definite	Medium	Yes	High	High	High
2. Indirect habitat alteration by groundwater disturbance	Unmitigated	Negative	Local	Medium	Permanent	Probable	Low	Yes	Low	Medium	Medium
	Mitigated	Negative	Local	Low	Permanent	Probable	Low	Yes	Low	Low	Low
3. Habitat fragmentation	Unmitigated	Negative	Local	Medium	Permanent	Highly Probable	Medium	No	High	Medium	Medium
	Mitigated	Negative	Local	Low	Permanent	Highly Probable	Medium	No	High	Low	Low
4. Reduction in populations of rare/protected species	Unmitigated	Negative	National *	Medium	Permanent	Possible	Low	Yes	Medium	High	High
	Mitigated	Negative	National *	Low	Permanent	Possible	Low	Yes	Medium	High	High
5. Soil and water pollution	Unmitigated	Negative	Local	Medium	Medium-term	Highly probable	Medium	Yes	Medium	Medium	Medium
	Mitigated	Negative	Local	Low	Medium-term	Probable	High	Yes	Medium	Low	Low
6. Dust pollution	Unmitigated	Negative	Local *	Medium	Short-term	Highly probable	High	No	High	Low	Low
	Mitigated	Neutral	Local	Low	Short-term	Probable	High	No	High	Low	Low
7a. Light pollution - construction phase	Unmitigated	Negative	Local *	High	Medium-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Partly Mitigated**	Negative	Local *	Medium	Medium-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Fully Mitigated**	Neutral	Local	Low	Short-term	Highly Probable	High	Yes	High	Low	Low
7b. Light pollution - operational phase	Unmitigated	Negative	Local *	High	Long-term	Highly Probable	Low	Yes	High	High	High
	Partly Mitigated**	Negative	Local *	Medium	Long-term	Highly Probable	Medium	Yes	High	Medium	Medium
	Fully Mitigated**	Neutral	Local	Low	Long-term	Highly Probable	High	Yes	High	Low	Low
8. Increased radiation levels	Unmitigated	Negative	Local	Low	Long-term	Possible	High	No	Medium	Low	Low
	Mitigated	Neutral	Local	Low	Long-term	Possible	High	No	Medium	Low	Low
9. Road mortality	Unmitigated	Negative	Local	Medium	Long-term	Highly Probable	High	No	High	Medium	Medium
	Mitigated	Negative	Local	Low	Long-term	Highly Probable	High	No	High	Low	Low
10. Increased risk of fire	Unmitigated	Negative	Local	High	Long-term	Highly Probable	High	No	High	High	High
	Mitigated	Negative	Local	Medium	Long-term	Probable	High	No	Medium	Medium	Medium
11. Spread of alien invasive invertebrate species	Unmitigated	Negative	Local *	High	Long-term	Highly Probable	Low	Yes	Medium	High	High
	Mitigated	Negative	Local *	Medium	Long-term	Probable	Low	Yes	Medium	Medium	Medium
12. Land invasion by employment seekers	Unmitigated	Negative	Local	Medium	Medium-term	Probable	Medium	Yes	Low	Medium	Medium
	Mitigated	Negative	Local	Low	Short-term	Probable	High	Yes	Low	Low	Low
13. Cumulative impacts	Unmitigated	Negative	Local	High	Long-term	Highly Probable	Low	Yes	High	High	High
	Mitigated	Negative	Local	Low?	Long-term	Highly Probable	Medium	Yes	High	Low	Low
14. Climate change	Unmitigated	Negative	Local	Medium	Long-term/permanent	Highly Probable	Low	Yes	Medium	Medium	Medium
	Mitigated	Neutral	Local	Low	Long-term/permanent	Highly Probable	Low	Yes	Medium	Low	Low
15. Positive contribution to conservation	Unmitigated	Neutral	National	N/A	Long-term	Highly Probable	High	Yes	High	Low	Low
	Mitigated	Positive	National	Medium	Permanent	Definite	Low	Yes	High	High	High

* Significant potential contributors to cumulative impacts at regional / national level. ** See discussion in section 5.1.7

Table 3.4: Assessment of unmitigated and mitigated impacts of access road construction on the terrestrial invertebrate fauna at all three sites

Access road construction		Nature	Extent	Intensity	Duration	Probability	Reversibility	Impact on irreplaceable resources	Confidence	Consequence	Significance
1. Duynefontein	Unmitigated	Negative	Local	Medium	Permanent	Definite	Low	Yes	High	Medium	High
	Mitigated	Negative	Local	Low	Permanent	Definite	Low	Yes	High	Low	Low
2. Bantamsklip	Unmitigated	Negative	Local	High	Permanent	Definite	Low	Yes	High	High	High
	Mitigated	Negative	Local	Medium	Permanent	Highly Probable	Low	Yes	High	Medium	Medium
3. Thyspunt	Unmitigated	Negative	Local	High	Permanent	Definite	Low	Yes	High	High	High
	Mitigated	Negative	Local	Medium	Permanent	Highly Probable	Low	Yes	High	Medium	Medium

Table 3.5: Assessment of unmitigated and mitigated impacts of spoil disposal on the terrestrial invertebrate fauna at all three sites

Spoil disposal		Nature	Extent	Intensity	Duration	Probability	Reversibility	Impact on irreplaceable resources	Confidence	Consequence	Significance
1. Duynefontein	Unmitigated	Negative	Local	High	Permanent	Definite	Low	Yes	High	High	High
	Mitigated	Negative	Local	Medium	Medium	Highly Probable	Medium	Yes	Medium	Medium	Medium
2. Bantamsklip	Unmitigated	Negative	Local	High	Permanent	Definite	Low	Yes	Low	High	High
	Mitigated	Negative	Local	Medium	Medium	Highly Probable	Medium	Yes	Medium	Medium	Medium
3. Thyspunt	Unmitigated	Negative	Local	High	Permanent	Definite	Low	Yes	High	High	High
	Mitigated	Negative	Local	Medium	Medium	Highly Probable	Medium	Yes	Medium	Medium	Medium

Table 3.6: Assessment of unmitigated and mitigated impacts of transmission line construction on the terrestrial invertebrate fauna at Thyspunt

Transmission line construction		Nature	Extent	Intensity	Duration	Probability	Reversibility	Impact on irreplaceable resources	Confidence	Consequence	Significance
3. Thyspunt	Unmitigated	Negative	Local	High	Medium	Definite	Medium	Yes	High	Medium	High
	Mitigated	Negative	Local	Medium	Short	Highly Probable	High	Yes	High	Low	Low

Table 3.7: Assessment of unmitigated and mitigated impacts of the "no-go" option on the terrestrial invertebrate fauna at Duynefontein, Bantamsklip and Thyspunt

Description of impact (See section 3.1 for full descriptions)		Nature	Extent	Intensity	Duration	Probability	Reversibility	Impact on irreplaceable resources	Confidence	Consequence	Significance
1. No development of an additional NPS at Duynefontein in the long term	Unmitigated	Positive	National	Low	Permanent	Definite	Low	Yes	High	High	High +ve
	Mitigated	Positive	National	Medium	Permanent	Definite	Low	Yes	High	High	High +ve
2. .No development of an NPS at Bantamsklip in the long term	Unmitigated	Negative	National	Low	Permanent	Definite	Low	Yes	High	High	High -ve
	Partly mitigated	Positive	National	Low	Permanent	Definite	Medium	Yes	High	High	High +ve
	Mitigated	Positive	National	Medium	Permanent	Definite	Low	Yes	High	High	High +ve
3. No development of an NPS at Thyspunt in the long term	Unmitigated	Negative	National	Low	Permanent	Definite	Low	Yes	High	High	High -ve
	Partly mitigated	Positive	National	Low	Permanent	Definite	Medium	Yes	High	High	High +ve
	Mitigated	Positive	National	Medium	Permanent	Definite	Low	Yes	High	High	High +ve

Please note:

1. Partly mitigated refers to a situation where Eskom retains ownership of the sites even though no development is to occur there in the long run, but continues with current management practices only and does not proclaim reserves or attempt to extend the area of the properties by purchasing adjoining farms.
2. The unmitigated scenario at Duynefontein is roughly equivalent to the partially mitigated situation at Bantamsklip or Thyspunt, with current management practices continuing, but reversibility is considered to be higher at the latter two sites as Eskom may relinquish control at a later date at these sites, but not Duynefontein.
3. The unmitigated situation at Bantamsklip and Thyspunt assumes that Eskom will sell the properties and that the new management will be less conservation-oriented than at present; conditions attached to the sale could prevent this.

4 ENVIRONMENTAL ASSESSMENT

A brief overview of the sensitivity of the sites and potential impacts of construction of an NPS at each of the sites, as well as the "no-go" option is presented below..

4.1 Site 1: Duynefontein

The Duynefontein site appears unlikely to be inhabited by significant populations of rare or threatened species and impacts of the construction of the proposed NPS on this site would be expected to have at most only a small impact on such species, but a somewhat more significant impact on natural habitats for invertebrates. Duynefontein was ranked as the least sensitive of the three sites.

4.1.1 Sensitivity assessment - Duynefontein

None of the butterflies likely to occur in the CFDS area are endangered or endemic. There is a remote possibility that *C. dicksoni* may occur in the ASF area but no development is planned there. The parts of the site where development is planned have moderate – low butterfly conservation value. While Picker's (2007) analysis suggested that this site had a high overall invertebrate diversity, and this is supported by the limited ant diversity survey carried out here, the butterfly desktop analysis suggests that this site has the lowest diversity of the three sites in this group. Apart from the very slight possibility of the one potential Red Data (RD) butterfly mentioned above, there does not appear to be any reason to disagree with Picker's conclusion that while diverse, the site was unlikely to support many rare or relictual species (the protected baboon spider species found was one that is widely distributed and the undescribed and potentially undescribed ant species belong to genera that are usually generalists and they are thus likely to be fairly widespread). In combination with the low predicted butterfly diversity we feel that this site should rank of lower sensitivity than either Thyspunt or Bantamsklip.

Sensitivity scores based on quantified butterfly data only, calculated for each vegetation type according to the procedure outlined in section 1.2.7 and presented in Table 2.1, were used to generate the sensitivity map shown in Figure 18 (A).

The non-vegetated and partially vegetated portions of the site were ranked as of Very Low and Low sensitivity respectively as indicated in Figure 18 (A). However, the lack of detailed data on other invertebrate taxa is a major deficiency in the ranking process and it is highly probable that a more detailed assessment would rate these areas as of higher sensitivity, though probably still less sensitive than the currently Medium-rated areas (which would then likely rank as High sensitivity).

The alternative ranking process as described in section 1.2.7 yielded a markedly different sensitivity map which is illustrated in Figure 18 (B). The high significance given to the undescribed species located in certain habitats resulted in parts of the EIA corridor ranked as Low sensitivity on the basis of butterfly diversity being given a High sensitivity rank. This however should be considered in the context of the discussion in section 2.1.5 of the additional January 2010 site inspection, which suggests that the portion of the EIA corridor immediately adjacent to the KPS is already sufficiently altered from its natural state that development here could be considered.

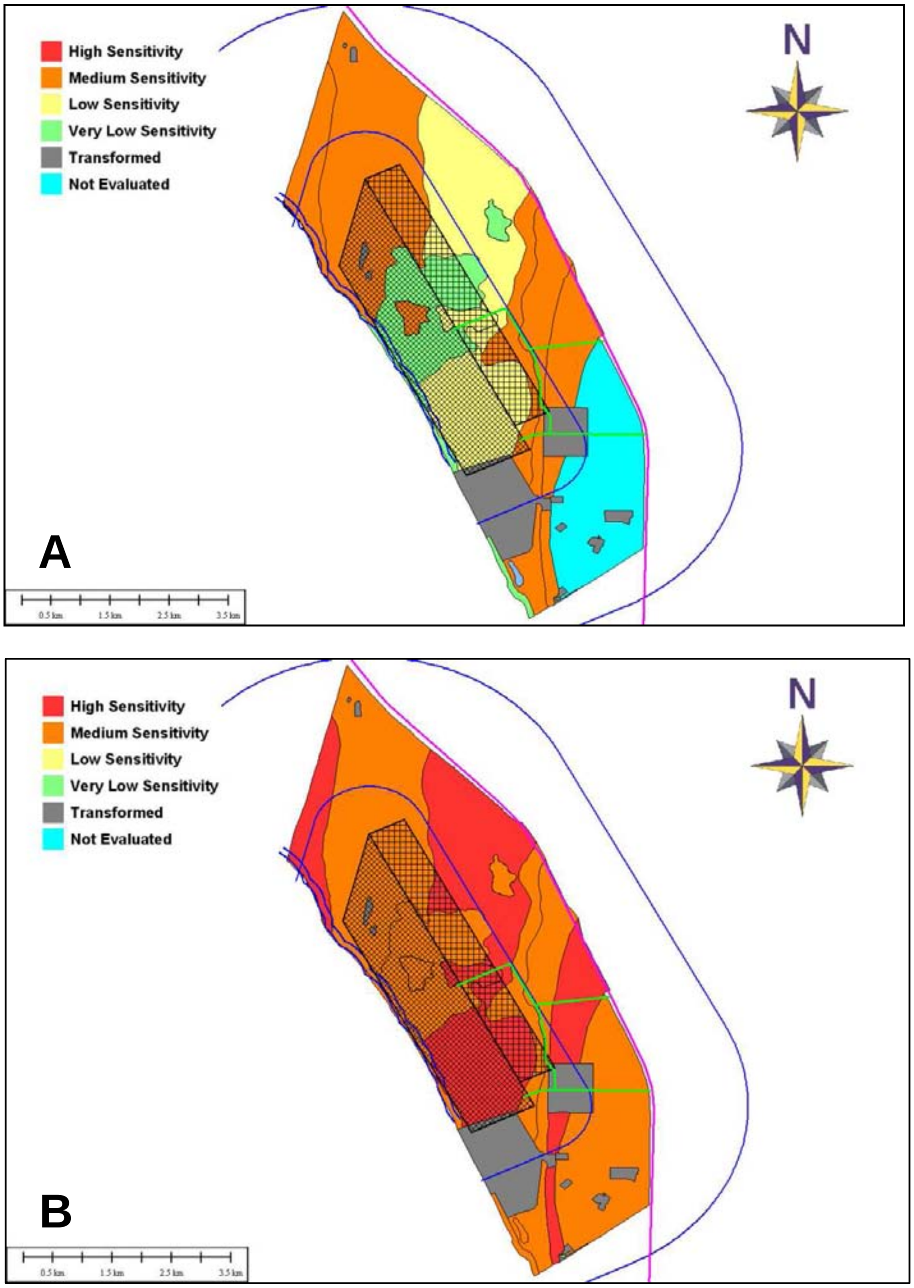

Figure 18: Terrestrial invertebrates sensitivity map of Duynefontein site based on **(A)** butterfly data only, and **(B)** alternative ranking criteria. EIA corridor is indicated by diagonal cross-hatching and HV yard corridor by vertical cross-hatching. Provincial road shown pink, proposed roads green, 100 m & 200 m lines from coast and 800 m & 3000 m lines from EIA shown in blue.

4.1.2 NPS position

While impacts of construction of the NPS on non-butterfly invertebrates would probably be lowest in the more northern parts of the Duynefontein site, where substantial stands of exotic plant species were noted, this would not be feasible unless further property was purchased to the north, due to the need for the 800m buffer to be within Eskom-controlled property. Since the northern areas were rated from a butterfly perspective as of higher sensitivity than the central and southern parts of the EIA corridor, on present information it does not seem that such a departure from current plans could be strongly motivated. On the basis of the butterfly assessment, siting of the NPS either centrally or in the southern part of the EIA corridor would be acceptable; but since the only known specimen of an undescribed ant species was found in the southern portion and this was also considered of slightly higher sensitivity than the central area from a butterfly perspective, the central option on the unvegetated dunes might appear to be the most preferred from an invertebrate perspective.

The southern portion of the site, immediately adjacent to the present Koeberg power station, is however no longer in its natural state while the unvegetated central dune field is more natural. It is therefore considered preferable to site the Nuclear 1 NPS adjacent to Koeberg as this would result in less fragmentation of the nature reserve and potentially allow mitigation of the disruption of natural dune formations to be effected.

4.1.3 Access roads

According to shapefiles provided, a total of approximately 6 km of roads is expected to be required to be built (1.6 km) or upgraded (4.4 km, of which 1km would be for light and 3 km for heavy vehicles) during construction of the NPS at Duynefontein. Additional roads would probably be required for transport of spoil for disposal if this is to be done on-site, but such routes cannot be assessed until spoil disposal sites have been selected. The access road shapefiles provided for assessment were clearly created with a southern NPS placement in mind, and the routes would require modification (with some additional sections) if siting of the NPS in the central unvegetated dune fields was selected. The additional sections required would however all fall within areas of Low or Very Low sensitivity (based on butterfly data), so this would not have a material impact on the assessment presented here.

Based on a total servitude width of 30m, the impact of upgrading existing roads would be expected to have a low impact on invertebrate populations, and this should not be substantially greater than the impact of current maintenance operations. The impact of new road construction would be greater as a larger area of undisturbed habitat would be either transformed or disturbed. Approximately 800 m of the proposed new road falls within Medium sensitivity and 800 m within Low sensitivity habitat; given the relatively small area that will be disturbed/transformed (at most 2.4 ha each of Low and Medium sensitivity habitat, with probably about an additional 6 ha of Low sensitivity habitat if the NPS is sited in the central dune fields), the impact is expected to be Low.

4.1.4 Spoil disposal

The impacts of spoil stockpiling or disposal on the site could be intense and can best be mitigated by off-site disposal, although some on-site disposal options may also be viable. Three possible disposal options are recommended for consideration:

- Disposal at sea: while clearly the least likely to impact on terrestrial invertebrates, the impacts of this option on marine communities needed to be considered. Since the Oceanographic Impact Assessment has indicated that the sand spoil could be disposed of at sea within acceptable impact limits (Giljam 2010), this is considered the preferred option from a terrestrial invertebrate perspective.
- Disposal on-site: 1) some areas of Duynefontein (mainly in the central to northern portions) remain heavily infested by alien invasive plant species, it is possible that rehabilitation could be assisted in some areas by covering dense infestations with a substantial layer of spoil (at least several metres deep) and rehabilitating at the new level; implications of this suggestion should be discussed with other biodiversity specialists, especially the botanist. A positive impact on the Duynefontein site might thus be effected by careful planning of spoil disposal. 2) the remaining Very Low sensitivity areas of the Duynefontein site, mainly represented by portions of the unvegetated dunes not proposed for siting of the NPS, could accept a substantial portion of the estimated volumes of spoil, but as this sensitivity ranking was based on butterflies only, this would need to be subject to further detailed investigation of the invertebrate communities of the dune fields.
- Disposal off-site at a more distant location: impacts of this option would be zero at the Duynefontein site, but potential impacts at the selected site would require separate evaluation that is beyond the scope of this report.

From the perspective of terrestrial invertebrate populations at Duynefontein, off-site alternatives would be the preferred option as, with the possible exception of onsite use of spoil in rehabilitation, these would have the lowest potential for negative impacts. While the unvegetated dunes may appear suitable for on-site disposal due to their low sensitivity from a butterfly perspective, the probability that sensitive invertebrate communities representing other taxa would be negatively impacted on is high. If off-site disposal is selected, temporary on-site spoil stockpiles should be kept as small as possible and situated on Low sensitivity portions within the EIA corridor.

4.1.5 Climate change

Of the three identified ways in which climate change is likely to impact on invertebrate communities on the Duynefontein site, only the first (reduction in available habitat) can be directly mitigated in terms of the Nuclear 1 project. Mitigation in this instance would be by siting the NPS sufficiently far back from the present shoreline to allow natural processes of vegetation/habitat gradient movement to progress as mean sea level changes. This would minimise loss of the primary dune-vegetated dune gradient so that habitat area loss would be largely limited to the more extensive vegetation types further from the shore. The loss of a small area of these habitat types would be of very low significance.

Indirectly, Nuclear 1 itself would contribute to mitigation of climate change on a global scale by effecting a reduction in South Africa's CO_2 emissions and would thus to a small extent (though probably immeasurable) mitigate the second two climate change impacts on invertebrate communities.

4.2 Site 2: Bantamsklip

Bantamsklip hosts at least one regional endemic butterfly and there is also a remote possibility that a Red Data species butterfly species could also occur here. The parts of site that are not alien infested have high butterfly conservation value. In addition, the local abundance of a probably new trapdoor spider species and the presence of a potentially new ant species with specialised prey requirements, combined with the likely presence of a number of rare & relictual taxa as listed by Picker (2007), indicate that the site should be considered sensitive. Construction impacts of the proposed NPS on both invertebrate populations of concern and their habitats could therefore be substantial. We feel that Bantamsklip should be considered as significantly more sensitive than Duynefontein and at least slightly more sensitive than Thyspunt, and it is thus ranked as the most sensitive site from a terrestrial invertebrate perspective.

4.2.1 Sensitivity assessment - Bantamsklip

Picker (2007) ranked Bantamsklip as lower than Duynefontein in terms of overall species richness, but considered the high potential for rare, endemic and relictual species to be sufficient to significantly raise its sensitivity ranking. There is a discrepancy between his and our analysis regarding *Chrysoritis thysbe mithras*, a Red Listed species, which Picker (2007) states could occur at Bantamsklip and Thyspunt. This species was described by Pringle (1994) from specimens taken at Brenton near Knysna, and reduced to a subspecies in a revision of the genus by Heath & Pringle (2007). Ball (2006) reviewed its Red List status and classified it as “Endangered”. He included the population from Stilbaai in his review, but noted some uncertainties as to its taxonomic status, and urged that specimens be obtained of the intervening populations such as the one at Mossel Bay. Dave Edge has been able to do this and has confirmed that the form at Mossel Bay is *C. thysbe thysbe.* This means that the Stilbaai form could not be *C. thysbe mithras*, since races (subspecies) do not have distributions that include another subspecies in the middle – in this case *C. thysbe thysbe* in the middle of *C. thysbe mithras*’s range. Consequently *C. thysbe mithras* only occurs at Knysna. The subspecies to the west is *C. thysbe thysbe* (which was confirmed at Bantamsklip in March 2009), and the subspecies to the east is *C. thysbe whitei,* which could possibly occur as far west as Thyspunt. The result of this would be a minor reduction in the sensitivity rating of Bantamsklip relative to the alternative sites, but there are several other reasons, including both Picker’s analysis and the discovery of a probably new mygalomorph spider species and a potentially new specialised ant species, to consider Bantamsklip as highly sensitive.

The ALF area at Bantamsklip, including patches and elements found within the ODS area, is likely to host at least one regional endemic butterfly and there is also a remote possibility that *C. dicksoni* could occur in the ODS area. The parts of the ALF and ODS areas that are not alien infested have high butterfly conservation value and the local abundance of a probably new trapdoor spider species and a potentially new ant species, combined with the likely presence of a number of rare & relictual taxa as listed by Picker (2007), indicate that construction impacts of the proposed NPS on both invertebrate populations of concern and their habitats could be substantial.

Based solely on the quantified butterfly data for Bantamsklip, the sensitivity of the various habitats on the site was ranked as in Table 2.2 and is illustrated in Figure 19 (A). However, it is our opinion that the entire area shown as Medium Sensitivity could be ranked as High Sensitivity if additional information on invertebrate communities was obtained. The alternative ranking process as described in section 1.2.7 yielded a rather different sensitivity map which is illustrated in Figure 19 (B).

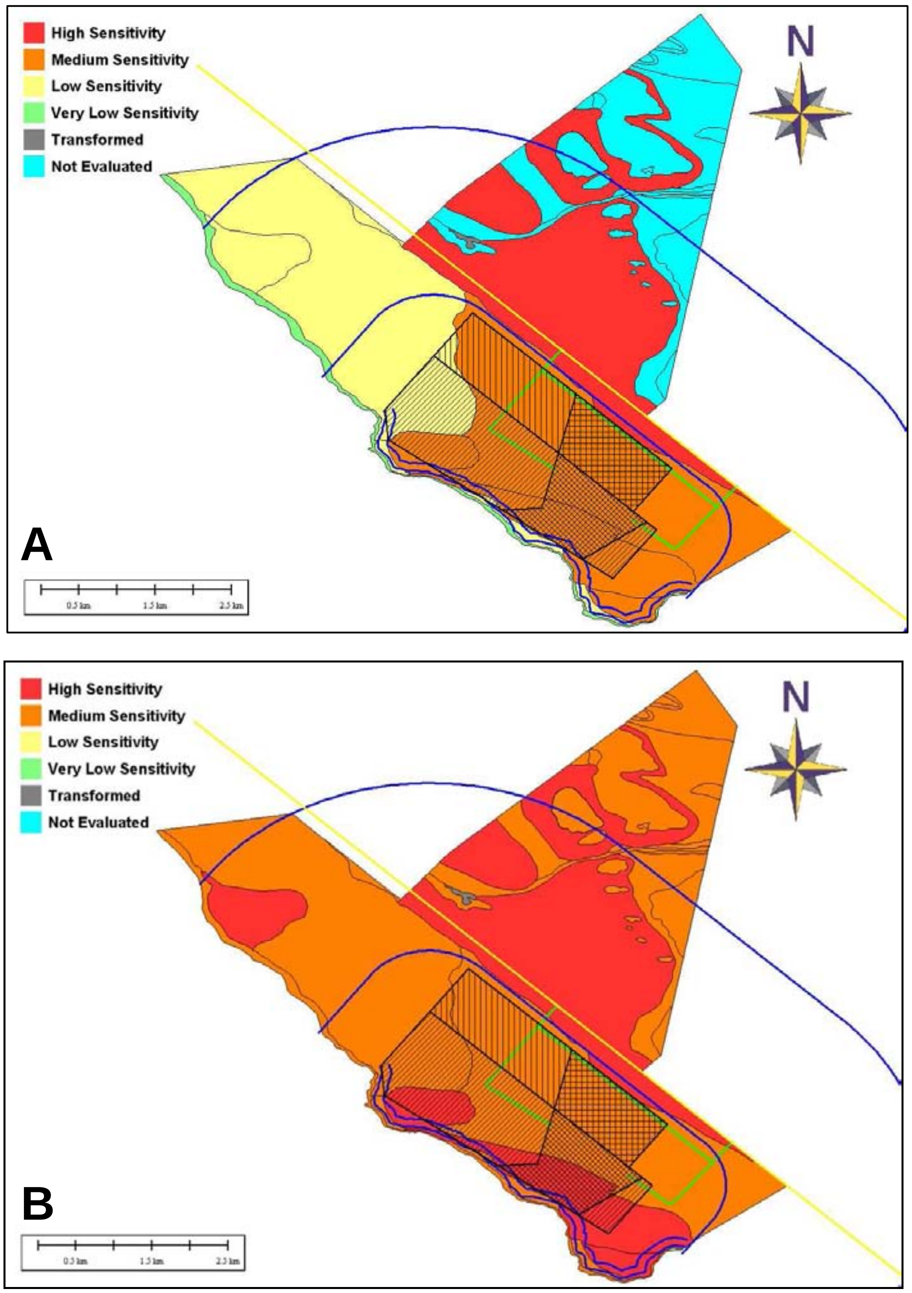

Figure 19: Terrestrial invertebrates sensitivity map of Bantamsklip site based on **(A)** butterfly data, and **(B)** alternative ranking criteria. EIA corridor indicated by diagonal cross-hatching (area currently owned by Eskom) and diagonal hatching (subject to purchase), HV yard corridor indicated by vertical cross-hatching (area currently owned by Eskom) and vertical hatching (subject to purchase). Provincial road shown

in yellow, proposed roads green, 100 m & 200 m lines from coast and 800 m & 3000 m lines from EIA shown in blue.

4.2.2 NPS position

If constructed within the EIA and HVY corridors as indicated by the shapefiles provided in May 2009, the NPS and associated switchyard would impact severely on an area designated as medium sensitivity from a butterfly perspective, and as high sensitivity from an overall invertebrate perspective. These corridors are too small to allow any meaningful adjustment of positioning of either the NPS or the HV yard and the optional areas to the west that could be purchased would bring the footprint closer to a highly sensitive area, so mitigation would be difficult unless the corridor is moved inland as far as possible. A modified corridor location and recommended footprint is indicated in Figure 22; within this area development should be kept as far from the coastal portions as possible so as to limit impacts on areas of Limestone Fynbos situated there.

4.2.3 Access roads

The access road shapefile provided for assessment at Bantamsklip indicated approximately 6.4 km of roads to be constructed on site; all of this falls within habitat classified as medium sensitivity based on objective butterfly data, but as High Sensitivity based on a subjective opinion based on additional data on other invertebrates.

If the siting of the NPS as suggested in Figure 22(A) is followed, access roads outside of the EIA and HV yard corridors would total approximately 6.3 km, all of which falls within Medium sensitivity butterfly habitat. The impact of access road construction, would thus be negative and significant, but could probably be substantially reduced if the access roads joined the provincial road closer together than indicated in the shapefiles provided.

4.2.4 Spoil disposal

With the exception of the extreme north-western portions of the EIA corridor, the entire Bantamsklip site is considered at least of medium or high sensitivity from an invertebrate perspective. The impacts of spoil stockpiling or disposal anywhere on the site would thus be intense and can only be mitigated effectively by off-site disposal. Three possible disposal options are recommended for consideration:

- Disposal at sea: while clearly the least likely to impact on terrestrial invertebrates, the impacts of this option on marine communities needed to be considered. Since the Oceanographic Impact Assessment has indicated that the sand spoil could be disposed of at sea within acceptable impact limits (Giljam 2010), this is considered the preferred option from a terrestrial invertebrate perspective.
- Disposal on adjacent State Forest land: since this area (to the west of the Bantamsklip site) is heavily infested by alien invasive plant species (personal observations indicate possibly as much as 40% coverage), it is possible that rehabilitation could be assisted in some areas by covering dense infestations with a substantial layer of spoil (at least several metres deep) and rehabilitating at the new level. Use of the topsoil layers removed during site clearing for the NPS in rehabilitation should allow fairly rapid establishment of natural plant and invertebrate communities; implications of this suggestion should be discussed with other biodiversity specialists, especially the botanist. A positive impact

on the greater Bantamsklip area could thus be effected by careful planning of spoil disposal.
- Disposal off-site at a more distant location: impacts of this option would be zero at the Bantamsklip site, but potential impacts at the selected site would require separate evaluation that is beyond the scope of this report.

Disposal of spoil on-site is not recommended, as there are no low-sensitivity areas of sufficient size to accept the large volumes of spoil that will be generated. If the spoil could be effectively incorporated into rehabilitation of the adjacent State Forest areas, this would be the recommended option. Temporary spoil stockpiles should be kept as small as possible and located within the EIA corridor as close as possible to the NPS footprint to concentrate impacts.

4.2.5 Climate change

Of the three identified ways in which climate change is likely to impact on invertebrate communities on the Bantamsklip site, only the first (reduction in available habitat) can be directly mitigated in terms of the Nuclear 1 project. Mitigation in this instance would be by siting the NPS sufficiently far back from the present shoreline to allow natural processes of vegetation/habitat gradient movement to progress as mean sea level changes. This would minimise loss of the primary dune-vegetated dune gradient so that habitat area loss would be largely limited to the more extensive vegetation types further from the shore. The loss of a small area of these habitat types would be of very low significance.

Indirectly, Nuclear 1 itself would contribute to mitigation of climate change on a global scale by effecting a reduction in South Africa's CO_2 emissions and would thus to a small extent (though probably immeasurable) mitigate the second two climate change impacts on invertebrate communities.

4.3 Site 3: Thyspunt

This site has in all probability the highest butterfly diversity and conservation value of the three sites studied. There is at least one regional endemic (*Aloeides pallida* ssp. nova) on the site and potential for another (*Aloeides carolynnae aurata*). At least one rare and localised butterfly occurs on the site and an unexpected relictual species of Onchyophoran was found in the north of the site. From the point of view of other invertebrate groups no further evidence was found during the brief survey to suggest that the site was of high significance, but the combination of high butterfly and ant diversity and the Onchyophoran species mentioned above indicate that the site does have significant conservation value, and we would rank it as of higher sensitivity than Duynefonten, and only marginally lower than Bantamsklip. More detailed surveys of the sites may, however, widen the latter gap if further significant species in the groups predicted by Picker (2007) for Bantamsklip are confirmed; at present we rank Thyspunt as the second most sensitive of the three sites.

4.3.1 Sensitivity assessment - Thyspunt

This site has in all probability the highest butterfly diversity and conservation value of the three sites studied. There is at least one regional endemic on the site (*A. pallida* ssp.) and potential for another (*C. thysbe whitei*) whose known habitat is ADS (Ball 2006). At least one rare and localised butterfly occurs on the site (*A. hippomeme hippomene*) and an unexpected relictual species of Onchyophoran was found in the north of the site. One undescribed and two possibly ant species, as well as another ant species apparently with a localised distribution and known from only four other collections during the past 108 years, were found at Thyspunt. The combination of high butterfly and ant diversity and the Onchyophoran species mentioned above indicate that the site does have significant conservation value, and we would rank it as of higher sensitivity than Duynefontein, and only marginally lower than Bantamsklip. More detailed surveys of the sites may, however, widen the latter gap if further significant species in the groups predicted by Picker (2007) for Bantamsklip are confirmed.

Based solely on the quantified butterfly data for Thyspunt, the sensitivity of the various habitats on the site was ranked as in Table 2.3 and is illustrated in Figure 20(A). However, the alternative ranking process as described in section 1.2.7 yielded a very different sensitivity map which is illustrated in Figure 20 (B).

The apparently high sensitivity of much of the site is however probably exaggerated in Figure 20 (B), largely due to the lack of detailed data on distributions of certain species of potential significance found at Thyspunt. This figure should thus be considered in the context of the discussion in section 2.3.6 of the results of the additional January 2010 site inspection: although the habitat within the area surveyed is structurally complex and may be considered sensitive, there is ample scope, outside the NPS footprint recommended (see Figure 23, section 6.4), for protecting representative areas of all habitat types and subtypes that would be disturbed. Such protection should offset the negative impacts of the proposed NPS development, which thus may be preferable to allowing residential development of the area.

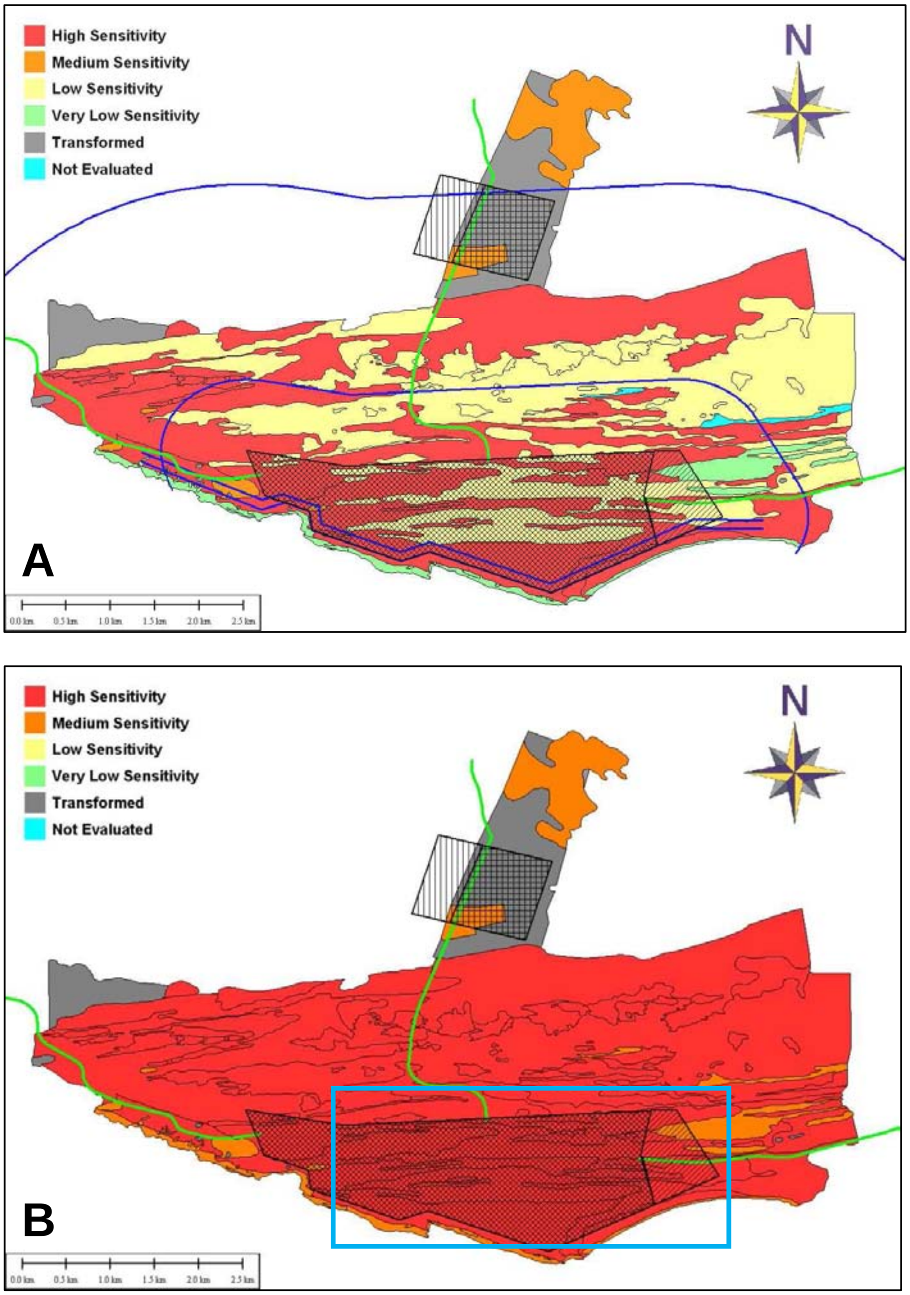

Figure 20: Terrestrial invertebrates sensitivity map of Thyspunt site based on **(A)** butterfly data only and **(B)** alternative ranking criteria. EIA corridor indicated by diagonal cross-hatching (area currently owned by Eskom) and diagonal hatching (subject to purchase), HV yard corridor indicated by vertical cross-hatching (area currently owned by Eskom) and vertical hatching (subject to purchase). 100 m & 200 m lines from coast and 800 m & 3000 m lines from EIA are shown in dark blue, region in which additional surveys were concentrated in December 2009 indicated by blue box in (B).

4.3.2 NPS position

On the basis of the butterfly assessment carried out, the area of least sensitivity within the EIA corridor is situated approximately centrally; however even this area contains a substantial proportion of High sensitivity habitat, and significant negative impacts on invertebrate populations are inevitable. More detailed sensitivity assessments taking into account other invertebrate taxa would be likely to further raise the sensitivity rating of this area. However, detailed inspection of this area and surrounding habitats revealed that all identified habitat types and subtypes within the central part of the EIA corridor could be effectively conserved by protection of the remainder of the Thyspunt site. As siting the NPS anywhere else within the EIA corridor raises risks of impacts on sensitive wetland ecosystems and/or the risk of seismic problems, the central area is thus preferred.

4.3.3 Access roads

Three access road routes were provided for assessment, one approaching the EIA corridor from Oysterbay in the west, one from Cape St Francis in the east, and a third via the proposed HV yard in the north.

The road approach from the east passes through the least High sensitivity area of the three options, but passes close to the wetlands situated on the eastern part of the site; while these were not considered of high sensitivity for butterflies, they may be important habitat for many other invertebrate species and are likely to be considered highly sensitive for other reasons. Use of this approach should thus be avoided.

The approach from the west passes through the largest amount of high sensitivity butterfly habitat, but does so along an existing road route which could be upgraded with relatively little further disruption of natural ecosystems; this would be the recommended route for light traffic.

The approach from the north via the HV yard also passes through a significant amount of High sensitivity butterfly habitat. As this route would presumably need to be suited to heavy traffic at least up to the HV yard, it is recommended that (subject to approval by the botany and dune geomorphology specialists) it be used in preference to the western approach as the heavy traffic route; in part it could also be used as access for installation of the 132 kV transmission line, depending on the precise route chosen for the latter.

4.3.4 Spoil disposal

The impacts of spoil stockpiling or disposal on this site could be intense and can best be mitigated by off-site disposal, although some on-site disposal options may also be viable. Four possible disposal options are recommended for consideration:

- Disposal at sea: while clearly the least likely to impact on terrestrial invertebrates, the impacts of this option on marine communities needed to be considered. Since the Oceanographic Impact Assessment has indicated that the sand spoil could be disposed of at sea within acceptable impact limits (Giljam 2010), this is considered the preferred option from a terrestrial invertebrate perspective.

- Disposal on-site: the Low sensitivity unvegetated dune slack areas of the Thyspunt site could probably accept most, if not all, of the estimated volumes of spoil. However, while these areas may appear suitable for on-site disposal due to their low sensitivity from a butterfly perspective, the probability that sensitive invertebrate communities representing other taxa would be negatively impacted on is high. Consideration of spoil disposal here would thus need to be subject to further detailed investigation of the invertebrate communities of the dune fields.
- Off-site disposal of sand spoil at St Francis Bay would impact positively on the proposed erosion remediation programme as well as partially solving the problem of spoil disposal from construction of the Thyspunt NPS, but the volume that could be utilised in this way is very small (about 5%) of the total sand spoil volume that is expected to be generated.
- Disposal off-site at a more distant location: impacts of this option would be zero at the Duynefontein site, but potential impacts at the selected site would require separate evaluation that is beyond the scope of this report.

From the perspective of terrestrial invertebrate populations at Thyspunt, off-site alternatives would be the preferred option as these would have the lowest potential for negative impacts. If off-site disposal is selected, temporary on-site spoil stockpiles should be kept as small as possible and situated on Low sensitivity portions within the unvegetated dunes.

4.3.5 HV Yard

The currently proposed siting of the HV yard will impact severely on approximately 10 ha of medium-sensitivity Sandstone Fynbos; by shifting the HV yard approximately 200m to the north-north-west (as indicated in Figure 23), the impacted medium-sensitivity area could be reduced to little more than 1 ha.

Extension of the HV yard corridor to the west by inclusion of optional additional land would increase the area of medium sensitivity Sandstone Fynbos impacted on, and this is not recommended.

4.3.6 Transmission lines

The recommended NPS location (Figure 23) allows an approximately 2500 m direct route for the 132 kV power line running almost due north to preferred HV yard location. This would allow for construction of the transmission line with only four masts erected outside of the EIA and HV yard corridors and without necessitating unusually high masts (which would incur high costs as well as being more visually intrusive). Approximately 1100 m of the transmission line would traverse high sensitivity butterfly habitat, while the remaining 1400 m would cross low sensitivity habitat. Only one mast would need to be erected within high sensitivity habitat. One span of the suggested transmission line route shown in Figure 23 could potentially be extended to substantially more than 500 m, as it crosses a substantial depression in the dune field, and thus allow more flexibility in the siting of the mast that is required in the High sensitivity habitat.

Impacts on High sensitivity habitat could be reduced by installing the relevant mast by helicopter.

4.3.7 Climate change

Of the three identified ways in which climate change is likely to impact on invertebrate communities on the Thyspunt site, only the first (reduction in available habitat) can be directly mitigated in terms of the Nuclear 1 project. Mitigation in this instance would be by siting the NPS sufficiently far back from the present shoreline to allow natural processes of vegetation/habitat gradient movement to progress as mean sea level changes. This would minimise loss of the primary dune and rocky shore-vegetated dune gradient so that habitat area loss would be largely limited to the more extensive vegetation types further from the shore. The loss of a small area of these habitat types would be of very low significance.

Indirectly, Nuclear 1 itself would contribute to mitigation of climate change on a global scale by effecting a reduction in South Africa's CO_2 emissions and would thus to a small extent (though probably immeasurable) mitigate the second two climate change impacts on invertebrate communities.

4.4 Alternative 4: No-Go option

The no-go option at any of the three sites would obviously have no direct negative impact on invertebrate communities and might thus be considered the most favourable option from a purely conservation perspective. However, since positive conservation impacts could result from protection of the areas surrounding the proposed NPS, in the medium- to long-term the no-go option might be less favourable to conservation of invertebrates, which could benefit substantially by control of access to the Eskom-owned properties as well as limitations on development in the Emergency Protection Zones, should these extend beyond the Eskom-owned properties.

There would be a net positive impact of the “no-go” option for invertebrate communities at Duynefontein, which stand little to gain from the positive spin-offs of the NPS unless surrounding properties are incorporated into the reserve, while for Bantamsklip and Thyspunt, the trade-off between negative impacts of the development and positive conservation spin-offs may mean that there would be a net negative impact for either site if the NPS is not constructed there (i.e. a net positive impact if the NPS is built). A profound negative impact could result from the “no-go” option at either of these sites if, as expected, Eskom relinquished control and the current management of these sites ceased

4.5 Site sensitivity

The paucity of comparable historical data for the three sites under consideration, in conjunction with the extremely limited time available to conduct field surveys to obtain new quantified objective data, renders ranking of the sites a difficult task. Below we discuss the findings of our brief survey and additional desktop assessment in relation to the analysis reported by Picker (2007) and use these to give a ranking of the sites based on current information.

While Picker’s (2007) analysis suggested that the Duynefontein site had a high overall invertebrate diversity, and this is supported by the limited ant diversity survey carried out here, the butterfly desktop analysis suggests that this site has the lowest butterfly diversity of the three sites. Apart from the very slight possibility of one potential RD butterfly (*Chrysoritis dicksoni*), there does not appear to be any reason to disagree with Picker’s conclusion that while diverse, the site was unlikely to support many rare or relictual species; in combination with the low predicted butterfly diversity we feel that this site should rank as the lowest of the three in conservation value and sensitivity.

While we were unable to confirm the presence of any of the predicted rare, endemic or relictual species the discovery of a probably new mygalomorph spider species and the higher predicted butterfly diversity than Duynefontein leads us to consider Bantamsklip as of higher sensitivity.

The combination of high butterfly and ant diversity (including at least two new and one rare and restricted species) at Thyspunt, which contrasts quite strongly with Picker's (2007) relatively low overall diversity score for this site, as well as the relictual Onchyophoran species found, indicate that the site does have significant conservation value. We therefore rank it as of higher sensitivity than Duynefontein, and only marginally lower than Bantamsklip, which is ranked higher due to both the discovery of a possibly new ant and a probably new trapdoor spider species and the much higher predicted diversity of rare and relictual species. More detailed surveys of the sites might widen the gap between Bantamsklip and Thyspunt if further significant species in the groups predicted by Picker (2007) for Bantamsklip are confirmed.

Our ranking of the three sites in order of increasing sensitivity is thus:

1. Duynefontein;
2. Thyspunt; and
3. Bantamsklip.

4.6 Potential impacts

From an invertebrate conservation perspective the most important potential **negative** impacts identified at all three sites were 1) the direct destruction of habitats and local populations of important invertebrates, including new and potentially new species, within the development footprint, 2) the wider impact of artificial lighting on invertebrate populations in the surrounding ecosystems and 3) the potential for alien invasive species to become established as a result of site disturbance and importation of materials and equipment. While the intensity of these impacts, and in particular the degree to which cumulative impacts could affect the surrounding communities, may differ somewhat between sites, the overall significance rating (calculated by weighting the significance ratings as High = 3, Medium = 2, Low = 1 and summing these for unmitigated impacts for each site) is very similar across all three sites (Duynefontein 31, Bantamsklip and Thyspunt both 32). The similarity is largely due to the lack of detailed information on the presence or absence of Red Data invertebrate species and other invertebrates of significance, which resulted in the significance of impacts being judged mainly on their impacts on invertebrate diversity as a whole. Most of the identified impacts can be avoided or reduced substantially, but the significance of some remains high or medium despite mitigation.

A more substantial difference between sites is seen in the assessment of potential **positive** impacts of the NPS; here the fact that the Duynefontein site already enjoys substantial benefits under the management of Eskom means that of all the sites it would experience the least improvement in its status if the NPS was sited there. Conversely, both Bantamsklip and Thyspunt would benefit substantially from formalisation of their protected status and the guarantee that Eskom's management would continue in the long term. Given the relatively low significance of most potential negative impacts if these are correctly mitigated, it is probable that construction of the NPS at either of these sites would have a net positive impact on invertebrate communities, and an argument could be made in favour of constructing a second NPS at a different site from the first, in order to increase the net positive impact at a regional/national level (constructing a second NPS at either site, as at Duynefontein, would have only negative impacts due to the additional area transformed, and no positive impacts since these would already have been achieved when the first was built).

5 MITIGATION MEASURES

It is very important to note that the impacts of proposed mitigation on the project as a whole, and the construction process in particular, should be assessed before putting the project out to tender, as implementation of mitigation measures can often significantly increase the cost and duration of construction. If not addressed in advance, this may result in unfair (real or perceived) penalties being imposed on the contractors; this in turn often results in poor compliance with EMP conditions. If this is not done, it is recommended that Eskom should remain open to renegotiation of costs and implementation deadlines if these are significantly affected by mitigation measures imposed in the EMP. Failure to do so may increase the risk of non compliance with the EMP conditions, with consequent costs to the environment.

5.1 Recommended mitigation measures for the Duynefontein, Bantamsklip and Thyspunt sites

Recommended mitigation measures for each potential impact identified in Section 3 are presented below. Please note that in many instances the impacts identified will overlap to a large degree with those identified in other specialist reports, and where suggested mitigation options differ between specialists, further discussion may be necessary. In cases where mitigation measures most effective for one aspect of the environment may conflict with mitigation measures appropriate for another (e.g. light pollution), a compromise option will need to be developed. In some cases mitigation measures, while of great importance from an invertebrate perspective, would be best formulated by specialists in other disciplines, and for these only very brief indications of some possible methods are given here. Such impacts, which we feel are of significance to invertebrate conservation, but for which we do not feel qualified to indicate comprehensive mitigation are indicated by a # symbol.

It should also be noted that although mitigation should in all cases result in a reduction in impact intensity, extent, duration, probability or reversibility, the coarse classification of consequence and significance levels applied often means that there is no resulting change in these ratings. This should not be taken as an indication that the mitigation recommended is of no consequence and can therefore be disregarded either at the level of decision-making or project implementation.

Mitigation for all three sites has been presented together here, as in most cases the general principles are identical for all sites. Where site-specific differences in approach for mitigation of a particular site are required, this is indicated. The phases during which the impact is expected, and hence mitigation required, are also indicated. Where a phase is omitted this is because no significant impact is predicted during this stage.

5.1.1 Mitigation of direct habitat destruction

This impact can be partially avoided and reduced to an extent by careful planning of construction activities.

Mitigation objective: minimise extent and intensity of habitat transformation during and after construction.

Construction phase:

- Restrict ***all development activities*** to the recommended areas:
  - At Duynefontein this is immediately adjacent to the KPS on the northern side,
  - At Bantamsklip this is as far north and east as possible within the EIA corridor (modified as per Figure 22),
  - At Thyspunt, this is in the central portion of the EIA corridor.
- Clearly demarcate the entire development footprint prior to initial site clearance and prevent construction personnel from leaving the demarcated area; and
- Fence off the entire development footprint and institute strict access control to the portions of the owner-controlled property that are to remain undisturbed as soon as possible after initial site clearance and ***prior to any further construction operations commencing***.

Operational phase

- Control all access to undeveloped portions of the property and ensure that it is used for non-destructive recreational and/or educational purposes only.

Decommissioning phase

- Dependant on decommissioning process followed, if demolition of the structures is to be carried out, then all recommendations applying to the construction phase would also apply here.

5.1.2 Mitigation of indirect habitat alteration / degradation by changes in groundwater regime

Mitigation objective: insignificant alteration of natural wetland ecosystems and minimal creation of artificial wetlands at the expense of other ecosystems.

All phases

- Restrict development to the recommended areas as indicated in section 5 of the Wetland Ecosystems specialist report (Day 2009);
- Take all necessary precautions to ensure that construction activities do not alter natural ground and surface water flows in areas identified as sensitive in the freshwater specialist report (Day 2009).

5.1.3 Mitigation of habitat fragmentation

This impact can be avoided to a significant extent by careful layout planning, and further reduced by choice of barriers that offer little impediment to the movement of small organisms.

Mitigation objective: insignificant impact on natural movement of invertebrates on the owner-controlled property.

All phases

- No solid perimeter walls should be erected. Fences should offer as little obstruction as possible to movement of both terrestrial and flying insects and other invertebrates. In general mitigation applicable to fencing that is suitable for vertebrates (see fauna report) will be more than adequate for invertebrates.
- Utilise existing roads where possible, minimise the number of access roads and align these so as to allow movement of organisms along natural corridors; where this is not possible options such as raising the road surface to allow movement to continue unhindered beneath the road e.g. *via* multiple culverts should be considered. As far as possible use of different access routes during construction and for permanent access during the operational phase should be avoided.

5.1.4 Mitigation of reduction in populations of rare / threatened / protected species

This impact cannot be entirely avoided, but can be reduced to an extent by minimising the development footprint and reducing other project-related impacts as indicated below.

Mitigation objective: minimise loss of individuals of rare or protected invertebrate species.

Construction phase

- All mitigation measures listed under *Mitigation of light pollution* and *Mitigation of road mortality*
- All mitigation measures listed under *Mitigation of direct habitat destruction*

Operational phase

- All mitigation measures listed under *Mitigation of light pollution* and *Mitigation of road mortality*

All phases

- Rescue and relocation is generally not recommended for invertebrate species for a number of reasons:
  1. Uncertainties regarding the suitability of the receiving environment for the relocated organisms;
  2. Uncertainties regarding potential negative impacts of the translocated individuals on the receiving environment due to either the carrying capacity of a naturally occurring species being exceeded or a new species potentially harmful to the ecosystem being introduced; and
  3. Low success rate worldwide of translocation attempts.

5.1.5 Mitigation of soil and water pollution

This impact can largely be avoided by strict adherence to EMP conditions including measures indicated below.

Mitigation objective: insignificant effect on soil and water quality.

Construction phase

- Ensure that all construction vehicles are inspected for oil & fuel leaks regularly and frequently, and that any vehicle showing signs of leaking is serviced immediately;
- Servicing of vehicles must occur in adequately bunded areas;
- Place drip-trays filled with sand under all parked construction vehicles and regularly dispose of any contaminated sand in an appropriate waste disposal site;
- Ensure that refuelling stations on site are constructed (e.g. on a concrete apron) so as to prevent spillage of fuel or oil onto the soil, and put in place measures to ensure that any accidental spillages can be contained and cleaned up promptly. All soil contaminated by accidental spillage should be removed from the site and properly disposed of;
- Ensure that all waste is properly disposed of and removed from the site; and
- Sewage should either be treated in a suitable plant or preferably removed from the site for treatment elsewhere

Operational phase

- Ensure that all waste is properly disposed of and removed from the site; and
- Sewage should be treated in a suitable plant and the effluent properly disposed of so as to avoid alteration of nutrient status of the site

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Decommissioning phase

- Mitigation will be dependant on method of decommissioning used, and requirements may be similar to the construction phase, but this cannot be determined at present.

5.1.6 Mitigation of dust pollution

This impact can largely be avoided by adherence to standard dust control principles; a comprehensive management and monitoring programme has been provided for the construction phase in the Air Quality Impact and Climatology Assessment Study (Airshed Planning Professionals 2009) and it is to be expected that if these controls are implemented, the impacts of dust pollution on invertebrate populations would be mitigated to a large degree.

Mitigation objective: insignificant impact of dust on invertebrate populations in surrounding ecosystems.

Construction phase

- Implement management as recommended in section 4.2.1 of the Air Quality Impact and Climatology Assessment Study (Airshed Planning Professionals 2009).
- Do not use raw sea water for dust control; only fresh water or desalinated sea water should be used.

Operational phase

- No mitigation should be necessary during the operational phase.

Decommissioning phase

- Mitigation will be dependant on method of decommissioning used, and requirements may be similar to the construction phase, but this cannot be determined at present; the Air Quality Impact and Climatology Assessment Study (Airshed Planning Professionals 2009) does not provide specific mitigation for decommissioning but notes that dust generation would occur and would require management and control.

5.1.7 Mitigation of light pollution

This impact can in theory be entirely avoided by elimination of all external lighting. In practice some external lighting is inevitable, especially during the construction phase, but the impacts of this can probably be reduced by well over 90% if recommended light sources and fittings are used.

Mitigation objective: insignificant level of deaths of invertebrates at external light sources and no measurable impact of light pollution on surrounding invertebrate populations.

Externally visible lighting should be kept to an absolute minimum, and wherever possible long-wavelength light sources (e.g. orange) should be used:

- Internal lighting should as far as possible be shielded by blinds, curtains or by eliminating outward-facing windows in building designs, to prevent spillage of light into the surrounding natural environments.
- If external lighting of structures is essential (e.g. for security reasons), light sources should be directed inward so as to light up the structure and result in this becoming a large diffuse light source, rather than having bright point sources directed outward into the natural environment. The current external lighting at Koeberg Power Station is a good example of how this should not be directed.
- Long-wavelength light sources should be used (at least 550 nm, preferably longer than 575 nm), preferably low-pressure sodium vapour, or yellow LEDs, as these result in very low disturbance of insect populations. Less preferable, but still better than mercury vapour or halogen lamps, would be high pressure sodium vapour or warm white LEDs. LED options, while initially more costly, may prove more economical and environmentally friendly in the long term, as a 20-year life span at 12 hours usage per day is achievable, with efficiency comparable to fluorescent lighting. Another alternative is to use ultraviolet (UV) filters which can reduce insect attraction to high pressure mercury vapour lamps to below that of high pressure sodium vapour lamps. Fluorescent lights, including compact versions, should **not** be used outdoors, as a significant amount of UV light is emitted by these, and this is highly attractive to insects.

Note that mitigation of light pollution in terms of invertebrate and vertebrate populations may in some cases be in conflict with measures appropriate for mitigation of visual impact from a human perspective (e.g. yellow lighting is NOT recommended for the latter, as human eyes are particularly sensitive to this part of the spectrum). It is therefore recommended that further consultation be undertaken with the relevant specialists to provide a coordinated mitigation plan that avoids or minimises potential conflict. One point of complete agreement between all of these disciplines is that minimal (preferably zero) use of external lighting is ideal.

During the construction phase the requirements for mitigation of light pollution from an invertebrate perspective may not be entirely in conflict with construction requirements, as the low pressure sodium vapour lighting recommended produces a light of a wavelength to which the human eye is particularly sensitive. Optimum lighting for construction work may thus be attainable without undue impact on invertebrate populations. This may not, however, be ideal from a visual impact perspective, but if lighting is directed inward the visual impact for humans would be minimised.

The complexity of the issues surrounding external lighting may lead to compromises and so two levels of mitigation have been evaluated in the assessment tables:

- Partial mitigation, where suboptimal light sources (e.g. high pressure sodium vapour) or relatively large amounts of ideal (e.g. low pressure sodium vapour) light sources are used and
- Full mitigation, where minimal or no external lighting is used and such lighting as is used is of the ideal type.

The extent to which these alter the significance of the impact of artificial lighting differs substantially. An additional complicating factor in the case of an NPS is that security measures required in terms of the National Key Points Act are likely to conflict substantially with the recommendations made here. The extent of this conflict will become apparent only after the required security measures have been set out. Further consultation between relevant specialists and the engineering team at this stage will therefore be required.

5.1.8 Mitigation of increased radiation levels

Historical data from Koeberg suggest that this impact can be largely avoided and substantially reduced.

Mitigation objective: no measurable accumulation of radiation in individuals of invertebrate populations in the surrounding areas.

Mitigation measures:

Operational phase:

- Ensure that correct operating procedures and safety precautions are strictly adhered to; this is clearly a complex issue that cannot be adequately addressed here.

Decommissioning phase:

- Dependant on decommissioning procedure; ensure that correct operating procedures and safety precautions are strictly adhered to; this is clearly a complex issue that cannot be adequately addressed here.

5.1.9 Mitigation of road mortality

This impact cannot be entirely avoided, but can be substantially reduced.

Mitigation objective: minimisation of road mortality impacts on invertebrate populations in the surrounding areas.

Mitigation measures:

All phases

- Institute strict speed limits on the site including the owner-controlled conservation area (recommended maximum – 40 km/hr) and construct speed humps / rumble strips to enforce these speed limits.

5.1.10 Mitigation of increased risk of fire

This impact is difficult to avoid entirely, but it can be reduced as evidenced by historical records from Koeberg.

Mitigation objective: no increase in frequency of fires in the areas surrounding the NPS development.

Mitigation measures:

Construction phase

- Institute strict control over cooking fires during construction period; if possible prevent use of such fires altogether;
- Maintain proper firebreaks around entire development footprint;
- Educate construction workers regarding risks and correct disposal of cigarettes.
- Allow smoking only at designated zones, which should be well within the footprint boundary, and institute strict control with harsh penalties for non-compliance;

Operational phase

- Maintain proper firebreaks around entire development footprint;
- Educate employees and visitors regarding risks and correct disposal of cigarettes.

5.1.11 Mitigation of spread of alien invasive invertebrate species

Mitigation objective: no invasion of the NPS sites and their surroundings by alien species.

Mitigation measures:

All phases, most importantly the construction phase

- Institute strict control over materials brought onto site, which should be inspected for potential invasive species and / or steps taken to eradicate these before transport to the site. Two possible approaches are
    - o a visual inspection of all materials, particularly those that have been stockpiled in high-risk locations, for presence of invasive species and

apply topical control (e.g. direct spraying with low residual insecticides) when necessary; and
    - routine fumigation or spraying of all materials with appropriate low-residue insecticides prior to transport to or in a quarantine area on site. The second option requires less highly trained personnel, but would probably result in much higher usage of pesticides.
- Rehabilitate disturbed areas as quickly as possible to reduce the area where invasive species would be at a strong advantage and most easily able to establish;
- Institute a monitoring programme to detect alien invasive species;
- Institute an eradication / control programme for early intervention if invasive species are detected, so that their spread to surrounding natural ecosystems can be prevented (see Appendix 7).

Monitoring programmes and control measures should be developed with reference to *inter alia* information provided by the IUCN SSC Invasive Species Specialist Group (http://www.issg.org/).

5.1.12 Mitigation of invasion of land by employment seekers

Construction phase

- Encourage local municipalities to enforce bylaws relating to occupation of land
- Use public awareness campaigns to reduce unrealistic expectations of employment opportunities

5.1.13 Mitigation of cumulative impacts

Avoidability of cumulative impacts is dependant largely on avoidance of each impact at the project level. Many of the impacts contributing to cumulative impacts are avoidable or reducible to a large degree, such that the overall significance ranking for cumulative impacts can be reduced from High to Low despite the construction of several NPS projects at one site.

Mitigation objective: insignificant cumulative effect of project-related impacts.

Mitigation measures:

All measures indicated in sections 4.1.1 - 4.1.11

5.1.14 Enhancement of positive contribution to conservation by protection of owner-controlled property and prevention of further development within an exclusion zone

As a positive impact, it is desirable to ***increase*** the extent, intensity and duration of this impact; all of which are probably achievable.

Mitigation objective: enhanced positive contribution to conservation by management of non-developed portions of the proposed NPS sites as reserves.

Mitigation measures:

- Institute strict control over access to the undeveloped portions of the proposed sites, especially during the construction phase;
- Plan the layout of the proposed NPS and especially additional units, so as to minimise the area removed from the potential reserve;
- Proclaim the undeveloped portions of the owner-controlled sites as protected areas;
- Continue and expand alien eradication and rehabilitation programmes;
- Investigate the possibility of expanding the reserve area by purchasing adjoining properties and incorporating these into the protected area; and
- Consider the possibility of constructing a single NPS at each of the proposed sites, rather than three stations at a single site; this would minimise cumulative impacts while maximising the positive effects of reserve management.

5.1.15 Recommended monitoring and evaluation programme

Recommended monitoring of impacts only of mitigation measures specific to invertebrates is suggested here. Where suggested mitigation falls more appropriately under a different discipline (e.g. dust would be best dealt with by the air quality specialist), despite its significance for invertebrate populations, the relevant specialist would be better able to determine appropriate monitoring methods and frequency and such recommendations have been made in other specialist reports.

All monitoring programmes to be implemented must be built into the EMP for the Nuclear 1 project, and auditing of the monitoring programmes must form part of the normal ongoing EMP audit process throughout the life of the project from construction, through operation and decommissioning until closure.

Table 5.1: Recommended invertebrate impact monitoring programmes for all sites

Recommended monitoring programme	Duration of monitoring	Reporting frequency	Management objectives
1) Invertebrate mortality caused by external lighting	Life of project: commence prior to construction to obtain baseline, continue throughout construction and operational phases	3-monthly until target reached, annually thereafter	Reduction of light-induced mortality to insignificant levels; no measurable impact of light pollution on surrounding invertebrate populations.
2) Invasion by alien invertebrate species	Life of project: commence prior to construction to obtain baseline, continue throughout construction and operational phases.	Annual	Detection of establishment of alien species to allow early intervention in terms of eradication / control.
3) Diversity and community structure of selected indicator groups such as ants and leafhoppers	Commence prior to construction to obtain baseline values and continue throughout construction (including post-construction rehabilitation of disturbed areas) and decommissioning phases.	Annual	Diversity and species composition of selected indicator taxa return to baseline values after successful rehabilitation.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Need for additional surveys

The extreme time and seasonal constraints on the surveys carried out introduced uncertainty to the sensitivity assessments and provided limited data, covering a very small subset of invertebrate taxa, on which to base selection of preferred areas within each site for development from a terrestrial invertebrate conservation perspective (see section 1.2.8).

Confirmation that the surveys to date have not been sufficiently detailed comes from the fact that on both occasions that general invertebrate surveys have been carried out, specimens of new, potentially new and/or rare species not previously recorded have been found at each of the sites, despite these visits having been very brief and the surveys relatively superficial. There is clearly much that is not known about the invertebrate fauna of these sites. Given the patchy distributions, apparently not linked to observable patterns of vegetation or soil type, of some of these important species, far more comprehensive surveys are clearly required to provide detailed sensitivity assessments.

In order to increase confidence in the sensitivity ranking, identify specific impacts in more detail, provide more valid input into the selection of least sensitive areas within sites and to provide baselines for monitoring of rehabilitation, it is strongly recommended that further invertebrate surveys be conducted. These surveys must be done timeously so that should major alterations to the conclusions regarding impacts on invertebrate communities result, there is still time to incorporate any necessary changes into the project design.

Investigation of potential impacts on the terrestrial invertebrate fauna should cover a broad spectrum of taxonomic groups with differing ecological roles and should ideally be carried out over at least a full active season. This would allow field surveys to be carried out at least during spring/early summer, mid/late summer and late summer / early autumn. Butterfly surveys should cover the months of October, November and February as an absolute minimum. If Bantamsklip is selected for NPS construction the status of the Almeida Copper Butterfly population at Bantamsklip should be investigated. In this instance the surveys should also include a component specifically aimed at finding male specimens of the probably undescribed trapdoor spider species (*Spiroctenus* sp.) found at Bantamsklip so that its status can be verified, as well as surveys of its distribution on and around the Bantamsklip site to aid in confirming preferred locations for NPS development and ensuring the conservation of the species. Full surveys of the ant fauna of any of the sites selected should be carried out prior to construction to provide a baseline for monitoring both of rehabilitation (especially of spoil stockpile areas) and potential invasion by alien ant species, as well as providing input to detailed sensitivity assessments and assessing the conservation status of the new species identified from each site. Leafhoppers would also provide effective monitoring of rehabilitation progress and should also be surveyed thoroughly prior to construction to provide baseline data. Other taxonomic groups should also be considered for inclusion in these monitoring programmes (see section 6.5).

6.2 Potential impacts and mitigation

The most significant potential **negative** impacts on invertebrates resulting from construction of the proposed NPS would be:

1. Loss of habitat for and populations of rare or threatened, as well as new and potentially new invertebrate species within the development footprint
2. Death and disruption of normal movement patterns of invertebrates caused by external lighting
3. Invasion of natural invertebrate communities by alien invasive species such as the Argentine ant (*Linepithema humile*) and alien land snail (*Thebe pisana*).

The first, and more particularly the second, of these impacts can be avoided and/or reduced to a significant degree by careful planning of the proposed development layout and lighting, especially in the construction phase, while the third is more difficult to control and will require rigorous control of materials and equipment being brought onto the site.

The most significant potential **positive** impact on invertebrates resulting from construction of the proposed NPS would be continued and enhanced protection of the invertebrate communities on the Eskom-owned properties, especially if surrounding properties are purchased to enlarge the reserve area. We feel that the positive benefits of managing these sites as reserves could substantially outweigh the negative impacts of NPS construction on what would amount to at most about 20% of the area of each site.

6.3 Sensitivity of sites

Conclusions regarding the sensitivity of the sites from the perspective of terrestrial invertebrate conservation must be regarded as tentative, due the survey limitations (see section 1.2.8). Although additional surveys might result in significant discoveries of important invertebrate species that would alter the sensitivity assessments of the three sites, we feel that such finds are more likely at Bantamsklip and Thyspunt than at Duynefontein. The small difference in assessed sensitivity of Bantamsklip and Thyspunt means that additional findings are more likely to alter the assessment of these sites with respect to each other. This would however not alter the overall conclusion that both sites are significantly more sensitive than Duynefontein and thus have both greater sensitivity to negative impacts and more to gain from positive impacts of the proposed NPS.

Thus from the perspective of the terrestrial invertebrate groups investigated, development at the Duynefontein site would have the least negative impact and at Bantamsklip the most. Conversely, due to the current status of the Duynefontein property, this site would also have the least to gain from positive impacts in terms of site protection and management, and both Bantamsklip and Thyspunt stand to gain far more from continued or enhanced management as conservation areas under Eskom stewardship.

Provided adequate mitigation of both negative and positive impacts is guaranteed, and further studies are carried out to refine assessment of preferred locations within the site, the site which from an invertebrate conservation perspective would benefit most from the Nuclear 1 NPS development would thus be Bantamsklip, with Thyspunt ranked a close second and Duynefontein third.

It should however be borne in mind that the above assessment is based on the assumption that a nuclear accident resulting in significant radioactive contamination of the environment will never occur. The risk of potentially disastrous negative impacts on the surrounding invertebrate communities would need to be balanced against the positive impacts described above. Although the reactor designs under consideration should be able to ensure that there is virtually zero risk of major radioactive release, if an accident risk assessment concludes that such an event does have a significant probability of occurrence, the order of the sites would probably be reversed, with Duynefontein being the site where the consequence of such an event would be least significant from the perspective of invertebrate conservation.

6.4 Preferred NPS positioning

The following conclusions regarding preferred NPS footprints are again tentative due to limitations of the initial surveys (see section 1.2.8). However, the additional site inspections carried out in December 2009 / January 2010 did allow confirmation that, in the case of Bantamsklip and Thyspunt, whatever the sensitivity of the habitats within the proposed footprint areas, there is sufficient scope for mitigation by protecting adequate amounts of similar habitat elsewhere on the site. At Duynefontein, while similar habitat outside the proposed footprint area is very limited, we are confident that the majority of invertebrate species within the proposed footprint will be adequately represented in other habitat types on the site. For all three sites, the following recommendations regarding preferred footprints are however made on the express understanding that thorough invertebrate surveys of the site(s) selected for NPS construction will be carried out prior to commencement of any construction activities to confirm that no unique species or communities will be threatened. These surveys will also be needed to contribute information to final selection of spoil stockpile and disposal sites.

We conclude that an NPS development at Duynefontein would have the least disruptive effect on conservation of the Koeberg Nature Reserve if it was positioned as close as possible to the existing KPS (see Figure 21), and that such positioning would not have unacceptable impacts on important invertebrate populations and communities.

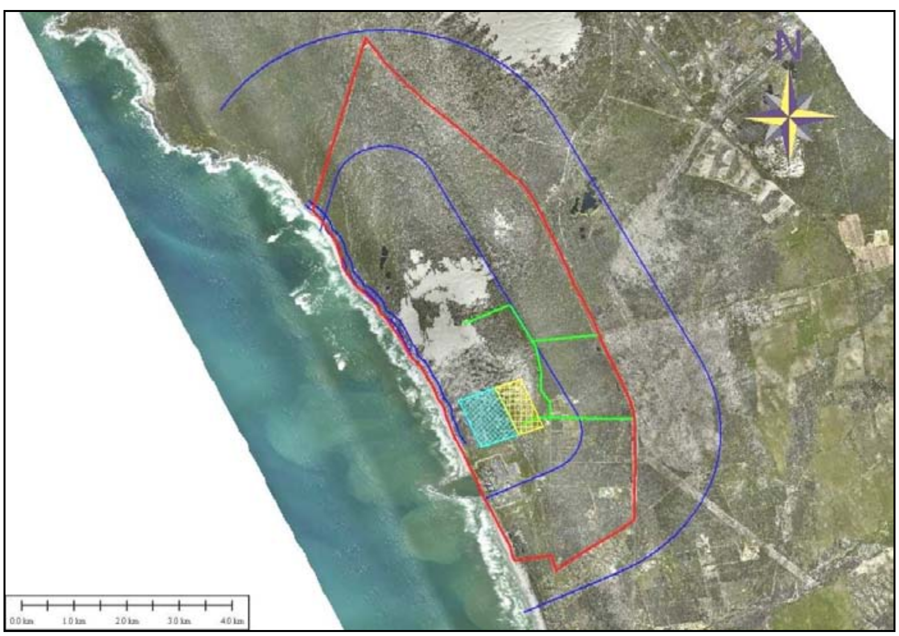

Figure 21: Recommended location for NPS (turquoise diagonal cross-hatching) and HV yard (yellow vertical cross-hatching) on the Duynefontein site (red outline). 800 m and 3000 m lines from EIA are shown in blue.

At Bantamsklip the construction of the NPS would probably have the least impact on important terrestrial invertebrate communities if it was positioned as far to the east of the site and as far from the coast as possible; the 800m from EIA line in Figure 22 has been moved inland as far as the provincial road in order to minimise impacts on Limestone Fynbos habitats close to the shore.

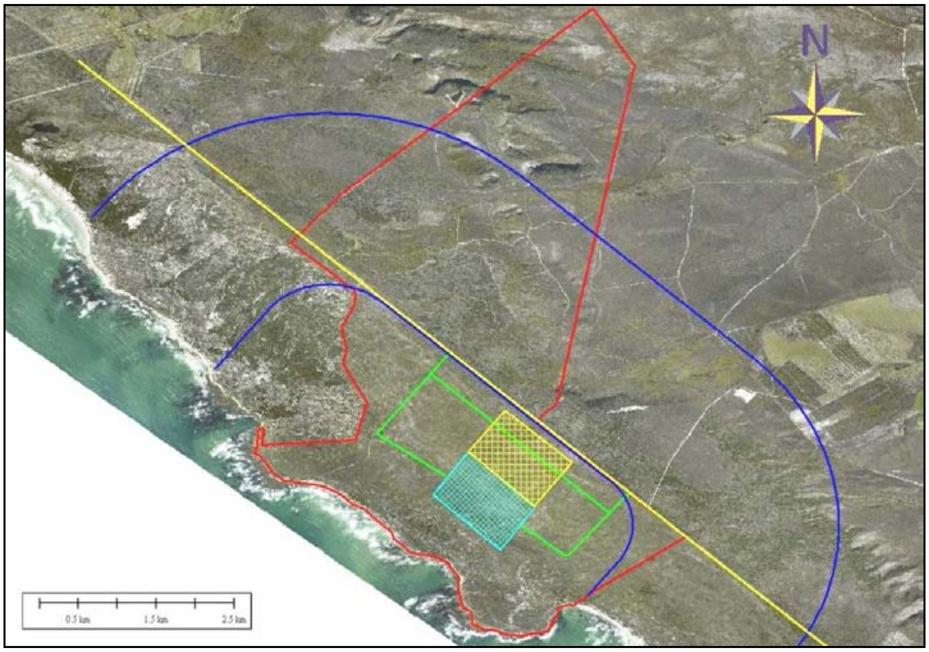

Figure 22: Recommended location for NPS (turquoise diagonal cross-hatching) and HV yard (yellow vertical cross-hatching) on the Bantamsklip site (red outline). 800 m and 3000 m lines from EIA are shown in blue.

At Thyspunt, while the consensus preferred footprint area from other specialist studies falls within an area in which several significant invertebrate species were found, all of the habitats identified within this area are adequately represented elsewhere on the site. In some instances the habitat areas outside the proposed footprint area are more extensive and are less impacted by invasive plant species than those within the footprint. The suggested area within which the NPS footprint should be located at Thyspunt is indicated in Figure 23; the suggested location of the HV yard is also indicated and it is recommended that this be placed in the northern portion of the HV corridor in order to minimise impacts on untransformed Sandstone Fynbos habitat.

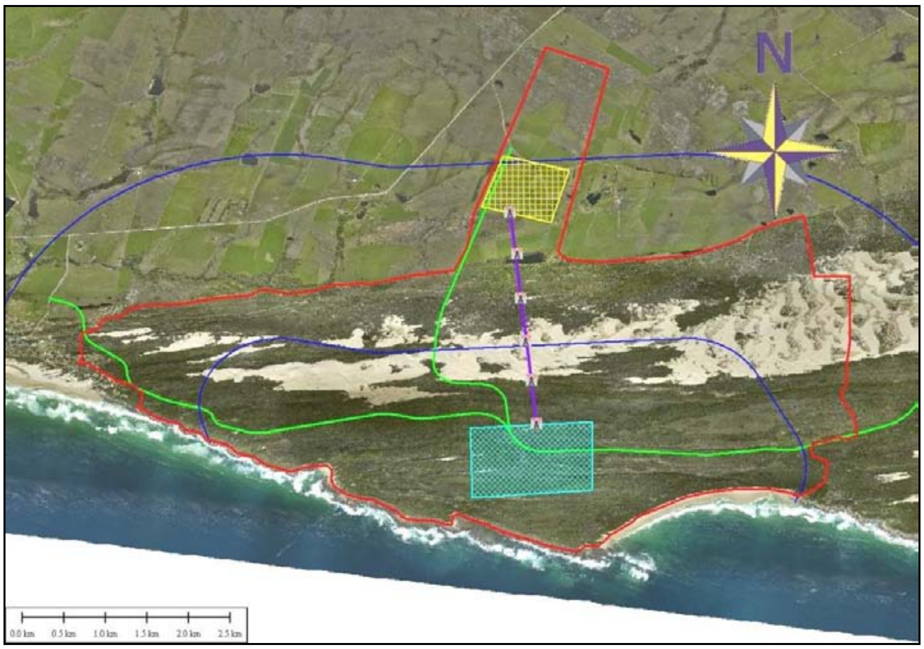

Figure 23: Recommended location for NPS (turquoise diagonal cross-hatching) and HV yard (yellow vertical cross-hatching) on the Thyspunt site (red outline). Recommended route for the 132kV power line is also indicated. 800 m and 3000 m lines from EIA are shown in blue.

6.5 Recommended monitoring

Monitoring of the impacts of externally visible lighting on the invertebrate communities is recommended, as well as monitoring of the ant and mollusc communities in the vicinity of the development footprint to enable early detection and eradication of alien invasive species. Monitoring of invertebrate communities, particularly ants and leafhoppers, but possibly also other taxa (e.g. dung beetles, fruit chafer beetles, ground beetle, true bugs, grasshoppers, millipedes and butterflies) as recommended by the external reviewer, is recommended in evaluating the progress of rehabilitation of areas disturbed during the construction process.

7 ACKNOWLEDGEMENTS

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Specialist signature	
Date	

9 APPENDICES

Appendix 1: Predicted butterfly diversity at the Duynefontein, Bantamsklip and Thyspunt sites, with coordinates of species observed in August/September 2008

FAMILY/GENUS	SPECIES	PROBABILITY OF OCCURENCE			CO-ORDINATES		FOOD PLANTS	HABITAT TYPES
NYMPHALIDAE		**Duynefontein**	**Bantamsklip**	**Thyspunt**	**S**	**E**		
DANAINAE								
Danaus	*chrysippus orientis*	0.95	0.8	0.95			*Asclepias* spp., *Ceropegia* spp., *Cynanchum* spp. (T), *Huernia* spp.	All veld types
Amauris	*echeria echeria*			0.5			*Tylophora* spp., *Cynanchum* spp. (T)	Forest margins
SATYRINAE								
Melanitis	*leda helena*			0.2			*Setaria* spp., *Pennisetum clandestinum* (D,B,T), *Cynodon dactylon* (B)	Coastal bush
Bicyclus	*safitza safitza*			0.5			*Ehrharta* spp. (D,B,T)	Coastal bush
Aeropetes	*tulbaghia*		0.1				*Ehrharta* spp. (D,B,T), *Pennisetum clandestinum* (D,B,T), *Hyparrhenia hirta*	Rocky hillsides
Dira	*clytus clytus*	0.99	0.99	0.99			*Panicum deustum* (T), *Ehrharta* spp. (D,B,T), *Stenotaphrum secundatum* (T), *Stipa* spp.	Any grassy area
Torynesis	*mintha mintha*		0.2				*Merxmuellera* spp.	Rocky hillsides
Tarsocera	*cassina*	0.95	0.5				*Lolium* spp., *Brachyopodium distachyon*	Coastal sand dunes
Cassionympha	*cassius*		0.9	1	34^{0}10'40.1"	24^{0}41'26.5"	*Juncus* spp., *Pentaschistis* spp. (B,T)	Forest and bush margins
Melampias	*huebneri huebneri*	0.5	0.2				*Avena* spp., *Ehrharta* spp. (D,B,T)	Coastal fynbos
Pseudonympha	*magus*	0.5	0.5	0.8			*Ehrharta* spp. (D,B,T), *Cynodon dactylon* (B)	Any grassy patches
Stygionympha	*vigilans*			0.2			*Ischyrolepis* spp. (D,B,T), *Ehrharta* spp. (D,B,T)	Rocky hillsides
ACRAEINAE								
Acraea	*horta*	0.1	0.2	0.5			*Kiggelaria africana*	Forest margins
Hyalites	*rahira*		0.2	0.2			*Conyza* spp., *Persicaria attenuata*	Wetlands
CHARAXINAE								
Charaxes	*varanes varanes*			0.5			*Allophylus decipiens*	Forest margins
Charaxes	*pelias*		0.1				*Rafnia* spp., *Hypocalyptus* spp.	Rocky hillsides, hilltops
Charaxes	*brutus natalensis*			0.2			*Ekebergia capensis*	Forest margins
NYMPHALINAE								
Eurytela	*hiarbas angustata*			0.2			*10 Dalechampia capensis*	Forest margins
Hypolimnas	*misippus*		0.2	0.5			*Portulacaria afra*	Forest and bush margins
Precis	*archesia*			0.5			*Plectranthus* spp.	Forest and bush margins
Precis	*hierta cebrene*		0.2	0.5			*Barleria pungens*, *Chaetacanthus setiger* (T)	All veld types

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Vanessa	*cardui*	0.8	1	0.95	34°40'49.9"	19°33'25.5"	*Arctotheca calendula, Arctotis* spp., *Berkheya* spp.	All veld types
Antanartia	*hippomene hippomene*			1	34°10'39.0"	24°41'29.5"	*Laportea* spp., *Didymodoxa* spp.	Moist coastal forest
LYCAENIDAE								
LIPHYRINAE								
Aslauga	*australis*			< 0.01			Unknown	Coastal bush
MILETINAE								
Thestor	*protumnus protumnus*	0.5					Aphytophagous	Coastal fynbos
Thestor	*rossouwi*		0.5				Aphytophagous	Coastal fynbos
Thestor	*overbergensis*		0.5				Aphytophagous	Coastal fynbos
THECLINAE								
Leptomyrina	*lara*	0.5	0.8	0.8			*Cotyledon* spp., *Crassula nudicaulis*	Rocky hillsides, hilltops
Deudorix	*antalus*	0.5	0.5	0.5			*Bauhinnia* sp., *Schotia* spp.	Most veld types
Myrina	*silenus ficedula*			0.5			*Ficus* spp.	Rocky hillsides
Axiocerces	*croecus*			0.2			*Acacia* spp.	Grassy hillsides
Phasis	*thero thero*	0.9	0.5				*Melianthus major*, *Rhus* spp. (D,B,T)	Coastal fynbos
Argyrocupha	*malagrida maryae*		0.1				Unknown	Limestone fynbos
Aloeides	*thyra thyra*	0.8	0.5				*Aspalathus* sp.	Coastal fynbos
Aloeides	*pallida* subspecies		0.5	1			Aphytophagous	Grassy roadsides
Aloeides	*carolynnae aurata*		0.5				*Aspalathus* sp.	Limestone fynbos
Aloeides	*egerides*		0.2				*Aspalathus* sp.	Coastal fynbos
Aloeides	*margaretae*		0.2				*Aspalathus* sp.	Coastal fynbos
Aloeides	*pierus*	0.5	0.5	0.5			*Aspalathus* spp. (T)	Coastal fynbos & dunes
Aloeides	*aranda*	0.5	0.5	0.5			*Aspalathus* spp. (T)	Most veld types
Chrysoritis	*dicksoni*	< 0.01	0.05				Aphytophagous	Coastal renosterbos
Chrysoritis	*zeuxo zeuxo*		0.5				*Chrysanthemoides monilifera* (B,T)	Coastal fynbos & dunes
Chrysoritis	*zonarius zonarius*	0.5					*Chrysanthemoides incana* (D)	Coastal fynbos & dunes
Chrysoritis	*felthami felthami*	0.2	0.2				*Zygophyllum* spp. (D)	Coastal fynbos & dunes
Chrysoritis	*chrysaor*	0.2	0.5	0.5			*Cotyledon orbiculata*, *Zygophyllum* spp. (D)	Coastal fynbos & dunes
Chrysoritis	*palmus marguerita*e			0.2			*Chrysanthemoides monilifera* (B,T), *Berzelia intermedia*	Gullies, hillsides
Chrysoritis	*pyroeis pyroeis*	0.5	0.2				*Zygophyllum spp. (D)*	Coastal fynbos & dunes
Chrysoritis	*thysbe thysbe*	0.9	0.9				*Zygophyllum* spp. (D), *Chrysanthemoides* spp. (D,B,T), *Aspalathus* spp. (T)	Coastal fynbos & dunes
Chrysoritis	*whitei*			0.2			*Zygophyllum* spp.	Coastal fynbos & dunes

Chrysoritis	*osbecki*	1			33^{0}40'18.6"	18^{0}26'24.3"	*Zygophyllum* spp. (D), *Chrysanthemoides* spp. (D,B,T), *Aspalathus* spp. (T)	Coastal fynbos & dunes
Chrysoritis	*pan pan*	0.8					*Chrysanthemoides incana* (D)	Coastal fynbos
Chrysoritis	*nigricans nigricans*		0.2				*Zygophyllum* spp., *Thesium* spp.	Rocky hillsides, hilltops
LYCAENINAE								
Lycaena	*orus*		0.1				*Polygonum* spp., *Rumex* spp.	Coastal fynbos
Anthene	*definita definita*		0.5	0.5			*Allophyllus decipiens, Pappea capensis, Morella* spp. (B,T)	Forest and bush margins
Anthene	*otacilia otacilia*			0.2			*Acacia* spp., incl. aliens (B,T)	Coastal bush
Cacyreus	*lingeus*		0.2	1	34^{0}10'40.0"	24^{0}42'02.7"	*Leonotis leonurus, Mentha* spp., *Plectranthus* spp., *Salvia* spp. (T)	Forest and bush margins
Cacyreus	*tespis tespis*		0.8	0.8			*Geranium* spp., *Pelargonium* spp. (B,T)	Most veld types
Cacyreus	*marshalli*	0.5	0.5	0.5			*Geranium* spp., *Pelargonium* spp. (B,T)	Most veld types
Cacyreus	*dicksoni*	0.2					*Geranium* spp., *Pelargonium* spp. (B,T)	Coastal fynbos
Leptotes	*pirithous*	0.9	0.9	1	34^{0}10'40.0"	24^{0}41'27.0"	*Plumbago* spp., *Rhynchosia* spp., *Indigofera* spp. (T), *Vigna vexillata*, *Medicago sativa*	Most veld types
Leptotes	*brevidentatus*	0.8	0.8	0.9			*Plumbago* spp., *Rhynchosia* spp., *Indigofera* spp. (T), *Vigna vexillata*, *Medicago sativa*	Most veld types
Lampides	*boeticus*	0.5	0.8	0.9			*Crotalaria capensis*, other legumes	Rocky hillsides, hilltops
Tarucus	*thespis*	0.9	0.9	0.9			*Phylica* spp. (B)	Coastal fynbos
Lepidochrysops	*littoralis*		0.5				*Selago* spp.	Coastal fynbos & dunes
Eicochrysops	*messapus messapus*	0.8	0.8	0.8			*Thesium* spp.	Most veld types
Cupidopsis	*cissus*			0.5			*Eriosema* spp., *Vigna* spp.	Grassy hillsides
Zizeeria	*knysna*	0.8	0.9	0.95			*Tribulus terrestris, Zornia capensis, Oxalis corniculata, Medicago sativa*, *Trifolium* spp., *Oxalis* spp.	Any open grassy patches
Azanus	*jesous jesous*	0.2	0.5	0.5			*Acacia* spp., incl. aliens (B,T)	Acacia veld (incl. aliens)
PIERIDAE								
Colias	*electo electo*			0.95			*Medicago sativa*, *Trifolium* spp., other legumes	All veld types - migrant
Catopsilia	*florella*			0.95			*Sesbania punicea, Chamaecrista capensis*	All veld types - migrant
Eurema	*brigitta brigitta*			0.5			*Sesbania punicea, Chamaecrista capensis, Hypericum aethiopicum*	Any grassy patches
Eurema	*desjardinsii marshalli*			0.2			*Chamaecrista capensis, Hypericum aethiopicum*	Coastal bush
Colotis	*antevippe gavisa*			0.8			*Capparis sepiaria, Maerua* spp.	Forest and bush margins
Colotis	*evippe omphale*			0.9			*Capparis sepiaria, Maerua* spp.	Forest and bush margins
Colotis	*evagore antigone*			0.5			*Cadaba aphylla, Capparis sepiaria, Maerua* spp.	Forest and bush margins
Belenois	*zochalia zochalia*			0.5			*Capparis sepiaria, Maerua* spp.	Forest and bush margins

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Belenois	*aurota*	0.95	0.95	0.95			*Capparis sepiaria, Maerua* spp.	All veld types - migrant
Belenois	*creona severina*			0.8			*Capparis sepiaria, Maerua* spp.	All veld types - migrant
Belenois	*gidica abyssinica*			0.5			*Capparis sepiairia*	All veld types - migrant
Dixeia	*charina charina*			1	34°10'40.0"	24°41'27.0"	*Capparis sepiairia*	Coastal bush
Pontia	*helice helice*	0.5	0.5	0.9			*Heliophila* spp., *Lepidium* spp., *Sisymbrium capense*	All veld types - migrant
Pieris	*brassicae*	0.2	0.5				*Lobularia maritima, Rorippa nudiuscula, Chrysanthemoides monilifera* (B,T)	All veld types - migrant
Mylothris	*rueppellii haemus*			0.2			*Tapinanthus* spp.	Forest and bush margins
Mylothris	*agathina*	0.8	0.8	1	34°10'39.0"	24°41'29.5"	*Osyris compressa* (T)	Coastal bush
PAPILIONIDAE								
Papilio	*dardanus cenea*			0.5			*Vepris lanceolata, Clausena anisata* (T)	Forest and bush margins
Papilio	*demodocus demodocus*			0.9			*Calodendrum capense, Vepris lanceolata, Zanthoxylon capense* (T)	Forest and bush margins
Papilio	*nireus lyaeus*			0.8			*Calodendrum capense, Vepris lanceolata, Zanthoxylon capense* (T)	Forest and bush margins
HESPERIIDAE								
PYRGINAE								
Eagris	*nottoana knysna*			0.5			*Grewia occidentalis* (T), *Scutia myrtina*	Coastal bush
Eritis	*djaelaelae*			0.5			*Chaetacanthus setiger* (T)	Coastal bush
Eritis	*umbra umbra*			0.5			*Chaetacanthus setiger* (T)	Coastal bush
Spialia	*nanus*	0.5	0.5				*Hermannia* spp. (T), *Hibiscus* spp.	Coastal fynbos
Spialia	*diomus ferax*	0.5	0.8	0.8			*Hermannia* spp. (T), *Hibiscus* spp., *Pavonia* spp.	Forest and bush margins
Spialia	*spio*	0.1	0.5	0.5			*Hermannia* spp. (T), *Pavonia* spp., *Hibiscus* spp., *Lavatera arborea*	Rocky hillsides, hilltops
Spialia	*mafa mafa*	0.1					*Hermannia* spp. (T), *Hibiscus* spp.	Coastal fynbos & dunes
Gomalia	*elma*			0.5			*Abutilon sonneratianum*	Coastal fynbos & dunes
HESPERIINAE								
Zophopetes	*dysmephila*			0.5			*Phoenix* spp.	Coastal bush
Pelopidas	*thrax inconspicua*		0.2	0.5			*Imperata cylindrica* (T), *Ehrharta* spp. (D,B,T)	Forest and bush margins
Gegenes	*niso niso*	0.8	0.8	0.9			*Ehrharta* spp. (D,B,T), *Pennisetum clandestinum* (D,B,T), *Themeda triandra* (B)	Most veld types
PROBABLE TOTAL SPECIES COUNT		**23.1**	**28.2**	**42.6**				
RED LIST SPECIES PROBABILITY		< 0.01	0.15	< 0.01				

Note: endemic species are indicated by green text, Red Data species by red.

Appendix 2: Quantified butterfly sampling protocol used during March 2009 surveys

Step 1: Selection of areas in which the surveys take place.

The sites were sampled according to vegetation maps generated from shapefiles provided by the botany specialist (Barrie Low, Coastec). (At Bantamsklip and to a lesser degree Duynefontein it was noted that some refinement of these maps would result if more intensive vegetation surveys could be carried out). At Thyspunt in the case of mosaics of different vegetation types, recording will be intermittent as one passes through the boundaries.

Step 2: Periods during which the surveys take place

Surveys start at 9.00 am, weather permitting, and continue until 4.00 pm. Observations are recorded on a data sheet in half hour periods. (At Thyspunt a stop watch was commenced at the start of each half hour period and if the observer passes out of the vegetation type being surveyed the watch is stopped, and restarted when back into the correct vegetation type. The minutes spent actually recording in the correct vegetation type are thereby recorded for each half hour segment.)

Step 3: Assessment of weather conditions

Five weather components are recorded on a scale between 0 (worst) and 5 (optimum), with half point scores used if necessary.

C: Cloud cover

5 No clouds at all
4 1-20% cloud cover
3 21-40% cloud cover
2 41-60% cloud cover
1 61-80% cloud cover
0 80-100% cloud cover

H: Humidity

5 Severely humid conditions
4 "Heavy" humid conditions
3 Some humidity
2 Crisp
1 Very crisp such as a dry winter's day on the highveld or dry days in the desert areas.
0 A score of 0 will rarely be given for humidity.

P: Precipitation

5 no rain, hail or snow
4 very slight fog or a very slight and very brief drizzle during the survey interval
3 light rain for a brief period (less than 10%) of the survey interval
2 light rain for some part of the survey interval
1 light rain for more than 70% if the survey interval
0 rain, hail or snow for more than 90% of the survey interval

W: Wind

5 No wind or almost no wind

4 Light wind blowing from time to time
3 Fresh wind blowing from time to time
2 Fresh wind blowing almost continuously or continuously
1 Strong wind blowing with intervals
0 Strong wind or stormy wind blowing almost continuously or continuously

T: Temperature

5 Very hot, almost unbearable.
4 Hot to very hot conditions
3 Hot enough for the normal lepidopterist to wear only a shirt
2 A jersey or jacket can be worn without discomfort
1 Three layers of clothes are needed.
0 Freezing; it appears that the temperature is at or below freezing point.

Weather scores are added and the total multiplied by 4 to give an optimality score. A score of at least 16 is considered necessary to make a count worthwhile, although rain or extreme wind alone could on their own prevent meaningful observations, even if the score was more than 16.

Step 4: Count or estimate of the number of individuals encountered for each species

In each area selected for sampling, walk through the area at random, taking GPS readings at the start and end of each 30 minutes period. Record all the species seen with a count of the individual observations of each species. Where identification is in doubt, a voucher specimen is taken for later identification. A GPS position of any significant observations of rare or localised species is taken. Although the search is not spatially structured repetition should be avoided, and as much of the habitat as possible should be covered. Recounts may occur but can be minimised if the butterflies or moths that stay in an area are noted, and some individuals can be recognized by specific damage or wear on the wings, slightly aberrant individuals, individual colouration, or males and females. If the weather deteriorates to below 16 during the count, then the data obtained during the good period is kept and additional search effort is made on another day, preferably during the period not covered during the earlier day.

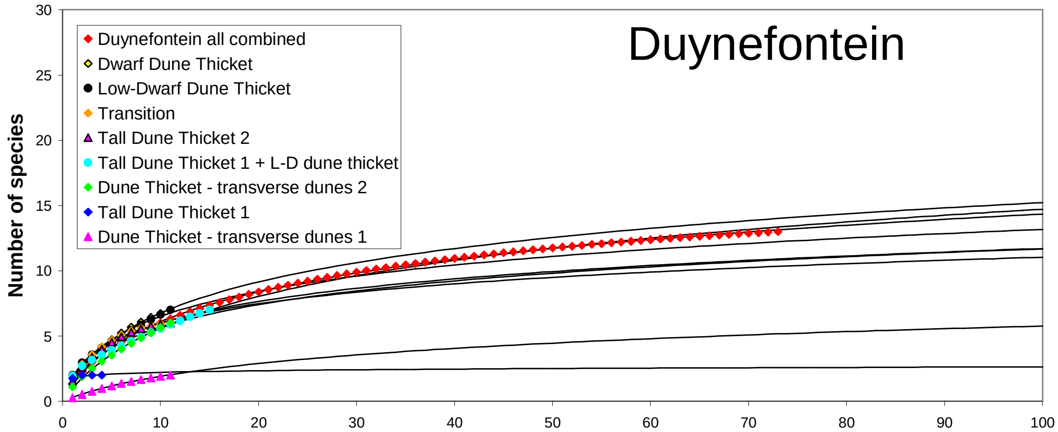
Appendix 3: Geographic distribution of the species or subspecies observed at the three study locations Duynefontein (Duy), Bantamsklip (Ban) and Thyspunt (Thy)

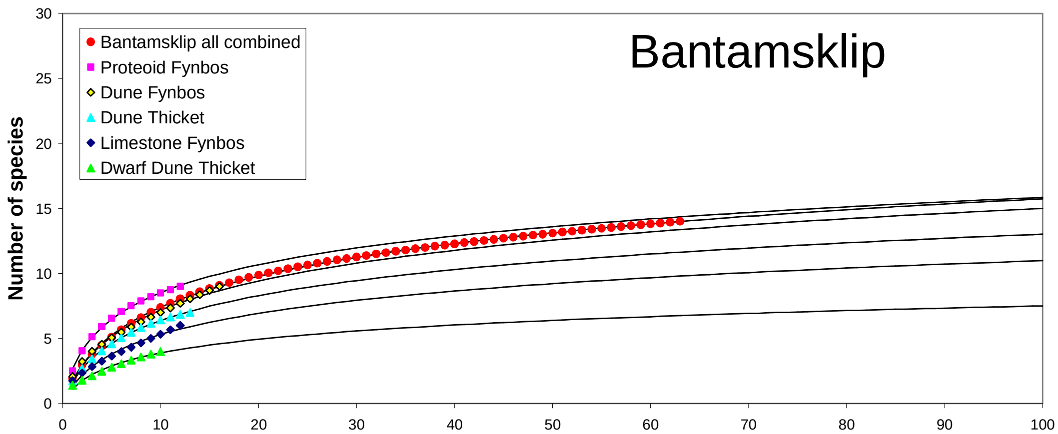
FAMILY/GENUS/ Species	Duy	Ban	Thy	Distribution
NYMPHALIDAE				
DANAINAE				
Danaus chrysippus orientis			1	Arotropical Region
SATYRINAE				
Dira clytus clytus			1	w Cape (Cape Peninsula) to E Cape Humansdorp
Torynesis mintha mintha		1		Cape peninsula across the Cape Flats to Riebeek-Kasteel and Sir Lowry's Pass, down to Cape Agulhas
Cassionympha cassius			1	From w Cape (Cape Peninsula) along eastern seaboard through E Cape to Kwazulu-Natal, eastern slopes of escarpment through Swaziland and Mpumalanga to Limpopo Province (Soutpansberg)
Pseudonympha magus			1	w Cape (Melkbosstrand) south to Cape Town, and along southern littoral, north to E Cape Stutterheim
CHARAXINAE				
Charaxes varanes varanes			1	Eastern side of South Africa (including Swaziland), into southern Mozambique and Botswana
NYMPHALINAE				
Precis hierta cebrene			1	Sub-Saharan Africa, western & southern Arabia and Socotra
Vanessa cardui	1	1	1	Cosmopolitan
Antanartia hippomene hippomene			1	W Cape (Knysna), E Cape (Amatola), n Kwazulu-Natal and Zululand (Eshowe)
LYCAENIDAE				
THECLINAE				
Leptomyrina lara	1			W Cape to E Cape, e Free State and Lesotho and N Cape and s Namibia
Phasis thero thero	1	1		From Cape Peninsula, north along coast to Lambert's Bay , East to Knysna
Aloeides thyra thyra	1	1		From Cape Peninsula, north-west to Lambert's Bay and east to Matjiesfontein
Aloeides pierus	1			W Cape (Cape Peninsula) to succulent Karoo in N Cape (Namaqualand); wide range of Nama Karoo over N. Cape, W Cape and E Cape, grassland in Free State
Aloeides almeida		1		Fynbos, Nama Karoo. From W Cape, Cape Peninsula and main Cape fold mountains, north to Ceres, east along Langeberg, Swartberg and parallel ranges such as Kammanassie and Tsitsikama, to E Cape Baviaanskloof
Chrysoritis felthami felthami	1	1		Coastal Fynbos in W Cape (Excluding Cape Peninsula), along west coast and coastal flats in Succulent Karoo to Hondeklip Bay, and south coast to Stilbaai area
Chrysoritis chrysaor	1		1	West coast of W Cape , in Nama Karoo of W Cape and E Cape (also in valley bushveld near Port Alfred), montane grassland of Kwazulu-Natal, Free State, s Mpumalanga, and Gauteng
Chrysoritis pyroeis pyroeis	1			Fynbos in W Cape, from Cape Peninsula north into Hawequas and Du Toit's Kloof Mountains, west coast

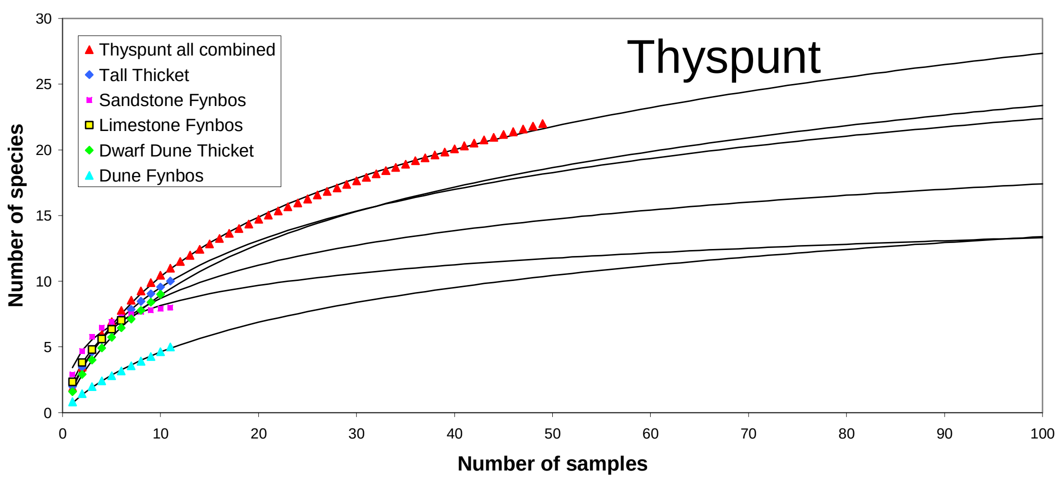
				Succulent Karoo to Hondeklip Bay (N Cape); also along south coast as far as Stilbaai
Chrysoritis thysbe thysbe		1		Cape peninsula to Mossel Bay
Chrysoritis thysbe thysbe f. osbecki	1			Melkbosstrand and up West Coast
LYCAENINAE				
Anthene definita definita		1		Eastern Africa from Uganda to South Africa (Cape) and recorded from Guinea, Cameroon & Zaire
Cacyreus tespis tespis		1		Generally at high elevations (except at the Cape) in Kenya, Uganda, Tanzania, Zaire, Rwanda, Burundi, Mozambique
Leptotes pirithous	1	1	1	Throughout Arabia, Africa, Malagasy Republic and much of Asia and Europe
Lampides boeticus		1	1	Throughout Africa, Madagascar, Arabia and the Indo-Australian region, and extending to southern Europe and Hawaii
Tarucus thespis	1	1	1	Succulent Karoo in N Cape (Namaqualand) south to Fynbos in the W Cape, and east to the Amatolas (E Cape)
Eicochrysops messapus messapus		1	1	W Cape (Cape Peninsula) north in Nama Karoo and east along coast and mountain chain to Free State (Springfontein)
Zizeeria knysna			1	Afrotropical region, North Africa, southern Spain and Old World warm temperate and tropical areas, including western and southern Arabia
PIERIDAE				
Colias electo electo			1	South Africa, southern Mozambique, Namibia, Zimbabwe and Zambia
Belenois aurota aurota	1		1	Throughout Afrotropical region, Egypt, Middle East, Iran and India
Belenois gidica abyssinica			1	Ethiopia, Kenya and Uganda to south eastern Zaire and South Africa
Dixeia charina charina			1	Eastern Cape to Kwazulu-Natal and into southern Mozambique
Pontia helice helice			1	South Africa and Zimbabwe
PAPILIONIDAE				
Papilio demodocus demodocus			1	Throughout Afrotropical Region except island of Socotra
Papilio nireus lyaeus			1	Kenya southern Sudan and uganda to Tanzania, southern Zambia, Malawi, Mozambique, Zimbabwe, Botswana and South Africa
HESPERIIDAE				
PYRGINAE				
Spialia sataspes		1		Fynbos of W Cape, along mountain chains N Cape, along coast to E Cape (Port Elizabeth) and inland to Bedford and Grahamstown
HESPERIINAE				
Pelopidas thrax inconspicua			1	Throughout sub-Saharan Africa
Gegenes niso niso			1	South Africa, southern Mozambique, Botswana and Zimbabwe

(*Antanartia hippomene hippomene* was observed on a previous sampling period at Thynspunt)

Appendix 4: Observed and estimated butterfly diversity.

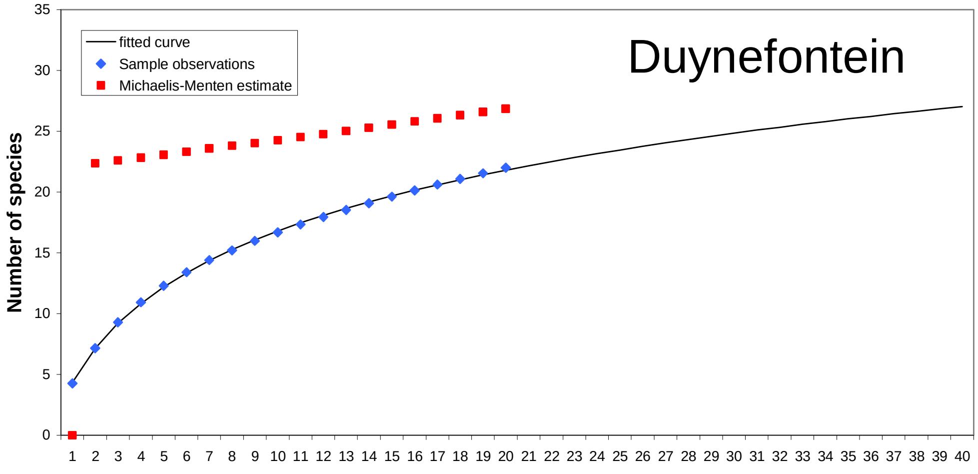


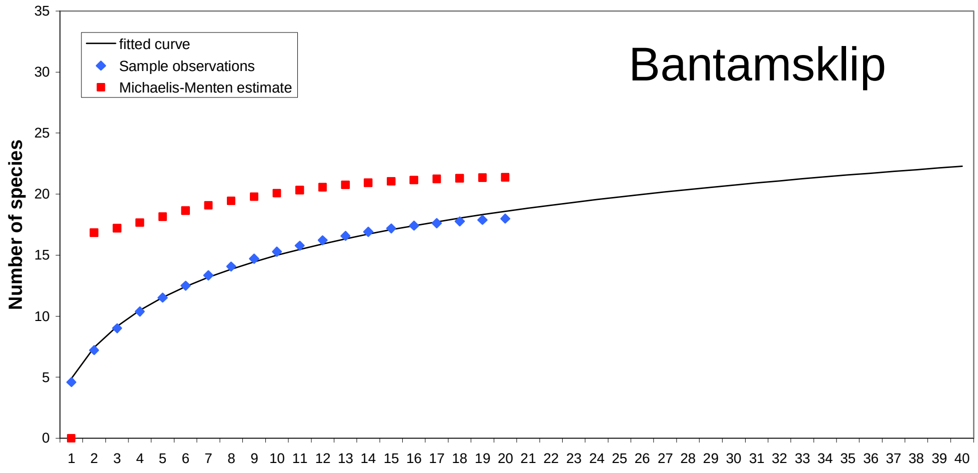


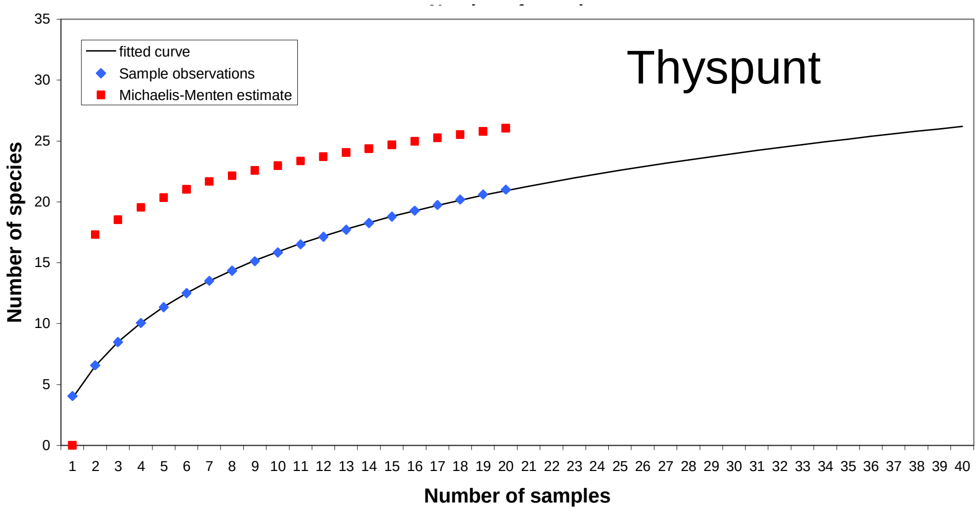


Graphs show the observed butterfly species for each site and for each vegetation type surveyed within each site, extrapolated as fitted curves of the form a = log(1+z*a*B)/z.

Appendix 5: Observed and estimated ant diversity.







Graphs show the observed ant species richness (blue diamonds) for each site, extrapolated as fitted curves of the form a = log(1+z*a*B)/z, with Michaelis-Menten estimate of total species richness indicated by red squares.

Appendix 6: Ant species recorded during the surveys carried out in August/September 2008

	Species	Site		
		Bantamsklip	Duynefontein	Thyspunt
1	*Acropyga arnoldi*	X	X	
2	*Anoplolepis steingroeveri*	X	X	X
3	*Camponotus mystaceus*		X	
4	*Camponotus niveosetosus*	X	X	X
5	*Camponotus* sp. AFRC-ECA-01	X		X
6	*Camponotus* sp. AFRC-WCA-02		X	X
7	*Camponotus* sp. AFRC-WCA-03	X	X	X
8	*Cerapachys* sp. AFRC-ECA-01 (*cribrinodis*-grp)			X
9	*Crematogaster peringueyi*	X	X	X
10	*Diplomorium longipenne*			X
11	*Hypoponera eduardi*		X	
12	*Lepisiota ? laevis*		X	X
13	*Lepisiota capensis*	X	X	X
14	*Lepisiota incisa*			X
15	*Leptogenys* sp. AFRC-WCA-01 (? sp. n.)	X		
16	*Meranoplus peringueyi*	X		
17	*Monomorium* sp. AFRC-WCA-01 (sp. n.)		X	
18	*Monomorium* sp. AFRC-ECA-01 (sp. n.)			X
19	*Monomorium ? taedium*			X
20	*Monomorium xanthognathum*		X	
21	*Myrmacaria nigra*			X
22	*Ocymyrmex ? barbiger*		X	
23	*Pachycondyla cavernosa*		X	
24	*Pheidole* sp. AFRC-WCA-01	X		
25	*Pheidole* sp. AFRC-WCA-02	X	X	
26	*Pheidole* sp. AFRC-WCA-03			X
27	*Pheidole* sp. AFRC-WCA-04			X
28	*Plagiolepis* sp. AFRC-WCA-01	X		
29	*Plagiolepis deweti*		X	
30	*Rhoptromyrmex transversinodus*	X		
31	*Solenopsis punctaticeps*	X	X	X
32	*Technomyrmex pallipes*	X	X	
33	*Tetramorium* sp. AFRC-WCA-01 (sp. n.)		X	
34	*Tetramorium* sp. AFRC-ECA-01 (? sp. n.)			X
35	*Tetramorium ? delagoense*	X		
36	*Tetramorium ? jejunum*	X		
37	*Tetramorium ? mossamedense*		X	X
38	*Tetramorium ? quadrispinosum*	X	X	X
39	*Tetramorium ? regulare*		X	
40	*Tetramorium ackermani*			X
	Total number of species found:	**18**	**22**	**21**

(cyan)	Extremely rarely encountered and with a very limited known distribution.
(yellow-orange)	Probably/possibly an undescribed species; further investigation required.
(orange)	Confirmed undescribed species.
(pink)	Widespread African species with tramping tendencies.
(magenta)	Exotic tramp species (probably of Mediterranean origin).

Appendix 7: Argentine ant management information sheet

(downloaded from
http://www.issg.org/database/species/reference_files/linhum/linhumman.doc),
September 2008.

ANT MANAGEMENT

Argentine Ant (*Linepithema humile*)

Compiled by the IUCN SSC Invasive Species Specialist Group (ISSG)

1.0 Preventative measures

Prevention, quarantine and rapid response are the best management strategies for preventing the establishment of invasive ants. To be successful they require active surveying, early detection and subsequent rapid treatment procedures often along with quarantines. This type of management approach remains the most practical strategy for dealing with invasive ants (Krushelnycky Loope and Reimer 2005).

1.1 Risk assessments

The first step to solving any problem is to identify whether it exists and define what it is. Preparing risk assessments is a vital management tool for addressing the issue of invasive ants in a country or region. Mapping the potential range of invasive ant species is also a useful tool for assessing risk, preparing risk assessments and estimating the potential threat an invasive ant poses to people and the environment.

Computer software that generates maps showing potential ant distribution based on survival range data are extremely useful management tools for assessing the potential impact of any given invasive ant. Based on over 200 records from around the globe Hartley Harris and Lester (2006) modelled the potential future range of the Argentine ant (*Linepithema humile*). They found that it is most likely to occur where the mean daily temperature is between 7 and 14℃ in mid-winter and maximum daily temperatures during the hottest month is an average of between 19℃ and 30℃. Un-invaded regions considered vulnerable to future establishment include: southern China, Taiwan, Zimbabwe, central Madagascar, Morocco, high-elevation Ethiopia, Yemen and a number of oceanic islands. For a discussion about modelling, decision-making and the accuracy of predictions please see Hartley Harris and Lester (2006).

In Haleakala National Park (Hawaii) the range of Argentine ant populations was analysed by scientists to map potential distribution. The patterns of spread of the two populations suggested that the Argentine ant have the potential to invade nearly 50% of the park and 75% of the park's subalpine shrublands and aeolian zones (Krushelnycky *et al*. in press b, in Krushelnycky Loope and Reimer 2005). This lends considerable support to its status as one of the most significant threats to the park's unique biodiversity.

In New Zealand an invasive ant risk assessment project (prepared for Biosecurity New Zealand by Landcare Research) identified ant species which pose the greatest potential threat to New Zealand. This project was divided into five sections: (i) gathering data on native and non-native New Zealand ants, (ii) producing a preliminary risk, (iii) producing information sheets on medium-risk and high-risk taxa, (iv) producing a detailed pest risk assessment for the eight highest-risk species, and (v) re-ranking these eight species (Harris undated). An assessment of the current risk of *L. humile* (already present in the country) establishing itself further in New Zealand (based on climate similarity of native and introduced ranges) lead to the prediction that it would be "likely to establish significant distribution in NZ, particularly in urban areas and disturbed habitat" (R. Harris unpubl. data, in Stanley 2004).

1.2 Quarantine and Monitoring

It is very importance to monitor ants following treatment and detect re-invasions. Xstinguish® bait has been successfully trialled to eliminate several populations of *L. humile* in large-scale operations in New Zealand and has successfully reduced populations to very low numbers, or even eradicated populations (Harris 2002, Harris *et al*. 2002a, in Stanley 2004). Failure to eradicate populations has usually been a result of lack of monitoring and follow-up treatment, rather than failure of the bait itself (R. Harris, pers. comm., in Stanley 2004).

1.3 Ant Prevention in the Pacific Region

The Pacific island region includes over 25 countries, most of which are served by two important regional international organizations, the Secretariat of the Pacific Community (SPC), which addresses agricultural issues, and the South Pacific Regional Environment Programme (SPREP), which addresses biodiversity issues. The biodiversity of the Pacific is particularly vulnerable to effects of invasive species (SPREP 2000).

Special concern regarding ant invasions has arisen now that the red imported fire ant occurs at or near the coast on both sides of the Pacific, and the little fire ant has arrived in Hawaii and is spreading in the western Pacific. These and other species threaten all Pacific islands, including Hawaii and the U.S. affiliated islands of Guam, Commonwealth of the Northern Marianas, Federated States of Micronesia, American Samoa, and Palau.

The SPC-Plant Protection Service (SPC-PPS) works in partnership with 22 Pacific members to maintain effective quarantine systems and to assist with regionally coordinated eradication/containment efforts. Priorities for emphasis are determined by member countries, which meet periodically as the Pacific Plant Protection Organization (PPPO).

A workshop sponsored by the Invasive Species Specialist Group (ISSG) of IUCN was held in Auckland, New Zealand, in September 2003, and resulted in the compilation of a draft Pacific Ant Prevention Plan (Pacific Invasive Ant Group 2004). The Pacific Ant Prevention Plan was presented to and embraced by 21 Pacific island countries and territories present at a PPPO meeting, the “Regional Biosecurity, Plant Protection and Animal Health” meeting held by SPC in Suva, Fiji, in March 2004 (Pacific Plant Protection Organization 2004). Like Hawaii’s Red Imported Fire Ant Prevention Plan, the Pacific Ant Prevention Plan is still a conceptual work, but ISSG and others are working toward obtaining the international funding needed to implement the plan with the assistance of SPC. The project presents an exceptional opportunity for agriculture and conservation interests to work together with international and bilateral aid entities at regional and country levels to build much needed quarantine capacity. Increased quarantine protection is desperately needed by PICT in order to address invasions that jeopardize both agriculture and biodiversity.

The information for this section was sourced directly from Krushelnycky Loope and Reimer (2005).

2.0 Chemical Control

2.1 General Considerations

Most if not all ant eradications have employed the use of baits and toxicants, many of which are developed for agriculture or urban settings. However, indiscriminate pesticide use in natural areas and fragile island ecosystems is not advocated. While some toxins such as hydramethylnon break down quickly in the environment, any and all pesticide use is likely to be accompanied by at least some undesirable non-target effects. These include increased runoff or drift outside the intended area, adverse affects on beneficial insects and non-target impacts on native species (Krushelnycky Loope and Reimer 2005).

Non-target impacts must be weighed up carefully against the benefits of ant eradication. Cleary, treating whole ecosystems or islands is too risky as entire populations of rare invertebrates may be at risk of extinction. On the other hand, eradicating populations of exotic ants before they become established in a natural ecosystem or island has the potential to prevent the potentially disastrous consequences of ant invasions (Krushelnycky Loope and Reimer 2005).

Baits should be designed with the specific foraging strategies of the target ant in mind. The preferred size, type and dispersal of bait and the nesting, foraging and behavioural traits of the ant should be considered in the planning stages of the operation. The use of appropriately designed and chosen baits and toxins will help reduce the impact of toxins on native ants and non-target fauna (McGlynn 1999). For information on non-target ant species please see Stanley (2004) which contains notes on food preferences of non-target ants and the attraction of toxic baits to non-target ants.

2.2 Bait Design

Baiting trials suggest that several invasive ants including *L. humile*, *Wasmannia auropunctata* and *Pheidole megacephala* consider carbohydrate-rich resources such as honey or sugar water equally, if not more, attractive than protein-rich resources such as tuna during much of the year (Baker *et al*. 1985, Krushelnycky and Reimer 1998, Rust *et al*. 2000, Brinkman *et al*. 2001, Hahn and Wheeler 2002, Cornelius and Grace 1997, in Ness and Bronstein 2004). Trials in Georgia found honey and canned tuna to be far more attractive to *L. humile* than peanut oil, with raw egg being somewhat attractive (Brinkman *et al*. 2001, in Stanley 2004). The preference for carbohydrates may be attributable to morphological traits that facilitate the storage of liquids (Davidson 1998, in Ness and Bronstein 2004). Researchers have stressed that broadcast baits for *L. humile* control should use protein as an attractant to target the queen in spring and summer when brood are being produced (Baker *et al*. 1985, Davis *et al*. 1993a, Rust *et al*. 2000, in Stanley 2004).

The carrier must also be considered in bait selection. Silverman and Roulston (2001, in Stanley 2004) found more *L. humile* workers fed on gel sucrose baits than liquid sucrose baits, but that substantially more of the liquid bait was consumed. Hooper-Bui *et al*. (2002, in Stanley 2004) found workers prefer solid bait particles in the range 840–1000 μm, while most commercial baits have a particle size of 1000–2000 μm. *L. humile* workers are strongly attracted to protein and carbohydrate paste formulations, provided the bait is reasonably fresh and moist (Harris 2002, Naidu 2002, in Stanley 2004).

2.3 Ant Toxins

Ant toxins can be classed into three categories: “stomach” poisons (or metabolic inhibitors), Insect Growth Regulators (IGRs) and neurotoxins. Stomach toxins include hydramethylnon (eg: Maxforce® or Amdro®), sulfuramid and sodium tetraborate decahydrate (eg: Borax). IGRs include compounds such as methoprene, fenoxycarb or pyriproxyfen. Neurotoxins include fipronil (eg: Xstinguish®). Stomach poison kills all workers and reproductives it comes into contact with. IGRs work by disrupting development of the queens ovarian tissues, effectively sterilising the colony. Neurological inhibitors disrupt insect central nervous systems by blocking neuron receptors. The onset of mortality is contingent upon the type of active ingredient. In general, ant baits that contain active ingredients that are metabolic inhibitors have a two to three day delay before extensive mortality occurs in the colony (Oi Vail and Williams 2000). Baits containing IGRs take several weeks before colony populations are reduced substantially (Oi Vail and Williams 2000). The latter (IGRs) provide gradual long-term control, while metabolic inhibitors provide short-term, localised and rapid control (Oi Vail and Williams 2000). This is because while stomach poisons are faster than IGRs, they sometimes eliminate workers before the toxin can be effectively distributed throughout the colony (O'Dowd Green and Lake 1999).

Many toxicants have been employed against the Argentine ant over the past century (Haney 1984). More recently, hydramethylnon, fipronil and sulfluramid have been used in agricultural, urban and natural areas to control the ant (Forschler and Evans 1994; Krushelnycky 1998b; Hooper-Bui and Rust 2000). Hydramethylnon suppresses normal colony activities, including budding dispersal, for some period of time. It has a low acute toxicity towards birds and mammals, is not taken up by plants, is practically insoluble in water and does not leach from soil (EPA 1998, Bacey 2000, in Krushelnycky *et al*. 2004). However the toxin is highly soluble in water and may harm aquatic invertebrates (Hoffmann and O'Connor 2004).

While the concentration of boric acid is too high in most available commercial baits, at low concentrations (e.g., 1% boric acid in 10% sugar-water) it is extremely effective at killing laboratory colonies of *Monomorium pharaonis*, *Tapinoma melanocephalum*, *Solenopsis invicta* and *L. humile* (Klotz and Williams 1996, Klotz *et al*. 1997, Ulloa-Chacon and Jaramillo 2003, in Stanley 2004). Klotz and Williams (1996, in Stanley 2004) found hydramethylnon killed only 40% of laboratory colonies, compared with the 100% mortality achieved by boric acid. High concentrations of boric acid in liquid baits (eg: 5.4% in Terro Ant Killer®) have been shown to kill ants too rapidly and prevent recruitment, and are also repellent to some species (Klotz and Williams 1996, Hooper-Bui and Rust 2000, in Stanley 2004). Borax and disodium octaborate tetrahydrate can be effective substitutes for boric acid in baits (Klotz *et al*. 2000a, in Stanley 2004).

Australian-manufactured IGR baits developed for *S. invicta* control, Engage® (methoprene) and Distance® (pyriproxyfen), have a lipid attractant and are unlikely to be attractive to such species as *Linepithema humile*, *Tapinoma melanocephalum* or *Paratrechina longicornis.* Soybean oil on defatted corn grits as a bait matrix is very attractive to *S. invicta*, however, many pest ant species including *L. humile* and *Paratrechina* spp. are not attracted to lipids. Commercial baits that use this matrix, such as Amdro®, are ineffective at controlling these species. However, the Amdro® Lawn and Garden bait has a matrix (protein and carbohydrate) that differs from the 'normal' Amdro® matrix and is more attractive to *L. humile* (Klotz *et al*. 2000b, in Stanley 2004)).

Fipronil can be formulated either as a bait or as a granular contact insecticide, both of which can be broadcast (Williams *et al*. 2001, in Stanley 2004). Fipronil baits have been used effectively to control ant species such as *S. invicta*, *L. humile* and *Anoplolepis gracilipes* (Barr and Best 2002, Harris 2002, Green *et al*. 2004, in Stanley 2004). Xstinguish® (fipronil) (protein and sucrose bait matrix) appears to be highly effective at controlling *L. humile* and the protein-based matrices of these baits make them highly attractive to species previously thought difficult to attract with baits. Fipronil appears to be more effective in controlling *L.*

humile colonies than hydramethylnon and previously trialled toxins (Hooper-Bui and Rust 2000, Harris 2002, in Stanley 2004). Stanley (2004) recommends using Xstinguish® against *L. humile* in New Zealand as it is already registered and available and is attractive to and effective at controlling *L. humile.*

While the more recent neurotoxins imidacloprid and thiamethoxam show promise, very low concentrations must be used to prevent rapid intoxication and mortality of workers (Klotz and Reid 1993, in Stanley 2004). Rust *et al*. (2004) found that very low (0.0005 to 0.005%) concentrations of imidacloprid and extremely low concentrations of thiamethoxam (<0.0001%) in sucrose solution had delayed toxicity in *L. humile* laboratory colonies. Thiamethoxam presents a low/slight toxicity risk to the environment and human health, a much lower risk than imidacloprid (in Stanley 2004).

3.0 Integrated Management

The potential of certain invasive ant species to reach high densities is particularly great in anthropomorphic (or human-modified) ecosystems. This may become particularly evident on land that is used intensively for primary production. *L. humile* reaches high densities in agricultural systems such as citrus orchards (which host mutualistic honeydew producing insects) (Armbrecht and Ulloa-Chacón 2003; Holway et al. 2002). Improved land management, including a reduction in monoculture and an increase in the efficiency of primary production, may help prevent population explosions of invasive ants and reduce the size of source populations which ants could spread from.

4.0 Research

4.1 Biosecurity New Zealand

Biosecurity New Zealand, the branch of government responsible for managing invasive species, has responded to a series of incursions of exotic invasive ant species by relying heavily on a small number of baits and toxins. The absence of a wide variety of effective baits may compromise the success of incursion responses. As a first step to ensuring effective incursion response, Biosecurity New Zealand commissioned Landcare Research to research and review international literature about the baits and toxins used for ant control (see Stanley 2004). The next step will be testing the most promising of these against a selected group of high-risk invasive ant species.

4.2 Bait and Toxin Research

Maxforce® Granular Insect Bait (hydramethylnon) has been used to contain the ant and prevent colony expansion of a supercolony in experimental plots in Haleakala National Park on Maui (Hawaii). This was found to consistently reduce the number of foraging ants by over 90% (Krushelnycky *et al*. 2004).

Research into alternatives to Maxforce® Granular Insect Bait and toxicant combinations for the purpose of Argentine ant eradication has included the toxicants fipronil, abamectin and the insect growth regulator methoprene in various bait carriers (W. Haines, P. Krushelnycky and E. Van Gelder unpubl. data., in Krushelnycky Loope and Reimer 2005).

Stanley (2004) suggests that future research on *L. humile* focus on:

- Testing the attractiveness of Presto® to *L. humile*
- Investigating the development of an aerially broadcast Xstinguish® bait

- Investigating the potential for indoxacarb (reduced risk pesticide) as a toxin to control *L. humile* colonies
- Further investigating the potential of IGR baits to control and attract *L. humile*

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