A quantitative study of butterfly assemblages from different biotopes at the Langebaan Peninsula

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One's work within an environment such as the West Coast National Park (WCNP) leads one to a renewed appreciation of nature and the astonishing powers of the One who created it. The fieldwork phase was more a privilege to me than a task. Where else does one encounter whales, while doing butterfly research? I would like to thank the Lord for the opportunity as well as the health and mental ability to work in these surroundings.

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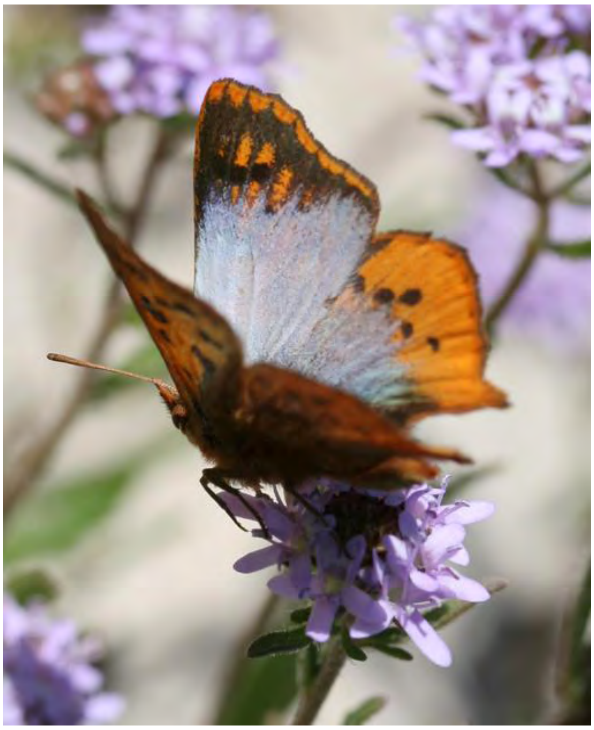

DEDICATION

This work is dedicated to my wife Janine, my little boy Renier and my girl Marnel.

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ABSTRACT

Lepidoptera (butterflies and moths) comprises a fairly well-studied invertebrate taxon. The body of knowledge that has been acquired, especially on butterflies, allows for more convincing assessments of the significance of species distributions, for example assessments of rarity and endemism. In spite of their taxonomically well-known status, little is known about the different ranges and limiting factors controlling habitat specificity amongst species at a local scale.

Aiming at ensuring more efficient and inclusive conservation planning for new developments and for rehabilitation of disturbed areas this study focused on the identification of species specific and local scale (biotopic) microhabitat attractants.

This was done by identifying and classifying locally occurring butterflies in the context of small scale habitat preferences on a spatial and temporal scale taking into account correlations in distributions of butterflies, plants and bio-physical gradients. Results were compared to previous studies to evaluate the use of recorded species as bio-indicators.

The methodology entailed the use of twelve 250m fixed belt transects that were sampled in alternating directions across four sites within the West Coast National Park. Seven sampling sessions were set out during four sampling months mainly during the summer of the 2006/07 season. Sampling was conducted through visual observations while walking transects at a constant pace.

Distributional variation between species was observed within a relatively small area with limited apparent variation in vegetation, topography and altitude. Pronounced temporal variation and correlation between butterfly species distribution and microhabitats were observed although this is strongly linked to the scale of the study in relation to the species studied. Factors that will affect the choice of microhabitat across time include amongst others: the prevailing sex ratio, temperature and the presence of invasive ants. The influence of plant distribution in predicting butterfly species distribution seemed to be less important. Myrmecophilous butterflies could probably play some role in bio-indication although much more work needs to be done to confirm this.

The identification of stepping stone sites with optimum microhabitats during the environmental assessment phase in areas with endangered butterfly species should determine the face of the development and not the other way around.

KEY WORDS: bio-indicators, biotopic, butterflies, distributional variation, local scale, myrmecophilous.

UITTREKSEL

Lepidoptera (skoenlappers en motte) is „n redelik bekende invertebraattakson. Die grootste gedeelte van bestaande kennis, veral oor skoenlappers, maak dit moontlik om meer bevestigende studies aangaande die belangrikheid van spesieverspreidings te doen, soos byvoorbeeld studies met betrekking tot skaarsheid en endemisme. Hul welbekende taksonomiese status ten spyt, is daar min bekend oor hulle verspreidingspatrone op „n lokale skaal asook van die beperkende meganismes wat die verspreiding bepaal.

Hierdie studie het ten doel om meer inklusiewe en effektiewe bewaringsbeplanning vir nuwe ontwikkelings asook die rehabilitasie van versteurde gebiede te verseker en die fokus was op die identifikasie van spesiespesifieke en lokale (biotopiese) mikrohabitatsvoorkeure.

Dit is bereik deur die identifikasie en klassifikasie van lokale skoenlapperspesies in die konteks van kleinskaal-habitatsvoorkeure in „n ruimtelike en tydskaal met inagneming van korrelasies in skoenlapperverspreidings, plantsoorte en biofisiese gradiënte. Die resultate is vergelyk met vorige studies om die nut van die spesies as bio-indikatore te bepaal.

Daar is gebruik gemaak van twaalf 250m belttransekte wat alternatiewelik in teenoorgestelde rigtings binne die studiegebied in die Weskus Nasionale Park gemoniteer is. Sewe sessies is behartig in vier opname-maande hoofsaaklik tydens die somermaande in 2006/07. Opnames is gedoen deur waarnemings binne die transekte terwyl daar teen „n konstante spoed deurbeweeg is.

Verspreidingsvariasie tussen spesies is waargeneem in „n betreklik klein gebied met beperkte waarneembare plantegroei-, topografiese en hoogtevariasie. Merkbare variasie oor tyd en korrelasie tussen skoenlapper-spesieverspreiding en spesifieke mikrohabitatte is waargeneem, alhoewel die waarnemings sterk gekoppel is aan die skaal van die studie met betrekking tot die betrokke spesie. Sekere faktore wat die keuse van mikrohabitat oor tyd beïnvloed sluit in die heersende geslagsverhouding, temperatuur en die teenwoordigheid van indringermiere. Die verspreiding van voedselplante in die bepaling van die verspreidingspatone van skoenlappers het „n kleiner as verwagte rol gespeel. Mirmekofiliese skoenlappers kan moontlik „n rol speel as bio-indikatore alhoewel daar steeds baie navorsing op die gebied gedoen moet word.

Die identifikasie van gebiede wat oor die nodige mikrohabitatskenmerke met betrekking tot die spesifieke spesie beskik tydens omgewingstudies waar bedreigde skoenlapperspesies voorkom, moet die uitleg van die ontwikkeling bepaal en nie andersom nie.

SLEUTELTERME: biotoop, bio-indikatore, lokale skaal, mirmekofilies, skoenlappers, verspreidingsvariasie.

CHAPTER 1:

INTRODUCTION

1.1 Importance of the study (problem statement).

Biodiversity is declining at an increasing rate and this drives the urge by conservationists and others to identify, describe and preserve it (Gaston 1996). The number of biodiversity-based studies and publications has escalated dramatically over the past 25 years as a result of concerns over the loss of natural environment and the long-term consequences of environmental degradation (Gaston 1996). By far the biggest cause of biodiversity and habitat deterioration is the adverse effects of human activities on the environment (Henning 2001; Edge 2005b; Gardiner *et al*. 2005; Henning *et al*. 2009).

The South African government ratified the Convention on Biological Diversity UNEP (1992) in 1995, thereby committing our nation to conserve existing biodiversity and to use biological resources in a sustainable manner. The inclusion of the environmental clause within the bill of rights and the more recent Biodiversity Act (Act No. 10 of 2004) are further steps in the conservation of the rich biodiversity of our country.

A number of reasons make the conservation of biodiversity important: stability and natural balance is a direct result of ecosystems that sustain diverse populations (Van Jaarsveld & Chown 1996). Such ecosystems also provide essential goods and services to human life such as the development and expansion of industries including agriculture, tourism, fisheries and forestry; and diverse ecosystems have considerable aesthetic and economic value (Van Jaarsveld & Chown 1996). In addition, humankind enjoys moral and ethical responsibilities to conserve biodiversity for future generations (Van Jaarsveld & Chown 1996).

In most diversity studies the focus is on the discernible and more admired species (Underwood 1995; Kitching *et al*. 2000), whilst insects and other small invertebrates are often disregarded (Hamer & Slotow 2002). This tends to ignore the fact that smaller organisms are directly or indirectly integrated in many critical ecological processes (Van Jaarsveld & Chown 1996; Horwitz *et al*. 1999) and that goes without mentioning that insects make up >60% of all known animal species (Speight *et al*. 1999; Odegaard 2000; Novotny *et al*. 2002; Hamer *et al*. 2003). To avoid the extinction of a large proportion of global diversity serious attention should be given to gain a better understanding of this group (Hamer & Slotow 2002).

In our journey to accomplish efficient conservation of insect biodiversity it is important that priorities in the identification of protected areas are set. For this aim appropriate and reliable decision criterion need to be developed to maintain the species diversity in selected conservation and other areas (Hein *et al*. 2007). This decision criterion is partly realized through the field of community ecology that seeks to understand the manner in which groupings of species are distributed in nature, and the ways in which these groupings can be influenced by their abiotic environment and by interactions among species populations. One challenge for community ecologists, however, is to discern and explain patterns arising from this multitude of influences (Begon *et al*. 2005).

Despite the relative wealth of information on the biology and general distribution of butterfly species in South Africa there are still huge shortcomings in our understanding of how ambience influences distributional patterns. Butterflies are the only insects for which there is a South African Red Data Book (Henning & Henning

1989) and a fairly comprehensive biological knowledge and yet quantitative data on local distributions of species as well as assemblage patterns are lacking.

Aviron *et al*. (2007) stated that the interactions between butterfly diversity and landscape features need to be further investigated with consideration of explicit measures of spatial connectivity and landscape heterogeneity. Terblanche *et al*. (2003) stated the importance of specific distribution records in order to resolve the problems that centre on the response of *Chrysoritis* butterflies to environmental change. Henning *et al*. (2009) pointed out the importance of optimal abiotic and habitat conditions and how this, with specific reference to the Lycaenidae, renders them vulnerable to disturbances. Holl (1996) has noted a similar concern when it comes to Lepidoptera in general.

Though distribution maps of butterflies in field guides are available, general quantitative benchmark studies of this nature are still relatively scarce (Kitching *et al*. 2000) and quantitative information about butterfly communities in local areas is almost non-existent within South Africa (Terblanche & Van Hamburg 2004; Henning *et al*. 2009). The latter further stated that detailed analysis of ecological requirements of all threatened butterfly species has to be undertaken, as has been the case with *Orachrysops niobe* (Edge 2005a) before effective conservation measures and management can be initiated (Heath 2001).

Realization of the above shortcomings prompted this study into some of the controlling mechanisms involved in differential habitat preferences amongst species. Quantitative techniques are used to explore the suitability of a transect method to study butterfly diversity in a Fynbos type of environment.

This study should be seen in the context of natural habitats found on the western coastline of South Africa, which are currently under tremendous developmental pressure. Development usually exerts the biggest impact on localized colonies (Henning 2001). Within the diurnal Lepidoptera the many site and locally endemic myrmecophilous lycaenids (Henning 1987; Fermon *et al*. 2001) is therefore no exception (Henning 2001). It is very difficult to address impacts of disturbances in the absence of any information about faunal community patterns in relatively natural areas (Henning 2001). Several studies have shown that anthropogenic habitat alterations reduced lepidopteran diversity in favour of more homogenised populations (Aviron *et al*. 2007). In addition, the presence of alien invasive plant species results in the loss of many habitats (Henning 1987; Henning 2001; Henning *et al*. 2009). In general, many areas that have been developed or that have been covered by alien invasive plant species will need restoration or rehabilitation in the floral component, although there is no current evidence that such action will be beneficial to butterfly communities. Insufficient knowledge of butterfly diversity and the predictors controlling this diversity (Ouin *et al*. 2008), could severely limit biodiversity conservation on the West Coast (Edge 2005b).

Numerous highly endemic butterfly species occur in the Western Cape including a number of species from genera such as *Chrysoritis* which is classified as a Cape Province centred genus (Cottrell 1985) as well as *Aloeides*, *Thestor* and *Lepidochrysops* (Claassens 2000). The first two of these genera are autochthonous (entire life cycle completed in the same vegetation type) (Henning 2001) which means that in addition to the other limiting factors they are very dependant on their local vegetation (Lewis *et al*. 1998).

The vast majority of related diversity studies focus on a regional or even global scale with the aim of creating distribution maps or determining distribution as coupled to vegetation types (Terblanche & Van Hamburg 2004). The size of the area for this study allows one to observe preferences for certain biotopes without too much variation in terms of geography, climate and host plant distribution.

1.2 Aim and objectives.

The aim of this study is to contribute to effectiveness of conservation planning by addressing gaps in current knowledge of butterfly diversity (Lepidoptera) along the West Coast to ensure decisions that more accurately target “land use type” conservation issues.

This study should be viewed as a first and explorative step to describe butterfly assemblages quantitatively at a locality along the West Coast. The area around Langebaan was selected because it had not seen the bulk of disturbances associated with urban and industrial development, although the rate of development is radically increasing. It would in future therefore be possible to draw comparisons (using the data from this study), between more or less pristine areas, especially in the West Coast National Park, in contrast to areas that had already been severely impacted upon by development in the town of Langebaan (Lewis *et al*. 1998). Studies of this kind in the area are still timely enough to direct developmental projects to encompass environmental considerations (Henning 1987). The area was chosen to be small enough to allow a sufficient number of repetitions within the time available and to ensure a study on a local scale that would be large enough to cover areas with enough characteristical variation in order to support a diverse faunal community (Terblanche & Van Hamburg 2004).

The peninsula area within the park was identified as a relatively unique area within the southern African regional context for several reasons: (1) The area would most probably show the greatest biotopic variation compared to the rest of the park, due to the exposed nature of some parts towards the sea (climatic fluctuations), in contrast to the shielded areas adjacent to the lagoon. (2) The Langebaan Peninsula sustains a large and relatively diverse plant community (Boucher & Jarman 1977; Manning 2001). (3) It is a classified Ramsar site and the lagoon acts as a host to many well-studied bird species such as the Langebaan Curlew Sandpiper (De Graaf 1993; Puttick 1980). (4) Due to the semi-arid to arid nature of the climate, plant and animal species in the area show several functional adaptations to this type of environment (Boucher & Jarman 1977; Manning 2001). (5) It is partially isolated from the mainland by a barrier (the lagoon itself) that stretches beyond the colonization ranges of a few species studied (White & Kerr 2007) which gives the area some characteristics that could (with limited application) be linked to island biogeography (Kitahara & Fujii 1997).

Broad biotopes have been identified for the study to explore what kind of species composition patterns and species specific patterns may emerge. A biotope is defined as an “area or habitat of a particular type, defined by the organisms (plants, animals and micro-organisms) that typically inhabit it, e.g. grassland or woodland” (Lawrence 2005). On a smaller scale it denotes a microhabitat (Lawrence 2005). In this study “biotope” refers to habitats that appear different, for example dune landscape as opposed to rocky hill.

Although the area appeared relatively homogenous, several different biotopes could be identified on closer investigation. The consideration was that a study conducted within an area with limited apparent variation would provide more reliable information, which could be used in areas that possessed more apparent variation.

The altitude variations of the landscape near the coast at the Langebaan Peninsula are 0 – 193 m above mean sea level (m.a.m.s.l.) compared to that of the Cape Peninsula just 100 km to the South which varies between 0 – 1000 m.a.m.s.l. (Renssen 2006). The apparent uniformity in topography of the area compared to that of the Cape Peninsula and the generally low rainfall raised a few questions regarding the factors affecting the local distribution patterns amongst butterflies.

The following specific questions were addressed:
(a) Do locally occurring butterfly species prefer specific biophysical micro-habitat characteristics and which species prefer what set of characteristics? (b) How is the distribution of these species affected by the above preferences? Answers to these questions would be the starting point in any distributional biodiversity study to be conducted on a local scale.

Numerous previous studies refer to a range of integrated factors strictly controlling butterfly distribution. Morris *et al*. (1994) stated that most insects, including butterflies, have a larger suite of ecological requirements over and above the basic requirement of their foodplant. The latter, however, must grow in the microhabitat preferred by the butterfly and in sufficient quantities to sustain viable butterfly populations (Edge 2005a; Henning *et al*. 2009). Specific habitats should be protected and integrated into development plans to cater for specific insect species (Lu & Samways 2002).

Objectives for the study were: (a) To study spatial patterns in local butterfly diversity in terms of species richness, diversity indices and species composition. (b) To use the above mentioned patterns (if any) to infer sets of local scale habitat preferences for obvious biotopic factors (sand cover, rockiness, distance from the shore, wind and conspicuous differences in vegetation) for the studied butterfly assemblages. (c) To establish groupings between locally occurring species based on their fine grain habitat preferences (Kremen 1994; Chust *et al*. 2003). (d) To determine whether there is temporal variation in the above preferences/patterns amongst species and (e) to evaluate the use of recorded species as bioindicators (McGeoch 1998) based on their known characteristics and observed preferences.

Apart from addressing important gaps in the knowledge of local butterfly diversity patterns, as stated above, contributions of the project towards conservation and environmental management would include:

- Expanding the knowledge about invertebrates in the West Coast National Park. Terblanche & Van Hamburg (2003) noted that for many of our National Parks even baseline information such as species lists does not exist. This study will serve as an explorative step to make a small yet important contribution in filling this gap especially in the light of the current status of the Langebaan lagoon area as a classified world Ramsar site (De Graaf 1993).
- A contribution to the South African Butterfly Conservation Assessment (SABCA) or “butterfly atlas”. This project by the Animal Demographic Unit

(ADU), Lepidopterist Society (LepSoc) and the South African National Biodiversity Institute (SANBI) rely on the quality of locality data for its success. The type of spatial and temporal butterfly distribution data of this project may be a valuable contribution. Habitat preferences are important for the interpretation of biogeographical distributions and species accounts in the atlas project.

- The information obtained during this study could be used to guide developers and environmental practitioners to incorporate a strategy of selective land use as part of environmental assessment processes, to leave enough "species specific" high quality habitat within the colonisation ranges of locally endemic species (Lu & Samways 2002). The quantitative data could be incorporated into Environmental Assessments and biodiversity studies to ensure more accurate information at the disposal of governmental decision makers.
- A study of this nature could contribute in informing large-scale ecosystem management.
- It could also be used to expand current conservation efforts through informed reintroduction programs where adaptations to specialized biotopes are considered (Henning 2001), especially those that aim at the protection of red listed species (Henning & Henning 1989). Studies have shown that releasing butterflies in unfamiliar biotopes will in most cases not be successful (Thomas & Harrison 1992).

According to literature it is hypothesised that in addition to variation in altitude and the presence of foodplants and attendant ants other physical predictors (Ouin *et al.* 2008) within a biotope attract different species to a variable extent (Lu & Samways

2002). This variability should manifest itself in distinct differences in butterfly assemblages across the four sites despite the small altitudinal gradient due to the relatively small ranges occupied by some of the *Chrysoritis* colonies (Henning 1987; Heath 2001). Sites with greater topographical variation should sustain more diverse butterfly populations directly through a greater number of available microhabitats and indirectly through a greater diversity in plant life (Heath 2001). There should be some temporal variation in assemblage composition between sites due to brood timing and the variability in shielding capability of the different microhabitats against the changing weather conditions. It is predicted that the genus *Chrysoritis* could have a limited use as an indicator species for other taxa (McGeoch 1998) due to its extremely complex and highly evolved interaction with other floral and faunal components (Heath 2001).

Differences in butterfly assemblages at different biotopes of the Langebaan Peninsula might not be obvious but could be significant. Coarse habitat predictors (Ouin *et al*. 2008) of butterfly species that were identified for the purpose of the study included rockiness, the presence of sand dunes and shelter from the coastal winds as well as distance to the shore.

CHAPTER 2:

STUDY AREA

2.1 Location.

The West Coast National Park (WCNP) was first established in 1985 as the Langebaan National Park to conserve the huge floral and faunal diversity in the area around the Langebaan lagoon. In 1988 after several land additions the name changed to “West Coast National Park”.

The park is situated in the area surrounding the Langebaan lagoon, which is a world Ramsar site since 1988 (Puttick 1980; De Graaf 1993). These are sites deemed to be of global significance to wetland bird species (De Graaf 1993). The park is to the southern side of Langebaan, a little town in the Western Cape Province of South Africa. This study was conducted on the “pseudo-peninsula”, a piece of land between the coastline and the lagoon within the WCNP, as can be seen to the left in Figure 1.

Fig. 1. Aerial photograph of the study area within the West Coast National Park towards the west (left) of the Langebaan lagoon.

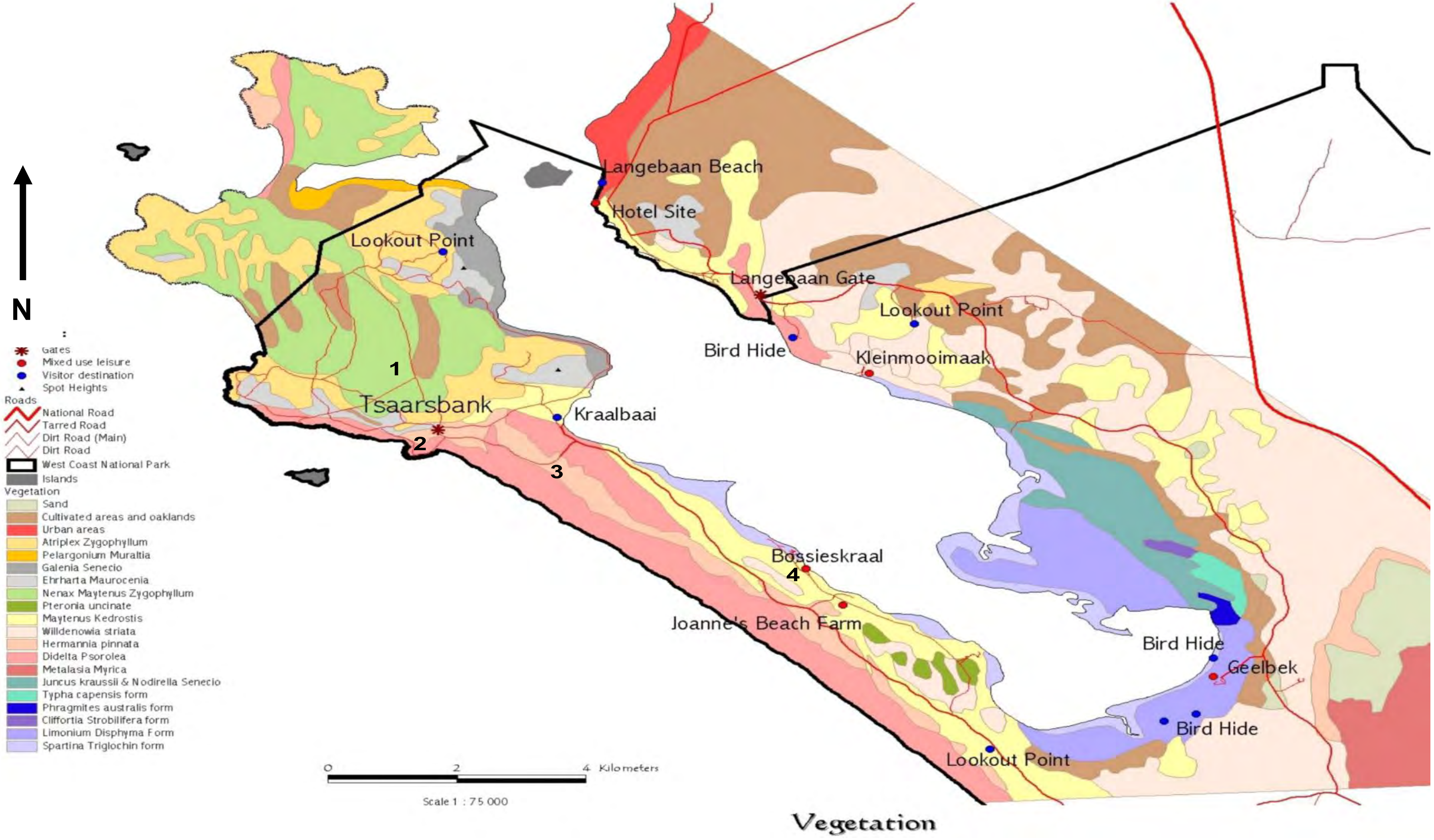

Fig. 2. Vegetation map of the area surrounding the Langebaan lagoon (Boucher & Jarman 1977). Selected sites indicated by numbers from (1 – 4).

2.2 Vegetation type.

Globally this area is classified within the Mediterranean Biome located on the western shores of continents (Mucina & Rutherford 2006). The study area lies within the Fynbos Biome which is dominated by small-leaved evergreen shrubs. The Fynbos Biome borders Succulent Karoo in the North and North-east and Albany Thicket in the East. The Fynbos Biome comprises three quite unique vegetation types namely Fynbos, Renosterveld and Strandveld (Mucina & Rutherford 2006). Figure 2 is a vegetation map of all areas surrounding the lagoon with the sites indicated as numbers one through to number four. Most of the study area forms part of the Western Strandveld while one site (2) is part of azonal coastal vegetation known as Seashore vegetation (Mucina & Rutherford 2006). Three vegetation types occur in the study area: Saldanha Granite Strandveld (Site 1; rocky hill), Langebaan Dune Strandveld (Sites 3 and 4) and Cape Seashore Vegetation as part of the Seashore vegetation near Tsaarsbank (Site 2).

2.3 Climate.

The Langebaan region, including the WCNP, consists of a temperate coastal climate and is subjected to some climatic variation with soaring coastal winds, high temperatures and often long spells of drought mainly during the summer period. Southerly winds predominate throughout the year although North-westerly winds are more frequent between May and August (Boucher & Jarman 1977; Mucina & Rutherford 2006).

A cyclonic annual rainfall occurs that varies from 250 mm in the North to 350 mm in the South, while this rainfall occurs almost exclusively during winter. The mean measured maximum and minimum temperatures for February and July are 26.1˚C and 7.8˚C respectively (Mucina & Rutherford 2006). Sea fog and dew contribute to moisture in summer and autumn.

Microclimatic conditions as well as vegetation may vary drastically over short distances, especially between the coastal side with its icy cold water and the lagoon side with warmer waters. In addition, weather conditions can change dramatically within minutes.

2.4 Geology and Topography.

The sites were chosen to represent different plant communities in areas with diverse geology, soil composition, aspect variation and overall geography (Boucher & Jarman 1977). The Langebaan Peninsula has an altitude variation of 0 - 193 m.a.m.s.l. (Renssen 2006). Small hills and rocky outcrops characterise the Postberg area to the North, with a sandy landscape showing variation between dune–rich and flat areas to the South of the Peninsula.

Geological features in the Langebaan area include exposure of the Malmesbury formation, Hoedjiespunt and Darling granites, Saldanha quartz porphyry and consolidated to unconsolidated limestone and lime rich sands (Visser & Schoch 1973; Mucina & Rutherford 2006). Deep, coarse sandy to loamy soils occur that are derived from the Vredenburg batholith in the North. The dominant geological land type is Ab as classified by Mucina & Rutherford (2006).

The landscapes of the park are products of a long and complex geological history. The basement rocks of the Malmesbury formation, laid down as marine sediments during the Pre-Cambrian 700 mya, were uplifted, folded and intruded by successive phases of igneous activity, which now form some exposed granite outcrops. The land surface was altered by drastic changes in sea level over millions of years (Visser & Schoch 1973; Tinley 1985).

2.5 Choice of study area.

Since it forms part of a National Park, the study area is shielded from developmental pressures or other anthropogenic influences. Some areas are exposed to human activities such as tourism, hiking and mountain biking. In spite of this all care has been taken to select sites with minimal as well as more or less equal degrees of disturbance. Organisms can thus be studied in their natural surroundings (Kitching *et al*. 2000), which lend more credibility to the accuracy of observed habitat preferences.

CHAPTER 3:

MATERIALS AND METHODS

3.1 Work procedure.

Fieldwork commenced with the identification of four distinct biotopes, each with relative homogenous intra-area characteristics based on geography, vegetation and microclimate. The study attempted to focus on species diversity and assemblage composition at the biotopic grain (Kremen 1994; Chust *et al*. 2003; Fleishman *et al*. 2003). It is acknowledged that no formal replicate sites were sampled although "within-site-replication" was conducted and analysed. Due to the spatial scale that the study focused on (microhabitat) the results at each site was calculated as a mean of all the different assemblages at patches across the site and could on this scale be viewed as several within-site-replications.

Once the biotopes were identified transects were measured out using a Global Positioning System (GPS). Subsequently these were marked out within each of four sites using painted wooden poles. The widely used fixed "belt transect" method (Kuussaari *et al*. 2007) was adapted and used to obtain data.

Prior to any field studies, and in order to aid in accurate identification, a literature study was conducted with a view to species with a high probability of occurring in the area (Clark & Dickson 1971; Claassens 2000; Woodhall 2005). After this a preliminary study was done to narrow down the species list that had been drafted in the course of the literature study. An important part of the preliminary studies was intensive on-site-training-sessions by a butterfly specialist, R.F. Terblanche. This allowed for a high degree of accuracy and efficiency in identifying butterfly species in the field. The author of this study consulted invertebrate (Clark & Dickson 1971; Fish 1999; Claassens 2000; Woodhall 2005) and floral (Boucher & Jarman 1977;

Goldblatt & Manning 2000; Manning 2001; Mucina & Rutherford 2006) field guides and literature, as well as photos of voucher specimens and various other literature sources (Heath 2001; Heath & Pringle 2004; Heath & Pringle 2007) on a regular basis throughout the course of the fieldwork part of the study to ensure proper and accurate identification. Any uncertainties in respect of identification were cleared up by referring the material or photos to a butterfly specialist R.F. Terblanche.

3.2 Design.

It is difficult to define optimal landscape units (Chust *et al*. 2003) when dealing with species with such diverse mobilization strategies. The chosen sizes for sites and transects were felt to be within the average range for the locally occurring species. Four sites with three transects each were marked out in the study area. The transects were 250 m long and 100 m apart parallel to each other and they were more or less parallel to the shoreline (Fig. 3).

All four sites were relatively close (<1 500 m) to the Atlantic Ocean and altitudes ranged from ≤40 m.a.m.s.l. for Sites 2 & 3 to ≤150 m.a.m.s.l. for Sites 1 & 4 (Renssen 2006). The sites were generally well secluded from adverse human activity.

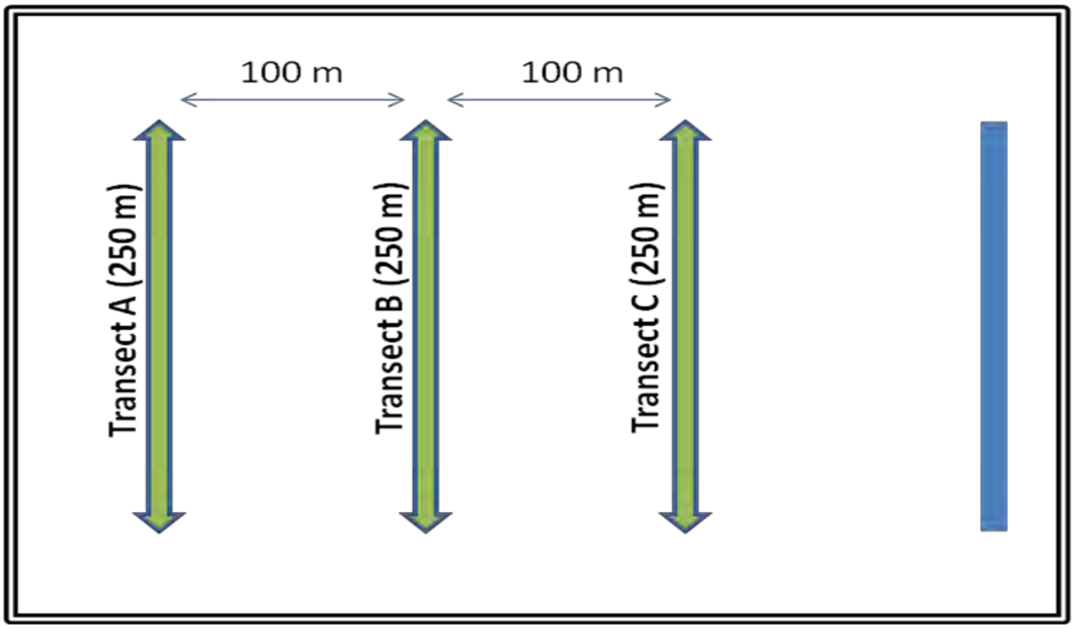

Fig. 3. General layout of butterfly transects (A-C) at selected study sites in the West Coast National Park. Blue band indicates shoreline. Not to scale.

The reasoning for transect selection parallel to the shoreline was to ensure that, should there have been species that preferred areas within a very specific distance from the sea, this would surface in the data. All transects were numbered in such a way that A was the furthest from and C the closest to the sea.

3.3 Site descriptions.

Information about the vegetation communities in which the four study sites were situated is available in Boucher & Jarman (1977), and is briefly summarised as follows:

Mucina & Rutherford (2006) classify the northern part of the study area as FS 2: Saldanha Granite Strandveld. This area includes Site 1 (rocky hill) and borders Site 2 (seashore bank). The vegetation consists of low to medium growing shrub land with some succulent elements that alternates with grassy and herb rich spots.

SITE 1 (rocky hill) (33° 08' 27.85''S 18° 00' 06.49''E) (Fig. 4): The site was located on a granite outcrop and transects were more or less parallel to the contour lines along the ridge. Within this site Transect B was located on the ridge and Transect A had North facing and C South facing aspects. The landscape at the site was characterised by aggregates of granite rock. The average gradient of the site was steeper than 1: 25. Boucher & Jarman (1977) state that vegetation in this area consists mainly of (in order of dominance):

Nenax – Gymnosporia – Zygophyllum Limestone Evergreen Shrubland.

Defining species: *Nenax hirta* and *Zygophyllum cordifolium*

Dominant species: *Ehrharta calycina, Zygophyllum flexuosum, Ruschia geminiflora, Senecio floribunda, Rhus longispina, Lasiochloa longifolia* and *Festuca scabra.*

Fig. 4. Site 1 (rocky hill) photographed from the South during the butterfly study in the West Coast National Park

SITE 2 (seashore bank) (33° 08' 50.91''S 18° 00' 02.35''E) (Fig. 5): This site was closest to the ocean and as such the most exposed. There was no barrier protecting the site from coastal winds. The coastline made a natural corner and, therefore, the site faced the ocean on two sides, namely the western and south-western sides. Transect C traversed a road more or less in the middle of the transect and the northern part lay upon the beach. The site was relatively flat with an average gradient of less than 1:250. Rocks were more or less evenly distributed across the area. The vegetation consisted mainly of (in order of dominance):

Didelta – Psoralea Littoral-dune Open Grassland

Defining species: *Didelta carnosa* var. *tomentosa* and *Psoralea repens*.

Dominant species: *Eragrostis cyperoides* and *Senecio elegans*.

Fig. 5. Site 2 (seashore bank) photographed during the butterfly study in the West Coast National Park.

Grasses and dwarf shrubs with succulence and hairiness were common within this area. The vegetation canopy was low, smooth and even–growing, in accordance with the findings of Boucher & Jarman (1977).

Mucina & Rutherford (2006) classify the vegetation type within which Sites 3 and 4 are located as FS 5: Langebaan Dune Strandveld. They describe this type as flat to slightly undulating old coastal dune systems and stabilised inland duneveld that supports closed, evergreen shrubs of up to 2 m tall as well as annual herbaceous flora that occur in gaps.

SITE 3 (coastal dune) (33° 08' 50,16''S 18° 00' 38,38''E) (Fig. 6): The largest part of this site fell within a natural valley with undulating sand dunes on the sides. There were a considerable number of open sand patches between aggregates of vegetation and no rocks on the site. Although the landscape was uneven, the undulating dunes gave a smoother appearance than the rocky hill of Site 1. The main vegetation types were summarised as follows (in order of dominance):

Hermannia pinnata Littoral-dune Dwarf Succulent Shrubland

Defining species: *Hermannia pinnata*

Dominant species: *Ehrharta villosa, Limonium perigrinum, Ehrharta calycina* and *Ruschia geminiflora.*

Fig. 6. Site 3 (coastal dune) photographed from the East towards the ocean during the butterfly study in the West Coast National Park.

SITE 4 (dune & calcrete) (33° 10' 26,96''S 18° 03' 32,60''E) (Fig. 7): Although some disturbance was evident on this site it was quite isolated from the main road and lay within a valley closer to the lagoon. It was well shielded from coastal winds and located furthest from the coast. The landscape was more even compared to Site 3, but it was definitely not flat. Transect B lay within the lowest part of the valley. The end points of Transect A were both on dune tops overlooking the Langebaan lagoon. Some areas within the site showed scattered calcrete rocky elements although these were far less extensive than those at Sites 1 and 2. Boucher & Jarman (1977) state the prominent vegetation of this site as follows (in order of dominance):

Gymnosporia – *Kedrostis* Consolidated-dune Dense Evergreen Shrubland.

Defining species: *Gymnosporia lucida* and *Kedrostis nana.*

Dominant species: *Euphorbia mauretanica, Gymnosporia lucida, Salvia lanceolata, Clutia daphnoides, Putterlickia pyracantha, Zygophyllum morgsana, Ehrharta villosa, Limonium perigrinum, Euclea racemosa, Senecio floribunda, Pentzia pilulifera, Ehrharta calycina, Zygophyllum flexuosum* and *Tetragonia fruticosa.*

Fig. 7. Site 4 (dune & calcrete) photographed during the butterfly study in the West Coast National Park

A single stratum of spiny evergreen shrubs occurred. These plants were drought-deciduous with an average height of 1.25 m. The shrubs were randomly distributed with interlocking crowns (Boucher & Jarman 1977).

Table 1. Main habitat characteristics obtained through subjective visual observation at selected sites in the West Coast National Park.

	SITE 1 (Rocky hill)	**SITE 2 (Seashore bank)**	**SITE 3 (Coastal dune)**	**SITE 4 (Dune & calcrete)**
Presence of rocks & boulders	High (Granite)	Medium (Granite)	Low	Medium (Calcrete)
Gradient (av.)	>1:25	<1:250	>1:25	>1:25
Approximate distance (m) from shore to centre of site	>500	<200	<500	>1 200
Shelter from elements	Medium	Low	Medium	High
Sand	Medium	Medium	High	Medium
Vegetation structure (height)	Medium	Low	Medium	High
Relative altitude (av.)	High	Low	Low	High
Aspect variation (within site)	High	Low	Medium	Medium

3.4 Butterfly diversity and distribution data collection.

Seven sessions were conducted in the WCNP during the summer months from October 2006 to April 2007. Each session consisted of four days during which any one of the four selected sites was surveyed on any one day. A survey at each site consisted of four repetitions per day on three transects. Session 1 was completed during October 2006. Sessions 2 and 3 were conducted in the course of December

2006, Sessions 4 and 5 during February 2007 and Sessions 6 and 7 during April 2007. The entire study comprised 28 repetitions per transect per site and 84 repetitions were performed per site. In total 336 transects were sampled.

The period between repetitions on sites was never less than four days to reduce temporal autocorrelation of the data as a result of local climatic influences. The repetitions within sites were conducted in such a manner that all transects were sampled within every hour between 10:00 and 14:00 daily. According to Holl (1996) and Gardiner *et al*. (2005) this is the period within which most butterfly species are probably active.

Transects were walked in alternating directions at a pace of 30 m per minute, which gave a total time of 8 min. 20 sec. per 250 m transect. All specimens within 5 m to either side of the centre line at a 120˚ angle in front of the observer were recorded using a dictaphone. According to Fermon *et al*. (2001) the method type used in this study ignores fast flying, mid-level and canopy species. The vegetation structure in the study area does not lend itself to the occurrence of the above species types (Manning 2001; Meiners & Obermaier 2004) which means that using this method in relatively low growing vegetation reduces the error of non randomized sampling due to differential vegetational structural preferences amongst species. The applied method was, therefore, felt to be best suited in this instance. Specimens that could not be identified immediately were identified by stopping the watch and by doing further investigation or by capturing the specimen for later identification.

The sampling method was designed in such a way that sampling effort and area were equal at all sites and during all periods (Blair 1999). This made direct comparison between species richness and other indices between sites and between times possible.

3.5 Disturbance indices.

All four sites had some measure of disturbance in human-induced as well as grazing categories. No significant invasion by exotic plant species was observed at any of the sites. Disturbance indices were estimated based on the surface area of disturbance compared to the total size of the site and this was subsequently calculated to a percentage of the total area.

At all selected sites human disturbance was present in some form or other, which consists mostly of unused roads on which some vegetation re-establishment has taken place. It was estimated that the degree of re-establishment of vegetation at the different sites was more or less similar and the differences in the severity of disturbance between the sites were, therefore, accepted to be negligible. The disturbance index results were found to be similar for all four sites. Based on similar disturbance indices the assumption was made that human-induced disturbance could not influence habitat preferences and, therefore, it could not influence the data set. Disturbance as an influential factor was, therefore, left out in further discussions.

3.6 Weather data.

Basic weather data, which included temperature, humidity, lack of precipitation, stillness of the wind and clarity of the sky were estimated through visual observations at the beginning of each day, transformed to a scale of 1 to 10 and recorded. These are reflected in Appendix A at the end of this document. These weather conditions could have an influence on a quantitative study of this nature. By recording these conditions daily, one could implement a system of cross-referencing in order to explain sudden variations in the data set. No fieldwork was performed on extremely cold (<15˚C) or very cloudy days (>50% cover) (Pollard 1977; Pollard & Yates 1993; Kuussaari *et al.* 2007). Surveys continued on windy days, since preference for wind as a biotopic characteristic formed part of the study.

3.7 Biophysical factors.

Biophysical data were recorded for all transects and an average for every factor was subjectively categorised by observation for each site. The biophysical factors included a hill index, rock index, sand index, disturbance index and average distance from the sea. All biophysical indices were categorised as continuous variables (Kuussaari *et al*. 2007) on a scale of 0 – 5 with 0 representing the least and 5 the most extreme case (Table 2). The distance from the shore was determined in the following way: all transects were compared and the one closest to the sea, namely Transect 2C was given a maximum value of 5. The idea was that obstructions within the line of site to the sea had to increase the "distance to shore" factor and, therefore, transects from which the sea was not visible were given a value of 0. All other values were compared to these extremes in a subjective manner taking into account a straight line distance from the centre of the transect and the number and size of obstructions from the centre of the transect to the sea. The above distance values for each transect were used to calculate an average for each site. The wind factor was determined subjectively, taking into account topography, distance from the sea as well as visual observations of wind direction and strength. Habitat type, landscape openness and average windiness were considered interrelated (Kuussaari 2007). Hilliness and rockiness were determined subjectively by means of on-site observation. Biophysical factors at the sites were so different that subjective observations were believed to be sufficient.

Table 2. Biophysical indices at selected sites during the butterfly study in the West Coast National Park.

		Site1				**Site 2**				**Site 3**				**Site 4**			
		Rocky hill				Seashore bank				Coastal dunes				Dune & calcrete			
		A	B	C	AV	A	B	C	AV	A	B	C	AV	A	B	C	AV
INDICES	Disturbance	2	1	1	1.3	1	1	2	1.3	1	2	1	1.3	1	1	2	1.3
	Wind exposure	3	5	4	4.0	3	4	5	4.0	1	1	2	1.3	2	1	1	1.3
	Hill	4	4	4	4.0	0	0	1	0.3	3	3	3	3.0	2	2	1	1.7
	Rock	4	3	1	2.7	1	2	1	1.3	0	0	0	0.0	3	1	0	1.3
	Sand	2	1	1	1.3	1	1	3	1.7	5	5	5	5.0	3	3	4	3.3
	Distance from shore	0	1	2	1.0	3	4	5	4.0	2	3	4	3.0	0	0	0	0.0

3.8 Vegetation data.

Quantitative vegetation data for all known host plants for the relevant butterfly species were recorded during December 2006 (Appendix B) by using six circular sample-plots with a radius of 2.5 m within each transect. The circular sample-plots were placed on the centre line of the belt transects at every 70 steps and included sample-plots at the beginning and end of transects. The crown heights were recorded for the relevant host plants at each sample point (Appendix B).

Consider that the end points of transects were determined using a GPS that provided the user with a straight line distance between points. By using 70 steps the recorder compensated for the unevenness of the terrain and ensured that six sample points fitted into each transect of 250 m. This method gave the most representative data with a view to vegetation along transects keeping in mind that it is a rapid survey method and a very small percentage of the transect surface area is sampled. The method provides a cross section of plant communities in the area and not a complete species list.

Abundance values for the six vegetation sample points were added up to obtain total abundance values for each transect with regard to each species. The totals for three transects at each site were averaged to obtain mean abundance values for each site. Comparisons were then drawn between geographical distributions of butterfly species in relation to their specific host plants.

3.9 Analysis.

The study followed a combination of the Q-mode (sites classified according to their faunal composition) and R-mode (species distribution analysis across study area to derive correlation with environmental variables) analysis methods (Davis *et al*. 2001; Ribera *et al*. 2001; Hamer *et al.* 2003). Especially on the scale of this study it is important to distinguish how much of observed distributional variation is an artefact of intra-site variation. That is the reason why alpha (within site) as well as beta (between site) diversity were taken into account throughout (Palmer & Dixon 1990).

Shannon diversity indices (Shannon & Weaver 1949; Magurran 1988) were calculated according to:

$$H = \sum_{i=1}^{s} - (P_i * \ln P_i)$$

Where **s** is the number of species recorded, $\boldsymbol{P_i}$ is the proportion of mean density of the $\boldsymbol{i}$**-th** species. These indices were calculated across the study, for the entire study area during each sampling month (to serve as temporal replications) as well as for every site separately throughout the study period to determine the correlation between butterfly species and niche diversity (Figs. 11 & 12). The index gives more weight to scarce species as opposed to the Simpsons diversity index (Begon *et al*. 1996; Edge *et al*. 2008).

Most of the raw data were found to show normal distribution so that parametric analyses were possible. Analysis of variance (one-way ANOVA) was performed using Statistica (StatSoft Inc. 2004). The Tukey Honest Significant Difference (HSD) test was used for post-hoc comparisons to establish compositional differences between the different sessions as well as between the different sites when ANOVA indicated significant differences.

Diversity index values were analysed using multivariate analysis methods in Statistica (2004). Pearson's correlations (r_s) between the abundance of species, and the environmental variables were calculated to identify any significant preference tendencies for specific biotopic characteristics. For all box and whisker plots, boxes represent standard error (SE) and whisker values were viewed to be the mean ± 0.95 standard deviation (SD). For all tests, the 95% confidence level ($p < 0.05$) was regarded as statistically significant.

Following the reasoning of Kremen (1994) and Holl (1996) a Detrended Correspondence Analysis (DCA) of the lepidopteran x site matrix was conducted using the CANOCO software program (Ter Braak & Smilauer 1998). Kremen (1994) used indirect ordinations to show relationships between target taxa and environmental heterogeneity and Aviron *et al.* (2007) used CANOCO ordinations to establish butterfly assemblages as coupled to different land management types.

Indirect ordinations were drawn up to show the relationship between species with regard to similarity in distribution based on quantitative data. Direct gradient analysis was conducted using CANOCO, clusters sites, within an *n*-dimensional space by their similarity in species composition and their relationship to a set of supplied environmental variables (Kremen 1994). CANOCO Gaussian curves and generalized linear models were used to display direct relationships between species and specific biophysical variables. Using the results, conclusions were drawn with regard to the most significant factors influencing the distribution of species within the area.

CHAPTER 4:

RESULTS

4.1 Broad summary.

It was found that the subfamilies Theclinae and Nymphalinae dominated the study area with the former represented by nine species and a single species (*Vanessa cardui*) with high abundance for the latter. All the other subfamilies combined made up less than 4% of the total (Fig. 8). *Thestor dicksoni malagas* was the only species recorded in the Miletinae subfamily. The bulk of recordings within the Theclinae were species currently classified in the *Chrysoritis* genus (Heath & Pringle 2007). They also displayed the highest values of abundance and species richness.

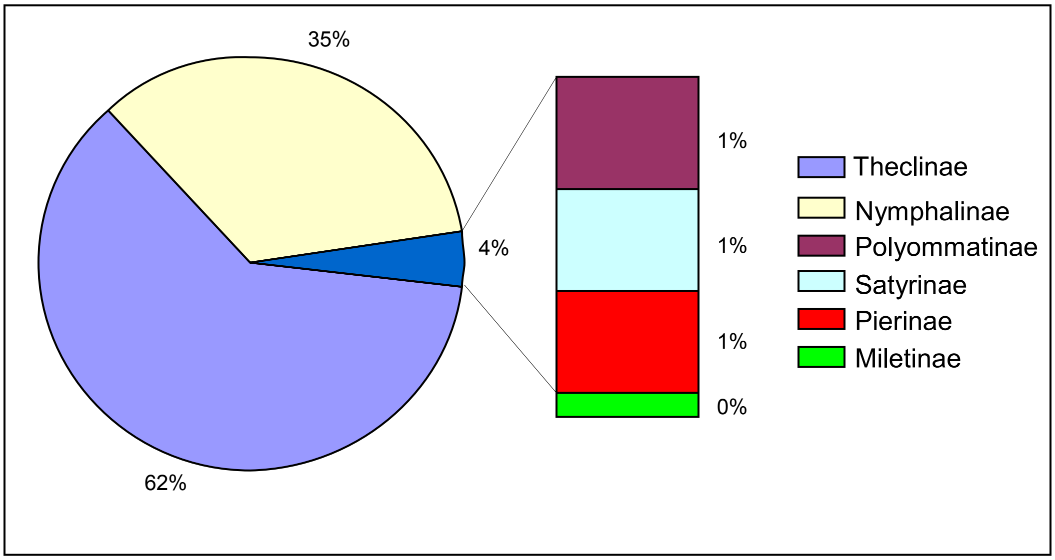

Fig. 8. Subfamily representation of butterfly species recorded at the West Coast National Park during the period October – April 2006/07.

A total of 17 species of butterflies were identified at transects in the course of this study (Table 3). The species list and associated larval host plants are included as Appendix B. Taxonomy of the genus *Chrysoritis* follows the latest revision by Heath & Pringle (2007) and that of *Thestor,* Heath & Pringle (2004).

Table 3. Classification of butterfly species recorded in the West Coast National Park during the period October – April 2006/07.

	Families [a]	Subfamilies [a]	Species	Common Names English
	PIERIDAE			Whites, Yellows and Tips
		PIERINAE		Whites and Tips
1			***Pontia helice helice*** (Linnaeus, 1764)	**African Meadow White**
	NYMPHALIDAE			Brush-footed butterflies
		SATYRINAE		Browns
2			***Melampias huebneri huebneri*** Van Son, 1955	**Boland Brown**
3			***Tarsocera cassina*** (Butler, 1868)	**Sand-dune Spring Widow**
		NYMPHALINAE		Pansy
4			***Vanessa cardui*** (Linnaeus, 1758)	**Painted Lady**
	LYCAENIDAE			Blues and Coppers
		THECLINAE		Hairstreaks and Coppers
5			***Aloeides pierus*** (Cramer, 1779)	**Dull Copper**
6			***Chrysoritis chrysaor*** (Trimen, 1864)	**Burnished Opal**
7			***Chrysoritis felthami felthami***	**Feltham's Opal**

		(Trimen, 1904)	
8		***Chrysoritis pan pan*** (Pennington, 1962)	**Pan Opal**
9		***Chrysoritis pyroeis pyroeis*** (Trimen, 1864)	**Sand-dune Opal**
10		***Chrysoritis thysbe osbecki*** (Aurivillius, 1882)	**Osbeck's Opal**
11		***Chrysoritis zonarius zonarius*** (Riley, 1938)	**West Coast Daisy Copper**
12		***Leptomyrina lara*** (Linnaeus, 1764)	**Cape Black-eye**
13		***Phasis thero*** (Linnaeus, 1764)	**Silver Arrowhead**
	POLYOMMATINAE		Blues and Ciliated Blues
14		***Oraidium barberae*** (Trimen, 1868)	**Dwarf Blue**
15		***Zizeeria knysna*** (Trimen, 1862)	**Sooty Blue**
16		***Zizula hylax*** (Fabricius, 1775)	**Gaika Blue**
	MILETINAE		Skollies and Woolly Legs
17		***Thestor dicksoni malagas*** Dickson & Wykeham, 1994	**Atlantic Skolly**

[a] The sequence of butterfly families and subfamilies is largely based on Wahlberg, Weingartner & Nylin (2003), for the Nymphalidae subfamilies and Vane-Wright (2003), for the Lycaenidae subfamilies with genus classification as mentioned above. For easier reference, species names follow alphabetically under the rubrics of subfamily.

Total number of individuals encountered during the study amounted to 1 037, but this included some individuals that were sampled more than once. Although the possibility for double sampling did exist within repetitions, the relative contribution of the different species in relation to the total should not be affected by this as this error would be relevant to all species and repetitions. This study, therefore, refers to numbers of individuals encountered not as “abundance” but rather as “abundance values”.

The abundance value total for all the surveys included 16 individuals that could not be identified due to the period or distance of observation, or individuals that were impossible to capture on account of obstructions or speed of flight. Unidentified individuals equalled 1.54% of the total encountered. The percentage of unidentified individuals was assumed to be low enough that it could be left out during further discussions. Ordinations (DCA at the species unit) with unknown species included vs. those with the unknown species excluded delivered similar results.

The percentage abundance values of all surveys as reflected in Figure 10 show the variation in dominance of butterflies amongst the four sites throughout the study. Very strong domination by a single species was observed at Sites 2 and 4 with regard to abundance values. Site 1 (rocky hill) showed the highest levels of evenness for abundance values.

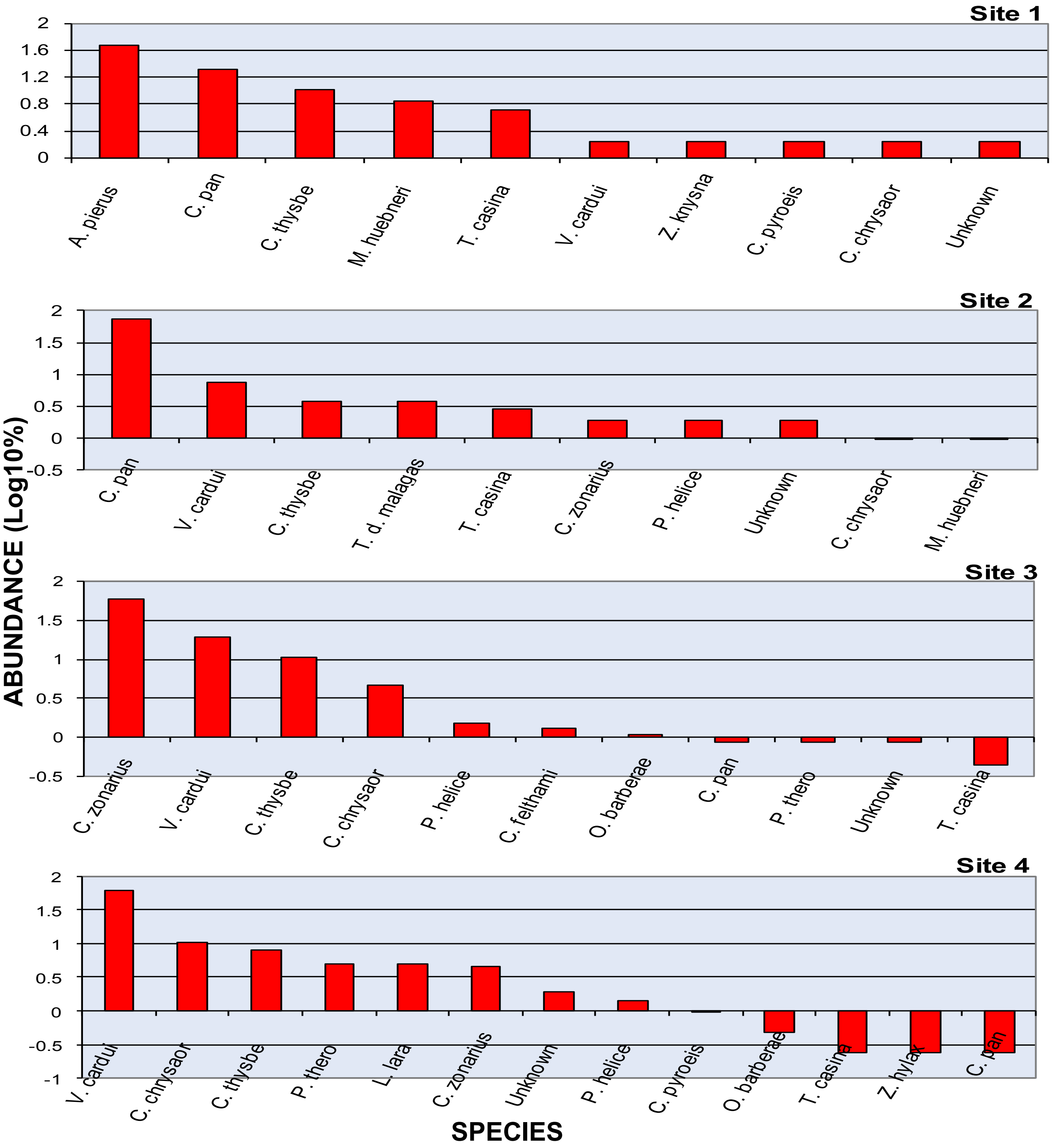

Fig. 9. Relative abundance expressed as Log 10 % of the total of species (n = 17) recorded at selected sites in the West Coast National Park during the period October – April 2006/07.

The results for the respective percentage dominance values of species (n = 17) at the four sites were: *Aloeides pierus* 47.3% at Site 1 (rocky hill), *Chrysoritis pan* 74.5% at Site 2 (seashore bank), *C. zonarius* 58.6% at Site 3 (coastal dune) and *Vanessa cardui* 61.5% at Site 4 (dune & calcrete). These results suggest clear preferences for specific biotopic characteristics and are analysed further by means of a breakdown of seasonal patterns and a more in depth comparison between the sites.

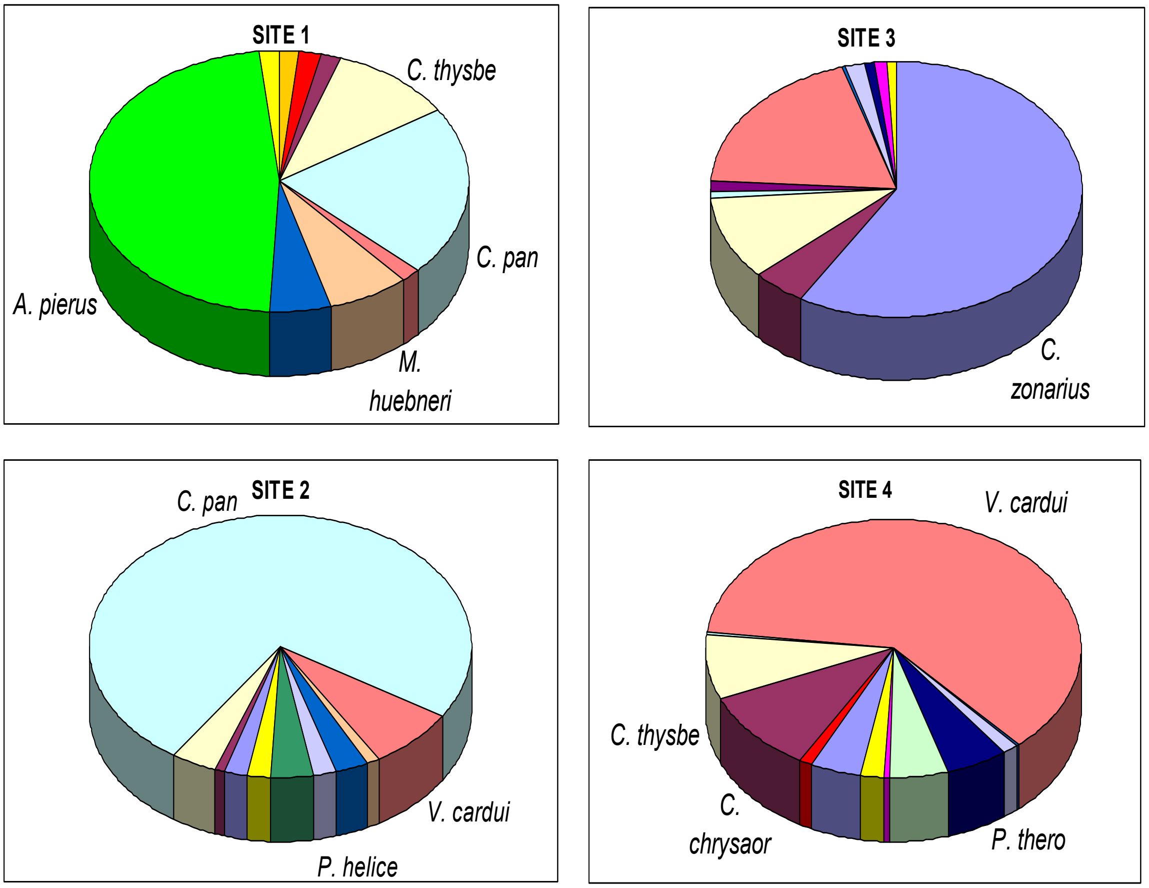

Fig. 10. Relative abundance of butterfly species (n = 17) at selected sites in the West Coast National Park during the period October – April 2006/07.

4.2 Spatial and temporal variation in diversity, abundance and species richness.

Shannon diversity, abundance and species richness values for the different butterfly communities with a view to each site as well as averages and SD/SE values are summarised in Figure 11.

Overall diversity based on the Shannon H' index is the highest at Site 4 (dune & calcrete) with an average value of H' =1.3 (n = 12). There is a statistically significant difference ($p > 0.05$) between Site 4 (dune & calcrete) and Site 2 (seashore bank) with the lowest average value of H' = 0.4 (n = 9).

Site 4 (dune & calcrete) also shows the highest overall species richness with a mean of 5.28 ($p < 0.05$), but there is no statistically significant difference between this site and any of the other three with mean values of 2.85; 2.42; 3.71 for Sites 1, 2 and 3 respectively ($p < 0.05$) (Fig. 11).

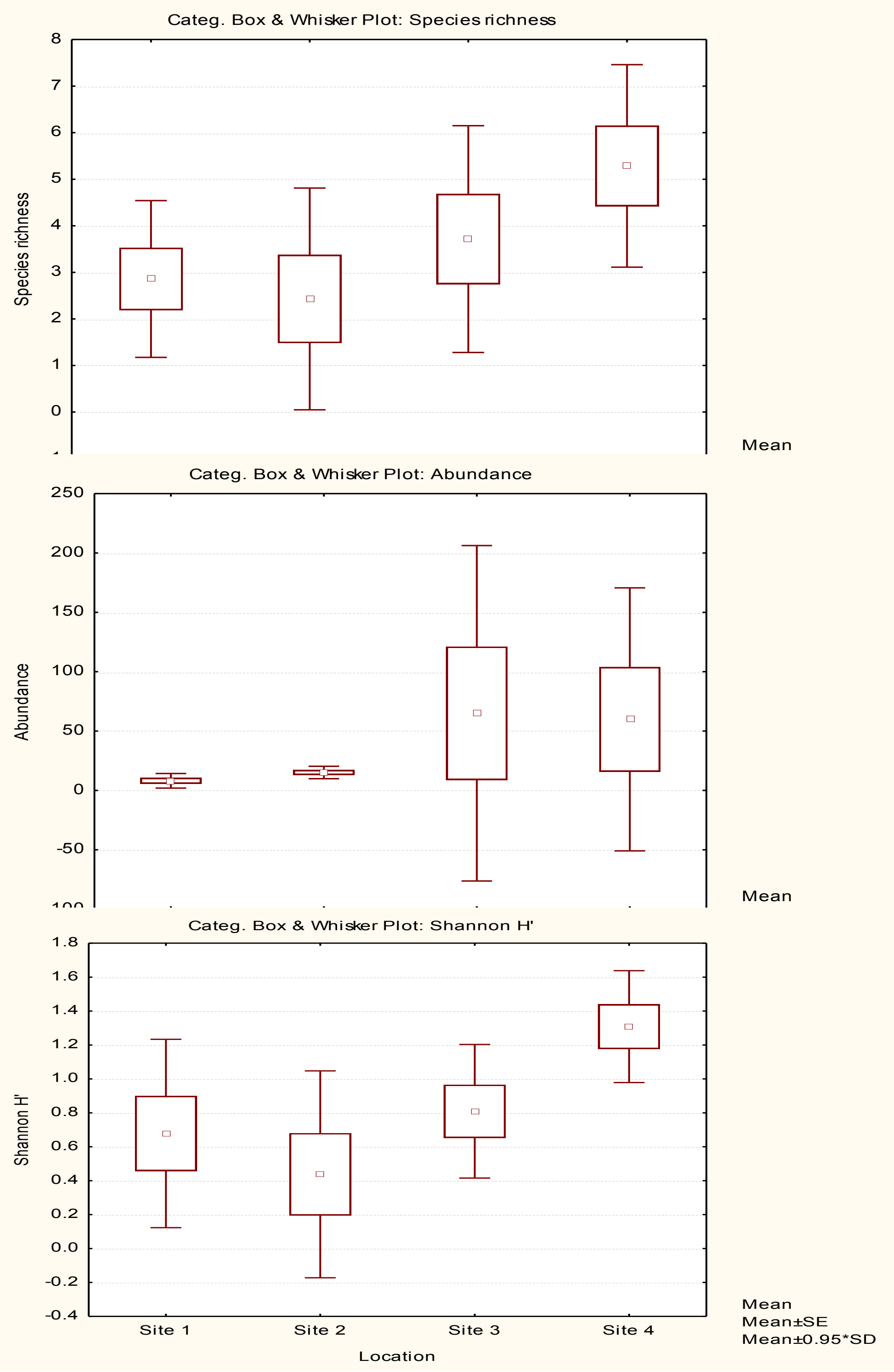

Fig. 11. Overall geographical variation of butterfly species composition (n = 17) at selected sites in the West Coast National Park during the period October – April 2006/07. Box and whisker plots indicate the mean ± standard error and standard deviation.

4.3 Temporal observations

4.3.1 Comparison of general seasonal patterns.

General seasonal patterns of butterfly diversity and abundance were observed at all selected sites. Species richness and abundance show overall mean values of 8.25 and 191 respectively, during Session 1 (October 2006). The highest Shannon diversity was also recorded during this period as can be expected in terms of the high richness and abundance values. The lowest overall diversity occurred in early February 2007 with a mean of 0.52 (Fig. 12).

The totals for Shannon diversity, species richness and abundance during Session 1 (October 2006) surpass all other sessions in all three variables (Fig. 12). Session 1 showed by far the highest values for abundance and species richness as indicated by the statistically significant differences between Session 1 and all the other sessions in terms of species richness, and between Session 1 and Sessions 2, 4, 5, 6 and 7 in terms of abundance ($p < 0.05$).

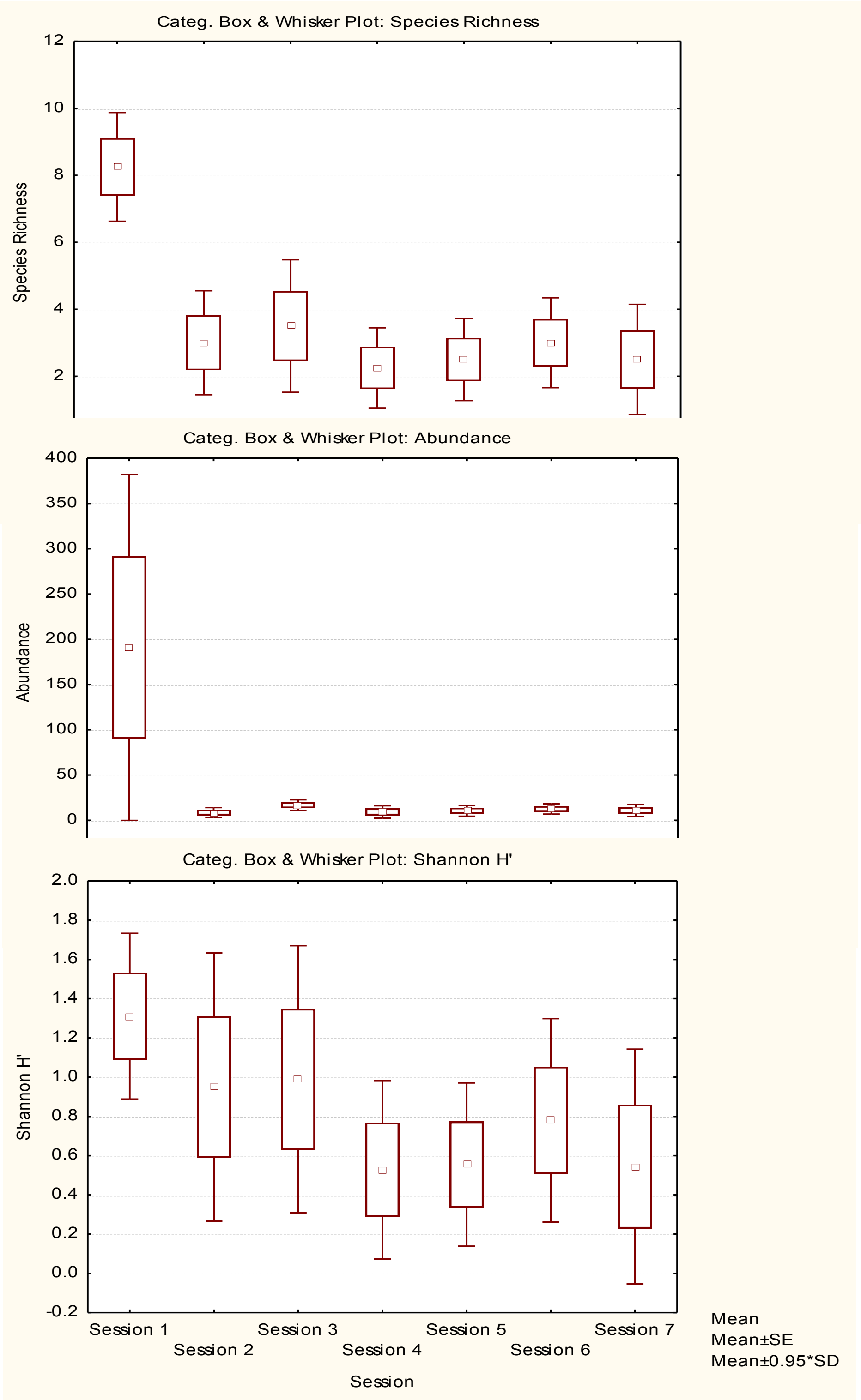

Fig. 12. Overall temporal variation of butterfly species composition (n = 17) through the study at selected sites in the West Coast National Park during the period October – April 2006/07. Box and whisker plots indicate the mean ± standard error and standard deviation.

4.3.2 *Temporal comparison between sites*.

Figure 13 shows that the Shannon Wiener diversity value for Site 2 plummeted from the highest recorded value during Session 1 (October 2006) to the lowest recorded value during December 2006. Only one species, *Chrysoritis pan,* was recorded during both sessions in December 2006. Site 4 constantly displays the highest Shannon diversity values of all sites over the course of each session throughout the study, with the exception of October 2006. Shannon Wiener values for species diversity in three of the four sites show a slight increase from the February to the April sessions (Fig. 13).

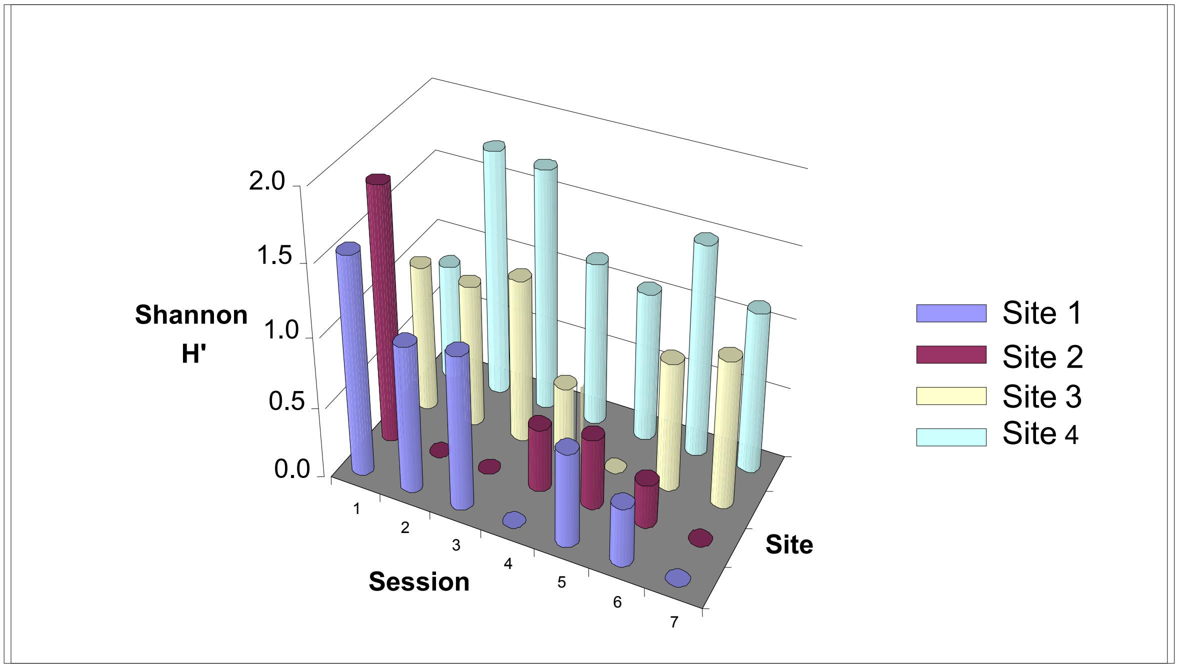

Fig. 13. Shannon diversity values for butterfly species (n=17) at four selected sites in the West Coast National Park during the period October – April 2006/07.

The trend with regard to Shannon diversity at Site 4 (dune & calcrete) across time is more or less inverse compared to that displayed by Site 2 (seashore bank). Sites 1 and 3 follow a more or less similar trend across time except for the first session which shows a strong dominance of *C. zonarius* at Site 3. Site 4 is the only site that exhibits the lowest diversity during Session 1 (in comparison to the other sessions), while this could also be due to dominance of a single species (Fig. 13).

Site 2 (seashore bank) shows the greatest dominance by a single species across the study, namely *Chrysoritis pan* (Fig. 14). The results indicate that *C. pan* was only recorded from the December sessions onwards at Site 2 (seashore bank). *C. thysbe* was only recorded during October at Site 2. Widely distributed species like *Vanessa cardui* was recorded at all four sites during Session 1 (October 2006). *C. thysbe* was also present at all four sites although the distribution became limited to mainly Sites 3 (coastal dune) and Site 4 (dune & calcrete) from Session 2 onwards. *Leptomyrina lara* was found exclusively at Site 4 and *Aloeides pierus* only at Site 1 (rocky hill) (Fig. 14). In general the "habitat specialists" were more constant in spatial distribution through time as could be expected. The species with intermediate distribution ranges on a local scale showed some adjustment of these ranges in response to seasonal changes.

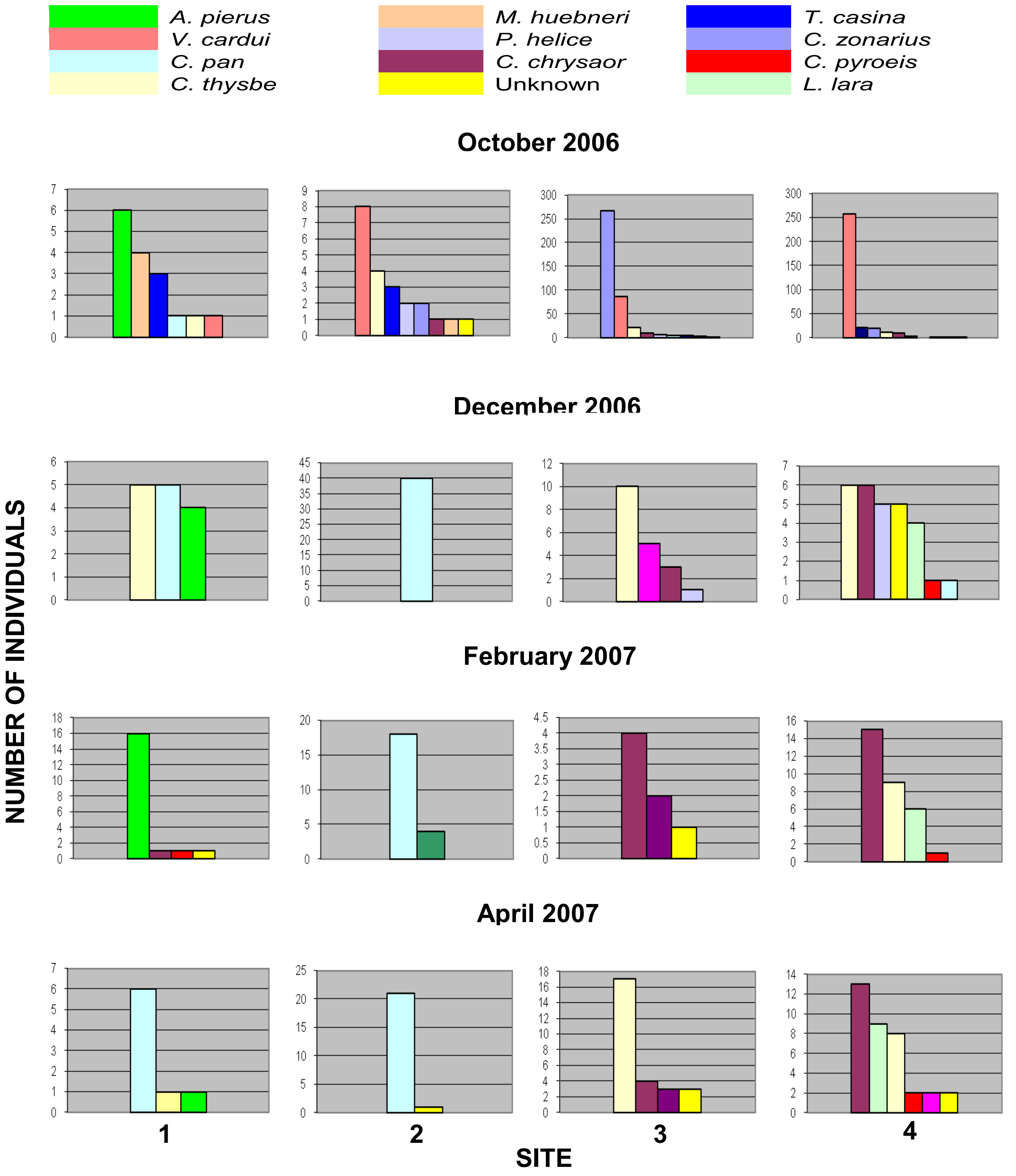

Fig. 14. Species composition of butterflies at selected sites in the West Coast National Park during the period October – April 2006/07.

4.3.3 *Temporal comparison of sites with regard to species composition.*

Figure 15, compare the four sites with regard to their similarity in composition through time. Site 2 (seashore bank) shows the most consistent results based on total species composition across the seven sessions, although this could be due to the very low species richness at the site from December 2006 onwards. Consider the close grouping between the different sessions at Site 2 (Fig. 15). Site 3 (coastal dune) shows considerable variation across the sessions, but a slightly stronger correspondence with Site 4 (dune & calcrete) than with Sites 1 and 2, which also showed some relationship between them (Fig. 15).

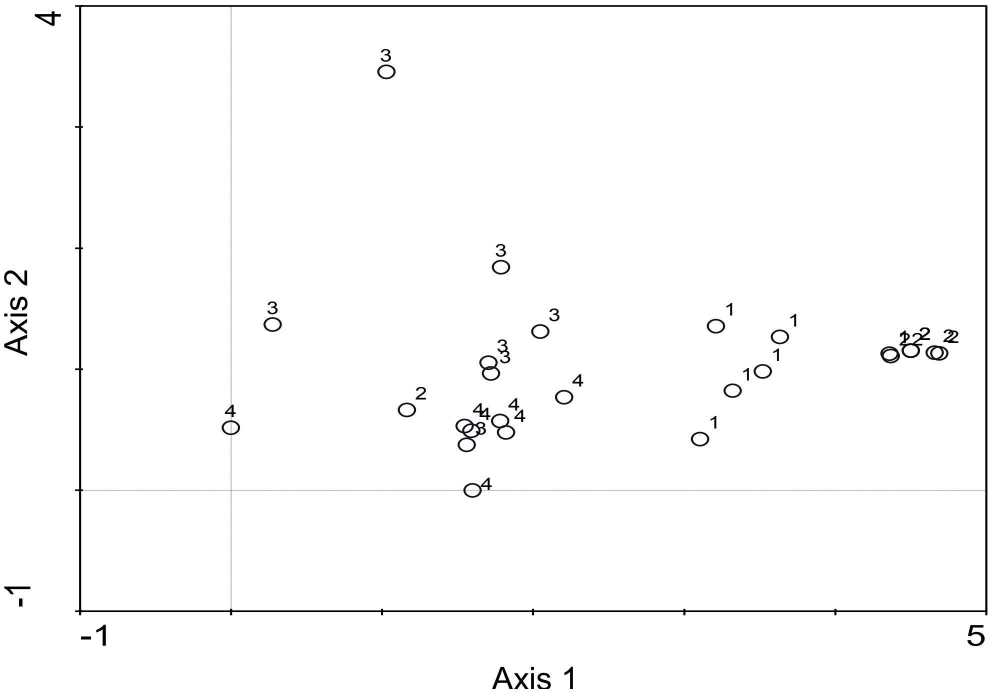

Fig. 15. Relationship (DCA indirect ordination) of butterfly species composition in relation to time at four selected sites in the West Coast National Park during the period October – April 2006/07. Circles represent sampling sessions at specific sites. *Zizeeria knysna* was deleted as outlier to prevent compression of the other data.

4.4 Spatial observations

4.4.1 *Indirect ordinations of species and species composition*.

In Figure 16, species are represented by the first three letters of the generic and specific epithets (Holl 1996). Species with high quantitative correlations in specific areas will be closer together in ordinational space, those with negative quantitative distributional correlations will be far apart. *Zizeeria knysna* was recorded only on a few occasions and were, therefore, deleted from the data set to avoid compression of other species.

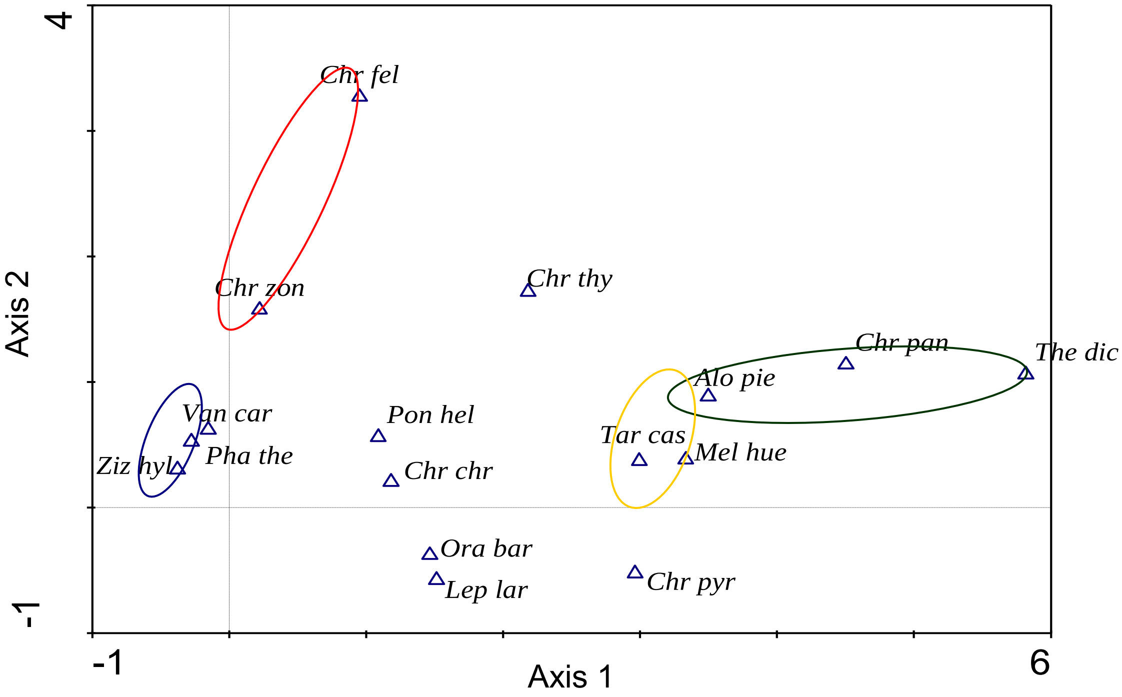

Fig. 16. Relationship (DCA indirect ordination) of overall distribution of butterfly species (n = 16) at selected sites in the West Coast National Park during the period October – April 2006/07.

4.4.2 *Direct ordinations showing the influence of abiotic factors on community structure*.

Some repetitive groupings were observed among specific species with regard to the distribution of individuals. The following groupings are based strictly on geographical distribution and reflect no temporal or seasonal fluctuation in terms of local distribution. *Tarsocera cassina, Melampias huebneri* and *Aloeides pierus* form an association when they are present and the association almost always correlates with high wind, and to a lesser extent with the rock and hill index (Fig. 17). *A. pierus* also shows a relatively strong correlation with *Chrysoritis pan* and *Thestor dicksoni malagas* when they are present.

According to the correlation matrix (CANOCO) wind shows the strongest correlation with Axes 1 with a weighted factor of 0.94, followed by sand with a negative correlation factor of -0.77. The hill index had the strongest correlation (-0.64) with Axis 2. The Monte Carlo test showed an Eigenvalue (λ) of 0.772; (p = 0.06; 499 permutations) with regard to the first axis. The (λ) indicates that Axis 1 represents a significant gradient in distribution preference. Axis 1 accounted for 15.4% of the variance in data where Axis 2 accounted for an additional 9.7%. On Axis 1 species are clustered (effect reduced after log transformation) towards the higher values of the sandiness index (λ = 0.772; p = 0.06).

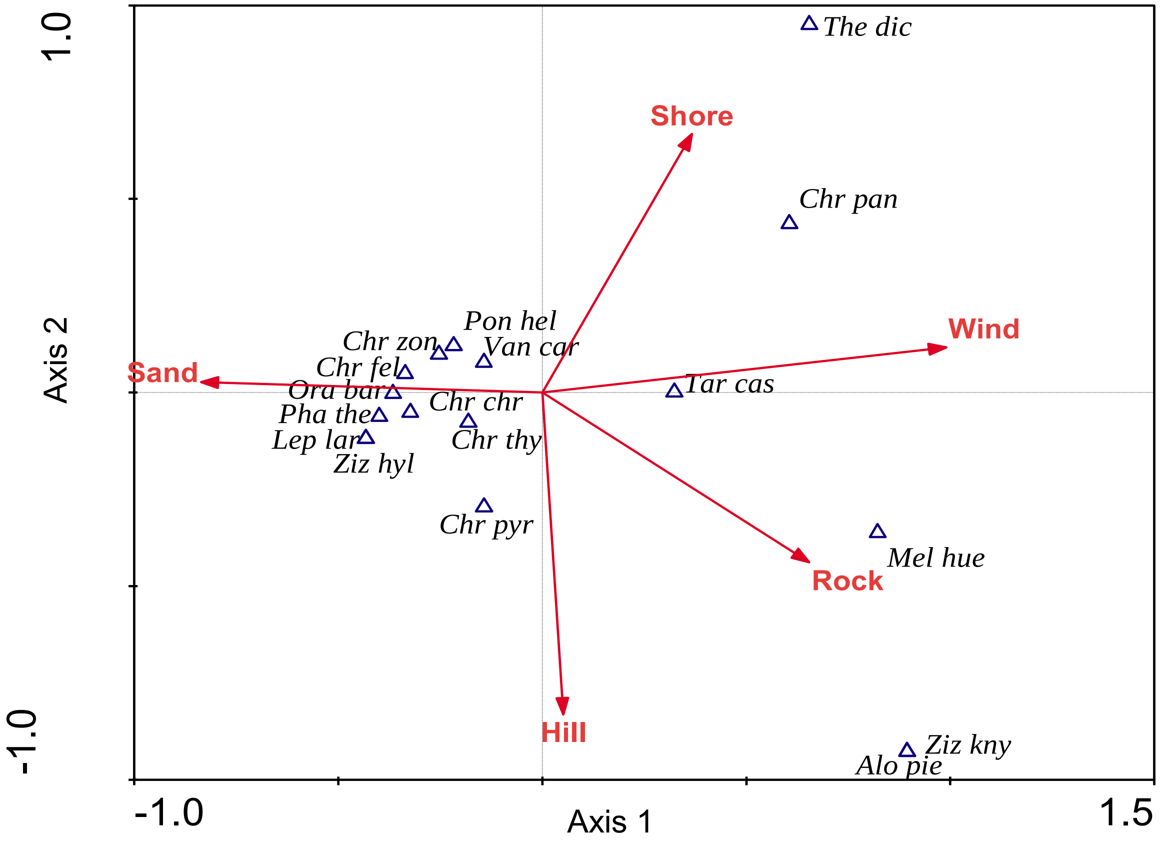

Fig. 17. CANOCO CCA direct species / environmental biplot for butterfly species (n = 17) at four selected sites in the West Coast National Park during the period October – April 2006/07.

The data was log transformed to distinguish between species with close distributional correlations. Length of arrows is proportional to their importance while the position with respect to an axis indicates the correlation of the axis with that factor. The angle between two arrows reflects the inter-relation between the two variables. Variables are positively correlated if their arrows subtend a small angle, orthogonal if their arrows are at 90˚, and negatively correlated if their arrows are in opposite directions (Breebaart et al. 2001).

Figure 18 is a Gaussian curve based on the Generalized Additive Model (GAM, CANOCO) to show response according to distribution of the most responsive species as correlated with the sand index. The Gaussian curve (Fig. 18) tends to exaggerate the response of species recorded at high abundance values, such as *Chrysoritis zonarius,* to some biophysical predictor. Figure 19 consist of generalized linear response curves (CANOCO) showing response to the other biophysical factors. Species with relatively flat gradients in Figure 19 are the more generalist type species, while those with steep positive angles show strong preference for that specific factor. The species with steep negative angles experience strong negative correlations with the relevant environmental index. The data was log transformed to distinguish between species with close distributional correlations.

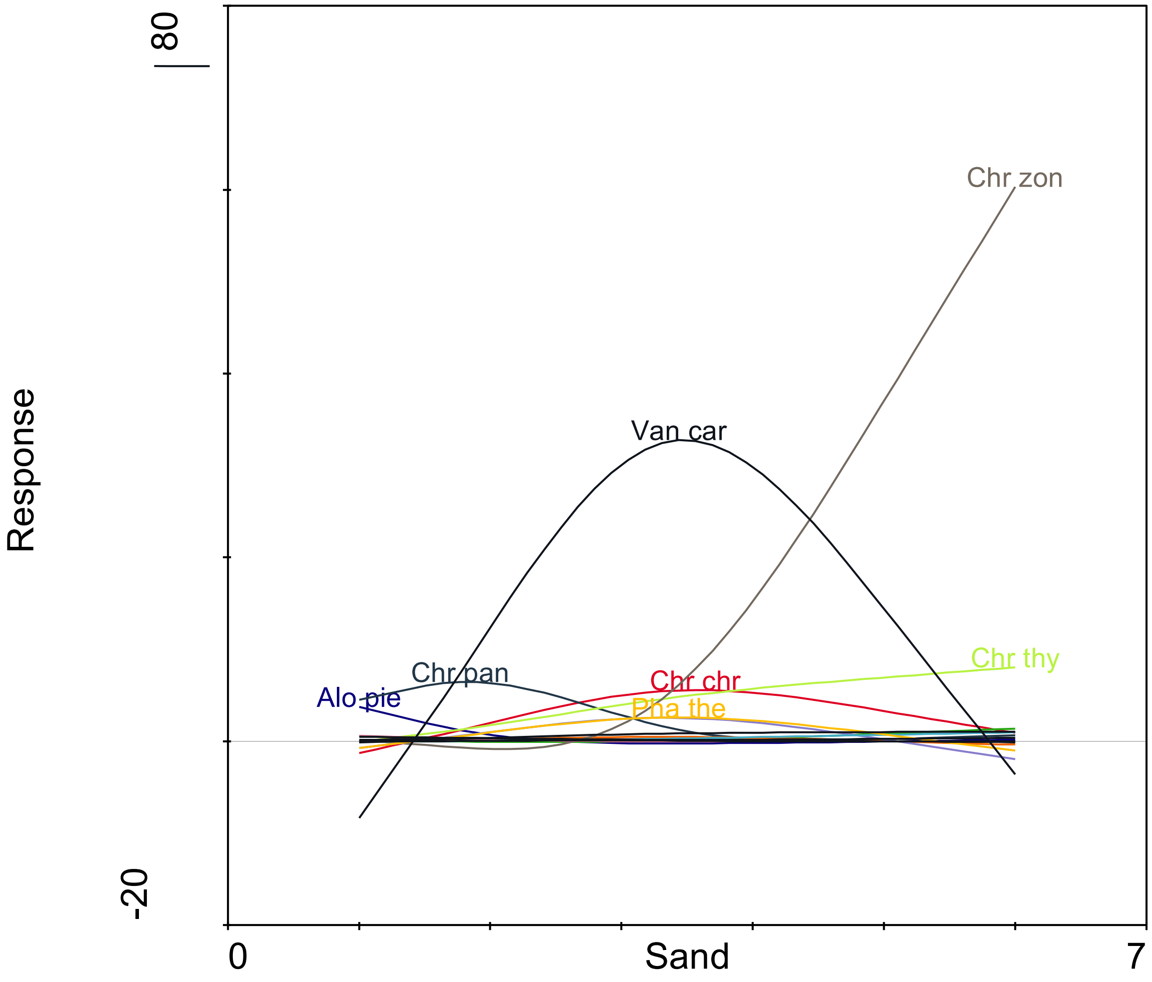

Fig. 18. Relationship between habitat sand index and the seven most responsive butterfly species recorded in the West Coast National Park during the period October – April 2006/07.

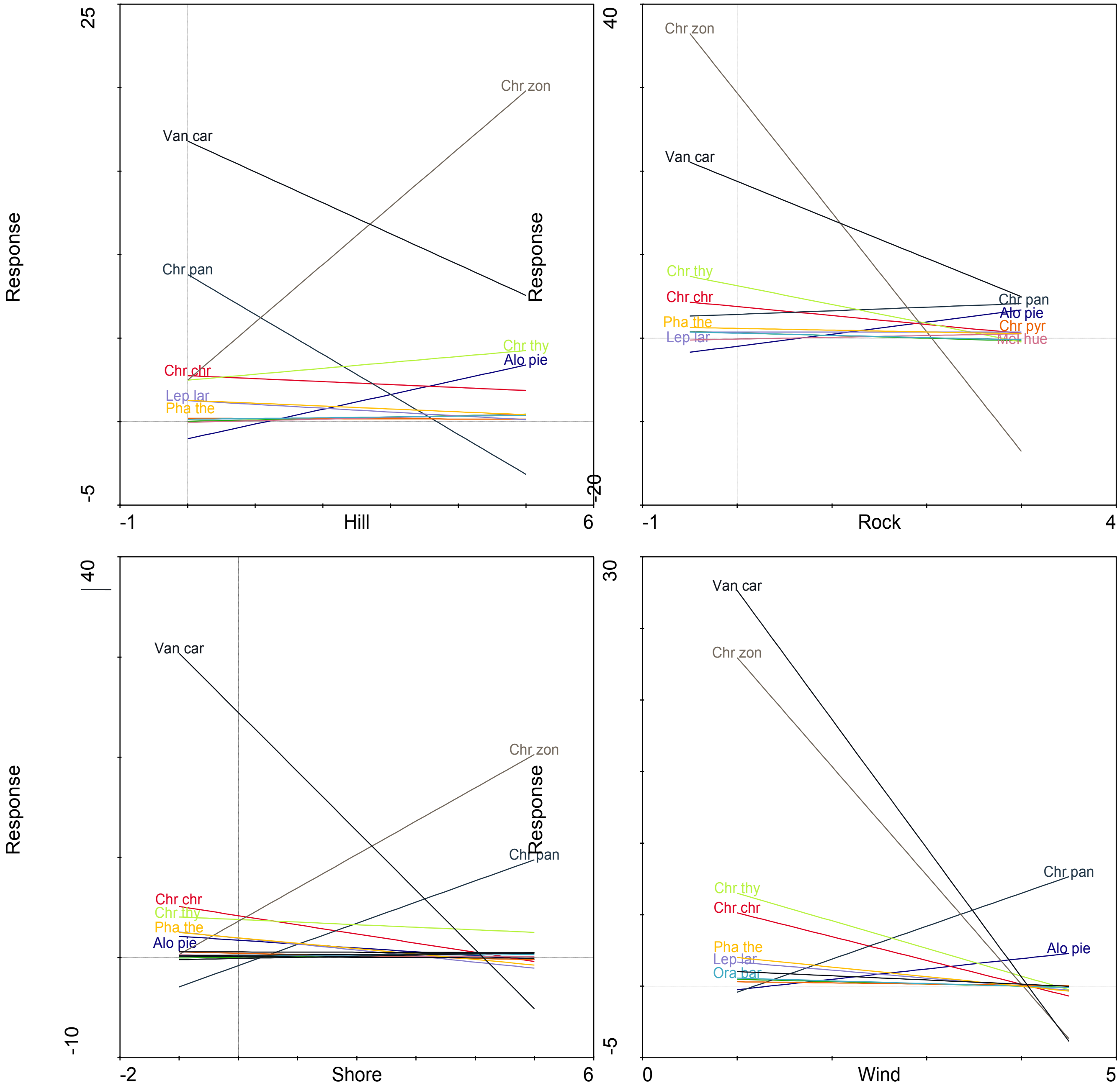

Fig. 19. Relationship between biophysical indices and the most responsive butterfly species recorded in the West Coast National Park during the period October – April 2006/07.

Table 4 provides a summary of the distribution and groupings within the *Chrysoritis* genus based on CANOCO ordinations, response curves, literature, and *in situ* observations, between the four biotopes. Some species show no obvious habitat preferences while others show very specific preferences. *C. chrysaor* and *C. thysbe* are grouped together according to distribution and both are widely distributed in the study area. *C. felthami* is very limited in distribution as well as in number of sightings.

Table 4. Habitat preference of *Chrysoritis* species from four biotopes in the West Coast National Park during the period October – April 2006/07.

Species	**Habitat preference**	**Study area distribution**	**Site presence**
C. chrysaor	Less exposed sandy areas. No specific preference for dune crests or dune valleys.	Widespread	1,2,3 & 4
C. felthami	No clear preference for rocky hill tops or valleys. Less dominant on dune tops than *C. thysbe*.	Limited	3
C. pan	Rocky and more exposed flat and windy areas. Generally closer to shore.	Moderate to widespread	1,2,3 & 4
C. pyroeis	Less exposed and more disturbed. Small sandy valleys between dunes.	Limited	1 & 4
C. thysbe	Dune tops (especially males), but occurs in valleys. Distance to shore less important.	Widespread	1,2,3 & 4
C. zonarius	Less exposed sandy areas. Common in duneveld during spring.	Moderate	2,3 & 4

Chrysoritis as the dominant genus in the area were classified separately and in combination with other genera (Table 5), to identify the amount and significance of within genus variation in habitat preference.

4.5 Variation within sites (Alpha diversity) (Fleishman *et al*. 2003).

Transect 1a, with an average Shannon diversity value of 0.0 for three sessions and no recordings for the rest of the study (Appendix F), is by far the lowest in diversity. Species richness and abundance for this transect are also much lower than those of the other transects. There were only two species recorded at this transect.

At Sites 1 (rocky hill) and 2 (seashore bank) the average Shannon diversity between transects are negatively correlated with distance to shore, while these results for Sites 3 (coastal dune) and 4 (dune & calcrete) are more or less even across transects (Appendix F). Transect 4a has the highest Shannon diversity, species richness and abundance values of all transects and this transect is also the closest to the lagoon. Appendix C presents all raw data.

4.6 Grouping of taxa based on biotopical preferences.

Table 5 reflects the groups that have been observed during the course of the study. It must, however, be stressed that some species within the same group do not co-occur within areas due to seasonal fluctuations within species. These groupings are based mainly on the nearest neighbour principle using (DCA) ordinations as well as statistically significant correlations between species at the $p < 0.05$ significance level (Statistica version 8 software) (Appendix D).

Within the groupings, *Chrysoritis zonarius, Melampias huebneri, Tarsocera cassina, Vanessa cardui, Zizula hylax* and *Phasis thero,* were only present during the early spring (Session 1) and *Thestor dicksoni malagas* only during February 2007.

It is interesting to note that the entire Group 4 is only present during Session 1. This group represents species with a wide distribution in the local area and some of the migrating species. Group 2 represents species that are extremely site-specific with a strong link to Site 1 (rocky hill). Group 5 consists of species that display a preference for sandy areas and Group 3 of species that prefer exposed areas like those at Site 2.

Table 5. Grouping of butterfly species (n = 16) in the West Coast National Park during the period October – April 2006/07 based on CANOCO biplots and the nearest neighbour principle in indirect DCA ordination. Colour codes under group headings are the same as those used in Figure 16.

Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
⬛	🟨	🟩	🟦	🟥
C. chrysaor	*A. pierus*	*A. pierus*	*P. thero*	*C. zonarius*
C. thysbe	*M. huebneri*	*C. pan*	*V. cardui*	*C. felthami*
C. pyroeis	*T. cassina*	*T. d. malagas*	*Z. hylax*	
C. zonarius				
L. lara				
O. barberae				
P. helice				

All the species in Group 1 associate strongly with sites towards the South, especially Site 4. Some species are intermediate between groups with preferences that fall in two groups, for instance in the cases of *Aloeides pierus* and *Chrysoritis zonarius*.

Table 6 provides a summary of the findings of the study with regard to geographical as well as temporal distribution, compared to the distribution of specific larval foodplants. It also gives the biotopic characteristics that every species prefers as derived from CANOCO DCA ordinations. The results are summarised in a presence/ absence format in order to draw comparisons between species distribution and foodplant distribution.

It must be emphasised that the only aim of the vegetation data (as presented in Table 6) was to get a broad idea of the distribution of certain relevant plants at specific points along transects. In no way should it be viewed as a complete or thorough reflection of the vegetational composition across any of the sites. The data are based on six circular quadrates within each transect with a radius of 2.5 m covering a very limited total area in comparison to the total area of the study. The chances for sampling error due to differential sampling and non-sampling of rare species are good.

Table 6. Occurrence of butterfly species (n = 17) recorded in the West Coast National Park during the period October – April 2006/07. F/P Loc, foodplant locality. Foodplants listed in order of importance.

Species	**Group**	**Site**	**Session**	**Habitat preference**	**Cited foodplants**	**F/P Loc**
Aloeides pierus	2 & 3	1	1 - 6	Wind/ Rock	*Aspalathus* spp.	Not recorded
Chrysoritis chrysaor	1	1 - 4	1 - 7	Sand	*Cotyledon orbiculata* , *Zygophyllum sessilifolium*, *Rhus* spp.	1 - 4
C. felthami	5	3	1,5 & 7	Sand/ Shore	*Zygophyllum flexuosum, Z. sessilifolium*	2 - 4
C. pan	3	1 - 4	1 - 7	Rock/ Wind/ Shore	*Chrysanthemoides incana*, *Zygophyllum retrofractum, Osteospermum* spp.	Not recorded
C. pyroeis	1	1 & 4	3 – 5 & 7	Sand	*Zygophyllum flexuosum, Thesium* spp.	2 - 4
C. thysbe	1	1 - 4	1 - 7	Sand	*Chrysanthemoides incana, C. monilifera, Osteospermum polygaloides, Lebeckia plukenetiana, Aspalathus* spp., *Thesium* spp., *Zygophyllum* spp.	1 - 4
C. zonarius	1 & 5	2 - 4	1	Sand/ Shore	*Chrysanthemoides incana*	Not recorded
Leptomyrina lara	1	4	1 - 7	Sand	*Kalanchoe lugardii, Cotyledon orbiculata*	4
Melampias huebneri	2	1 & 2	1	Wind	*Avena sativa, Ehrharta erecta*	1
Oraidium barberae	1	3 & 4	2,3 & 6	Sand	*Exomis axyrioides*	Not recorded

Pontia helice	1	2 - 4	1 - 3	Sand	*Alyssum* sp, *Heliophila linearis, Lepidum capense, Sisymbrium* sp., *Rapistrum rugosum*, *Reseda odorata*	Not recorded
Phasis thero	4	3 & 4	1	Sand/ Rock	*Rhus undulata, R. incise, Melianthus major*	Not recorded
Tarsocera cassina	2	1 - 4	1	Wind	*Lolium* spp., *Brachypodium distachyon.*	1 - 4
Thestor dicksoni malagas	3	2	4 & 5	Shore	Unknown *(Probably no foodplant).	Not recorded
Vanessa cardui	4	1 - 4	1	Sand/ Rock	*Carduus* spp, *Arctotheca calendula, A. stoechadifolia, Gazania* sp., *G. purpureum, G. luteo-album, Berkheya discolor*, *Malva parviflora.*	1 - 4
Zizula hylax	4	4	1	Sand/ Rock	*Paulopsis imbricata, Ruellia* spp., *Justicia* spp., *Chaetacanthus setiger*, *Dyschoriste* spp., *Oxalis corniculata*.	Not recorded
Zizeeria knysna	Outlier	1	7	Insufficient data	*Amaranthus deflexus, A. viridis, Euphorbia* sp., *Oxalis corniculata, Medicago sativa, Zornia* sp., *Tribulus terrestris.*	1 & 4

* Current research indicate that most species in the *Thestor* genus do not make use of a specific/ any larval foodplant although much more work needs to be done on the life cycle of the genus to confirm this.

CHAPTER 5:

SPECIES REVIEW AND DESCRIPTION

5.1 Background

The local distribution of species has a key role to play in habitat conservation (Thomas & Harrison 1992; Lu & Samways 2002). No conservation effort should focus only on the regional or larger scale (Sutcliffe *et al*. 1996) as the choice of scale can affect the results and complicate comparison between studies (González-Megías *et al*. 2007). To draw up distribution records of populations can be very useful as a quick reference of where to look for which species, but an in depth study of local distribution can serve as a record to determine migration tendencies, to observe changes in population distribution dynamics and to find explanations for these changes. The study was introduced outlining the trade off between development and conservation and in this section it is once again emphasised: any development effort should be preceded by an in depth study on local scale distribution not just with regard to butterflies, but taking into account all species that form part of the ecosystem (Lu & Samways 2002).

When modifying land for development especially in cases in which rare or endangered species are concerned, it is important to conserve areas with the optimum availability of larval foodplants and nectar resources combined with the proper niche requirements as preferred by all and especially endemic species (Henning 2001; Thomas *et al*. 2001; Lu & Samways 2002; Edge 2005a; Habel *et al*. 2007). Decisions about the preservation of an appropriate habitat should be guided by distribution preferences on multiple spatio-temporal extents (Fleishman *et al*. 2003).

In most development projects today this is not the case due to the fact that there is not always enough of the required taxonomic expertise and resources (Sandham *et al*. 2005). Creating and updating a database of biotopic habitat preferences of protected species, especially in areas identified for conservation, will ensure that this type of information is readily available. A specialist study in these regions conducted as part of a developmental project could then only serve a confirmatory role.

Blair (1999) showed that although butterfly species richness (for the species he studied) peaked in an area at intermediate levels of development, abundance was negatively correlated with the level of development as opposed to the abundance in birds that peaked at intermediate levels of disturbance. Unfortunately it is abundance that is important in the protection of rare species and that is what makes quantitative studies so effective in identifying suitable habitat for conservation (Lu & Samways 2002).

Biotopic habitat preferences can not be analysed without identifying and incorporating specific small scale behavioural patterns between species. This chapter will attempt to bring the preferred microhabitats as identified throughout the course of this study in context with the known behavioural patterns and general characteristics of the different species. Several previous studies touched on biotopic preferences of specific species and in most instances this corresponds with the observations of this study to a surprising degree. Information presented in this chapter can be used to guide conservation officials (especially locally) to identify suitable microhabitats that possess all the relevant niche requirements within the distribution ranges of specific species for conservation.

5.2 Species assessments

5.2.1 *Aloeides pierus* (Cramer, 1779) Dull Copper.

Foodplants: *Aspalathus* spp. (Fabaceae).

Fig. 20. *Aloeides pierus.* Photograph by C.K. Willis. 2008. Northern Cape.

The distributional range of *Aloeides pierus* extends from the Western Cape to the Eastern Cape, parts of the Free State and the lower-lying areas of Lesotho (Pringle *et al*. 1994). A number of divergent floral regions are covered by its range which includes sandy patches and dunes along the coastline to open veldt and mountainsides more inland. Pringle *et al*. (1994) mentions Saldanha Bay as a known locality of *A. pierus*.

Its normal flight period is from September or October to late April, with lesser numbers in some localities in midsummer (Pringle *et al*. 1994; Claassens 2000). This species display a strong association with high hill, rockiness and wind indices as is evident in the extreme position it occupies in the species/environmental biplot ordination (Fig. 17) and the linear response curves (Fig. 19).

Aloeides pierus at Site 1 (rocky hill) is in sympatry with *Melampias huebneri*. The species seem to overlap in distribution without obvious interspecific competition for resources. They were found perching in sandy patches between vegetation on the sides or tops of hills. *A. pierus* is distributed more toward the southern side of the rocky hill at Site 1. The distribution of the species is limited to Site 1 and based on the total number of individuals for the entire study, it could be said to dominate the site (Figs 9 & 10). There was some variation in abundance of the species in the course of the study with a peak during late February 2007 (Session 5) (Fig. 12). It is the only species recorded at Transect 1A with its North facing aspect. This species is grouped together with *Chrysoritis pan, Melampias huebneri* and *Thestor dicksoni malagas* in accordance with local patterns of distribution, although the range of *A. pierus* extends slightly more towards the North and towards higher ground in contrast to *T.d. malagas* which occur on or close to rocks in flat areas (Heath & Pringle 2004).

Conservation: The most recent global extinction risk assessment of *A. pierus* based on IUCN categories and criteria (IUCN 2001), is Least Concern (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.2 *Chrysoritis chrysaor* (Trimen, 1864) Burnished Opal.

Foodplants: *Cotyledon orbiculata* (Crassulaceae), *Zygophyllum sessilifolium* (Zygophyllaceae), *Rhus* spp. (Anacardiaceae).

Fig. 21. *Chrysoritis chrysaor*. Photograph by A. Jones 2007. Eastern Cape.

West Coast populations were hitherto known as *Poecilmitis lycia* / *Chrysoritis lycia*. At present *Chrysoritis chrysaor* and *C. lycia* are regarded as conspecific. The species has a distribution range from Lambert's Bay, South to Cape Town and north-east into the Western Cape, Eastern Cape, Free State, Lesotho, south-eastern Gauteng and the southern parts of Mpumalanga (Pringle *et al*. 1994).

Chrysoritis chrysaor seldom gathers in any numbers at one spot and during this study they were found at sea level in areas that enjoy slightly less exposure to coastal winds. The bulk of *C. chrysaor* individuals are found at sandy secluded sites in the South. The study shows further that individuals are found to be evenly distributed within the sites. There is no obvious preference for higher ground or rocky areas. Individuals or pairs are found fluttering around their foodplants wherever these occur. This butterfly flies swiftly, settling often on shrubs in the higher as well as lower areas of Sites 3 and 4. They fly throughout the year and from early December (Session 2) onwards, results show that they were the dominant species at Site 4 (Fig. 14). They are similar in distribution to *C. thysbe, Pontia helice, Leptomyrina lara* and *Oraidium barberae.* Results show a strong avoidance trend for windy areas (Figs 17 & 19).

Conservation: The most recent global extinction risk assessment of *Chrysoritis chrysaor* based on IUCN categories and criteria (IUCN 2001), is Least Concern (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.3 *Chrysoritis felthami* (Trimen, 1904) Feltham's Opal.

Foodplants: *Zygophyllum flexuosum* and *Z. sessilifolium* (Zygophyllaceae).

Pringle *et al*. (1994) gives the Cape Flats near Cape Town, Durbanville, Melkboschstrand, Yzerfontein, Bitterfontein, Lambert's Bay and Hondeklip Bay along the western coastal areas of South Africa as localities for the nominate subspecies of *Chrysoritis felthami*. They have a tendency to flutter low to the ground and often settle on low bushes or open ground (Pringle *et al*. 1994). In the course of the study only a limited number (6) individuals were observed, and all individuals of this species occurred at Site 3 (coastal dune) (Fig. 14 & Appendix C). This is a strong indication for very specific local scale preferences for the type of conditions found at Site 3, especially in the light of the significant distributional variation displayed by the other species occurring at this site.

As in the case of *Chrysoritis chrysaor*, this study shows that there does not seem to be any specific attraction towards either dune tops or low-lying areas although there is a definite attraction to sand. The species is omnipresent throughout the site although it does not occupy the dune tops where *C. thysbe* are present. The latter appears to have a strong dominance on certain dunes at Site 3. *C. felthami* has a flight-period that starts in September and stretches into June (Claassens, 2000) and it was observed to occur throughout the course of the field study except in December 2006 which concurs with the findings of Pringle *et al*. (1994). *C. felthami* forms part of Group 5 and has a sympatric geographical distribution with *C. zonarius*.

Conservation: The most recent global extinction risk assessment of *Chrysoritis felthami felthami* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et. al*. 2009) – the taxon is under no immediate threat.

5.2.4 *Chrysoritis pan pan* (Pennington, 1962) Pan Opal.

Foodplants: *Chrysanthemoides incana* (Asteraceae), *Zygophyllum retrofractum* (Zygophyllaceae) and *Osteospermum* spp (Asteraceae).

Fig. 22. *Chrysoritis pan*. Photograph by S. Mecenero. 2007. Western Cape.

The species has been found at the lower southern slopes of the Tygerberg at Cape Town, near Mamre, at Melkboschstrand, Platrug and Yzerfontein at the West Coast as well as Struisbaai on the southern Cape Coast (Pringle *et al*. 1994). Except for a few individuals *Chrysoritis pan* shows a strong correlation with the types of environments found at Site 1 (rocky hill) and Site 2 (seashore bank). These individuals generally occur in the more exposed parts of the study area which agrees with the findings of Pennington (1962). The fact that *C. pan* occurs in noteworthy numbers in both Site 1 and the flat area close to the sea (Site 2), indicates that there are no specific preferences for high or low lying terrain close to the sea.

A fascinating observation is that Site 2, in which *Chrysoritis pan* dominates by far according to overall abundance, shows no such individuals during Session 1 (October 2006 at the end of the flower season) (Fig. 14)**,** although individuals are present at some of the other sites. A look at indirect ordinations reveals that *C. pan* became more closely associated with *Aloeides pierus* during the course of the December sessions. A possible explanation for this could be that certain broods occupy this site throughout the year due to a lack of a more attractive alternative. This alternative only presents itself once a year during the flower season when broods hatch that are adapted to other areas. A less plausible explanation could be that the species are excluded from the area either by *Chrysoritis thysbe* or by *Tarsocera cassina* although it is unlikely that such exclusion would account for zero recordings during October 2006. Whatever the reason might be, the results point to substantial temporal variation in local scale habitat preferences within the same species.

The distribution of the species within Site 2 is strongly polarized towards the A Transect furthest from the sea. Differences in plant structure across the site could have played a role in this polarization (Meiners & Obermaier 2003). Observations made at the time indicate that rocky material was present more or less evenly across the whole of Site 2 although some large boulders were observed only at Transect A. These boulders, as well as those at Site 1 Transect B, could serve as "keystone structures" for some species (Daily *et al*. 1991; Tews *et al*. 2004). It was found, furthermore, that the average height of plants at Transect A was higher than the averages of plants at Transects B and C (see Appendix B). The estimated groundcover at Transects B and C was also much less especially at the northern part of Transect C which lay on the beach. Although the increased plant biomass at Transect A could influence the data, some studies have shown that preferences for biophysical microhabitat characteristics could override the influence of host plant and nectar resource distribution on butterfly species distributions (Sharp *et al*. 1974; Henning 2001).

It appears that the distance from the shore plays an important role when it comes to the study as a whole and especially with regard to this species that tends to have an overall distribution closer to the coast in comparison with the rest of the species studied. *Chrysoritis thysbe* with its wider overall distribution was also briefly present at Site 2 during October 2006, although *C. pan* preferred Sites 1 and 2 in general. *C. pan* is associated with the ant *Crematogastor liengmei* during its juvenile stages (Heath & Pringle 2001).

Conservation: The species was listed under the Indeterminate category in the first red data book of South African butterflies (Henning & Henning 1989). The taxon was, therefore, regarded as threatened in 1989, but owing to insufficient knowledge it was listed under higher categories of threat such as Rare or Vulnerable. The most recent global extinction risk assessment of *Chrysoritis pan pan* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.5 *Chrysoritis pyroeis pyroeis* (Trimen, 1864) Sand–dune Opal.

Foodplants*:* *Zygophyllum flexuosum* (Zygophyllaceae) and *Thesium* spp (Santalaceae).

Fig. 23. *Chrysoritis pyroeis pyroeis.* Photograph by J.C. McMaster. 2007. Western Cape.

Chrysoritis pyroeis pyroeis have been collected all along the Cape coast from Hondeklip Bay in Namaqualand to Stilbaai in the south coast (Pringle *et al*. 1994). The insect also have been found high up in the Cape mountains and localities include the summit of Gydo mountain (1 800 m), above Garcia Pass (1 200 m), the top of Franschoek Pass, Du Toit's Kloof Pass, the Langeberg and the Outeniqua mountains (Pringle *et al*. 1994). At the coast of Lambert's Bay *C. pyroeis pyroeis* has been observed to fly among the sand dunes above the beach. The butterfly flies close to the ground and often settles on low bushes (Pringle *et al*. 1994).

At sea level this species prefers sandy patches surrounded by vegetation. It was found that within the study area it normally avoids exposed and windy areas although one individual was recorded on the hilltop at Site 1 (rocky hill). Even at Site 4 (dune & calcrete) where most individuals occurred they were few and far apart! In general it could be said that *Chrysoritis pyroeis* prefers the more disturbed areas with lower growing vegetation along Transect B at Site 4. These areas are also low-lying in a valley between ridges although, as mentioned, they can occur at very high altitudes.

The species/ environmental biplot (Fig. 17) shows that *Chrysoritis pyroeis* enjoys a strong preference for sandy areas. The species is grouped together with *Leptomyrina lara, C. chrysaor* and *C. thysbe* as part of group 1 based on the CANOCO nearest neighbour principle for the purpose of this study. *C. pyroeis* was recorded during all sessions from early December (Session 2) onwards (Fig. 14).

Conservation: The most recent global extinction risk assessment of *Chrysoritis pyroeis pyroeis* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.6 *Chrysoritis thysbe osbecki* (Aurivillius, 1882) Osbeck's Opal.

Foodplants: *Chrysanthemoides incana* and *C. monilifera* (Asteraceae), *Osteospermum polygaloides* (Asteraceae), *Lebeckia plukenetiana* (Leguminosae-Papilionoideae), *Aspalathus* spp. (Fabaceae), *Thesium* spp. (Santalaceae) and *Zygophyllum* spp. (Zygophyllaceae).

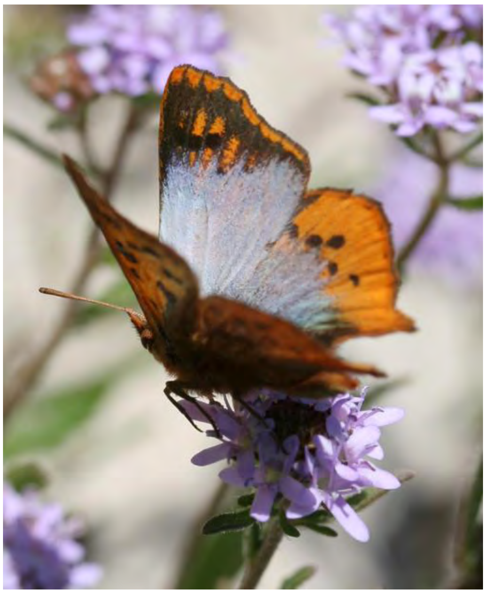

Fig. 24. *Chrysoritis thysbe osbecki.* Photograph by R.F. Terblanche. 2008. Western Cape.

Chrysoritis thysbe osbecki and *C. pan pan* are the two *Chrysoritis* species in the study area that belong to the *C. thysbe* group*.* *C. thysbe* males dominate all higher ground in the sandy areas of Sites 3 (coastal dune) and 4 (dune & calcrete) which agrees with the findings of Pringle *et al*. (1994). They frequently congregate on the tops of hills or ridges during the warmer hours of the day. The females are slower-flighted, and are normally found fluttering around their foodplants on nearby lower slopes (Pringle *et al*. 1994). At Transect 4A, *C. thysbe* was found defending territories at the tops of sand dunes, while some *Leptomyrina lara* individuals normally surround these territories on the slopes of the dunes. At Site 3 the same individuals were normally found hill-topping on the same dunes, as was established in the course of consecutive repetitions of recordings at the transects. The species was recorded at all four sites and the strongest force of attraction seemed to be areas with a higher sand index close to water (not necessarily the ocean), which explains the higher abundance at Sites 3 and 4, especially in the case of Transect

4A. Throughout the empirical study, they were recorded during every session in more or less constant numbers with a slight peak during Session 1 (October 2006). It should be noted that the *osbecki* form seemed to exclude the nominate *thysbe* form entirely from the study area (Heath & Pringle 2007). No phenotypic variation was observed throughout the study area or period although the scale of the study is small in comparison to the phenotypic variations as referred to by Heath & Pringle (2001) in *C. thysbe* at the West Coast.

Conservation: The most recent global extinction risk assessment based on the IUCN categories and criteria (IUCN 2001) of *Chrysoritis thysbe osbecki* is Least Concern (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.7 *Chrysoritis zonarius zonarius* (Riley, 1938) West Coast Daisy Copper.

Foodplants: *Chrysanthemoides incana* (Asteraceae).

Fig. 25. *Chrysoritis zonarius.* Photograph by R.F. Terblanche 2008. Western Cape.

The species has been found at Het Kruis, Saldanha Bay and near Lambert's Bay at Leipoldtville (Pringle *et al*. 1994). The latter noted that many *Chrysanthemoides* shrubs had been stifled by the spread of gums and other trees in the two decades prior to the publication in 1994. This species does not occur at Site 1 (rocky hill) and no specific preference with regard to hilltops or rocky terrain was noticed at the time of the empirical study. In fact, most of the observations were made in low lying areas (Fig. 14). In general, the species is evenly distributed in the areas where they occur with a number of recordings at all three transects at Site 3 (coastal dune) and two of the three transects at Site 4 (dune & calcrete). *Chrysoritis zonarius* prefers sandy areas in which its foodplant *Chrysanthemoides incana* (Asteraceae) occurs (Woodhall 2005). The species prefer areas that are more shielded from the strong coastal winds such as at Sites 3 and 4 although it occurs relatively close to the ocean. *C. zonarius* dominates Site 3 when it comes to the total numbers of individuals for the entire study (Fig. 9) and all recordings were made during Session 1 (Fig. 14). The species is associated with *Chrysoritis felthami* in local distribution and the ant species *Crematogaster peringueyi* attends the larvae (Heath & Pringle 2001).

Conservation: The most recent global extinction risk assessment of *Chrysoritis zonarius zonarius*, based on the IUCN (2001) categories and criteria, is Least Concern (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.8 *Leptomyrina lara* (Linnaeus, 1764) Cape Black-eye.

Foodplants: *Kalanchoe lugardii* (Crassulaceae) and *Cotyledon orbiculata* (Crassulaceae).

Fig. 26. *Leptomyrina lara.* Photograph by K. Drummond-Hay. 2007. Western Cape.

The species is found across most of the western, eastern and northern Cape, the mountains of Lesotho and also in Namibia (Pringle *et al*. 1994). *Leptomyrina lara* also occurs on a number of mountains in the eastern Free State (R.F. Terblanche pers. comm.). At Site 4 *L. lara* is very closely associated with *Chrysoritis thysbe,* although this tendency does not repeat itself in the rest of the study area which could possibly be explained by the absence of rocks (especially calcrete) at Site 3. The species always occurs close to tops of sand dunes although it is less dominant than *C. thysbe* and it normally occupies the areas surrounding the dune tops. Individuals fly fast and settle on rocks and on open patches. It was recorded during every session throughout the study although it did not occur in large numbers during any particular time.

Clark & Dickson (1971) mentioned how commonly the species occurs on rocky mountain sides and ledges. This behaviour was not observed during the course of this study (absence at Site 1), although it must be emphasised that *Cotyledon orbiculata*, the larval foodplant for this species, was not recorded at Site 1 (rocky hill). The observations of this study show that the species displays a strong negative correlation with the wind index. The distribution of *C. orbiculata* on a local scale could have influenced this pattern, since it is found only at Site 4. This species forms part of the *C. thysbe* group (Group 1).

Conservation: The most recent global risk assessment of *Leptomyrina lara* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.9 *Melampias huebneri huebneri.* Van Son, 1955. Boland Brown.

Foodplants*:* The indigenous *Ehrharta erecta* (Poaceaea).

Fig. 27. *Melampias huebneri.* Photograph by S. Mecenero. 2007. Western Cape.

The nominate subspecies occurs along coastal regions from the Clanwilliam area southwards to the Cape Peninsula and then eastwards to near the Gouritz river bridge (Pringle *et al.* 1994). *Melampias huebneri huebneri* is also found along the high escarpment from Nieuwoudtville to Sutherland (Pringle *et al*. 1994).

This is the earliest satyrine butterfly to appear in the south-western Cape and emerges as early as June until the end of November when the larva enters a period of aestivation as its foodplant withers (Clark & Dickson 1971; Pringle *et al*. 1994; Woodhall 2005). Current literature corresponds with the observations made during this study: the species was recorded only during Session 1 (October 2006). The individuals encountered displayed a strong affinity for hilly and rocky terrain. During the course of this study individuals were observed at Transect B on top of the hill and at Transect C with its south facing aspect at Site 1 (rocky hill).

It is unfortunate that the number of specimens encountered does not allow one to draw any conclusions when it comes to the butterfly's potential preference for specific sides or aspects of hills. Although *Aloeides pierus* individuals also occupy territory in a sympatric manner across the hill there does not seem to be much interaction between the species (Appendix C).

Geographical distribution of the species correlates with the distribution of *Ehrharta erecta* in the area (Boucher & Jarman 1977). *Melampias* is a monobasic genus according to the current classification and is centred in the Capensis (floral) region (Cottrell 1985). This study finds that local distribution shows a strong association with *Tarsocera cassina* and *Aloeides pierus*.

Conservation: The most recent global extinction risk assessment of *Malampias huebneri huebneri* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.10 *Oraidium barberae* (Trimen, 1868) Dwarf Blue.

Foodplants: *Exomis axyrioides* (Chenopodiaceae).

Localities of *Oraidium barberae* are found in the western, eastern and northern Cape, KwaZulu-Natal, Free State, Mpumalanga, Limpopo, Gauteng, North West Province, Lesotho, Botswana and Zimbabwe (Pringle *et al*. 1994). Individuals occur at Site 3 in the low-lying areas between hilltops sitting in sandy patches and the species has been reported to occur in short grass with preference for stony areas in grassland (Swanepoel 1953; Pringle *et al*. 1994). A strong association with Sites 3 and 4 became evident, and no individuals were found in exposed areas, windy areas or close to the shore.

Oraidium barberae is grouped with *Leptomyrina lara, Chrysoritis chrysaor* and *Pontia helice,* although the low numbers encountered show no statistically significant correlation with any of these species recorded during the December and April sessions.

Conservation: The most recent global extinction risk assessment of *Oraidium barberae* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.11 *Phasis thero* (Linnaeus, 1764) Silver Arrowhead.

Foodplants: *Rhus undulata*, *R. incisa* (Anacardiaceae) and *Melianthus major* (Melianthaceae).

Fig. 28. *Phasis thero.* Photograph by H. De Klerk 2007. Western Cape.

This butterfly is largely confined to the south-western Cape and the Cape Peninsula, though it has been found northwards to the Vanrhynsdorp district and eastwards along the coast as far as the western Knysna Head (Pringle *et al*. 1994). It flies from August to November and a second brood occurs from March to May (Pringle *et al*. 1994; Claassens 2000; Woodhall 2005). It is very prominent in the sandier area further from the coast and less exposed to the weather (Site 4). Although the species often settles on taller-growing vegetation interspersed within the sandy area, it occurs in the more inland areas too (Pringle *et al*. 1994).

Some plant species recorded in the area include *Melianthus elongates* and *Rhus glauca*. All recordings of *Phasis thero* were made during Session 1 and the bulk of them were made at Site 4 (dune & calcrete), while a few individuals were found at Site 3 (coastal dune). The study indicates that *P. thero* displays specific habitat preferences as well as a definite demarcation of the different broods. There was no indication of a second brood from March to May within the study area and no individuals were encountered after October 2006 (Session 1). The study finds, furthermore, that the species is similar in distribution to those of *Vanessa cardui* and *Zizula hylax* when these species are present (see Appendix C).

Conservation: The most recent global extinction risk assessment of *Phasis thero* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.12 *Pontia helice helice* (Linnaeus, 1764) African Meadow White.

Foodplants: *Alyssum* sp. (Brassicaceae), *Heliophila linearis* (Cruciferae), *Lepidium capense* (Cruciferae), *Sisymbrium* sp. (Cruciferae) and *Rapistrum rugosum* (Cruciferae), *Resada odorata* (Resedaceae).

“I have yet to come across a place in South Africa where *Pontia helice* does not fly” (Swanepoel 1953). One of South Africa’s most widely distributed butterflies (Claassens 2000; Woodhall 2005) as reflected in this study with recordings at all sites except for Site 1 (rocky hill).

Fig. 29. *Pontia helice helice.* Photograph by S. Mecenero. 2007. Western Cape.

In December 2006, the last specimen of *Pontia helice* for the study was found. Individuals travel large distances relative to the study area and they often fly close to the ground, searching for suitable foodplants for their larvae, or for flowers to feed on within open areas (Pringle *et al*. 1994). The species prefers areas that enjoy slightly greater shelter against the elements. It is present in large numbers in the sandy areas (Sites 3 and 4). *P. helice* is similar in geographical distribution to the Group 1 species.

Conservation: The most recent global extinction risk assessment of *Pontia helice helice* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.13 *Tarsocera cassina* (Butler, 1868) Sand-dune Spring Widow.

Foodplants: *Poaceae* grasses, *Lolium* spp. (Poaceae) and *Brachypodium distachyon* (Poaceae).

The species has long been known in the south-western Cape ranging from Lambert’s Bay to Bredasdorp (Pringle *et al.* 1994). They are found along or fairly close to the coastal belt and sometimes flies on the slopes of lower hills even reaching the summit in certain localities such as the Darling area (Pringle *et al.* 1994).

Tarsocera cassina enjoys a slightly wider distribution than *Melampias huebneri* although these species are closely associated as can be gathered from DCA ordinations and visual observations made during the course of this study. The wider distribution could be ascribed to greater relative freedom with regard to foodplant locality, since the species uses a greater variety of larval foodplants. As with *M. huebneri* the only brood that was recorded occurred during Session 1. Pringle *et al*. (1994) noted a flight period from October and November that extends into December in some localities. In correlation with the observations by Pringle *et al*. (1994) there was an affinity towards the Site 1 and 2 environments with their high wind and hill indices. Although the number of individuals recorded does not allow concrete conclusions, no individuals were observed outside the Site 1 and 2 regions. The species forms part of Group 2 for the purposes of this study (Table 5).

Conservation: The most recent global extinction risk assessment of Tarsocera cassina is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.14 *Thestor dicksoni malagas.* Dickson & Wykeham, 1994. Atlantic Skolly

Foodplants: All *Thestor* species are believed to be aphytophagous though the complete life history of none of the 27 species (and additional seven species = 34 taxa) in this genus are known. Females observed up to date do not lay eggs on specific host plants, but on various plants near ant nests. For the nominate subspecies *Thestor dicksoni dicksoni* immature stages of the ant *Anoplolepsis custodiens* Smith, "race *fallax*" Mayr. (Clark & Dickson 1971). Nothing has been published about the early stages of this ant subspecies (Henning *et al*. 2009).

Specimens of *Thestor dicksoni malagas* were first found by H. Selb and T. Waters in March 1981 (Pringle *et al*. 1994). The closest relatives of this subspecies occur at considerable elevation and some appreciable distance from the coast (Pringle *et al*. 1994). According to Heath & Pringle (2004), species in the *Thestor* genus prefer sparsely vegetated arid or montane habitats which exemplify the conditions at Site 2. During Sessions 3 and 4 (February 2007) only four individuals of this red listed (vulnerable) species (Henning *et al*. 2009) were recorded. All of them occurred at Site 2 within a relatively limited area between Transects A and B. As mentioned the larvae is aphytophagous (Pringle *et al*. 1994; Heath & Pringle 2004) which makes its limited distribution and persistence in a specific area with weak colonization tendencies interesting behavioural patterns for which causal mechanisms still need to be described. The distribution of the *Thestor* genus is well correlated with the distribution of the Capensis floral element which is significant given the absence of any known direct butterfly-plant interaction (Cottrell 1985). The study further finds that *T.d. malagas* groups together with *Chrysoritis pan* although the former is univoltine and much more habitat specific in contrast to the latter species (see Appendix C).

Thestor dicksoni malagas is entirely endemic to a very small area just North of Tsaarsbank with a couple of sightings to the North of the lagoon and is one of only two species in the genus to occur so close to the sea (Heath & Pringle 2004). The latter stated that the butterfly species is heavily dependent on the ant symbionts and their associated Homoptera and this, together with their aphytophagous nature, could explain its distribution so close to the ocean. If this is the mechanism controlling distribution it does not explain why the rest of the genus does not follow suit.

The single brood occurring during February each year (Woodhall 2005) makes the species even more vulnerable to adverse external influences such as severe weather conditions and human induced disturbance. Seeing that there is no direct connection between the species and any plant the only factors limiting the distribution of this species is the distribution range of its host ant (*Anoplolepis custodiens*) (Heath & Pringle 2004) and the biophysical microhabitat conditions specific to Site 2.

Conservation: *Thestor dicksoni malagas* was not listed in the first red data book of South African butterflies (Henning & Henning 1989) because it was only described in 1994 by Dickson and Wykeman in the second edition of Pennington's Butterflies of southern Africa (Pringle *et al*. 1994). The most recent global extinction risk assessment of *T. d. malagas* is Vulnerable (VU D2) owing to the small area of occupancy which corresponds with the small 4 km^2 extent of occurrence (Henning *et al*. 2009).

5.2.15 *Vanessa cardui* (Linnaeus, 1758) Painted Lady.

Foodplants: *Carduus* spp. (Asteraceae), *Arctotheca calendula* (Asteraceae), *Arctotis stoechadifolia* (Asteraceae), *Gazania* sp. (Asteraceae), *Gnaphalium purpureum, G. luteo-album* (Asteraceae), *Berkheya discolor* (Asteraceae), *Lavatera arborea* (Malvaceae), *Malva parviflora* (both introduced species) (Malvaceae), *Phaseolus vulgaris* (Fabaceae), *Boehmeria nivea* (Urticaceae) and many other plants, including hollyhocks and lupins.

The nearly cosmopolitan species is named after one of its many foodplants, *Carduus*. The butterfly is known to migrate over long distances and is frequently present in the veldt or in gardens and yet only limited inland movements have been recorded in southern Africa (Pringle *et al*. 1994). The larvae feed on a large variety of plants and are present almost throughout the year. Eggs are laid singly on leaves of foodplants (Woodhall 2005).

Vanessa cardui are said to be found on the tops of ridges or along roads, where they frequently settle on the ground with open wings. During the course of this study, the species was found in great numbers at Site 4 with representation at all the other sites across the study area in October. The species showed a wide distribution with a preference for sites located further away from the coast compared to other recorded species. The preference was manifested in the distinct increase in numbers towards the southern side of the study area (Sites 3 and 4). This increase could indicate a preference for the lower side of the wind gradient although it could be a sampling error resulting as a function of the spatial scale of the study compared to the scale of the distribution range of the species (González-Megías *et al*. 2007; Werling & Gratton 2008).

Vanessa cardui individuals seemed to be migrating through the area, while foraging, without much interaction with or effect on the more established species in the area. Although there are distributional correlations with most of the species the most significant one is with *Phasis thero*.

Conservation: The most recent global extinction risk assessment of *Vanessa cardui* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.2.16 *Zizeeria knysna* (Trimen, 1862) Sooty Blue.

Foodplants include: *Amaranthus deflexus, A. viridis* (Amaranthaceae), *Euphorbia sp.* (Euphorbiaceae), *Oxalis corniculata* (Oxalidaceae)*, Medicago sativa* (Fabaceae), *Zornia sp.* (Fabaceae) *and Tribulus terrestris* (Zygophyllaceae)*.*

Fig. 30. *Zizeeria knysna.* Photograph by P. Webb 2007. Mpumalanga.

Although it does not usually occur numerously in any one locality, *Zizeeria knysna* is one of South Africa's most widely distributed butterflies and regarded as the most common of all the small blue butterflies. It is one of a few southern African lycaenids which also occur in Europe (Pringle *et al*. 1994). Swanepoel (1953) noted that the *Z. knysna* is often found on pavements of towns and in city suburbs. One of its favourite foodplants is the thorny weed *Tribulus terrestris* and it seldom moves more than a meter before settling on the ground, a leaf or a blade of grass (Pringle *et al.* 1994). These small butterflies are on the wing throughout the year (Woodhall, 2005).

Only a single *Zizeeria knysna* individual was recorded and captured in the course of this study. It is, therefore, impossible to draw conclusions about its local distribution except to say that this species is not as abundant at the Langebaan peninsula as might be the case elsewhere. *Z. knysna* has been deleted as outlier in the drawing up of ordinations to avoid the compression of the rest of the dataset.

Conservation: The most recent global extinction risk assessment of *Zizeeria knysna* is Least Concern according to the IUCN (2001) categories and criteria (Henning et al. 2009) – the taxon is under no immediate threat.

5.2.17 *Zizula hylax* (Fabricius, 1775) Gaika Blue.

Foodplants: *Phaulopsis imbricate* (Acanthaceae), *Ruellia* spp. (Acanthaceae), *Justicia* spp. (Acanthaceae), *Chaetacanthus setiger* (Acanthaceae), *Dyschoriste* spp. (Acanthaceae) and *Oxalis corniculata* (Oxalidaceae).

Fig. 31. *Zizula hylax.* Photograph by S. Adam 2008. Western Cape.

Zizula hylax has been recorded from most of southern Africa, except the main Karoo tracts (Pringle *et al*. 1994). There are a few records from the south-western Cape. The delicate and feeble flight of this insect is immediately noticeable (Pringle *et al*. 1994).

During the course of this study only one individual was encountered at Site 4 during Session 1. This data does not allow one to draw conclusions with regard to local distribution and, therefore, although the species has been grouped along with the rest in ordinations, it has been discarded in further discussions.

Conservation: The most recent global extinction risk assessment of *Zizula hylax* is Least Concern according to the IUCN (2001) categories and criteria (Henning *et al*. 2009) – the taxon is under no immediate threat.

5.3 Species summary.

It is obvious that *Thestor dicksoni malagas* would need special attention and protection from habitat destruction in future. The topographical preferences of this species separate it from most of the other species in the *Thestor* genus and this could indicate an advanced state of speciation. Annual quantitative monitoring should take place and special attention should be given to the species in the park management plan.

Though the Satyrinae species (*Tarsocera cassina* and *Melampias huebneri*) are relatively well-known butterflies from the south-western Cape in South Africa, the natural indigenous host plants of the butterflies remain unconfirmed (R.F. Terblanche pers. comm.). This means that though the life histories of these butterflies have been described in detail, their life cycles in the wild are poorly known which implies that conservation management and planning for these butterflies at the West Coast are limited.

Most of the species dealt with during the course of this study are under no immediate threat. In order to maintain this status it is essential to stimulate as much public interest as possible to ensure an increase in the number of specialists in the field in future. The pressure on our natural resources increases every day which necessitates a greater “counter force” in the form of more conservationists and scientists armed with extensive and accurate knowledge to effectively target conservation issues.

CHAPTER 6:

DISCUSSION

6.1 Overall composition and diversity

According to DCA ordinations as well as correlation matrices, it is evident that there are some spatio-temporal stable groupings of species as far as local geographical distribution is concerned. Physical habitat characteristics play an important role in the direct delimitation of butterfly distributional ranges (Sharp *et al*. 1974; Holl 1996; Henning 2001; Lu & Samways 2002). Observed patterns can, therefore, mainly be ascribed to differential microhabitats across the study area and territorial behaviour motivated by a preference for these microhabitats (Lu & Samways 2002). In his paper Emmel (1964) referred to unexplainable intrinsic factors that govern distribution. The extrinsic factors influencing these intrinsic preferences are now known to be the small scale biotopic conditions and several different combinations of these conditions.

Habitat type might even influence observed behaviour (Habel *et al*. 2007). Kuussaari (2007) reported that the quality of habitat plays a much more important role than habitat quantity. Henning (2001) mentioned the preference of *Chrysoritis aureus* for specific biotopical characteristics. Although the right foodplant and host ant were present in surrounding areas on a mountain slope, the species did not occur there. The study of Lu & Samways (2002) provided similar results.

Information about local preference and behaviour of individual species in this study, as summarised in Tables 5 & 6, will hopefully contribute to our understanding of which habitat type each species prefers. This study covers a limited number of species within the genus *Chrysoritis* and some other genera. Hopefully this kind of information can be extended to include at least the local habitat preference of all red listed species in South Africa (Henning 2001).

Since this is a quantitative study, it focussed on a relatively small area within the WCNP, in a winter rainfall region with very low rainfall (Mucina & Rutherford 2006). Despite these constraints, a remarkable number of species (n = 17) were recorded. Very low rainfall figures occurred especially during the 2006 winter season and this would have influenced the plant biomass production. The plant diversity in the area is obviously much lower in comparison to that of Table Mountain (Boucher & Jarman 1977; Goldblatt & Manning 2000; Manning 2001) and this will affect butterfly diversity to a certain extent (Habel *et al*. 2007).

Taking all these factors into account and realising that the study was conducted in a "natural" area relatively isolated from society, one could argue that the number of species provides a well defined cross section of the naturally occurring assemblages in the study area. The number and types of species are well correlated with this type of environment (Claassens 2000; Edge 2005b; Woodhall 2005) and the study serves as additional confirmation of the dominance of the Lycaenidae in the Fynbos areas.

The results reflect the dominance of the *Chrysoritis* genus (*Theclinae with nine species*) despite the high presence of *Vanessa cardui* in the course of Session 1 (Fig. 14). Previous studies showed that most of the *Chrysoritis* species recorded during this study have a larval foodplant distribution that stretches much further inland (Boucher & Jarman 1977; Goldblatt & Manning 2000; Manning 2001), despite the fact that most of the recorded taxa do not seem to be as dominant in the inland areas (Clark & Dickson 1971; Woodhall 2005).

6.2 Assemblage structure

The overall percentage abundance values (Figs. 9 & 10) show four different species dominating at the four selected sites. This serves as confirmation that the study area shows at least enough characteristical variation to sustain distinct dominant species assemblages in the different biotopes. Two of the dominant species namely *Chrysoritis zonarius* (site endemic) (Hamer & Slotow 2002) and *Vanessa cardui* (cosmopolitan distribution) (Woodhall 2005) were only recorded during Session 1 (October 2006) in the flowering season. Assuming that the flower season bloom influenced their distribution (Manning 2001) and removing them from the equation on this basis, one is still left with four different species at the respective sites. *C. thysbe* would then dominate Site 3 and *C. chrysaor* Site 4 (Fig. 9).

An interesting tendency that surfaced on the scale of this study is that the overall Shannon diversity values (H') for the four selected sites (Fig. 11) are directly and positively correlated to the distance from the shore. Site 2 (seashore bank) with the lowest overall diversity is the closest to the ocean and Site 4 (dune & calcrete) with the highest diversity is the furthest away. Sites 1 and 3 are more or less similar in distance and diversity. This could be another indication of the direct influence of coastal winds or it could indicate a combination of coastal wind and other coastal influences. Salt and humidity have an indirect effect on butterfly species in that these factors create a mesophytic / xerophytic type of plant environment (Manning 2001). The coastal wind on the West Coast is dry due to cold sea currents (Mucina & Rutherford 2006). Salty dry conditions influence vegetation composition and character in the area.

Species richness, abundance and Shannon diversity values reflect the end of the flowering season well with soaring mean values (8.25; 191, 1.31 respectively) in all three of these categories during Session 1, relative to the other sessions. From Session 2 onwards these values normalize and regardless of variation in species composition at the different sites, remain relatively constant (Fig. 12). The Shannon (H') values for the December sessions are still slightly higher than for the sessions that occurred later on. The high temperatures during December may have caused more individuals to be active (Pollard 1977; Pollard & Yates 1993), but the associated high wind speeds (Mucina & Rutherford 2006) may also have excluded some of the less wind-adapted species from the exposed sites, especially in the case of Site 1 (Dover 1996).

***Session 1* -** Tukey HSD tests have shown that Session 1 show statistically significant differences in comparison with all other sessions in terms of species richness and most of the other sessions in terms of abundance. As has been discussed, this could be a direct result of the flower season (Manning 2001) with the associated attraction factors and the correspondence of natural broods of the different species in response to these factors (Clark & Dickson 1971; Masako *et al*. 2009). It could also be in response to accelerated growth causing changes in the structure of plants (Holl 1996) or a combination of the above.

Higher overall species richness could also be the result of the movement of some migrant species such as *Vanessa cardui* into the area (Holl 1996) and their subsequent co-occurrence with some of the more prevalent species groups during the course of Session 1 (Aviron *et al*. 2006). As has been shown extensively, differential niche requirements (Thomas *et al*. 2001) could ensure sympatric distribution amongst even closely related taxa on the microhabitat scale (Kremen 1994). At Site 3 a number of *Chrysoritis zonarius* individuals were found at territories that are all included in the same geographical area as the territory of a *V. cardui* individual. These species are separated in resource utilization requirements as well as the scale in which they perceive the local environment (Sutcliffe *et al*. 1996; Chust *et al*. 2003; Fleishman *et al*. 2003) and are, therefore, not in competition.

Higher overall abundance values are observed due to migrants in the area as well as increased resources such as higher plant biomass and more plants flowering at the end of the rainy season. These factors are all reflected in the higher diversity values that pertain to Session 1.

Shannon evenness values for Session 1 are slightly lower in Sites 3 and 4 due to high abundance in certain dominant species (Fig. 13). Sites 1, 3 and 4 show an increase in evenness values from Session 1 onwards: this variation can be the result of stabilization in the environment after the flower season bloom. The strong dominance by one or two species at these sites shows a decrease after the first session in October.

During Session 1 (October 2006) the highest Shannon (H’) diversity of all sites for the study was observed at Site 2 (seashore bank) (Fig. 13). Given the low diversity at this site during the remainder of the study, this is an interesting inversion of the regular trend. The composition of species during this period appears to be a hybrid between the typical Site 1 groupings with *Melampias huebneri* and *Tarsocera cassina* and the typical Site 3 groupings of *Chrysoritis zonarius, C. chrysaor and Vanessa cardui*. Most of the species which occurred at Site 2 (seashore bank) at that time were only recorded during Session 1 which could be incidental, or it could be linked to the physiological nature of host plants in the area. Site 2 is located between Sites 1 and 3 and it is relatively close to Site 1 (rocky hill) (See map Fig. 2). This could mean that some of the individuals recorded at Site 2 were part of an expansion of the colonisation ranges (Spitzer *et al*. 1993) of the Site 1 colony during the bloom in October 2006 (Neve *et al*. 1996). The numbers in most species could have been so extremely high that the subdominant individuals were forced from the hilltop at Site 1 and had to settle for less favourable foraging areas. This scenario, however, is unlikely seeing that there were still plenty of flowers available and the larvae of the different species are differentially selective in host plant selection (Clark & Dickson 1971; Heath & Claassens 2000; Heath & Pringle 2007). Whatever the reason, a few dominant individuals from the same species occupied the hilltop at Site 1. The distance between the two sites if compared to the colonisation ranges of the relevant species could have resulted in autocorrelation within the data set (Sutcliffe *et al*. 1996) during Session 1 which is taken to be insignificant (only two species) and only relevant to Session 1 (seeing that species composition between the two sites show substantial variation throughout the rest of the study).

***Sites 1 and 2* -** During the remainder of the study, Sites 1 (rocky hill) and 2 (seashore bank) were characterised by low species richness and abundance. This could have been a result of the greater exposure to winds from the sea in these areas, which may well have influenced the occurrence of butterfly species directly and indirectly in accordance with the structural composition of the vegetation types found there (e.g. low growing vegetation) (Gruebler *et al*. 2007). Kuussaari *et al*.

(2007) also found reduced species richness in exposed areas that could be due to the increased impact of winds.

Site 2 (seashore bank) is located relatively close to the parking area at Tsaarsbank, a picnic spot in the National Park. The extremely low diversity at this site during Sessions 2 and 3 (December 2006) (Fig. 13) could in part be credited to an increased number of holiday-makers moving about in the area. It must be said that although human activity increased close by, relatively few people moved around in the study area itself and it has been shown that human activity close to naturally occurring butterfly populations might not have any effect on the populations as long as suitable habitat is not affected (Blair 1999).

It is possible that this type of area with its naturally low growing succulent vegetation (Boucher & Jarman 1977) could be low in butterfly diversity throughout the year. The butterfly species at Site 2 (seashore bank) could be much more “flower season dependant”, which would explain the high diversity in October 2006.

According to Figure 15, Site 2 (seashore bank) shows the most consistent results with regard to species composition throughout the study, which might be an artefact of the low number of species recorded here during most of the study.

Sites 3 and 4 – The latter sites show much higher total abundance values for the study than Sites 1 and 2 (Fig. 11). Site 3 (coastal dune) has a relatively large sand dune that shields it from direct coastal winds (Fig. 6). Site 4 (dune & calcrete) is located more toward the lagoon side of the peninsula compared to Site 3 and is, therefore, well shielded.

These sites enjoy slightly greater protection against the elements, which may well explain the higher abundance of species that are not suitably adapted to high wind. Observations made during the study confirmed that it was normally the “bigger body sized” species that were present at Site 4 (Woodhall 2005). The average height of vegetation at Sites 3 and 4 is also higher compared to those at Sites 1 and 2. This might cause a further reduction in the wind factor and provide more shelter for individuals, as well as greater larval host plant biomass and foraging opportunity.

Site 3 shows the most variation with regard to species composition across the study (Fig. 15). Many of the species present at this site had a wide overall area of distribution (e.g. *Chrysoritis thysbe*) and yet, even these species show substantial variation in occurrence at the site through time (Fig. 14). This serves as additional confirmation that there is variation in habitat preferences amongst species on a local scale across time.

Site 4 is slightly more diverse in topographical and biophysical character with high and low-laying ground, some calcrete rocks, sandy areas and a more or less equal distance to the ocean and the lagoon. Rocky material (which comprises calcrete stone) at Site 4 was mostly confined to the hilltop. Site 3 (coastal dune) had no rocks. As was the case at Site 3, transects at Site 4 traversed some hilltops and some areas with sandy valleys.

Areas with a greater number of dunes such as Site 4 (dune & calcrete) showed a greater variety of “dune related” species in general, as well as a greater variety on single dune tops (increased diversity on two spatial scales linked to local scale habitat characteristics) (Werling & Gratton 2008). Site 4 with its greater overall niche diversity (Thomas *et al*. 2001) had the highest overall butterfly species diversity. Sharp *et al*. (1974); Kitahara & Fujii (1997); Tews *et al*. (2004) and White & Kerr (2007) are all in agreement that butterfly species richness is strongly affected by habitat heterogeneity. Palmer & Dixon (1990) observed an increase in habitat breadth with increased within-quadrat heterogeneity although those results show a decrease in abundance which could not be duplicated here. The observations also agree with the findings of Aviron *et al*. (2006) that areas with higher plants species richness serve as host areas for a combination of generalist and specialist feeders.

6.3 Assemblage composition

In general, species with a single brood (univoltine species) (Aviron *et al*. 2007) such as the *Chrysoritis zonarius* and *Melampias huebneri* groups were found to be rather limited in their local scale distribution (Fig. 14). The mentioned species displayed territorial-like behaviour around host plants. Individuals could be followed as they did not stray too far from specific plants. The number of *C. zonarius* individuals at Site 3 during Session 1 suggests small and possibly overlapping territories, although this was not directly assessed and falls outside the scope of this study. *C. zonarius* and *M. huebneri* can be classed between the typical and tolerant specialist species groups in the Kitahara & Fujii (1997) classification. *C. zonarius* was recorded only during October 2006 although they occurred in extremely large numbers at Site 3. The large numbers observed indicate that Site 3 contains some microhabitats with strong attractive forces for this species. Observations during this study agree with current literature on the timing of broods for these two species (Claassens 2000; Woodhall 2005).

***Session 1* –** With reference to the above, it is important to point out that a few migrant species were also present only during Session 1, but they occupied a very large part of the study area in general. This observation may perhaps be a result of a different set of causation factors like the correlation of broods with the prominent and well defined flower season (Manning 2001). Though *Vanessa cardui* breeds in the area (R.F. Terblanche pers. comm.), it is regarded as a xenotopic species (Henning 2001). The high numbers at Site 4 (dune & calcrete) may possibly be ascribed to a migration of the species during Session 1 (October 2006) as a result of their high mobility and large distribution ranges (Holl 1996; Werling & Gratton 2008). Some diurnal Lepidoptera commonly pass through habitats which they do not reside in (Holl 1996). Great care must be taken when making deductions based on exclusive recordings during Session 1, due to the sudden and radical changes in ecosystem dynamics in the flower season (Manning 2001). This said, it is still interesting to note that the species in general prefers areas slightly further inland with a few stray individuals recorded at Sites 1 and 2.

Session 1 corresponds with the end of the flowering season on the West Coast (Boucher & Jarman 1977; Goldblatt & Manning 2000; Manning 2001), which would explain the high overall abundance values that have been observed. Many of the species recorded during Session 1 are migrants and some of them have a national or even near-cosmopolitan distribution (e.g. *Vanessa cardui*) (Woodhall, 2005). Some adults of the more localised species such a *Chrysoritis zonarius* (endemic to the West Coast) (Woodhall, 2005) appeared only during spring.

***Sites 1 and 2* -** At Site 2 (seashore bank), behavioural associations were coupled to the location of host plants and possibly the distance to the sea with the bulk of

Chrysoritis pan sharing its distribution between the two exposed Sites 1 and 2 close to the ocean. At Site 1 (rocky hill) behavioural associations were coupled to the hill top itself in that species display variable preference for different aspects associated with the hill (Lu & Samways 2002).

Transect 1a shows the lowest diversity of all transects across the study. It is situated on the north-facing slope of the rocky hill and there is some disturbance that occurs along this transect. Habitat disturbance affects parameters like temperature, light and humidity levels which in turn all influence adult butterfly activity (Wood & Pullin 2002; Hein *et al*. 2007). The disturbance at this transect is comparable to those at other transects and should not influence numbers to this extent. It is possible that the microclimatic conditions at the north-facing aspect are ill suited for the larval host plants for most of the locally occurring species which could have influenced numbers (Lu & Samways 2002). White & Kerr (2007) showed that on fine spatial scales microtopography (e.g. aspect) (Thomas *et al*. 2001) largely determines microclimatic conditions. A more plausible explanation, however, and backed by various studies, is that the aspect, creates certain undesirable microhabitat conditions which directly influence butterfly species distribution (Lu & Samways 2002). The only species observed here was *Aloeides pierus*.

Distance from the shore of the Atlantic Ocean has some indirect influences on the distribution of butterfly species in that the salty and windy conditions cause a change in the vegetational character close to the ocean. There is, however, only a single significant direct gradient coupled to the distance from the sea and this is in the case of *Chrysoritis pan*.

It seems that *Chrysoritis pan* is the species best adapted to the salty exposed conditions (Fig. 17). With the low overall diversity at Site 2 (seashore bank) from Session 2 onwards in mind it is important to note that the abundance of *C. pan* (the only species recorded during Sessions 2 and 3 at Site 2) was higher during the December sessions than during any of the other sessions. The higher values in *C. pan* might be a function of the warmer temperatures that would have led to greater activity during these sessions, although this would have affected the entire study area and all the butterfly species, which was not the case. Nectar resources and foodplants for locally occurring butterfly species are relatively limited at Site 2 (Boucher & Jarman 1977; Woodhall 2005). The possibility exists that the high numbers of *C. pan* are a result of decreased interspecific competition. It may also be that *C. pan* is so well adapted to this environment (e.g. it is adapted to wind through stronger powers of flight) (Dover 1996) that they excluded other, less adapted species from the area. The larger sized species within the study area seem to be less adapted to high winds, but various studies have found that larger sized species in general has stronger flight capabilities and thereby reduce the need for sheltered habitats (Dover 1996). The only larger species found in exposed areas during this study was *Melampias huebneri* and *Tarsocera cassina* at Site 1 with some recordings at Site 2 (seashore bank). This observation is in line with descriptions in previous literature (Pringle *et al*. 1994).

Whatever the reason might be, the fact remains that *Chrysoritis pan* is generally attracted to the microhabitat characteristics present at Site 2 (seashore bank) and that biophysical conditions play a primary role in this attraction (Sharp *et al*. 1974). *Chrysoritis pan* displayed definite distributional variation during Session 1 (no species recorded at Site 2) compared to the rest of the study in which the distribution of the species shifted between Sites 1 and 2 with dominance of abundance at Site 2 which indicates that there is temporal variation in habitat preferences amongst species on a local scale. This variation could be explained by the equilibrium and non-equilibrium dynamics (Tews *et al.* 2004) or the change in seasons could somehow draw species away from otherwise preferred areas. Thomas (1991) indicated that temporal variability could also take place on a larger scale due to the transient nature of some habitats (Neve *et al*. 1996). As mentioned, conclusions regarding temporal variability should only be made in the context of the spatial scale used (Thomas 1991).

The red data species (listed as vulnerable) which occurs in this area, *Thestor dicksoni malagas,* is extremely limited in distribution (Heath & Pringle 2004; Woodhall 2005) and can be classified as a site endemic according to Hamer & Slotow (2002). Adults occur on the ground and on rocks (Heath & Pringle 2004) and the flight path is always close to the ground which makes the structural characteristics of vegetation at Site 2 significant (low growing vegetation). It would fall in the vicinity of the “typical specialist” category of Kitahara & Fujii (1997) according to distribution although it can not be classified as such seeing that the larvae are most probably aphytophagous and the females do not seem to have any plant preference for ovipositioning and may even use bare rocks (Heath & Pringle 2004).

Recordings made exclusively during February 2007 confirm current knowledge on brood timings (Heath & Pringle 2004; Woodhall 2005). The only recordings were at Site 2 and care should be taken to manage the movement of tourists in the area in accordance with the precautionary principle seeing that no current records of the exact distribution range of *Thestor dicksoni malagas* exists (R.F. Terblanche pers. comm.). The known areas are in and around Kreef Bay with unconfirmed reportings at the Saldanha steel plant area (Henning *et al*. 2009) although these two can be described as separate populations (Thomas & Kunin 1999). The occurrence of this specialist species at Site 2 again confirms the exclusive biophysical conditions at the site which, in turn, links up with the low overall species richness observed from Session 2 onwards (Fig. 12).

6.4 General findings

Across the study area hill and/or dune-topping behaviour has been observed and these areas were always thought to be prime sites for dominant individuals within some species. This study found that in the same manner, the bottom of little valleys between sand dunes can serve as prime sites for dominant individuals in other species.

Some species normally occur in pairs and some in aggregates such as *Chrysoritis zonarius*. Individuals of species such as *C. pyroeis* and *Aloeides pierus* are almost always found sitting on open sandy patches surrounded by vegetation whilst *C. pan* always occupies exposed areas.

A brief vegetation study was conducted to subjectively determine what amount of the observed variation could be described by the floral element. This, however, is a tedious process and a complete and thorough vegetation study must be conducted separately in order to determine meaningful relationships. Foodplants as indicated below are those that provide food to the species during its larval stages (Clark &

Dickson 1971). The host plants are specific to the South African region (Manning 2001; Woodhall 2005).

One component of the vegetational study was to place additional emphasis on butterfly species with limited larval foodplant representation in the area. The idea was that species with very specific and geographically limited larval foodplants would in itself be limited in distribution.

Considering that most of the lycaenid and some of the other species that occur in the area have a foodplant distribution in more than half of the study area (Table 6) (Boucher & Jarman 1977; Mucina & Rutherford 2006). *Chrysanthemoides monilifera* most probably dominates Site 3 and *Zygophyllum* spp. Site 2 in the number of individuals and in dry biomass. A high number of Poaceae type plants are present at Site 4.

The propensity of *Chrysoritis thysbe* to be more concentrated among Sites 3 and 4 is definitely reflected in the concentration of *Chrysanthemoides monilifera* with an average of 31 plants per transect at Site 3 and nine at Site 4 (Appendix B). Site 2 has an average of only 0.66 plants per transect. During the study at Langebaan the bulk of *Chrysoritis zonarius* individuals were recorded at Site 3, although the entire area was dominated by *Chrysanthemoides monilifera* and no *Chrysanthemoides incana* plants were recorded. This could mean that *Chrysanthemoides monilifera* also serves as a larval foodplant for *Chrysoritis zonarius* which could act as a functional monophagous feeder (Henning 2001) in the area given the absence of *Chrysanthemoides incana.* This has not been assessed as part of this study and further investigations should be conducted. Henning (2001) and Heath & Pringle

(2007) have shown that many butterfly species could switch between closely related plant taxa as food for larvae if the preferred plant species is absent.

The distribution of *Chrysoritis chrysaor* with a strong preference for Site 4 does not seem to be affected by the distribution of its foodplants. The species is recorded with a uniform distribution across much of the area. *Ehrharta erecta* was recorded only at Site 1, and since this is the only larval foodplant of *Melampias huebneri* (Claassens 2000; Woodhall 2005) in this area, it could definitely explain the limited distribution of the species. The same goes for the larval foodplants of *Leptomyrina lara* (*Cotyledon orbiculata*) (Claassens 2000; Woodhall 2005) with observations confined to Site 4. *Zygophyllum flexuosum* is widely distributed between the sites although in low numbers and the geographical influence on *Chrysoritis felthami* is, therefore, considered to be insignificant for the purposes of this study. No *Aspalathus* spp. was recorded during the study at Langebaan and the influence of the location of larval foodplants on the limited distribution of *Aloeides pierus* could, therefore, not be determined.

Another factor that could have an influence on butterfly distribution with specific reference to *Chrysoritis* is the local distribution of ant populations in the area (Clark & Dickson 1971; Edge 2005a; Edge 2005b; Heath & Pringle 2007), since many *Chrysoritis* species are myrmecophilous. More research needs to be conducted about the distribution of attendant ants as well as the invasive Argentine ant *Linepithema humile* (Mayr) (Edge *et al*. 2008) on a local scale in the area.

6.5 Summary of findings.

During the study at Langebaan it was found that community patterns already came to the fore within the time span of a single season. The study extended over a relatively small area (a part of the peninsula) with very little variation other than the biotopic differences between the sites and yet these differences accounted for definite community patterns that did not occur by chance.

No matter how we approach or manipulate the data, the variation in assemblages at the four sites is undeniable. The geographical variation and associations seem to be just as strong as the temporal variation between species. The degree of preference for specific biotopic characteristics is different in every single species studied (Lu & Samways 2002).

The attraction toward a microhabitat “type” or biotope (with a certain set of bio-physical characteristics) (Henning 2001), makes it possible to link species to microhabitat types as part of a habitat type as part of a biotope as part of a region etc. Certain species will initially be linked at larger scale levels depending on the mobility of the species (Werling & Gratton 2008).

6.6 Value as bio-indicators.

A biological indicator is defined as a species or group of species that readily reflects the abiotic or biotic state of the environment, while the species or group of species represents the impact of environmental change on a habitat, community or ecosystem (McGeoch, 1998). Alternatively, the species or group of species may be indicative of the diversity of a subset of taxa, or of wholesale diversity, within the area (McGeoch, 1998).

Lycaenid butterflies show a certain level of sensitivity to disturbances as a function of their scale of endemism as well as their integrated nature with other elements of the ecosystem, i.e. myrmecophily. Many of the species studied possess a number of qualifying criteria that could make them useful as bio-indicators (Hilty & Merenlender 2000). This said, it must be kept in mind that the mere fact that they are drawn to specific biotopes on a local scale would mean that certain species would be absent in areas that otherwise hold a strong “ecosystem health” (Hilty & Merenlender 2000). Just because these areas do not have the preferred biotopic characteristics does not mean that they show signs of anthropogenic or other disturbances, environmental stressors or reduced diversity in other species.

Certain studies have suggested that Lepidoptera are not reliable indicators of single habitat variables (Holl, 1996). Fleishman *et al*. (2003) emphasised that both scale dependence in biodiversity patterns within a taxonomic group and differences in scale dependence among taxonomic groups constrain the application of surrogates such as indicators of system integrity. However, some lycaenids studied here could serve the purpose of bio-indicators for biodiversity (McGeoch, 1998) at the biotopical grain (Chust *et al*. 2003; Fleishman *et al*. 2003) due to their integrated nature (Kremen 1994). Using species as bio-indicators with a great number of integrated ecological and niche requirements on a local scale is, nonetheless, not suggested here (Hein *et al*. 2007). In addition, there are still some taxonomic discrepancies among many of the species studied which will make them especially unsuitable for use as bio-indicator species (Heath 2001; Heath & Pringle 2004).

CHAPTER 7:

CONCLUSIONS

A kaleidoscope of variation with regard to microhabitat type preferences became evident during the course of this study. The strength of preferences varied amongst species on a local scale (biotopic grain) (Chust *et al*. 2003; Fleishman *et al*. 2003). In general it was found that in accordance with Lewis *et al*. (1998) the endemic species were biotope specialists and the geographically restricted species occur in the most species rich areas. The univoltine species were fairly limited in distribution. Although some species are to a certain extent limited by the distribution of their foodplants and their associated ant species (Heath 2001; Lu & Samways 2002), oligophagy (feeding specialisation) (Kitahara & Fujii 1997) did not seem to limit distribution significantly and in many cases bio-physical microhabitat characteristics played a more important role than foodplant distribution and distribution of nectar resources (Sharp *et al*. 1974; Holl 1996; Heath 2001; Lu & Samways 2002). Physical conditions within a biotope will be the dominant factor determining distribution amongst non-migrant foodplant generalists or species with a wide foodplant range distribution (Habel *et al*. 2007).

Emergent properties appear when the community (species assemblage) is the focus of attention. A cake has emergent properties of texture and flavour that are not apparent simply from a survey of its ingredients. In the case of ecological communities the limits that apply to the similarity of competing species is an example of an emergent property (Begon *et al*. 2005). These limits ensure that where distributional models between species in preferred habitats overlap, they are still able to co-exist in harmony through fine scale temporal and spatial segregation, e.g. niche and resource partitioning (Kremen 1994; Thomas *et al*. 2001). In other words, every species that co-occurs in the same or in habitats with relatively similar characteristics has its own “niche level”-related distributional fingerprint (Thomas *et al*. 2001; Lu & Samways 2002).

Definite habitat preferences occur in all species studied although the spatial scale (González-Megías *et al*. 2007; Werling & Gratton 2008) at which these preferences were manifested depends to a certain extent on the distribution range of the species (Sutcliffe *et al*. 1996). Some species show strong preferences at a fine grain (Kremen 1994; Chust *et al*. 2003) for microhabitats while others show strong preferences at a coarser grain for larger areas. Just as the characteristics of fluttering differ between the different species so does their distributional model and scale (Sutcliffe *et al*. 1996; González-Megías *et al*. 2007; Werling & Gratton 2008) according to the way the species perceive and react to their environment (Chust *et al.* 2003; Fleishman *et al*. 2003).

Preferences differ in intensity and nature among the different species and this cause certain species to be repetitively recorded in certain microhabitats during some seasons. In many cases species are observed with a much more specific distribution than would be the case if host plant location were the only determining factor (Lu & Samways 2002). The study showed that plant and bio-physical habitat diversity at a local scale is positively correlated to butterfly diversity. With enough data at hand, models based on microhabitat type related distribution could aid in resolving some current taxonomic uncertainties that led to the extensive revision of the *Chrysoritis* genus among others (Heath 2001; Heath & Pringle 2007).

Variation on a temporal scale can in part be described by coupling it to the known floral variation (Lu & Samways 2002). Nonetheless, some interesting temporal tendencies came to light that are not exclusively linked to vegetation, e.g. the absence of *Chrysoritis pan* individuals at Site 2 during Session 1 shows that there is temporal variation in the habitat preference tendencies amongst species on a local scale that is not linked to the distribution of foodplants. In many instances sudden and co-ordinated reversals of the general trend would occur during a specific season just to return to the normal distribution afterwards.

In some instances habitat preference varied in accordance with food availability for larvae during some seasons, but this changed to preferences for a specific microhabitat when food was abundant. In general insects as is the case with all poikilotherms show a reduction in numbers during cooler seasons (not as pronounced in winter rainfall areas) although the strength of this response varies from taxon to taxon (Kitching *et al*. 2000).

The strongest case in favour of microhabitat preferences can be found with *Thestor dicksoni malagas*. The species is not dependant on any specific foodplant and yet it is limited to a very specific area. The only factor that could influence this distribution is the microhabitat conditions at this site. Unfortunately as mentioned this narrow tolerance range to variation in habitat could eventually cause its demise. The range location of this species might provide us with the false confidence that it is protected within a nature reserve and yet nowhere is the importance of holistic thinking when it comes to conservation more important. What would be the effect of rising sea levels due to global warming on a species with such a narrow and specific range so close to an ocean, and what can be done to ensure its continued existence?

Additional factors influencing the spatio-temporal variation might also be: the sex ratio of the species and perching behaviour which in turn could be influenced by temperature and solar radiation (Daily *et al*. 1991; Lu & Samways 2002), pH, micro-elements, etc. The alien and invasive Argentine ant *Linepithema humile* (Mayr) (Edge *et al*. 2008) that could alter distribution patterns directly or through the disruption of seed dispersal of larval foodplants (Skaife 1961) has been previously noted as an influential factor on this study. Certain studies even found butterfly diversity to be positively correlated with bird and mammal species richness (Holl 1996) although this could be due to similar biotopical requirements.

The mosaic model of habitat patches (Henning 2001) was the golden thread throughout the course of this study. A hierarchy of overlapping patches (Neve *et al*. 1996; Chust *et al*. 2003) were observed linked to specific and yet simple bio-physical conditions, the size of the patches mainly dependant on the distribution range of the species and the scale at which the species perceive its environment (Kitahara & Fujii 1997; Fleishman *et al*. 2003; Werling & Gratton 2008).

In species with a low turnover rate (Werling & Gratton 2008) between patches in the metapopulation (Neve *et al*. 1996; Henning 2001; Thomas *et al*. 2001; Habel *et al*. 2007) like many of the specialised and univoltine *Chrysoritis* species and *Thestor dicksoni malagas*, development might destroy a large number of their “fine grain” (Kremen 1994; Chust *et al*. 2003) suitable habitats and prove critical for the population or maybe even for the entire species. As has been indicated, this very trait (local- /site endemism) is one of the qualifying criteria for the genus to be used as a suitable bio-indicator (Hilty & Merenlender 2000). This is ironic, since species that prefer certain localised biotopic characteristics would most probably not make good bio-indicators due to distributional variation linked to these very characteristics.

Obligate and facultative butterfly-ant associations that are prominent in many of the lycaenids with specific reference to the myrmecophilous *Chrysoritis* (Henning 1987; Heath & Pringle 2001; Pierce *et al*. 2002) offer clear evidence of the intricate part that this genus plays in the ecosystem. This type of mutualistic relationships exist within many components of every ecosystem and in most cases these processes and causation mechanisms probably still remain undiscovered by science. This is why it is so important for us to study and focus on the known interactions in order to determine the underlying mechanisms that prevail among species and to try and conserve these mechanisms at all cost.

Most of the species that have been studied here are endemic to South Africa, which means the WCNP, in addition to all its other functions, is important for the conservation of insects. Natural areas are important in insect conservation as they increase alpha as well as beta diversity (Werling & Gratton 2008).

This study clearly indicates that the South African West Coast which gives the impression at first glance of a dry homogeneous area with low topographical diversity and altitudinal variation, is in fact much more diverse than one could perceive. Specific preferences were observed in this study using very simple microhabitat characteristics. Using more complicated characteristics such as pH, micro-element compositions, etc. would lead to more detailed segregation of preferences. The biodiversity is known when it comes to the floral category, but in this study it is demonstrated among faunal populations. Distributional variation was prominent not just among sites, but also within sites between different transects. Relatively short distances showed major changes in species composition. This could be an indication that there might still be several unknown and undescribed butterfly species even within our National Parks.

Finally, it can be concluded that 1) there are clear preferences for specific microhabitat types and biotopes among adult butterflies of the Lycaenidae and other groups at the Langebaan peninsula, 2) these preferences vary in degree among different species and 3) the preferences will influence distributional patterns of those species on different spatial scales (Werling & Gratton 2008).

If different assemblages demonstrate themselves so strongly within a limited area that appears to be homogenous at first, how much more will this be evident in areas with more obvious variation locally such as the Cape Fold Mountains for instance? Most of the species studied were found at very specific places through several repetitions. This observation shows that most species are very sensitive to minute changes in their direct environment. Effective environmental management through environmental impact assessments and decisions on land use should work towards the goal of incorporating this knowledge into planning. Invasive plant species should be vigorously controlled in the habitats of red listed species. The paramount factor of long-term sustainability among butterfly species is habitat suitability (Neve *et al*. 1996).

7.1 Recommendations for future studies.

A more detailed study with replication sites carried out over the duration of the flower season in the Park (August to October) could shed light on the life histories of species and could provide further information about small scale distribution ranges. Variation in species composition within this short time span is so great as to justify a temporal scale magnification.

A metapopulation study (Neve *et al*. 1996; Henning 2001; Habel *et al*. 2007) that focuses on the distribution range of *Thestor dicksoni malagas* and the identification of relevant habitat patches as well as the controlling mechanisms limiting the species to these patches (Henning *et al*. 2009) is recommended. This aphytophagous species could possibly be limited by the distribution range of the Homoptera spp. that serve as food for the butterfly (Cottrell 1984; Cottrell 1985) in combination with the specific biotopic habitat preferences. A study of this nature that includes detailed demographic information would be a fruitful avenue of future research to determine the minimum viable population (MVP) and the minimum dynamic area (MDA) (Terblanche & Edge 2007), especially in the light of planned developments in the region. This information can be used to draft a habitat management plan in order to avoid inappropriate habitat conditions that could cause a population collapse (Aviron *et al*. 2007).

Despite the above mentioned complicating factors of using the *Chrysoritis* genus in some role for bio-indication, it is still felt to be worthwhile to establish the levels of tolerance to external stressors among some species within the genus. This type of study might reveal potential within the genus for a use in an ecological role as bio-indicator (McGeoch 1998).

The possibility of *Chrysanthemoides monilifera* acting as the host plant for *Chrysoritis zonarius* in the absence of *Chrysanthemoides incana* should be investigated. A locally well known botanical specialist and expert on West Coast plants (Kobie Truter) were consulted and reported that in some areas along the West Coast plants occur that seem to be a hybrid between *Chrysanthemoides monilifera* and *C. incana,* but none of these were observed at Site 3. A closely related species *Chrysoritis zeuxo* that occur on the Cape South Coast has been known to feed on C*hrysanthemoides monilifera* during its larval stages (Manning & Goldblatt 1996).

7.2 Guidelines for environmental management and planning.

A massive research effort is needed to use ecological experimental procedures to evaluate the effects of ("the hypothesis proposed by") managerial decisions (Underwood 1995). Further studies within national parks and nature reserves that were established encompassing a certain geographical area (through managerial decisions) of this nature could make a significant contribution in achieving this (research 2 type) (Underwood 1995). Lewis *et al*. (1997) mentioned the possibility of combined studies to determine the cumulative effect of anthropogenic influences and abiotic gradients on butterfly richness. Comparing quantitative data in natural areas (Kitching *et al*. 2002) with those at different levels of disturbance should provide meaningful results.

Evaluation of distribution patterns among certain butterfly species in the peninsula area revealed that priorities within the WCNP as far as butterfly conservation is concerned should include the range delimitation of *Thestor dicksoni malagas.* Although the species is thought to have a very small distribution (<200 m^2 in some *Thestor* species) (Heath & Pringle 2004), this area is situated right on the boundary of the park and very close to a picnic spot (as a result of a managerial decision) (Underwood 1995). It might be necessary to implement stricter control measures, prevent any further development, and to exclude the movement of tourists in the area. The area to the North of this locality is closed to the general public throughout the year except for the flower season. It is suggested that this area of exclusion should be expanded towards the South so that it would include Site 2, as referred to in this study, in order to ensure minimum disturbance of this microhabitat type.

An information board erected at the parking area of the picnic spot at Tsaarsbank as well as at the information centre at “Geelbek” within the park, would enhance public knowledge and stimulate interest with regard to the presence of *Thestor dicksoni malagas*.

There is so much emphasis on biodiversity analysis and hotspot identification in recent studies that one tends to forget that other sub-components of biodiversity, like the concentrations of locally endemic taxa, are also important (Davis 2002). A similar initiative to the “narrow range endemics programme” in New South Wales (Hamer & Slotow 2002) could be very useful locally to capture distributional data with the aim of the delineation of areas important for range restricted invertebrates. SABCA (South African Butterfly Conservation Assessment), a tripartite association between ADU at the University of Cape Town, the South African National Biodiversity Institute (SANBI) and the Lepidopterist’s society of Africa which aims at compiling a comprehensive butterfly atlas for South Africa, Lesotho and Swaziland (Henning et al. 2009), could be expanded on, to fulfil this role.

Terblanche & Van Hamburg (2003) stated that species appear on red data lists and not unique habitats. Habitat studies with a focus on preferences for specific local conditions should be conducted within the known distribution ranges of all red listed butterfly species in South Africa to ensure that conservation efforts are efficient and effective. Habel *et al*. (2007) highlighted the importance of especially small scale heterogeneity for conservation management with regard to butterflies and more specific the myrmecophiles. The evaluation of microhabitat characteristics should take place in a holistic manner in which individual and combinations of different predictors are acknowledged (Habel *et al*. 2007) in order to define predictor sets for future conservation (Kitching *et al*. 2000). This is a prerequisite in developing a conservation strategy and action plan (Lu & Samways 2002).

The focus should shift away from protecting a piece of land as a habitat towards protecting a complete support system that satisfies all the requirements of the specific species. This system does not need to consist of a large core site (Kitahara & Fujii 1997), but rather smaller optimal stepping stone sites necessary for recolonisation (Neve *et al*. 1996). These sites should be linked by corridors that are wide enough to facilitate the movement of the most habitat restricted species in the area (Haddad & Baum 1999). Of course, it is a phenomenal task to accommodate all living plant and animal species within an area following this type of approach. Fortunately, many (even diverse) taxa are so integrated that small areas chosen to include the correct microhabitats could satisfy the needs of most species (Clark & Dickson 1971; Heath & Claassens 2000). This approach is already followed when it comes to relocating larger animals for developmental purposes: why should it be any different in the case of butterflies? The added advantage following this approach with insects is that a system like this could be incorporated in new developments through intelligent ecological landscaping (McGeoch 2002).

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Appendix A: Relative weather data (scale of 1 - 10) on days of butterfly surveys conducted in the West Coast National Park during the period October – April 2006/07.

	18-Oct-06	***19-Oct-06***	***22-Oct-06***	***25-Oct-06***				
Clarity of the sky	10	9	5	7				
Humidity	4	4	5	4				
Lack of presipitation	10	10	9	8				
Stilness of the wind	6	9	8	5				
Temperature	4	6	5	3				

	04-Dec-06	***05-Dec-06***	***08-Dec-06***	***10-Dec-06***	***11-Dec-06***	***12-Dec-06***	***13-Dec-06***	***20-Dec-06***
Clarity of the sky	9	10	8	8	10	10	9	9
Humidity	8	3	5	4	5	5	7	5
Lack of presipitation	10	9	7	8	10	10	9	8
Stilness of the wind	2	8	5	2	8	8	4	5
Temperature	2	7	4	2	7	6	4	5

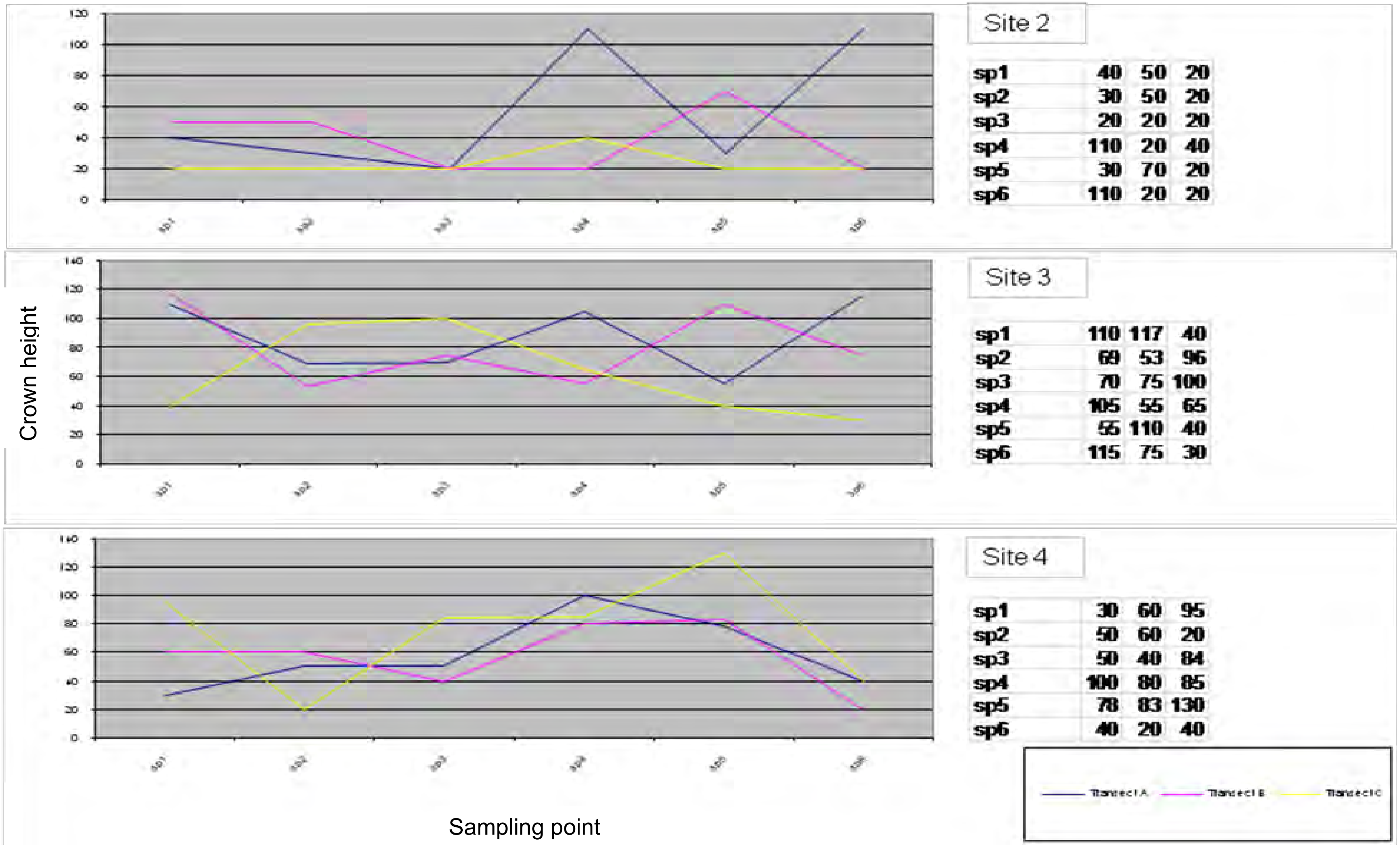
	05-Feb-07	***06-Feb-07***	***07-Feb-07***	***13-Feb-07***	***14-Feb-07***	***15-Feb-07***	***27-Feb-07***	***28-Feb-07***
Clarity of the sky	9	10	9	9	7	8	4	10
Humidity	5	5	5	4	6	4	8	4
Lack of presipitation	10	10	10	9	8	9	7	9
Stilness of the wind	6	4	4	4	7	6	8	7
Temperature	4	4	6	3	6	4	4	6

	11-Apr-07	***12-Apr-07***	***13-Apr-07***	***14-Apr-07***	***15-Apr-07***	***17-Apr-07***	***18-Apr-07***	***19-Apr-07***
Clarity of the sky	9	7	9	10	10	6	9	10
Humidity	7	6	7	6	7	6	6	7
Lack of presipitation	5	5	8	9	10	7	8	10
Stilness of the wind	7	7	8	10	7	7	5	6
Temperature	4	4	4	4	6	3	4	6

Appendix B: Number and average height (cm) of host plants associated with butterfly species at sampling points along transects (A - C) at selected sites in the West Coast National Park during the period October – April 2006/07. No host plant species recorded at Site 1 (Rocky hill).

	Seashore bank (Site 2)			Av	Coastal dunes (Site 3)			Av	Dune & calcrete (Site 4)			Av	
Plant species	A	B	C		A	B	C		A	B	C		**Butterfly species**
Amaranthus deflexus													*Zizeeria knysna*
A. viridis													*Z. knysna*
Arctotheca calendula													*Vanessa cardui*
Arctotis spp.					0	2	2	1.3	25	0	0	8.3	*V. cardui*
Berkheya discolor													*V. cardui*
Carduus spp.													*V. cardui*
Chaetacanthus setiger													*Zizula hylax*
Chrysanthemoides incana													*Chrysoritis thysbe / zonarius*
C. monilifera	0	0	2	0.7	14	29	50	31.0	4	7	16	9.0	*Chrysoritis thysbe*
Cotyledon orbiculata									4	14	3	7.0	*Chrysoritis chrysaor / L. lara*
Dyschoriste spp.													*Zizula hylax*
Ehrharta erecta													*Melampias huebneri*
Exomis axyrioides													*Oraidium barberae*
Gazania spp.	0	0	1	0.3	1	2	29	10.7					*Venessa cardui*
Heliophila spp. (linearis)													*Pontia helice*
Justicia spp.													*Zizula hylax*
Kalanchoe lugardii													*Leptomyrina lara*
Lebeckia plukenetiana													*Chrysoritis thysbe*
Lepidum capense													*Pontia helice*
Lobularia maritima													*P. helice*
Malva parviflora													*Venessa cardui*
Medicago sativa													*Zizeeria knysna*
Melianthus major									0	0	2	0.7	*Phasis thero*
Osteospermum polygaloides													*Chrysoritis thysbe*
O. spp.													*C. pan*
Oxalis corniculata													*Zizeeria knysna / Zizula hylax*
Paulopsis imbricata													*Zizula hylax*
Poaceae grasses									300	240	55	198.3	*M. huebneri / T. cassina*
Rapistrum rugosum													*Pontia helice*
Reseda odorata													*P. helice*
Rhus undulata (glauca)	1	0	0	0.3	3	1	1	1.7	0	0	1	0.3	*Phasis thero*
Ruellia spp.													*Zizula hylax*
Thesium spp.	14	0	0	4.7									*Chrysoritis thysbe / pyroeis*
Tribulus terrestris													*Zizeeria knysna*
Tylecodon paniculatus													*Chrysoritis chrysaor*
Zornia spp.													*Zizeeria knysna*
Zygophyllum flexuosum	0	0	2	0.7	1	0	3	1.3	2	1	2	1.7	*Chrysoritis pyroeis / felthami*
Z. retrofractum													*C. pan / chrysaor*
Z. sessilifolium													*C. chrysaor / felthami*
Z. spp.(morgsana)	6	4	4	4.7	9	8	11	9.3	9	3	3	5.0	*Chrysoritis thysbe*
Other													*Thestor dicksoni malagas*

Appendix B Continued:



Site 2

sp1	40	50	20
sp2	30	50	20
sp3	20	20	20
sp4	110	20	40
sp5	30	70	20
sp6	110	20	20

Site 3

sp1	110	117	40
sp2	69	53	96
sp3	70	75	100
sp4	105	55	65
sp5	55	110	40
sp6	115	75	30

Site 4

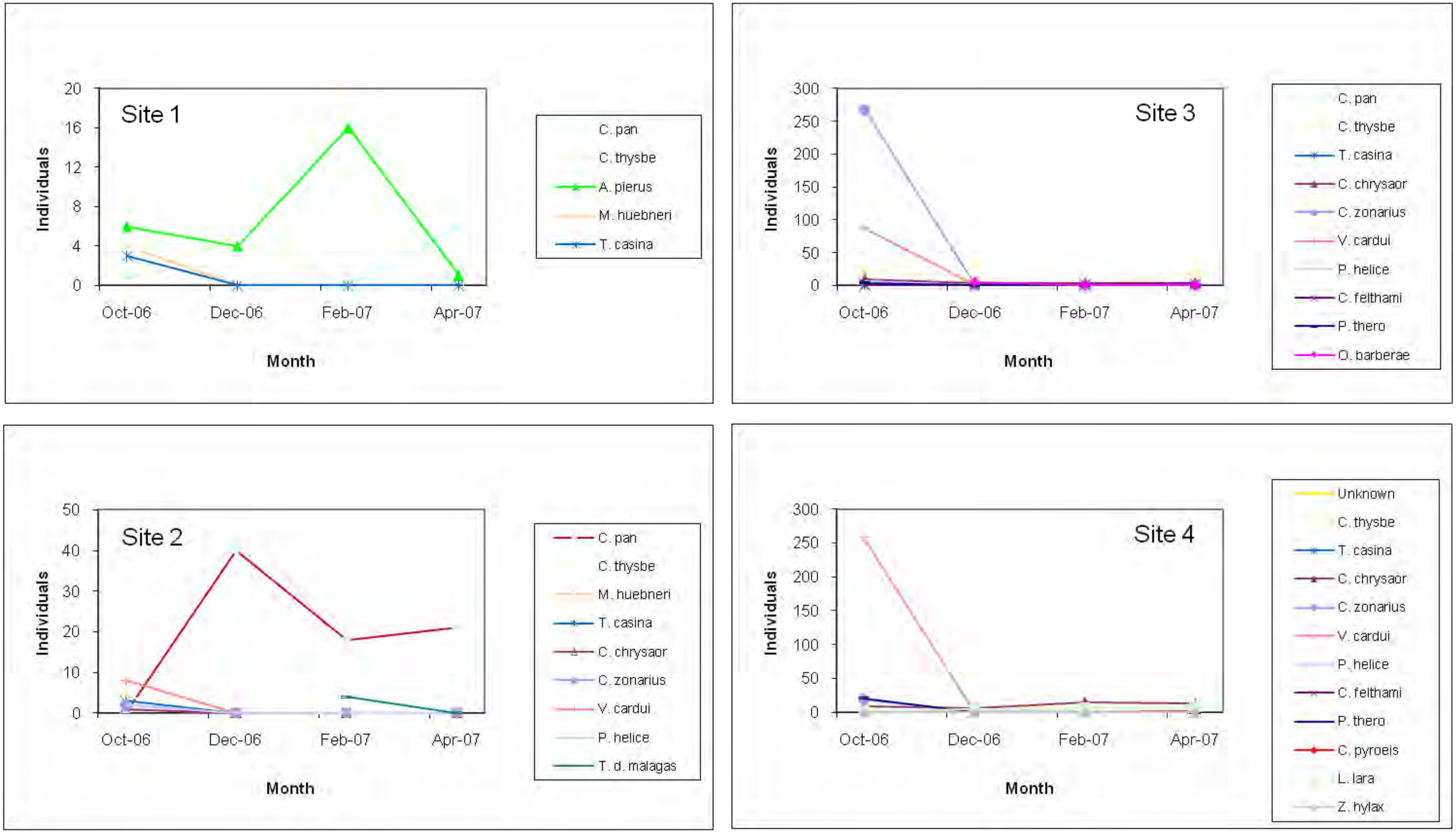
sp1	30	60	95
sp2	50	60	20
sp3	50	40	84
sp4	100	80	85
sp5	78	83	130
sp6	40	20	40

Appendix C: Correlation matrix between all butterfly species (n = 17) recorded in the West Coast National Park during the period October – April 2006/07.

Correlations (Master)
Marked correlations are significant at p < .05000
N=28 (Casewise deletion of missing data)

Variable	C. zonarius	Z. knysna	C. pyroeis	C. chrysaor	C. thysbe	C. pan	C. felthami	V. cardui	M. huebneri	T. casina	P. helice	P. thero	L. lara	Z. hylax	A. pierus	O. barberae	T.d. malagas	Unknown
C. zonarius	1.00	-0.04	-0.08	0.49	0.75	0.01	0.22	0.35	-0.05	0.40	0.79	0.22	-0.09	0.03	-0.07	-0.07	-0.06	-0.11
Z. knysna	-0.04	1.00	-0.07	-0.14	-0.14	-0.11	-0.06	-0.05	-0.05	-0.07	-0.08	-0.04	-0.10	-0.04	-0.07	-0.07	-0.05	-0.11
C. pyroeis	-0.08	-0.07	1.00	0.46	-0.09	-0.23	-0.12	-0.10	-0.09	-0.15	0.07	-0.09	0.55	-0.07	0.25	-0.13	-0.11	0.20
C. chrysaor	0.49	-0.14	0.46	1.00	0.67	-0.36	0.03	0.53	-0.16	0.14	0.48	0.48	0.67	0.40	-0.20	0.02	-0.20	0.20
C. thysbe	0.75	-0.14	-0.09	0.67	1.00	-0.28	0.35	0.54	-0.08	0.35	0.68	0.45	0.18	0.32	-0.19	0.19	-0.19	0.18
C. pan	0.01	-0.11	-0.23	-0.36	-0.28	1.00	-0.15	-0.11	-0.11	-0.14	-0.12	-0.11	-0.31	-0.11	-0.15	-0.20	0.27	-0.28
C. felthami	0.22	-0.06	-0.12	0.03	0.35	-0.15	1.00	0.01	-0.07	0.00	0.11	-0.02	-0.17	-0.06	-0.11	-0.11	-0.09	-0.01
V. cardui	0.35	-0.05	-0.10	0.53	0.54	-0.11	0.01	1.00	-0.05	0.29	0.32	0.99	0.13	0.95	-0.09	-0.09	-0.07	0.06
M. huebneri	-0.05	-0.05	-0.09	-0.16	-0.08	-0.11	-0.07	-0.05	1.00	0.74	-0.02	-0.05	-0.12	-0.05	0.32	-0.08	-0.07	-0.09
T. casina	0.40	-0.07	-0.15	0.14	0.35	-0.14	0.00	0.29	0.74	1.00	0.44	0.22	-0.14	0.15	0.14	-0.13	-0.11	-0.04
P. helice	0.79	-0.08	0.07	0.48	0.68	-0.12	0.11	0.32	-0.02	0.44	1.00	0.21	0.07	0.07	-0.14	-0.03	-0.11	0.35
P. thero	0.22	-0.04	-0.09	0.48	0.45	-0.11	-0.02	0.99	-0.05	0.22	0.21	1.00	0.15	0.98	-0.08	-0.08	-0.06	0.08
L. lara	-0.09	-0.10	0.55	0.67	0.18	-0.31	-0.17	0.13	-0.12	-0.14	0.07	0.15	1.00	0.17	-0.18	0.16	-0.15	0.38
Z. hylax	0.03	-0.04	-0.07	0.40	0.32	-0.11	-0.06	0.95	-0.05	0.15	0.07	0.98	0.17	1.00	-0.07	-0.07	-0.05	0.10
A. pierus	-0.07	-0.07	0.25	-0.20	-0.19	-0.15	-0.11	-0.09	0.32	0.14	-0.14	-0.08	-0.18	-0.07	1.00	-0.12	-0.10	-0.01
O. barberae	-0.07	-0.07	-0.13	0.02	0.19	-0.20	-0.11	-0.09	-0.08	-0.13	-0.03	-0.08	0.16	-0.07	-0.12	1.00	-0.09	0.01
T.d. malagas	-0.06	-0.05	-0.11	-0.20	-0.19	0.27	-0.09	-0.07	-0.07	-0.11	-0.11	-0.06	-0.15	-0.05	-0.10	-0.09	1.00	-0.16
Unknown	-0.11	-0.11	0.20	0.20	0.18	-0.28	-0.01	0.06	-0.09	-0.04	0.35	0.08	0.38	0.10	-0.01	0.01	-0.16	1.00

Appendix D: Temporal variation of butterfly assemblages at selected sites in the West Coast National Park during the period October – April 2006/07.



Appendix E: Breakdown of Shannon diversity, species richness and abundance values as compared between individual transects across seven sessions in the West Coast National Park during the period October – April 2006/07.

Summary of Shannon H' values for single transects - Open cells indicate 0 recordings and 0 Shannon values indicate a single species.

	Site 1			Site 2			Site 3			Site 4			Av
	a	b	c	a	b	c	a	b	c	a	b	c	
Session 1		1.4	1.3	0.6	1.1	1.5	1.1	0.8	1.1	0.5	0.9	1.0	1.0
Session 2		0.0	0.7	0.0	0.0		1.0			1.0		1.1	0.6
Session 3		1.0	1.1	0.0	0.0		0.9		0.0	1.3	1.1	1.3	0.7
Session 4			0.0	0.5	0.0		0.0	0.0	0.0	0.7	0.8	0.0	0.2
Session 5	0.0	0.6	0.6	0.0	0.7			0.0		1.0	0.0	0.6	0.4
Session 6	0.0	0.0		0.0	0.6	0.0	0.0	1.0	1.0	0.9	0.5	1.1	0.6
Session 7	0.0			0.0	0.0		0.7	0.9	0.5	0.6	0.8	0.0	0.4
Av	0.0	0.6	0.7	0.2	0.3	0.7	0.6	0.6	0.5	0.8	0.7	0.7	

Summary of Abundance values for single transects

	Site 1			Site 2			Site 3			Site 4			Av	Total
	a	b	c	a	b	c	a	b	c	a	b	c		
Session 1	0	11	5	4	5	13	116	155	131	152	91	81	75.3	764
Session 2	0	2	2	8	9	0	6	0	0	4	0	3	3.2	34
Session 3	0	4	6	22	1	0	11	0	2	10	5	6	6.3	67
Session 4	0	0	2	10	2	0	2	1	2	7	7	4	3.7	37
Session 5	3	3	11	5	5	0	0	2	0	7	2	4	3.6	42
Session 6	1	6	0	7	3	1	2	4	5	13	5	3	4.3	50
Session 7	1	0	0	10	1	0	2	9	5	4	9	2	4.2	43
Av	0.7	3.7	3.7	9.4	3.7	2.0	19.9	24.4	20.7	28.1	17.0	14.7		
Total	5	26	26	66	26	14	139	171	145	197	119	103		1037

Summary of Species Richness values for single transects

	Site 1			Site 2			Site 3			Site 4			Av
	a	b	c	a	b	c	a	b	c	a	b	c	
Session 1	0	5	4	2	3	5	7	7	7	6	7	8	5.6
Session 2	0	1	2	1	1	0	3	0	0	3	0	3	1.3
Session 3	0	3	3	1	1	0	3	0	1	4	3	4	2.0
Session 4	0	0	1	2	1	0	1	1	1	2	3	1	1.3
Session 5	1	2	3	1	2	0	0	1	0	3	1	2	1.3
Session 6	1	1	0	1	2	1	1	3	3	3	2	3	1.9
Session 7	1	0	0	1	1	0	2	3	2	2	3	1	1.5
Av	0.4	1.7	1.9	1.3	1.6	0.9	2.4	2.1	2.0	3.3	2.7	3.1	