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Vegetation associated with the critically endangered butterfly *Chrysoritis dicksoni* (Gabriel, 1947) (Lepidoptera: Lycaenidae: Aphnaeinae) at Witsand, Western Cape Province

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Abstract: A vegetation study conducted at the sites containing the last known populations of the critically endangered butterfly *Chrysoritis dicksoni* is described, results presented and their ecological implications discussed. Recommendations are made for how the sites can best be managed to ensure the sustained survival of the species.

Key words: *Chrysoritis*, limestone fynbos, butterfly, vegetation analysis, disturbance, herbivores, nature reserve, climate change.

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INTRODUCTION

The Critically Endangered butterfly *Chrysoritis dicksoni* (Gabriel, 1947) was originally discovered near Melkboschstrand north of Cape Town, but now only occurs in a restricted area to the north of Witsand on the southern Cape coast (Curle & Ficq, 2009; Mecenero *et al*., 2013; Heath, 2014; Giliomee & Edge, 2015).

A research programme was initiated by Edge & Terblanche (2010), aiming to fill some gaps in the known autecology of *C. dicksoni*, to describe elements of its synecology, and to develop a conservation management plan. They were subsequently appointed as custodians of *C. dicksoni* under the COREL programme (Edge, 2011a). As part of this research, the author has been investigating the vegetation associated with *C. dicksoni* and its trophic associates *Crematogaster peringueyi* Emery and various scale insects (Coccoidea) (Giliomee & Edge, 2015).

Vegetation studies are being increasingly employed in South Africa to understand the functioning of the complex and dynamic ecosystems that host many of the country's threatened Lepidoptera (e.g. Deutschländer & Bredenkamp, 1999; Edge *et al*., 2008; Bazin & Edge, 2015). Despite the known fact

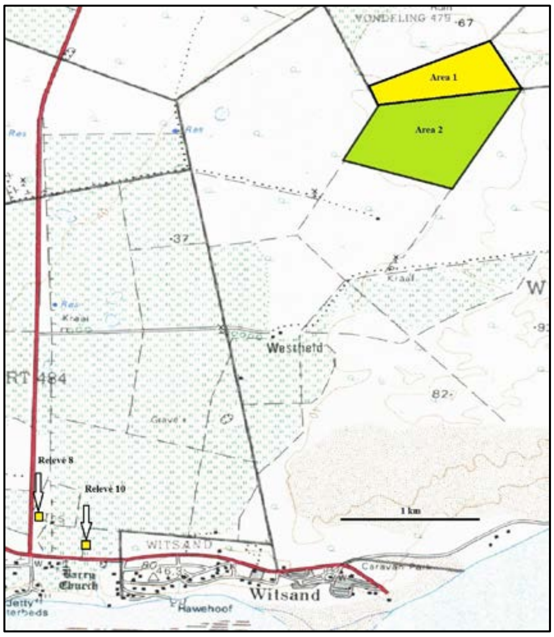

Figure 1 – The areas north of Witsand where *C. dicksoni* occurs, on the farms Westfield 478 (Area 1) and 483 (Area 2); and closer to Witsand at relevés 8 and 10.

that the immature stages of *C. dicksoni* are aphytophagous and therefore have no direct "host-plants" (Heath, 2014), a vegetation association intermediated by the trophic associates may very well exist. *C. dicksoni* adults may also have a need for a certain vegetation structure in which to practice their territorial and mating behaviour, as was apparently the case for *Thestor brachycerus brachycerus* (Trimen, 1883), another aphytophagous butterfly (Bazin & Edge, 2015).

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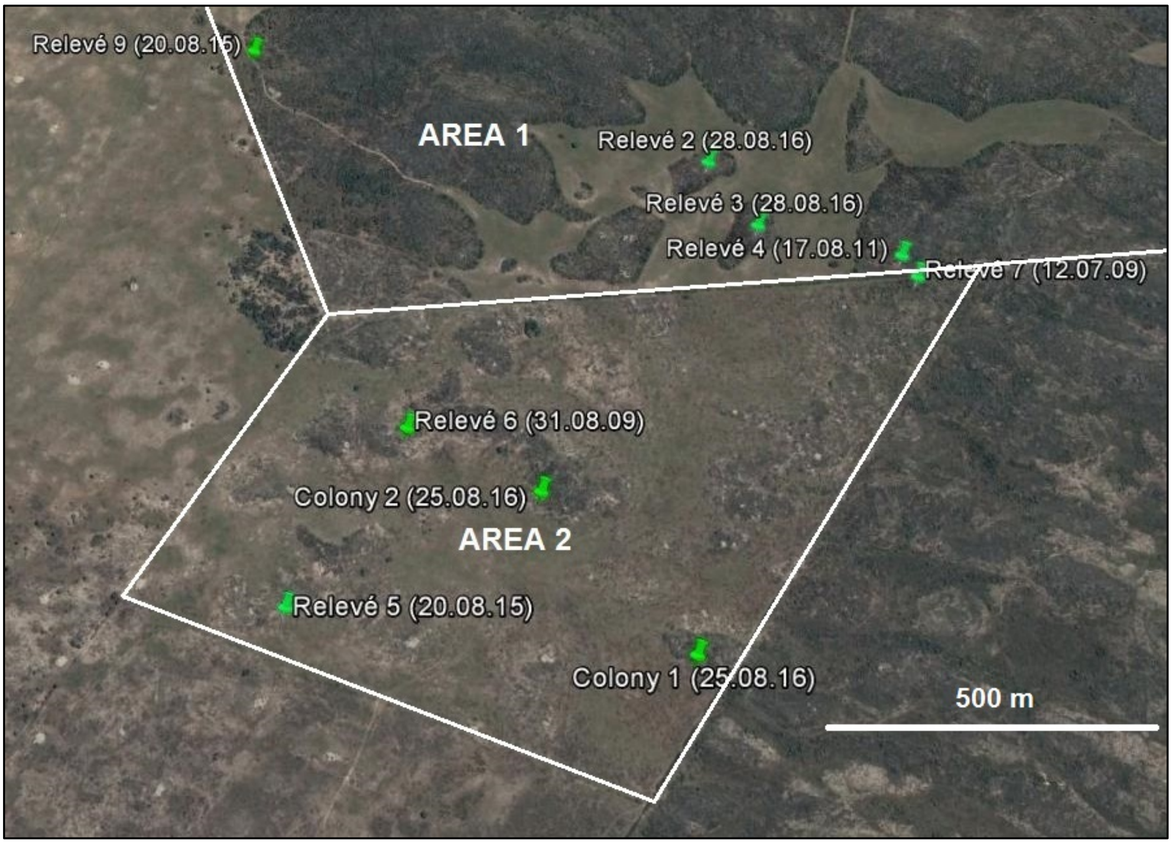

Figure 2 – Position of *C. dicksoni* breeding areas on the farms Westfield 478 (Area 1) and Westfield 483 (Area 2). "Relevés" refer to areas where the site was sampled for vegetation. "Colonies" are sites not sampled for vegetation where significant *C. dicksoni* metapopulations were observed.

MATERIALS AND METHODS

Study sites

Two of the study sites are close to the Witsand village and the other seven are approximately 4 km north of Witsand, on the farms Westfield 478 (Area 1) and 483 (Area 2; Figs 1–3). All of the sites are on fairly level ground which originally formed the ancient floodplains of the lower Breede river.

Area 1 in Fig. 2 is a patchwork of areas converted to pastures (lighter) with "islands" of relatively undisturbed vegetation (darker), and no alien plants. Area 2 is more disturbed and degraded, with heavy infestation of *Acacia cyclops* in some parts.

Using the Köppen-Geiger classification system (Köppen & Geiger, 1936) Witsand area has a BSk cold arid climate ($P_{ann} > 5\ P_{th}$; $T_{ann} < +18$ °C, where P_{th} is the dryness threshold in mm, and $= 2T_{ann}$ for a winter rainfall area in which >⅔ P_{ann} falls in the "winter" months (21 March–21 September) (Conradie, 2012). The nearest weather station to Witsand is Stilbaai, where the mean P_{ann} is 436 mm. The coefficient of annual variation of precipitation is c. 32%; the mean frost days per annum is 3, and the mean annual days of soil moisture stress is 71% (Mucina & Rutherford, 2006).The average daily maximum and minimum temperatures are 22.1°C and 12.3°C. Wind speeds are up to 11 m/s, with prevailing east-southeasterly winds during summer and west-northwesterly during winter (climate data from the SA Weather Service). Fig. 4 shows that relevés 2–7 and 9 are in Canca Limestone Fynbos (FFl3). Mucina & Rutherford (2006) described the underlying soils and geology of FFl3 as "shallow alkaline to neutral grey regic sands and Glenrosa and Mispah forms on limestone of the Bredasdorp formation". The limestone outcrops are relatively young – only a few million years old. This vegetation type extends from Witsand in the west to Mossel Bay in the east and is considered threatened (Heydenrych *et al.*, 1994, Willis *et al.*, 1996).

Relevés 8 & 10 are in Albertinia Sand Fynbos (FFd9).

Sampling and data recording

Sampling was carried out during August and September 2009, and more recently October 2015 (relevé 8) and August 2016 (relevés 9 & 10). Each of the 5 m x 5 m square relevés were set up at the centre of a sub-population of *C. dicksoni*. The floristic composition and structure of the vegetation were determined, using quantitative Braun-Blanquet methodology (Werger, 1974). Samples were identified by Compton Herbarium (NBG) staff and the plant names follow Manning & Goldblatt (2012). Plant species were allocated to a life-form category (graminoids, geophytes, forbs, shrubs and trees) (see Edwards, 1983), and their average height estimated. The areal extent and nature of the bare ground in each relevé was recorded. Each relevé and colony site was thoroughly searched and records were made of the number of ♂ and ♀ *C. dicksoni* seen.

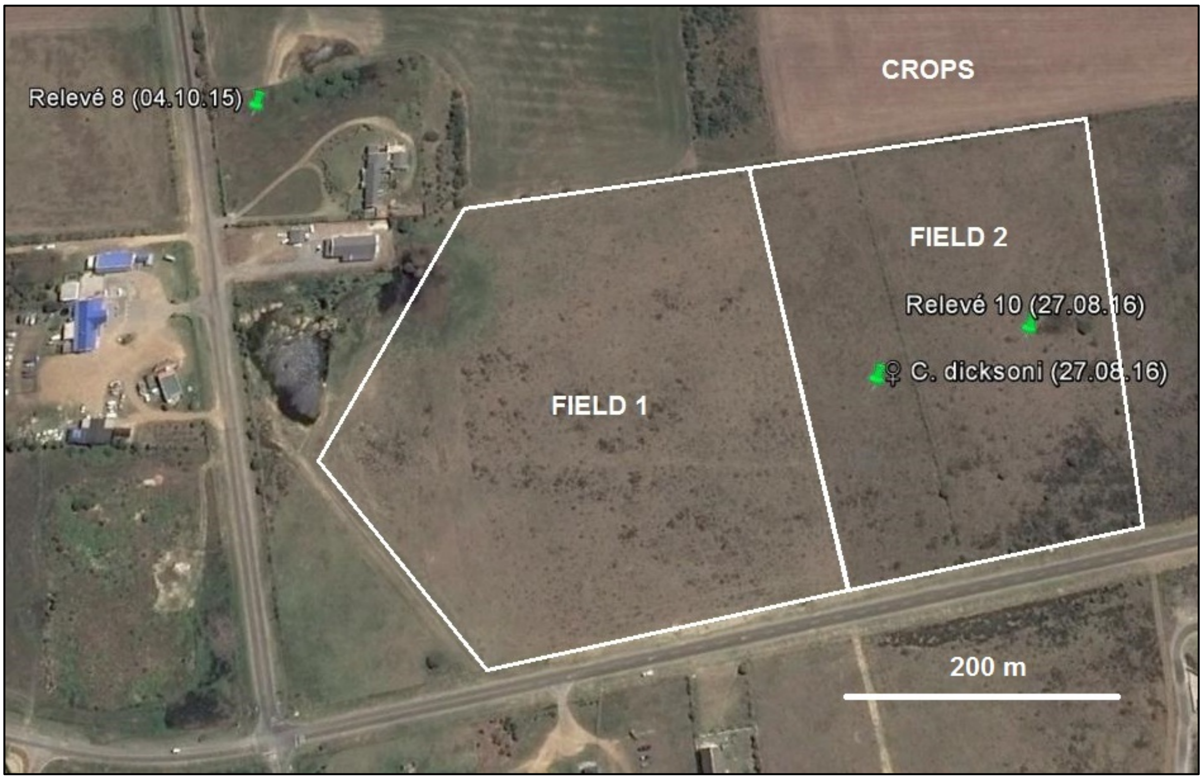

Figure 3 – Position of *C. dicksoni* breeding areas close to the town of Witsand. "Relevés" refer to sites sampled for vegetation. Field 1 has been heavily grazed with a very low plant and butterfly diversity. Field 2 has been only lightly grazed.

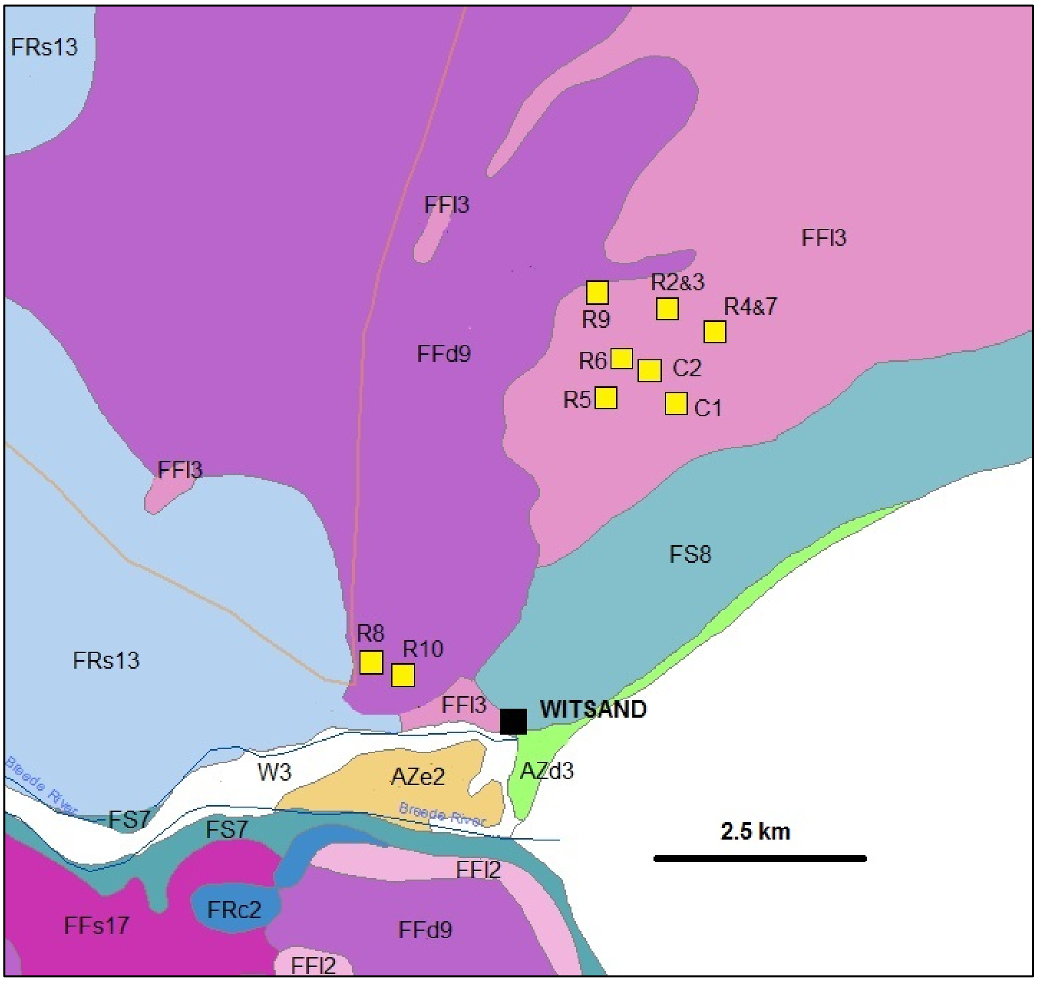

Figure 4 – Vegetation types occurring in the Witsand area (for codes see Table 4 and Mucina & Rutherford, 2006), with the positions of the relevés (R2, R3, etc.) and *C. dicksoni* colonies (C1 & C2) shown as yellow boxes.

In order to systematically record oviposition, *C. dicksoni* ♀s were followed until they laid eggs, and the plant species within a one metre radius of fifteen oviposition sites were recorded. The number of ant nests and the occurrences of scale insects at each relevé were recorded, with the size and height of the nests, and in which plant species they were recorded.

Data analysis

The Primer © version 6.1.15 software programme was used for data analysis (Clarke, 1993; Clarke & Gorley, 2006). Midpoint values of the Braun-Blanquet scale of cover abundance were inserted into two-way data matrices (species and samples) for the ordinations. Plant species for which only very low abundances were recorded and no identification had been made were eliminated from the data set. A Principal Components Analysis (PCA) ordination algorithm was applied to the standardised data set, to assess floristic relations between the relevés. Environmental data were included in some of the ordinations. A stepwise ordination approach was adopted to deal with the heterogeneity of the data set.

The alpha diversity of the plants recorded at each relevé was assessed from the number of species (richness) and by computing Shannon diversity indices H' (which give more weight to rare species).

RESULTS

Floristic composition – relevés & oviposition sites

91 vascular plant species (26 monocotyledons, 65 dicotyledons) were recorded in the relevés at the *C. dicksoni* sites (Table 1). The most abundant plant species in the relevés were *Passerina galpinii* (12.0% average cover), *Pentameris calcicola* (7.6%), *Thamnocortus pluristachyus* (5.2%), *Phylica ericoides* (4.6%) and *Searsia glauca* (3.8%) (Table 2). A two-way data matrix showing the abundances of all species whose average abundance in the relevés equals or exceeds 0.5% appears in Table 2, normalised so that the overall coverage of each site (including bare ground) totals 100%. The plant species occurring more than once within one metre of the 15 oviposition sites is listed in Table 3. Vegetation types found in the Witsand area are listed in Table 4.

Description of the relevés

Relevé 1 (centre 34°21'24.1"S; 20°51'37.9"E) was close to relevé 3 and sampling was incomplete, so the data was not used.

Relevé 2 (Fig. 2) (centre 34°21'20.0"S; 20°51'34.9"E) is on the westernmost “island” of relatively intact natural vegetation in Area 1 and is level. It has 15% limestone and 23% sand and has more graminoids (30.7%) than shrubs (27.0%). *C. dicksoni* were very plentiful here in 2009, but numbers have steadily decreased in recent years.

Relevé 3 (Fig. 2) (centre 34°21'22.9"S; 20°51'38.1"E) is in the southern part of the central “island” in Area 1 and is level. It is as sandy as (25%), but with less limestone than (3%) relevé 2, and has more shrubs (46.7%) than graminoids (18.5%). *C. dicksoni* have been consistently plentiful here from 2009 to 2016.

Relevé 4 (Fig. 2) (centre 34°21'25.6"S; 20°51'46.8"E) is close to the boundary between Areas 1 and 2, and has a slope of 8.5°. It is sandier than relevés 2 and 3 (32%), but with more limestone (12%) than relevé 3. It has similar shrubs to relevé 3 (45.8%), but with much less graminoids (5.7%). *C. dicksoni* were only present here from 2009 to 2012.

Relevé 5 (Fig. 2) (centre 34°21'45.3"S; 20°51'11.2"E) is the southernmost relevé in Area 2 and has a 2° slope. The extent of limestone is higher (30%) than the sandy areas (15%), although the graminoids are very low (3.7%) and the shrubs quite high at 43.4%. This has been the most consistent breeding area for *C. dicksoni*, up to 2016.

Relevé 6 (Fig. 2) (centre 34°21'36.6"S; 20°51'17.3"E) is further north in Area 2 and is fairly level. The bare ground has a similar character to relevé 5, but the coverage of graminoids is much higher (36.5%) and shrubs lower (27.3%). *C. dicksoni* were only seen here in 2009, and much of this site has subsequently become infested with aliens.

Relevé 7 (Fig. 2) (centre 34°21'26.4"S; 20°51'47.6"E) is quite close to relevé 4 and is in a firebreak, with an 8° slope. It has similar sand to relevé 4 (35%), but with no limestone, and a lot of molehills (10%). Graminoids dominate (45%), with shrubs a very low 7%. No ant nests were found here but *C. dicksoni* ♀s were seen ovipositing on various plants in 2009 and 2010.

Relevé 8 (Fig. 3) (centre 34°23'24.8"S; 20°49'35.7"E) is c. 4 km to the south west from the other sites across cultivated fields. There is very little bare sandy ground (5%), and the relevé is dominated by graminoids (37.1%) – mostly Poaceae but also some Restios. Shrubs are 39.0% but the forbs are well represented (15.2%) with many nectar sources. There are only records of several ♂ *C. dicksoni* nectaring, from 2015, when the site was discovered. The original vegetation of this site was Albertinia Sand Fynbos (FFd9 – see Fig. 4).

Relevé 9 (Fig. 2) (centre 34°21'15.1"S; 20°51'05.2"E) is close to the western boundary of Area 1, and is in the ecotone between vegetation types FFl3 and FFd9. It is in relatively natural vegetation (52.7% shrubs, 10.1% graminoids and 7.2% forbs). *C. dicksoni* ♂s were observed here in 2015 and 2016, but so far no ant nests have been located.

Relevé 10 (Fig. 3) (centre 34°23'32.9"S; 20°49'50.8"E) is c. 500 m east of relevé 8, in Field 2, and was also originally FFd9 (see Fig. 4). Its substrate is sand (4%) and sandstone rocks (8%). The field has been moderately grazed by sheep, and this has led to a low plant diversity, with dominance of just three species (*Helichrysum teretifolium*, *Ehrharta calycina* and *Phylica ericoides*). Three *C. dicksoni* ♀s were observed here, displaying interest in *P. ericoides*.

Ordinations

The first PCA ordination, based on plant species only, shows all of the relevés (Fig. 5) and reveals that relevé 7 is completely different to the other relevés (being in a firebreak), and that relevé 6 may also be an outlier. The second ordination (Fig. 6) includes some basic abiotic factors and confirms the status of relevé 7. The third ordination, with relevé 7 removed (Fig. 7), confirms that relevé 6 is an outlier. The fourth ordination (Fig. 8) shows the relevés splitting into two groups – one comprising relevés 2–5, and the other relevés 8–10.

Vegetation structure and abiotic factors

The vegetation structure and some basic abiotic factors for each relevé are summarised in Table 5. Graminoids and shrubs are the dominant vegetation, with the only trees being the alien *Acacia cyclops* and the tree aloe *Aloe ferox.*

Alpha diversity assessment

These statistics are at the bottom of Table 5, and show that the outlier relevés 6 & 7 have the lowest diversity, followed by the sheep-grazed relevé 10.

Plant species associations

Table 6 presents a quantitative assessment of the plant species observed as being of possible ecological importance for the breeding success of *C. dicksoni* and its insect symbionts, *Crematogaster peringueyi* and various Coccoidea scale insects.

Faunal associations

The full records of all the nests of the host ant *Cremotogaster peringueyi* Emery found, and of the occurences of scale insects appeared in Tables 1 & 2 of Giliomee & Edge (2015). This information is summarised, and combined with the records of *C. dicksoni* adults at each relevé, in Table 7. This yields a composite picture of the faunal elements associated with *C. dicksoni* per relevé.

DISCUSSION

Vegetation associations

Six of the nine relevés appear to be situated in FFl3 (Fig. 4), whereas two are situated in FFd9 (8 & 10), and a third one (9) is in the ecotone between FFl3 and FFd9. This difference also shows up quite clearly in the fourth ordination (Fig. 8). However, Mucina & Rutherford (2006: 144) say that the ecotone between FFl3 and FFd9, is defined by soil depth, with FFl3 “confined to skeletal soils”. Closer study of Fig. 2 in the context of the larger area (Fig. 4) shows that there are FFl3 “islands” in a matrix of FFd9 “lower areas”. Thus one can say that all of the relevés except 8 & 10 are in the ecotone between FFl3 and FFd9, and this includes the newly discovered *C. dicksoni* colonies 1 and 2 in Area 2 of Fig. 2.

The dominant plant species in the purely “FFd9” relevés (8 & 10) are *Phylica ericoides* and *Helichrysum teretifolium*; whereas in the “FFl3” relevés *Passerina galpinii* and *Thamnocortus pluristachyus* are co-dominant.

The relevés 6 and 7, which have been eliminated from Fig. 8, have a low alpha diversity (Table 5), and are dominated by a graminoid *Pentameris calcicola*. *C. dicksoni* was only recorded at these relevés in 2009 (Table 7).

The plant species most clearly associated with *C. dicksoni* was *S. glauca* (Table 6), because of the frequent presence of ant nests and scale insects in these shrubs, even though no oviposition was recorded. This is probably because *S. glauca* is generally out of the preferred height range for oviposition (Table 3). *Adenandra obtusata* and *Muraltia spinosa* appear to be important indicator species, for oviposition in the former and scale insects the latter.

Disturbances

All of the relevés had been subjected to some degree of disturbance, either through grazing by domestic and/ or wild animals (relevés 2, 3, 4, 5, 6, 9 & 10), or by the creation of a firebreak (relevé 7), or by cultivation followed by a succession of ruderal plants (relevé 8). The places where *C. dicksoni* was found generally had a relatively “open” appearance compared to the completely natural vegetation, in which no *C. dicksoni* activity has so far been detected.

Herbivores

Disturbance from low intensity livestock grazing seems to be beneficial for *C. dicksoni*, but higher intensity grazing when shrubs are eaten is detrimental (e.g. Field 1 compared to Field 2). Game such as bontebok (*Damaliscus pygargus*), which is a specialist short grass grazer, would not deplete the important shrub layer on which oviposition occurs (Table 3). A recent publication comparing the effect of wild herbivore versus livestock grazing reinforces this observation (Pryke *et al.*, 2016).

Restricted range of *C. dicksoni*

It is not clear why the distribution of *C. dicksoni* is restricted to this area close to Witsand (and the area near Melkbosstrand where it was originally found). A survey by Giliomee (2014) showed that nests of *C. peringueyi* containing scale insects occur over a wide area along the western and southern coasts of South Africa. In this respect *C. dicksoni* is similar to a number of other endangered butterfly species in South Africa, such as *Orachrysops niobe* (Trimen, 1862) and *Thestor brachycerus brachycerus* (Trimen, 1883). Their distribution is also confined to fairly small areas where their strict habitat requirements are met (Mecenero *et al*., 2013).

Climate change

C. dicksoni has been identified (Edge, 2011b) as one of South Africa’s butterflies most susceptible to climate change. This is because of its location very far south and its emergence very early in the season – evidence that it is a cold adapted insect. As global temperatures increase in the coming decades it will be unable to adapt by moving polewards or to higher altitudes, as has been witnessed in Europe and elsewhere (Hannah *et al*., 2005; Palmer *et al*., 2015).

Its disappearance from its former haunts on the west coast north of Cape Town may therefore be indicative of increasing climatic stresses (Jury, 2013) as much as habitat loss.

MANAGEMENT RECOMMENDATIONS

Reserve status

During this study the importance of establishing formal conservation status for at least one of the two sites on which the species is known to occur was again realised. The landowner of Westfield 483 (Stellenbosch University) and CapeNature, have agreed that the best way to conserve the site is to have the whole of it (1200 ha) declared as a contract nature reserve. A management plan will then be drawn up between these parties, with advice from the Lepidopterists' Society of Africa. These steps are consistent with the comments by Terblanche & Van Hamburg (2003) who stated that this butterfly is "in the process of vanishing if conservation strategies are not implemented in the near future".

Alien plants

An urgent management priority is the eradication of the alien *Acacia cyclops* in Area 2 (Fig. 1). A programme to effect this commenced in 2015 under the leadership of CapeNature, and significant progress has already been made towards achieving this goal by the end of 2018.

Herbivores

It is surmised that some level of natural disturbance in the form of herbivore feeding is necessary to sustain the populations of *C. dicksoni*. The new contract nature reserve would be ideal for the introduction of a sustainable herd of bontebok to fulfil this ecological need, as they undoubtedly did in the past (Lloyd & David, 2008).

Further research

The vegetation at the sites of colonies 1 & 2 in Area 2 (Fig. 2) needs to be surveyed by setting up two more relevés, and in the case of more colonies being discovered in future, these should also be surveyed. When resources become available some nearby undisturbed sites without *C. dicksoni* could be sampled. More oviposition observations are also needed to expand the dataset and enable more robust conclusions to be drawn.

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Table 1 – Plant species recorded at the Witsand *Chrysoritis dicksoni* sites. Names from Manning & Goldblatt (2012); Red List status from Raimondo *et al.* (2009). DEC=Declining; EN=Endangered; NT=Near Threatened; VU=Vulnerable.

Family	**Species**	**Red List Status**	**Author(s)**
MONOCOTYLEDONAE			
Asphodelaceae	*Bulbine lagopus*		(Thunb.) N.E.Br.
Asphodelaceae	*Trachyandra revoluta*		(L.) Kunth
Cyperaceae	*Ficinia oligantha*		(Steud.) J. Raynal
Cyperaceae	*Ficinia praemorsa*		Nees
Hypoxidaceae	*Hypoxis argentea*		Harv. Ex Baker
Hypoxidaceae	*Pauridia minuta*	NT	(L.f.) T.Durand & Schinz
Iridaceae	*Babiana patula*	DEC	N.E.Br.
Iridaceae	*Babiana nana*	EN	(Andrews) Spreng.
Iridaceae	*Ixia dubia*		Vent.
Iridaceae	*Ixia orientalis*		L.Bolus
Iridaceae	*Moraea (Homeria) bulbillifera*		(G.J. Lewis) Goldblatt
Poaceae	*Avena sativa*		L.
Poaceae	*Cynodon dactylon*		(L.) Pers.
Poaceae	*Ehrharta calycina*		Sm.
Poaceae	*Hordeum murinum*		L.
Poaceae	*Koeleria capensis*		(Steud) Nees
Poaceae	*Lolium multiflorum*		Lam.
Poaceae	*Pentameris calcicola* var. *calcicola*	NT	(H.P.Linder) Galley & H.P.Linder
Poaceae	*Poa annua*		L.
Poaceae	*Sporobolus africanus*		(Poir.) A.Robyns & Tournay
Poaceae	*Themeda triandra*		Forssk.
Poaceae	*Tribolium hispidum*		(Thunb.) Desv.
Poaceae	*Triticum vulgare*		L.
Restionaceae	*Restio (Ischyrolepis) leptoclados*		Mast.

Restionaceae	*Thamnochortus pluristachyus*	VU	Mast.
Restionaceae	*Thamnochortus insignis*		Mast.
DICOTYLEDONAE			
Aizoaceae	*Carpobrotus edulis*		(L.) L.Bolus
Aizoaceae	*Delosperma mariae*	VU	L. Bolus
Aizoaceae	*Drosanthemum hispidum*		(L.) Schwantes
Aizoaceae	*Drosanthemum intermedium*		(L.Bolus) L. Bolus
Aizoaceae	*Mesembryanthemum canaliculatum*		Haw.
Anacardiaceae	*Searsia crenata*		(Thunb.) Moffett
Anacardiaceae	*Searsia glauca*		(Thunb.) Moffett
Asparagaceae	*Asparagus burchellii*		Baker
Asparagaceae	*Asparagus capensis*		L.
Asphodelaceae	*Aloe ferox*		Mill.
Asteraceae	*Adenandra obtusata*		Sond.
Asteraceae	*Arctotheca calendula*		(L.) Levyns
Asteraceae	*Arctotis reptans*		Jacq.
Asteraceae	*Berkheya rigida*		(Thunb.) Ewart, Jean White & B.Rees
Asteraceae	*Chrysanthemoides monilifera* ssp. *rotundata*		(L.) T. Norl.
Asteraceae	*Dimorphotheca nudicaulis*		(L.) DC.
Asteraceae	*Eriocephalus africanus*		L.
Asteraceae	*Felicia tenella*		(L.) Nees
Asteraceae	*Gazania krebsiana*		Less.
Asteraceae	*Gazania pectinata*		(Thunb.) Spreng.
Asteraceae	*Helichrysum niveum*		(L.) Less.
Asteraceae	*Helichrysum patulum*		(L.) D.Don
Asteraceae	*Helichrysum* cf. *petiolare*		Hilliard & B.L.Burtt
Asteraceae	*Helichrysum teretifolium*		(L.) D.Don
Asteraceae	*Metalasia calcicola*	NT	P.O.Karis
Asteraceae	*Metalasia densa*		(Lam.) P.O.Karis
Asteraceae	*Metalasia dregeana*		DC.
Asteraceae	*Oedera uniflora*		(L.f.) Anderb. & K.Bremer
Asteraceae	*Osteospermum scariosum*		DC.
Asteraceae	*Othonna auricifolia*		Licht. Ex Less.
Asteraceae	*Senecio arenarius*		Thunb.
Asteraceae	*Senecio lanifer*		Mart. ex C. Jeffrey
Asteraceae	*Ursinia nudicaulis*		(Thunb.)
Caryophyllaceae	*Herniaria schlechteri*		F. Herm.
Ericaceae	*Erica regia* Bartl. ssp. *mariae*		(Guthrie& Bolus) E.G.H.Oliv. & I.M.Oliv.
Ericaceae	*Erica spectabilis*		Klotzsch ex Benth
Fabaceae	*Acacia cyclops*		A.Cunn. ex G.Don
Fabaceae	*Aspalathus nigra*		L.
Fabaceae	*Aspalathus* sp.		
Fabaceae	*Indigofera meyeriana*		Eckl. & Zeyh.
Fabaceae	*Indigofera angustifolia*		L.
Fabaceae	*Tephrosia capensis*		(Jacq.) Pers.
Fabaceae	*Wiborgiella sessilifolia*	NT	(Eckl. & Zeyh.) Boatwr. & B.-E.van Wyk
Geraniaceae	*Geranium incanum*		Burm.f.
Geraniaceae	*Pelargonium alchemilloides*		(L.) Aiton
Geraniaceae	*Pelargonium caucalifolium* ssp. *convolvulifolium*		Van der Walt
Geraniaceae	*Pelargonium lobatum*		(Burm.f.) L'Hér
Malvaceae	*Hermannia decumbens*		Willd. Ex Spreng.
Malvaceae	*Hermannia flammula*		Harv.
Malvaceae	*Hermannia ternifolia*		C.Presl ex Harv.
Polygalaceae	*Muraltia filiformis*		(Thunb.) DC.
Polygalaceae	*Muraltia pappeana*	NT	Harv.
Polygalaceae	*Muraltia* (= *Nylandtia*) *spinosa*		(L.) F.Forest & J.C.Manning
Polygalaceae	*Polygala umbellata*		L.
Proteaceae	*Leucadendron meridianum*		I. Williams
Rhamnaceae	*Phylica ericoides*		L.
Rubiaceae	*Anthospermum spathulatum* ssp. *spathulatum*		Spreng.
Rutaceae	*Agathosma* cf. *capensis*		(L.) Dummer
Santalaceae	*Limonium scabrum*		(H.P.Linder) Galley & H.P.Linder
Scrophulariaceae	*Chaenostoma calciphilum*		(Hilliard) Kornhall
Scrophulariaceae	*Jamesbrittenia calciphila*	NT	Hilliard
Scrophulariaceae	*Manulea calciphila*		Hilliard
Scrophulariaceae	*Selago aspera*		Choisy
Thymelaeaceae	*Passerina galpinii*		C.H. Wright
Zygophyllaceae	*Roepera flexuosa*		(Eckl. & Zeyh.)

Table 2 – Extract from two-way data matrix of plant species abundance versus relevé. Name of plant species abbreviated as first two letters of genus and species, and listed in descending order of overall abundance, down to species with more than 0.4% average abundance.

	Abundance per relevé									Average (%)
Relevé no. / **Species (code)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Passerina galpinii (Paga)	0.15	0.25	0.22	0.16	0.25			0.046		12.0
Pentameris calcicola (Peca)	0.01	0.004	0.01		0.28	0.37		0.008		7.6
Thamnochortus pluristachyus (Thpl)	0.25	0.15	0.03	0.015	0.025					5.2
Phylica ericoides (Pher)							0.15	0.12	0.15	4.6
Searsia glauca (Segl)	0.01	0.07		0.15		0.02		0.095		3.8
Helichrysum teretifolium (Helt)						0.005			0.3	3.4
Restio leptoclados (Rele)	0.03	0.005		0.015	0.05		0.05	0.052		2.4
Ehrharta calycina				0.007		0.005	0.015	0.004	0.18	2.3
Tribolium hispidum (Trhi)		0.005	0.001			0.035	0.15	0.001	0.009	2.2
Asparagus burchellii (Asbu)	0.03	0.05		0.015	0.005		0.02		0.043	1.8
Muraltia spinosa (Musp)			0.001					0.155		1.7
Asparagus capensis (Asca)	0.01	0.01	0.005	0.008	0.005		0.04	0.048	0.021	1.6
Arctotheca calendula (Arca)						0.005	0.04		0.065	1.2
Sporobolus africanus (Spaf)						0.005	0.1			1.2
Anthospermum spathulatum (Ansp)			0.08			0.02				1.1
Avena sativa (Avsa)							0.025		0.056	0.9
Eriocephalus africanus (Eraf)	0.03		0.02					0.031		0.9
Helichrysum niveum (Heni)		0.03					0.05			0.9
Searsia crenata (Secr)				0.06						0.7
Agathosma capensis (Agca)		0.03	0.03							0.7
Berkheya rigida (Beri)					0.005		0.05			0.6
Drosanthemum intermedium (Drin)				0.015	0.005	0.005		0.023	0.006	0.6
Metalasia dregeana (Medr)			0.05		0.002					0.6
Pelargonium lobatum (Pelo)	0.005	0.03	0.005					0.011		0.6
Helichrysum petiolare (Hepe)		0.005	0.03			0.01				0.5
Hermmania ternifolia (Hert)								0.011	0.034	0.5
Lolium multiflorum (Lomu)	0	0	0	0	0	0.005	0.02	0	0.016	0.5
Thamnochortus insignis (Thin)	0	0.001	0.01	0	0	0.03	0	0	0	0.5
Indigofera meyeriana (Inme)	0.006	0.005	0.005	0.008	0.005	0	0.005	0.006	0	0.4
Dimorphotheca nudicaulis (Dinu)	0	0	0	0	0	0	0.04	0	0	0.4

Table 3 – Occurrence of plant species recorded twice or more within 1 metre of 15 oviposition sites

Species (code) / **Site nos.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Totals**	**Oviposition height (m)**
Adenandra obtusata (Adob)	1		1	1			1	1	1	1	1	1	1	1	1	**12**	0.2
Thamnochortus pluristachyus (Thpl)		1	1	1		1		1		1				1		**7**	0.3
Thamnochortus insignis (Thin)			1					1	1	1	1			1	1	**7**	0.3
Passerina galpinii (Paga)			1	1			1			1	1		1			**6**	0.4
Manulea calciphila (Maca)			1	1		1					1		1		1	**6**	0.1
Helichrysum petiolare (Hepe)		1				1					1					**3**	0.4
Agathosma capensis (Agca)						1					1					**2**	0.3
Aspalathus nigra (Asni)	1	1														**2**	0.4
Helichrysum niveum (Heni)						1								1		**2**	0.3
Pentameris calcicola (Peca)				1						1						**2**	0.2
Ficinia oligantha (Fiol)							1			1						**2**	0.2
Erica spectabilis (Ersp)			1					1								**2**	0.3
Anthospermum spathulatum (Ansp)	1	1														**2**	0.4
Drosanthemum intermedium (Drin)	1	1														**2**	0.1
Lolium multiflorum (Lomu)			1										1			**2**	0.3

Table 4 – Codes for the vegetation types found in the Witsand area, according to Mucina & Rutherford (2006), and shown in Fig. 4.

Code	**Vegetation type**	**Code**	**Vegetation type**
AZd3	Cape Seashore Vegetation	FFs17	Potberg Sandstone Fynbos
AZe2	Cape Estuarine Salt Flats	FRc2	Rûens Silcrete Renosterveld
FFd9	Albertinia Sand Fynbos	FRs13	Eastern Rûens Shale Renosterveld
FFl2	De Hoop Limestone Fynbos	FS7	Overberg Dune Strandveld
FFl3	Canca Limestone Fynbos	FS8	Blombos Strandveld

Table 5 – Vegetation structure expressed as % coverage and height of life forms. Abiotic factors are also given, including the substrates exposed on the bare ground; and two indices of diversity are recorded.

Relevé no. **Life form**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average**
Graminoids (%)	30.7	18.5	5.7	3.7	36.5	45.0	37.1	10.1	26.1	23.7
Graminoids (height – m)										0.39
Shrubs (%)	27.0	46.7	45.8	43.4	27.3	7.0	39.0	52.7	51.4	37.8
Shrubs (height – m)										0.63
Forbs (%)	3.8	6.7	4.3	5.7	2.2	3.0	15.2	7.2	10.5	6.5
Forbs (height – m)										0.22
Geophytes (%)	0.5	0.1	0.2	2.2	0	0	3.7	0	0	0.74
Geophytes (height – m)										0.27
Trees (%)	0	0	0	0	0	1.0	0	0	0	0.11
Trees (height – m)										1.80
Bare ground (%)										
Sandy	23	25	32	15	12	35	5	25	4	19.7
Limestone/ rocks	15	3	12	30	22			5	8	10.2
Molehills						10				1.1
Slope (°)			8.5	2		8				
Alpha diversity										
Species richness	27	31	29	21	17	18	28	24	11	
Shannon index H'	2.10	2.24	2.23	2.24	1.46	1.46	2.84	2.52	1.88	

Table 6 – The plant species assessed as probably being of ecological importance for the breeding success of *C. dicksoni* and its insect symbionts. The indicators of breeding success are expressed as the percentage of total observations made. Data sources: [1] = Table 3 above; [2] = Table 1 of Giliomee & Edge, 2015; [3] = Table 2 of Giliomee & Edge, 2015; [4] = Table 2 above, plus data for species < 0.4% not shown in Table 2.

Plant species	**Indicators of breeding activity of *C. dicksoni***			**Totals**	**Plant average % abundance in relevés[4]**
	Oviposition[1]	***C. peringueyi* ant nests[2]**	**Scale insects[3]**		
Searsia glauca (Segl)		55.6	25.0	80.6	3.8
Muraltia spinose (Musp)			33.3	33.3	1.7
Thamnochortus pluristachyus (Thpl)	7/59 = 11.9	11.1		23.0	5.2
Adenandra obtusa (Adob)	12/59 = 20.3			20.3	0.2
Passerina galpinii (PaGa)	6/59 = 10.2	8.3		18.5	12.0
Metalasia dregeana (Medr)			16.7	16.7	0.6
Searsia crenata (Secr)		5.6	8.3	13.9	0.7
Thamnochortus insignis (Thin)	7/59 = 11.9			11.9	0.5
Helichrysum petiolare (Hepe)	3/59 = 5.1	5.6		10.7	0.5
Manulea calciphila (Maca)	6/59 = 10.2			10.2	0.1

Table 7 – *C. dicksoni* oviposition, *C. peringueyi* ant nests and various Coccoidea scale insects occurring in or near the relevés. Oviposition only recorded in detail during 2009; thereafter only chance observations. Systematic searching for *C. peringueyi* ant nests began in 2010, and for scale insects during 2014.

Year	**Relevé no.** **Insect records**	**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
2009	*C. dicksoni* ♂ ♀	0	0	0	0	0	0	11	1	3	2	0	2	-	-	-	-	-	-
2009	*C. dicksoni* oviposition	6		2		7		1		0		2		-		-		-	
2009	*C. peringueyi* ant nests	0		1		1		0		0		-		-		-		-	
2010	*C. dicksoni* ♂ ♀	0	0	15	5	0	0	0	0	0	0	-	-	-	-	-	-	-	-
2010	*C. peringueyi* ant nests	5		2		3		0		0		-		-		-		-	
2011	*C. dicksoni* ♂ ♀	2	1	6	2	2	0	0	1	0	0	-	-	-	-	-	-	-	-
2011	*C. dicksoni* oviposition	0		1		0		0		0		-		-		-		-	
2011	*C. peringueyi* ant nests	3		5		2		0		1		-		-		-		-	
2012	*C. dicksoni* ♂ ♀	0	0	2	1	-	-	4	0	-	-	-	-	-	-	-	-	-	-
2012	*C. peringueyi* ant nests	1		4		-		0		-		-		-		-		-	
2013	*C. dicksoni* ♂ ♀	2	0	3	0	1	0	6	1	-	-	-	-	-	-	-	-	-	-
2013	*C. peringueyi* ant nests	1		4		0		0		-		-		-		-		-	
2014	*C. dicksoni* ♂ ♀	0	0	0	0	-	-	19	6	-	-	-	-	-	-	-	-	-	-
2014	*C. peringueyi* ant nests	1		3		-		5		-		-		-		-		-	
2014	*Coccoidea* scale insects	2		3		1		7		-		-		-		-		-	
2015	*C. dicksoni* ♂ ♀	3	1	10	3	-	-	8	1	-	-	-	-	5	0	4	0	-	-
2015	*C. dicksoni* oviposition	0		1		-		0		-		-		0		-		-	
2015	*C. peringueyi* ant nests	1		5		-		5		-		-		0		-		-	
2015	*Coccoidea* scale insects	1		3		-		3		-		-		0		-		-	
2016	*C. dicksoni* ♂ ♀	3	0	14	0	0	0	0	5	-	-	-	-	5	0	6	0	0	3
2016	*C. dicksoni* oviposition	0		0		0		0		-		-		0		0		2	

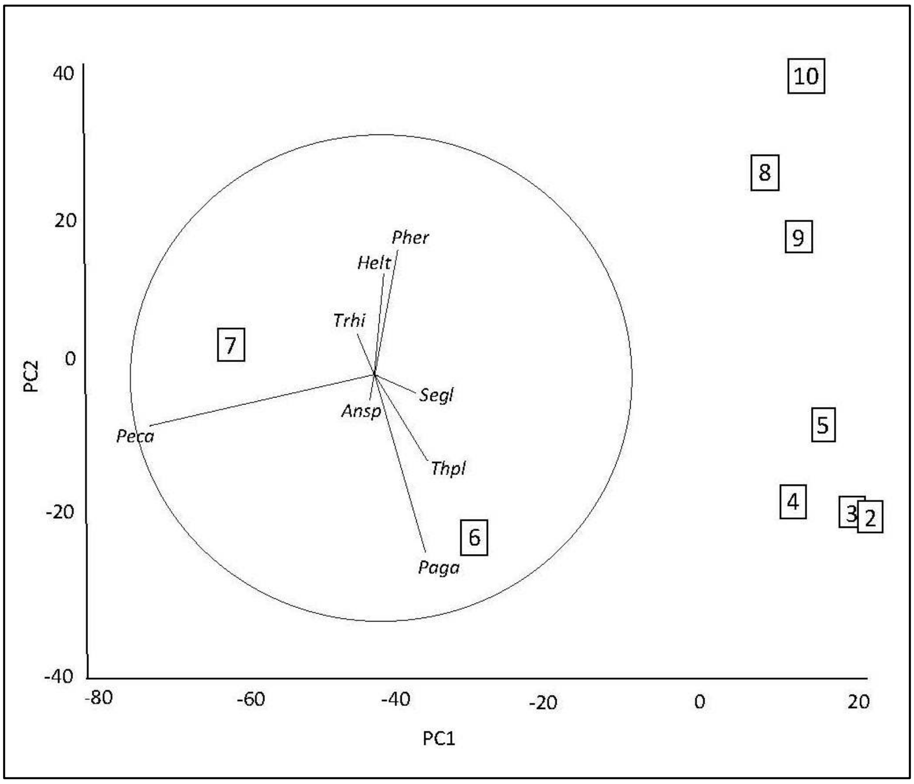

Figure 5 – PCA analysis of vegetation occurring at the Witsand localities of *Chrysoritis dicksoni*. The samples (boxed) are nine relevés and the variables are the 45 plant species with an overall average abundance of more than 0.2%. Refer to Table 2 for the abbreviations of the plant species names.

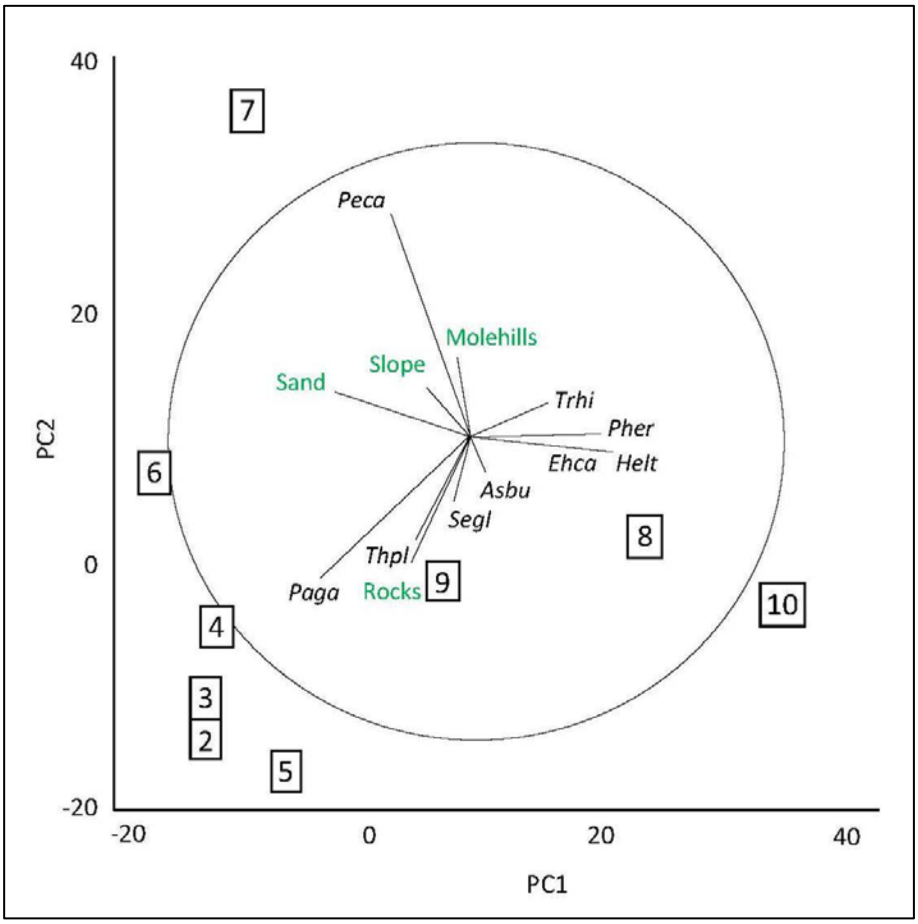

Figure 6 – PCA analysis of vegetation and abiotic conditions occurring at the Witsand localities of *Chrysoritis dicksoni*. Otherwise data as per Fig. 5.

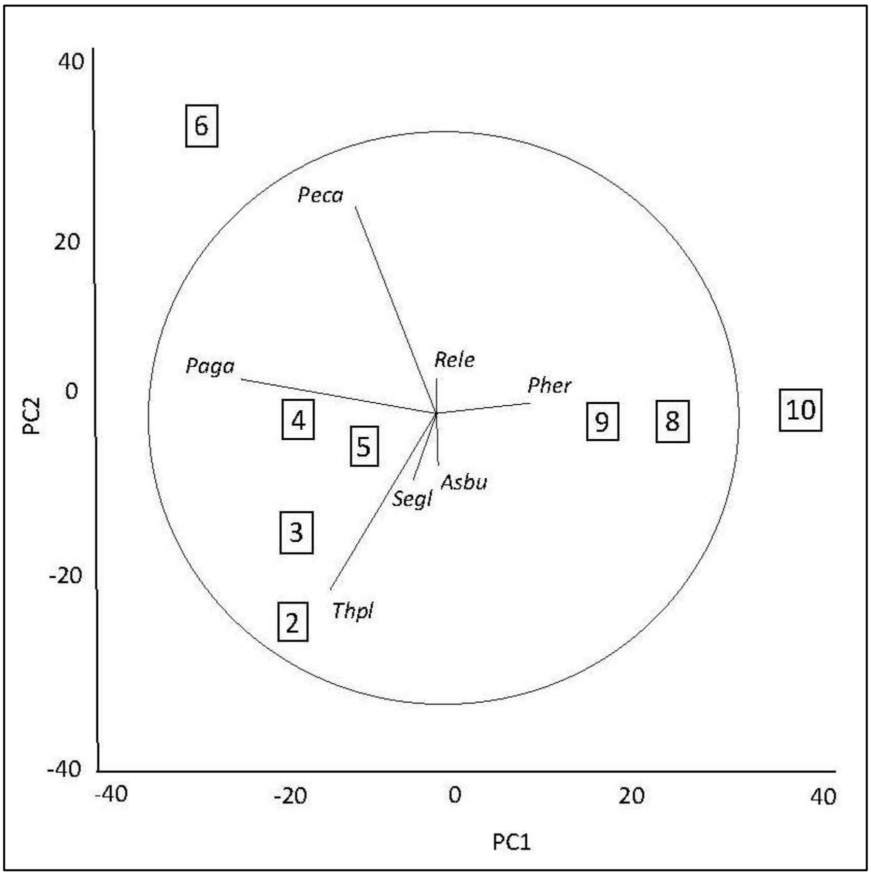

Figure 7 – PCA analysis of vegetation occurring at the Witsand localities of *Chrysoritis dicksoni.* As per Fig. 5, except relevé 7 removed from data set.

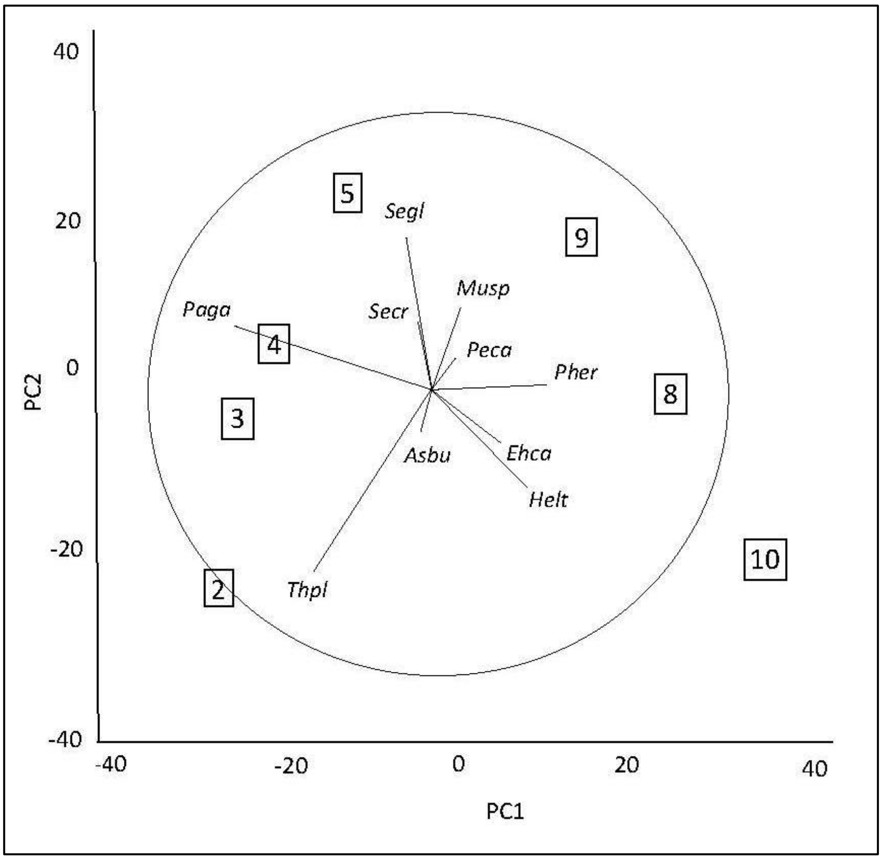

Figure 8 – PCA analysis of vegetation occurring at the Witsand localities of *Chrysoritis dicksoni.* As per Fig. 5, except relevés 6 and 7 removed from data set.