METAMORPHOSIS
LEPIDOPTERISTS' SOCIETY OF AFRICA
Volume 31(1): 139–147
ISSN 1018–6490 (PRINT)
ISSN 2307–5031 (ONLINE)

The status and distribution of Pennington's Protea butterfly *Capys penningtoni* (Lepidoptera: Lycaenidae: Theclinae)

Published online: 23 December 2020

Adrian J. Armstrong [1,2]
[1] Ezemvelo KZN Wildlife, P.O. Box 13053, Cascades, 3202, KwaZulu-Natal, South Africa. Email: Adrian.Armstrong@kznwildlife.com
[2] Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg, 3209, South Africa.

Abstract: The Red List status of Pennington's protea butterfly *Capys penningtoni* has deteriorated from Vulnerable to Critically Endangered since 2009. This species is endemic to part of the midlands and Drakensberg foothills of the province of KwaZulu-Natal, South Africa. *Capys penningtoni* is restricted to protea savanna where its hostplant, *Protea caffra*, occurs. A research programme was started when the Red List status of the species was Vulnerable, with the aims of preventing the extinction of *C. penningtoni* and improving its conservation status. An initial requirement was to more accurately determine the distribution and conservation status of *C. penningtoni*. A further requirement was to ascertain what might be the main threats facing the species in the wild. Surveillance of the species at some sites was carried out to try and ascertain whether the conservation status of the species was deteriorating further. Our knowledge of the distribution range of the species has improved with the identification of seven previously unknown sites where the species was present. A distribution model was developed for the species that predicted that *C. penningtoni* could be more widely distributed in the central midlands and Drakensberg foothills of KwaZulu-Natal. The model did not predict the occurrence of the species at three of the newly discovered sites. Further ground-truthing of the model is required. Surveillance results suggest that *C. penningtoni* may have become locally extinct or less abundant at sites where it was previously recorded, indicating that its conservation status has deteriorated. The main threats to *C. penningtoni* appears to be the presence of the alien invasive Harlequin ladybird beetle *Harmonia axyridis* and the inappropriate fire regimes and burning practices in the protea savanna habitat of the species.

Key words: Critically Endangered, predicted distribution, surveillance, *Harmonia axyridis*, inappropriate fire regimes.

Citation: Armstrong, A.J.. 2020. The status and distribution of Pennington's Protea butterfly *Capys penningtoni* (Lepidoptera: Lycaenidae: Theclinae). *Metamorphosis* **31(1)**: 139–147. DOI: https://dx.doi.org/10.4314/met.v31i1.24

INTRODUCTION

Pennington's protea butterfly *Capys penningtoni* is only known from the central midlands and Drakensberg foothills of KwaZulu-Natal (Pringle *et al*., 1994), in the greater Mkhomazi River basin (Cockburn & Woodhall, 2015). Its host plant is the common sugarbush *Protea caffra* (Henning & Henning, 1989). Owing to its deteriorating IUCN Red List status over the years (Rare: Henning & Henning, 1989; Vulnerable: Henning *et al*., 2009; Endangered: Mecenero *et al*., 2013), work was started on determining its distribution range and its current conservation status. The purpose of this paper is to present the results of this work, the consequences of the findings, and to encourage lepidopterists to find other sub-populations and assist with the conservation of the species.

MATERIAL AND METHODS

A simple distribution model for *C. penningtoni* was developed as follows. Distribution records for *C. penningtoni* of spatial resolution ≤ 250 m were extracted from the Ezemvelo KZN Wildlife Biodiversity Database. This totalled eight separate localities. These data and the following references were used to help determine which predictor variables and their categories or ranges should be included in the distribution model for *C. penningtoni*. The species is found on mountain slopes where its host plant *Protea caffra* occurs (Henning & Henning, 1989; Hilliard & Burtt, 1987), and the males can be found higher up above the proteas, even on the mountain peaks (Swanepoel, 1953; Henning & Henning, 1989). The larvae go into diapause in the winter months (Henning & Henning, 1989), and temperature is important in inducing and breaking diapause in some Lycaenidae (Leimar, 1996; Hiruma *et al*., 1997; Nylin & Gotthard, 1998; Sands & New, 2008). The predictor coverages and their categories or ranges of values that were used to develop the predicted distribution model for *C. penningtoni* are indicated in Table 1.

The predictor variables used to model the distribution of *C. penningtoni* were converted to Idrisi raster format, WGS84 datum, Transverse Mercator lo31 central meridian projection, with a pixel size of 200 x 200 m (the pixel sizes of the original coverages were: landcover – 20 m x 20 m, vegetation type and slope – 200 m x 200 m, and minimum temperature – 1' x 1'; no increase in the resolution accuracy of the minimum temperature variable was assumed). The predictor coverages were refined to output coverages by extracting those areas that matched the categories or value ranges indicted in Table 1. The

Received: 11 September 2020
Published: 23 December 2020

Table 1 – Predictor coverages and their categories or ranges of values that were used in the development of the predicted distribution model for *Capys penningtoni*.

Coverages	Categories or ranges in values	References
Vegetation type	Drakensberg Foothill Moist Grassland Southern KwaZulu-Natal Moist Grassland	KwaZulu-Natal Provincial Pre-Transformation Vegetation Type Map – 2009 [*kznvegforwet0509_wdd*]; based on Mucina & Rutherford (2006)
Land cover	Untransformed bushland Untransformed grassland Untransformed woodland	KZN Land cover 2005 v2 [*Clp_KZN_2005_LC_V2_grid_w31*]
Slope (°)	8 – 29	KZN Slope [kznslope]
Mean Minimum Daily Temperature July (°C)	-1 – 4	*KZN Mean Daily Minimum Temperatures July 06*; Schulze (2007)

output coverages were then overlaid (by multiplication) in the Idrisi Andes GIS (Eastman, 1999) to produce the initial predicted distribution map for *C. penningtoni*, i.e. the areas where all the output coverages overlapped.

The initial predicted distribution map for *C. penningtoni* was further refined using Ramas GIS (Akçakaya, 2005) to produce a potential metapopulation map. An assumption made was that *C. penningtoni* could regularly fly up to two kilometres over landcover types not considered potential habitat in search of other potential habitat, providing the landcover types did not act as barriers to flight nor impede flight unduly. The assumed ease of flight over the various landcover types was represented by the friction values assigned to each landcover type (Table 2). A patch map that contained 35 patches was created by the Ramas GIS programme using those parameters. Two of those patches contained records of *C. penningtoni*, and so all of the other patches were excluded from the final predicted distribution map as they were not considered available for colonisation by *C. penningtoni*, either in the past or currently.

The remaining two patches formed the final potential habitat (i.e. predicted distribution) map. The potential habitat was grouped into contiguous areas (contiguous pixels) that were categorised as either (1) potential habitat in which one or more distribution records of spatial resolution ≤ 1000 m (10 separate localities extracted from the Ezemvelo KZN Wildlife Biodiversity Database) fell, or (2) those parts that were contiguous habitat in which no *C. penningtoni* distribution records fell but where protea savanna and in particular *P. caffra* had been recorded, or (3) the remaining potential habitat.

Some sites previously known to have had the species and whose locations were adequately known were visited during the period 2014 to 2015 to ascertain whether the species still existed there (Table 3, first column). Other sites that had the host plant species were visited to ascertain whether the species occurs there (Table 3, first column, including Lotheni Nature Reserve where the species had been recorded previously but with imprecise locality co-ordinates). Repeat visits were made to some sites in a year (including years when the species was found there) and/or for several years up until 2020 on an *ad hoc* basis. The reasons for the repeat visits were to increase the probability of *C. penningtoni* being recorded if it was not seen during the first visit, and to ascertain whether *C. penningtoni* may be in danger of local extinction in subsequent years if the number of *C. penningtoni* seen at a site was very low or if none were observed.

Two methods were used to determine presence of *C. penningtoni*. These were the following:

1. searching suitable flower buds for eggs, larvae or pupae. If the number of *P. caffra* was few, all were searched. If the number was high, as many of the *P. caffra* trees were searched as possible in accordance with time constraints. Searching for pupae was the only method used in July as adults would not likely be on the wing in that month. During 2017 and 2018, searching for eggs, larvae and pupae (and including adults) was confined to three 20 x 20 m plots set up at six sites to determine the effects of fire on *P. caffra* (Impendle Nature Reserve, original farm Lot 93 1821, Marwaqa Nature Reserve, Clairmont Mountain Nature Reserve, Mt le Sueur and Lotheni Nature Reserve) (S. Louw, unpublished data). The latter method was sometimes combined with the following method;
2. searching for adults during the hotter and less windy hours of the day. Known (from previous records) and potential hill-topping sites were searched. Searches were not carried out in very windy or rainy weather and ceased by 14h00.

Where eggs were recorded (Fig. 1), geographical co-ordinates of the *P. caffra* host-plants were taken using a Garmin hand-held GPS, and if possible the *P. caffra* host-plants were revisited before the date of probable eclosure of the adults from the pupae to check whether the eggs were indeed of *C. penningtoni* (Fig. 2). Pupae found were taken into captivity (Fig. 3) to ensure that they were of *C. penningtoni*, and if the adults eclosed (Fig. 4) they were released back at their natal sites (Fig. 5).

Whether a congener of *C. penningtoni*, *Capys alpheus extentus*, was observed at each site was recorded. This was done in case eggs or pupae were found, to exclude the possibility that *C. a. extentus* was also using *P. caffra* as a host plant, which has not been documented to date. The presence of the omnivorous alien invasive harlequin lady beetle *Harmonia axyridis* was also recorded if it was observed at the sites, owing to it being a known predator of early life history stages of Lepidoptera (Koch *et al*., 2003; Roy *et al*., 2016). However, it was only looked for once it became noticeable on account of its numbers, so its presence at a couple of the earlier sites visited may not have been recorded.

Table 2 – Friction values assigned to landcover types in terms of assumed ease of flight of *Capys penningtoni* over them.

Friction value	Ease of movement	Landcover types
1	No restriction	Medium bush (< 70% canopy cover) Woodland & Wooded Grassland Bush Clumps / Grassland Grassland Natural Bare Rock
10	Less likely to be traversed	Degraded Bushland (all types) Degraded Grassland KZN Main & District Roads
100	Not likely to be traversed as a matter of course	Forest (indigenous) Dense thicket & bush (70 – 100 % canopy cover) Bare Sand Degraded Forest Erosion KZN National Roads
1000	Probable barrier to movement	All other landcover types (e.g. Water, Plantation, and Cultivation (various types); Wood & Samways (1991); Pryke & Samways (2001)

Table 3 – Localities visited to search for *Capys penningtoni*. The stage of the life cycle found at each site where the species was present, the years in which the sites were visited, and the observed presence of the congener *Capys alpheus extentus* (CAE) and of the alien invasive *Harmonia axyridis* (HA) at the sites are indicated. P = present, N = not observed, figures in parentheses = number of visits to the site with dates of visits indicated, A = adult(s), E = egg(s); J = pupa(e).

Locality	**Year (Sampling occasions)**								**CAE?**	**HA?**
	< 2014	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**		
Previously known sites										
Bulwer Mountain (including Marwaqa Nature Reserve)			P (A)		P (J)	P (A)	P (A)	P (A)	P	P
Nhlosane Mountain (Inhluzani Mount 5303)		P (E)	P (J remains)						N	N
Lotheni Nature Reserve			P (J)		N (2: 28–29 Aug)	N (2: 13–14 Nov)			P	P
Original farm Lot 93 1821, Mkhomazi River Valley			P (J)	P (A)	N (2: 7–8 Aug)	N (4: 6–8 Aug & 28 Sep)	N (1: 17 Oct)	N (1: 25 Aug)	P	P
Impendle Nature Reserve (Lundy's Hill area)	P (J): 2012		N (2: 28 July & 28 Sept)	N (1: 24 Aug)	N (2: 1 Aug & 2 Aug)	N (2: 1–2 Aug)		P (A) new site	N	P
New Forncett			P (J remains)?	N (4: 29 Aug & 12 Sep & 4 Oct & 6 Oct)		N (1: 28 Aug)		N (1: 27 Aug)	P	P
Sevontein Prison Farm (Howard Hill)	P (J): 2003		N (1: 9 Oct)	P (A)					N	P
Manshonga ridge, near Boston (locality of first known specimen)			N (1: 6 Oct)						N	N
New sites										
Ivanhoe (Heatherdon 5358)		P (J)	N (1: 20 Jul)						N	N
Good Hope		P (E)	P (J)						N	N
Mount Shannon		P (J)							N	P
Clairmont Mountain Nature Reserve		P (J)		N (1: 20 Sep)	N (2: 20–21 Sep)	N (2: 18–19 Oct)			N	P
Nkawini Mountain	P (E): 2008		P (A)	P (A)			P (A)	P (A)	N	P
Cottingham	P (E): 2008								N	N
Mount Le Sueur			P (A)		N (2: 30–31 Aug)	N (2: 30–31 Oct)			P	P

Locality	Year (Sampling occasions)								CAE?	HA?
	< 2014	2014	2015	2016	2017	2018	2019	2020		
Other sites visited										
Norwood		N (1: 28 Aug)							N	P
Mkhomazi section, uKhahlamba Drakensberg Park (UDP)			N (2: 6 Aug & 10 Aug)						P	N
Adjacent to Monks Cowl section, UDP			N (2: 22 Aug & 24 Aug)						P	P
Trewirgie Farm					N (1: 3 Oct)				N	N

Figure 1 – Egg of *Capys penningtoni* laid on a *Protea caffra* host plant bud at Good Hope.

Figure 2 – This male *Capys penningtoni* eclosed nine months and three weeks after the egg was found at Good Hope and its location recorded. The *Protea caffra* host plant was revisited the year following the discovery of the egg and the pupa was taken into captivity. The adult was released back at the natal site after eclosure.

Figure 3 – Pupa of *Capys penningtoni* from Ivanhoe from which the adult later eclosed.

Figure 4 – The adult male *Capys penningtoni* that eclosed from a pupa from Ivanhoe (Fig. 3) before release.

Figure 5 – Release at the natal site of an adult male *Capys penningtoni* that eclosed from a pupa collected at Lotheni Nature Reserve (left) and of an adult female *Capys penningtoni* from a pupa collected at Mount Shannon (right).

RESULTS

Potential habitat map

The potential habitat map is indicated in Figure 6, with the distribution records of spatial resolution of ≤ 1000 m shown as well as the new distribution records collected during fieldwork. The co-ordinates of three of the records where *C. penningtoni* was found at new sites during the field survey were situated in mapped potential habitat. The co-ordinates of two other records were situated immediately adjacent to mapped potential habitat (52 m and 155 m away, i.e. in a neighbouring pixel). When the potential habitat map and the co-ordinates of these two records were overlaid on Google Earth, the habitat in which the co-ordinates of each of the records were situated was seen to continue into the mapped potential habitat areas. Therefore those co-ordinates most likely did not fall into the delimited potential habitat owing to the different scales at which the predictor variables were mapped combined with the pixel size of the potential habitat map. The co-ordinates of the final three records from sites where *C. penningtoni* was newly discovered during the field survey were situated between 3.11 and 7.39 km away from the nearest mapped potential habitat. As indicated by plotting the records on the predictor coverages used (Table 1), the main reasons for this were that the minimum July temperature range was too narrow (it needed to be -1 to 6 °C) and two vegetation types were missing (Southern Drakensberg Highland Grassland and Midlands Mistbelt Grassland). *C. penningtoni* was not observed at four sites that had *P. caffra* but that were not predicted to have the butterfly species (Mkhomazi section and adjacent to the Monks Cowl section of the uKhahlamba Drakensberg Park World Heritage Site, Norwood and Trewirgie).

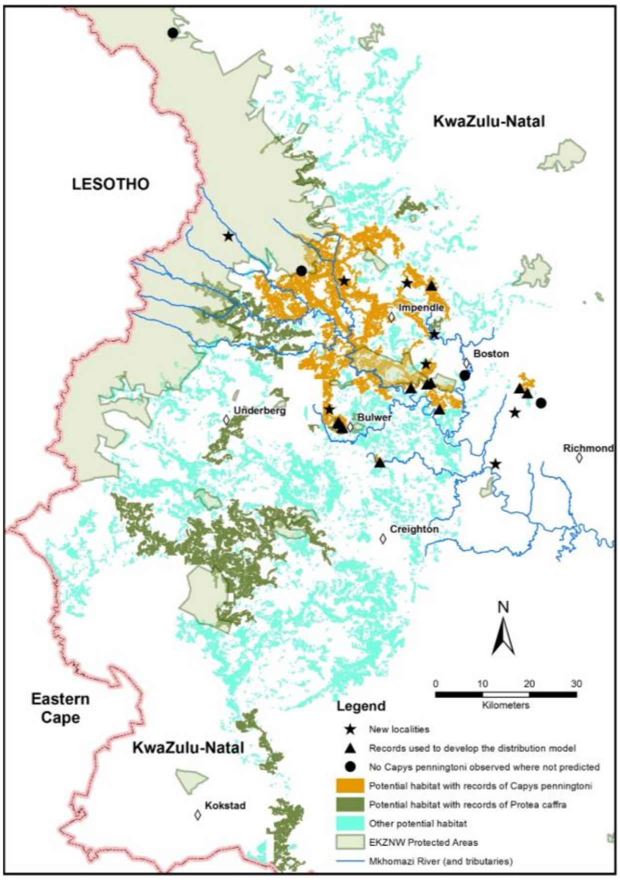

Figure 6 – Map of the predicted distribution of *Capys penningtoni*.

New distribution records

Capys penningtoni was recorded at seven new sites (Table 3; Figs 1–4, Figs 6–7), six during the main survey period (2014 to 2015).

Surveillance

Intermittent surveillance for *C. penningtoni* at eight sites between 2016 and 2020 indicated the persistence of the species at only two of the sites (Bulwer and Nkawini Mountains). At the other six sites, the species was not observed during the surveillance period (Table 3).

Figure 7 – Proof of occurrence of *Capys penningtoni* at new sites: Mount Shannon (top left), Nkawini Mountain (top right), Cottingham (middle left), Mt le Sueur (middle right), Clairmont Mountain Nature Reserve (bottom).

Presence of *Capys alpheus extentus* and *Harmonia axyridis*

Capys alpheus extentus was recorded at five of the sites visited where *C. penningtoni* has been recorded and two of the sites visited where *C. penningtoni* has not been recorded (Table 3). At a couple of sites the male was seen to perch on *P. caffra*. However, no evidence was found that this congener used *P. caffra* as a host plant. Only *C. penningtoni* was observed to eclose from eggs or pupae recorded from *P. caffra*.

Harmonia axyridis was recorded from most of the sites visited (Table 3). At some sites, such as Lotheni Nature Reserve and Bulwer Mountain, it was recorded in large numbers. The beetle was regularly found on *P. caffra* trees, including the buds that are potential oviposition sites for *C. penningtoni* (Fig. 8).

Discussion

Capys penningtoni is endemic to the KwaZulu-Natal Province in South Africa, and so far is only known to occur in the greater Mkhomazi River basin (Cockburn & Woodhall, 2015; Fig. 6), from near Richmond in the south-east to Lotheni Nature Reserve in the north-west. It is found where *P. caffra* grows in montane protea savanna within an approximate altitudinal range of 1 000 to 2 100 m. Previously assessed as Endangered (Mecenero *et al*., 2013), the present study has confirmed that this species is in danger of extinction (see also Armstrong, 2017). The current Red List status of *C. penningtoni* is Critically Endangered (Armstrong, 2016).

Figure 8 – *Harmonia axyridis* photographed at Mount Shannon on a flower bud of a *Protea caffra*.

Although *C. penningtoni* was recorded at seven new sites during the study, and the predicted distribution model needs to be ground-truthed to the south of the known distribution range, the conservation status of this species cannot be said to have improved. Very few adults were seen overall during surveillance initiated after the 2013 Red List assessment, and because no adults were seen, or only one or very few, at known sites between 2015 and 2020, even after repeat visits, the implication is that the species is near extinction. The known overall population size is declining. Local extinction has occurred or is close to occurring at several sites where formerly *C. penningtoni* was relatively abundant (Quickelberge, 2012; pers. obs.). The species may be locally extinct where it was first recorded (Manshonga Ridge, on the original farms Good Hope 962 and 16526, near Boston), where only four adult *P. caffra* were observed on 6 October 2016, and also at known sites at Impendle Nature Reserve, original farm Lot 93 1821 and New Forncett (Table 3). However, even if locally extinct, and providing the threats to this species are controlled or eliminated, surveillance should continue to ascertain whether *C. penningtoni* may re-establish itself over time at some of these sites by immigration from elsewhere.

Few *C. penningtoni* have been seen at other sites, such as at the type locality, Nhlozane Mountain (last recorded in 2014). The number of adults seen at Sevontein Prison Farm (Howard Hill) is much lower than in the mid-1900s. Only one adult was recorded there during the flight period in 2015 and 2016 despite three visits in search of the species, whereas K.M. Pennington collected 12 pupae in July 1940 and D. Swanepoel collected more than 40 adult specimens on 25 September 1946 at that site (Swanepoel, 1953; Pringle *et al*., 1994). Survey work done on *P. caffra* at six sites where *C. penningtoni* has been previously recorded, in three 400 m^2 plots per site and over two years (2017–2018), revealed only two pupae at Bulwer Mountain and no pupae or eggs at the other five sites (Clairmont Mountain Nature Reserve, Impendle Nature Reserve, Lot 93 1821, Lotheni Nature Reserve, Mount Le Sueur; S.L. Louw, unpublished data). An adult male eclosed from one of the pupae and a wasp emerged from the other (Armstrong, 2017). Adults were also looked for at these sites, and none found (pers. obs.; S.L. Louw, unpublished data). The qualitative data from this study suggest that *C. penningtoni* has decreased in abundance over the past three to four decades and is now rare at the sites where it still occurs. Therefore a continuing decline in population size and number of mature adults is evident.

The most imminent threat to the species might be from *H. axyridis*. This generalist feeder can be common to abundant in the protea savanna habitat occupied by *C. penningtoni* during its egg-laying period and has been seen many times wandering over *P. caffra* including the flower buds on which the butterflies lay their eggs exposed on the surface. Direct observation of the ladybird beetle feeding on these eggs has yet to be made, but it feeds on lepidopteran eggs and larvae elsewhere in the world (Koch *et al*., 2003; Roy *et al*., 2016). Whether the eggs of *C. penningtoni* (and of *C. alpheus extentus*, which may also be threatened by this beetle species) have one or more adaptations that prevent *H. axyridis* from eating them is unknown.

The effect of *H. axyridis* on the *C. penningtoni* population since the 2013 Red List assessment is unknown; surveillance of *C. penningtoni* sub-populations only began after that assessment. *Harmonia axyridis* was first recorded in South Africa in 2001 in the Western Cape Province; however, the beetle was widely spread and well established in the higher-lying temperate region of KwaZulu-Natal by the end of 2011 (Stals, 2010; Stals, undated). Although not recorded from some sites during this study, it is likely that the beetle would have reached those sites at some stage owing to its widespread distribution in that region of KwaZulu-Natal. A research project that commenced in 2017 on this invasive ladybird species found none in plots at six sites where both *C. penningtoni* and *H. axyridis* had been recorded previously, indicating a collapse in its numbers (S. Mbatha, unpublished data). What caused this collapse is unknown. Subsequently, relatively small numbers of *H. axyridis* have been observed at a couple of the sites where *C. penningtoni* has been recorded in the past (pers. obs.). Research on the magnitude of the impact that *H. axyridis* might be having on the butterfly population is required, as is the design of a trap that can remove substantial numbers of the beetle from the wild at the sites where the butterfly species still exists, should the numbers of *H. axyridis* increase again to former levels.

The second major threat facing this species is the apparent increased intensity and frequency of fires in the protea savanna it inhabits and the threat that these pose to its host plant, *P. caffra*. Intense fires kill *P. caffra* trees and bushes, reduce their regeneration and likely enhance the fire trap from which juvenile *P. caffra* plants must escape to establish themselves (Adie *et al.*, 2011; cf. Smith & Granger, 2016). Increased establishment of bracken fern *Pteridium aquilinum* in protea savanna, especially under and around *P. caffra* shrubs and trees, is a cause of the greater fire intensities (Adie *et al*., 2011). The same is likely true of the observed establishment of alien invasive American bramble *Rubus cuneifolius* around and under the canopies of *P. caffra* (pers. obs).

Some protea savanna is burnt annually to prevent uncontrolled fires or to enhance the palatability of the grass sward to cattle of subsistence farmers, and this probably enhances the fire trap that prevents recruitment of *P. caffra* from seed. Protected areas are subject to management plans, but intrusive fires can result from uncontrolled burning of neighbouring grassland. Poultney (2014) found that *P. caffra* trees had generally increased at five sites (where *C. penningtoni* has not been recorded) in the uKhahlamba Drakensberg Park World Heritage Site, with declines in abundance of *P. caffra* mainly occurring at higher altitudes. However, he also found that greater decreases in *P. caffra* numbers occurred in areas with high fire frequency and little protection from rocky areas, and where *P. aquilinum* was evident. The frequent incidence of uncontrolled intrusive fires moving into protected areas where *C. penningtoni* has been recorded has likely exacerbated the impacts of fires on the host plant species. Some such fires have possibly even caused mortality of the larvae and pupae of *C. penningtoni*, particularly intensive fires moving uphill with tall flame heights at inappropriate times of the year for the species.

Mesic grassland areas should generally be burnt during late winter to early spring (SANBI, 2014). Annual burning of Drakensberg Foothill Moist Grassland is not beneficial for biodiversity conservation as it homogenizes the plant communities (Joubert *et al*., 2014). The recommended fire return interval for mesic grassland is between two and five years (SANBI, 2014), depending on various factors such as dead biomass accumulation and the grazing regime. Grazing by cattle at Bulwer Mountain, Lot 93 1821, Impendle Nature Reserve, New Forncett, Sevontein Prison Farm, Ivanhoe, Clairmont Mountain Nature Reserve and Mt le Sueur (and possibly at other sites that are not fenced) would reduce the fuel loads at those sites to some degree.

Smith & Granger (2016) recorded significantly higher survivorship over eight years of juvenile *P. roupelliae* in a fire-exclusion protea savanna plot than in protea savanna plots burnt biennially, and juveniles in the latter plots had significantly higher survivorship than juveniles in a plot burnt annually on average. However, these authors found that the survival probability of juveniles under a seven-year fire-return interval dropped to zero after 14 years, whereas it was above zero for juveniles in biennially burnt plots. Smith & Granger (2016) suggested this was a result of higher fuel loads in the infrequently burnt plot. Juvenile *P. roupelliae* had highest survivorship, survival probability and life expectancy when the plots were burnt during the period June–August when the proteas were dormant. *P. roupelliae* seedlings may require 17 years to escape the fire trap (Smith & Granger, 2016). *Protea roupelliae* occurs in sympatry with *P. caffra* at some of the sites where *C. penningtoni* has been recorded (e.g. Bulwer and Clairmont and Nhlosane Mountains), so similar considerations regarding the appropriate fire regime for *P. caffra* might apply.

In order for recruitment of *P. caffra* from seed to occur, the fire return interval would have to be more than the one to two years that has been recorded recently at some of the sites (N. Kheswa, A.J. Armstrong & S.L. Louw, unpublished data). Burning for the recovery of excessively fire-damaged *P. caffra* savanna might be achieved with cool fires, fires that are burnt under moist conditions such as early in the morning, late in the afternoon, or after a light rain (SANBI, 2014), in combination with fires with low flame heights at an appropriate fire regime. The impact of burning on *P. caffra* in areas where *C. penningtoni* has been recorded is the subject of a study (S.L. Louw, unpublished data). Alien invasive and indigenous encroacher plant control under and near *P. caffra* would be required to reduce the intensity of fires that would otherwise severely damage the host plants.

Regarding climate change, the protea savanna inhabited by *C. penningtoni* is usually on hills and mountains. Rainfall may not change significantly in the next decade in the extent of occurrence of the species (Kruger & Nxumalo, 2017), and its area of occupancy is expected to be resilient in terms of the climate being relatively stable and the habitat remaining relatively intact for the next few decades (Jewitt *et al*., 2015a). The impact that the drought during the period 2014 to 2016 (Swemmer *et al*., 2018) may have had on the population size of *C. penningtoni* during the study period is unknown.

Afforestation has reduced the extent of potential habitat for the species in the past (Woodhall, 2013), and escape of timber trees from plantations into neighbouring protea savanna is occurring (pers. obs.). Land transformation is proceeding apace in KwaZulu-Natal (Jewitt *et al*., 2015b) and has probably caused the isolation of various areas of suitable habitat for *C. penningtoni* because transformed areas can act as barriers to lycaenids and other non-migratory, sedentary species (e.g. Pryke & Samways, 2001). Appropriate management of habitat can prevent the local extinction of colonies or sub-populations of lycaenid butterfly species (e.g. Armstrong & Louw, 2013). However, local extinction of isolated subpopulations of *C. penningtoni* may well be inevitable without appropriate management once sustained reduction in numbers occurs, if they cannot be rescued by natural immigration of adults from other sub-populations. Such local extinction may have happened already. How far apart areas of *P. caffra* savanna can be for regular movement of *C. penningtoni* between them is unknown. Quickelberge (1979) records a *C. alpheus* adult that was at least 30 km from the nearest known population, but how regular such movements are and whether *C. penningtoni* is capable of similar flight distances is not known. Owners and managers of land where the species occurs are being informed about how to manage the land, but this process needs to be formalized and expanded.

Various more localized threats to the population of *C. penningtoni* have been recorded. Casual collection of flower heads of the host plant has occurred occasionally at the type locality where the butterfly species is very rare (pers. obs.), and this may affect recruitment of the host plant there. Harvesting of relatively high numbers of adults and pupae has occurred in some areas in the past (e.g. Swanepoel, 1953; Quickelberge, 2011). The breeding area on Lot 93 1821 in the Mkhomazi River Valley is threatened by the potential rerouting of the R617 road at the proposed site of the Smithfield Dam on the Mkhomazi River.

Continued surveillance of the various subpopulations of *C. penningtoni* is needed combined with appropriate management of its habitat. Without these actions, the species may inevitably and unknowingly slip to extinction. One glimmer of hope is that the largest number of *C. penningtoni* yet seen and photographed at one site on a single day by the author (eight, individually identified by the underwing patterns) was observed in September 2019 (Fig. 9). Previously only one individual had been seen by the author there on any one day during the study period. Perhaps the downward trend in the conservation status of *C. penningtoni* can be reversed.

Figure 9 – Eight *Capys penningtoni* photographed at a site on 17 September 2019.

ACKNOWLEDGEMENTS

Grateful thanks to all who accompanied me in the field to search for Pennington's protea butterflies, especially John Craigie, Caroline Leslie, Alicia Gomez, Sharon Louw, Eddie Nicklin, the Kyle family, Wendy Arnott, Rob Speirs, Akeel Rajak, Reshmee Brijlal, Brent Coverdale, Erin-Jane Cleasby, S-R. Harris, J. Madzibane and Richard Langley, and to the owners or managers of the land on which we worked, particularly Martin Arnold, John Campbell, Lyn Clelland, Justin Laurens, Mondi, SAPPI Forests, the Seele family, and Wesley & Sanele at Tillietudlem. André Coetzer is thanked for a recent record of *C. penningtoni* at one of the sites, and Professor Huib van Hamburg and Dr Dave Edge for useful comments on the manuscript.

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