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The Brenton Blue butterfly – A conservation odyssey

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Abstract: The Brenton Blue butterfly became nationally famous in the 1990s when the Lepidopterists' Society of Africa (LSA) launched a campaign to prevent its imminent extinction, because of the development of a luxury housing estate at Brenton-on-Sea on the southern coast of South Africa. This campaign gained support from national and international NGOs as well as the South African public and pressure mounted on the National Government to intervene. Eventually the Brenton Blue Butterfly Reserve (BBBR) was established to protect the butterfly in 1997, with the status of a "special nature reserve". An intensive research project was conducted from 2000–2005, which uncovered the butterfly's unusual ecological requirements, including the caterpillar's habit of feeding on the rootstock of its host plant *Indigofera erecta* under the protection of *Camponotus baynei* ants. The vegetation composition and dynamics, the biology of the host plant, the ant community and the population dynamics of the butterfly were also outcomes of this research. This facilitated the development of a reserve management programme, which for over 20 years seemed to ensure the butterfly's survival. Fire exclusion was practiced because of the risk to the host ants, which nest in dead wood on the surface. Despite these precautions, during the unprecedented Knysna fire in June 2017 the entire butterfly reserve was burnt, and even though some butterflies emerged in November 2017, these were the last ones seen at the BBBR.

Key words: Ecological research, extinction, fire exclusion, nature reserve, population dynamics, reserve management, rootstock feeding.

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INTRODUCTION

The beauty and fascinating life history of butterflies has made them a subject of admiration, study and scientific investigation throughout the ages. In modern societies, the plight of many butterfly species, particularly in Europe and North America, in the face of habitat loss and degradation caused by human activities, has pricked the public conscience. Butterflies have become one of the emblems of the conservation movement, the insect equivalents of the Giant Panda and the Blue Whale (New, 1997). As it was put by Pyle (1995) "In just a quarter of a century, Lepidoptera conservation has grown from an arcane topic to a commonplace concern".

Butterfly conservation, like any other conservation endeavours, is an extremely complex goal, which depends as much on methodical, painstaking scientific research as it does on public and institutional support. Early efforts to save endangered butterflies such as the Large Blue *Maculinea arion* in England initially failed despite considerable effort and expense (Thomas, 1980). Not only do endangered butterfly habitats need to be protected from human activities, they also need to be managed to sustain them in a state optimal for the butterflies to breed, and in order to determine what that state is, all aspects of the ecosystem in which a particular butterfly breeds need to be understood (Pullin, 1995). The later success of the reintroduction of *M. arion* to the sites in England where it had gone extinct shows what can be achieved armed with the right information on the ecology of the endangered taxon (Thomas, 1989).

Conditions in South Africa are somewhat different from those in Europe and North America. Habitats of many rare and endangered butterflies in South Africa are in remote mountainous regions (Samways, 1993), with no or minimal human impacts other than grazing animals. By contrast, in the northern hemisphere many endangered invertebrate taxa have adapted to human presence over the last 30 000 years and persist in anthropogenically modified habitats (Pullin, 1995).

Compared to Europe and America, there is a paucity of scientific workers and resources being applied to research on butterfly ecology and conservation in South Africa. A large proportion of our endangered butterflies have highly complex life histories and relationships with other organisms, many of which are not yet known. Despite that much has been achieved. The first red data book on southern African butterflies was published 35 years ago (Henning & Henning, 1989), revised 20 years later (Henning *et al.*, 2009), followed by an Atlas Red-Listing all southern African species using IUCN criteria (Mecenero *et al.*, 2013). The conservation assessments of 154 taxa of conservation concern and seven new taxa were updated, using more accurate distribution data (Mecenero *et al.*, 2020).

The Brenton Blue *Orachrysops niobe* (Trimen, 1862) was described from three male specimens collected at Knysna in 1858 by Roland Trimen, curator of the South African Museum in Cape Town. There were no further records from Knysna following Trimen's discovery until it was rediscovered in 1977 at Nature's Valley by Jonathan Ball of Cape Town (Henning and Henning 1989), who realised it was Trimen's *niobe*, different from all other *Orachrysops*

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found farther east, previously assumed to be conspecific with *O. niobe*. The Nature's Valley population unfortunately went extinct in the late 1980s, following property developments. After extensive searches in the southern Cape by many lepidopterists the population at Brenton-on-Sea was found in November 1991 by Pringle.

ESTABLISHMENT OF THE BRENTON BLUE BUTTERFLY RESERVE

The Brenton Blue campaign

Dave Edge, a lifelong amateur lepidopterist, had retired from a career as an engineer and relocated to Knysna in September 1993. His friend Ernest Pringle asked him to be on the lookout from late October for *O. niobe* which Ernest had found near Brenton in 1991. Edge encountered his first one on the 29 October 1993, and over the next few weeks discovered exactly where they were most plentiful, about 400m up a narrow and rutted gravel track going eastwards towards a large FM tower close to the Heads. Males and females flew up and down a 30 m stretch of this track or emerged from the dense fynbos on either side. Three months later a second brood emerged during the last week of January 1994. These findings were published in a *Metamorphosis* article in March 1994, which brought it to the attention of John Plumstead of the Brenton Local Council (BLC), who claimed to have good contacts with provincial politicians. The land had already been approved for luxury housing development by the Brenton Development Company (BDC), which had announced its intention to develop the land in early 1994. Edge met the man in charge of the BDC project, Alan Rostovsky, initially in March 1994 along the gravel road to the where the butterflies were flying and later in May at the Brenton Hotel. Rostovsky was dismissive of the butterfly threat to his project and famously said to Edge "you mean to tell me that this little gogga can prevent a multi-million Rand project". Little did he know that this gogga-butterfly could sting like a bee! Realising that the developer was legally in a very strong position Pringle (a lawyer) and Edge felt they needed some political support it made sense to cooperate with Plumstead, who was energetically supporting the project.

The Brenton Blue project was formalised by the LSA in June 1994, with the main objective of establishing a nature reserve to protect the butterfly. Edge and Pringle began to work with Plumstead and created a local Brenton Blue campaign, assisted by Lorna Watt (who was Chair of the BLC and of the Wildlife & Environment Society of Southern Africa [WESSA] Knysna), and Greg Vogt (a marketing expert working for the Brenton Hotel, owned by Eddie Bain). When it became clear that the BDC were not going to cooperate, LSA decided to launch a media campaign (press, television, radio) aimed at fostering local and public support, and fund raising events were held in Knysna, and later nationally. National media such as the Sunday Times, and the TV programme 50-50 aroused public opinion further, and this began to put pressure on the BDC. Greg Vogt brought a film producer Richard van Wyk into the project team, and he produced half a dozen films about butterflies and the plight of the Brenton Blue. The public interest generated was enormous and the Brenton Blue became a household name in South Africa. The BDC found it had become impossible to sell stands at the butterfly site and declared a moratorium on further sales of "butterfly" stands until funds could be raised to purchase the land or the state intervened. This campaign had placed butterflies firmly on the national biodiversity conservation agenda.

Formation of the Brenton Blue Trust

In the meantime approaches had been made by LSA to various conservation NGOs such as the World-Wide Fund for Nature (WWF), the Endangered Wildlife Trust (EWT), WESSA, and Nedbank's Green Trust. It was decided that, given their track record with endangered species, the EWT should lead since they had the expertise and resources to bring a more professional approach to the campaign. The Brenton Blue Trust (BBT) came into being on 26 February 1997, founded by Richard van Wyk; chaired by EWT (John Ledger); with other trustees WESSA (Keith Cooper), Cape Nature Conservation (CNC – Johan Neethling), LSA (Stephen Henning), and the Brenton Transitional Local Council (BTLC – John Plumstead). The primary aims of the BBT were to prevent the extinction of the Brenton Blue butterfly by securing its last known habitat; to re-establish it at Nature's Valley, and to establish it in new habitats.

Figure 1 – The Brenton Blue Butterfly Reserve (BBBR).

Establishment of the Brenton Blue Butterfly Reserve (BBBR)

EWT and other NGOs were able to exercise their influence in government circles, and the sustained and more focused pressure on government convinced the Minister of Environmental Affairs and Tourism (Pallo Jordaan) to invoke his powers under Section 31A of the Environment Conservation Act (ECA), and suspended any further development on the site, pending further scientific investigations by independent scientists and possible acquisition by the state. These investigations (see below) confirmed the uniqueness of the Brenton site and the certain extinction of the butterfly if development proceeded. Consequently government, mindful of its obligations as a signatory of the Convention on Biological Diversity, decided to purchase the land, and the Brenton Blue Butterfly Reserve (BBBR) came into being on 30 April 1997 (Steenkamp & Stein, 1999). The BBBR is managed by CapeNature, with scientific input from LSA members led by Dave Edge, LSA's local representative in the southern Cape.

SUMMARY OF THE SCIENTIFIC RESEARCH CONDUCTED ON THE BRENTON BLUE

The genus *Orachrysops* (Vári & Kroon, 1986)

The Brenton Blue was described from Knysna by Trimen (1862) as *Lycaena niobe* and later transferred to *Lepidochrysops* by Hedicke (1923). It became the type species of the genus *Orachrysops* erected by Vári & Kroon (1986), with the second and third species being *Orachrysops ariadne* from the KZN Midlands, and *Orachrysops lacrimosa* from northern KZN, the eastern Free State, and Mpumalanga. Henning & Henning (1994) revised the genus and added seven new species and one subspecies (*O. subravus*, *O. regalis*, *O. mijburghi*, *O. violescens*, *O. montanus*, *O. nasutus*, *O. nasutus remus* and *O. warreni*). Heath (1997) described a further species from the Kammanassie Mountains in the southern Cape, *Orachrysops brinkmani*, which for a short time was thought to be *O. niobe* (which nearly ended the Brenton Blue campaign).

Research at the BBBR to determine *O. niobe's* host plant, host ants and vegetation composition

Williams, 1996

The Brenton colony, the only population of the butterfly known presently, is threatened by housing development, and attempts to save it were underway. The author was recognised as an expert on ant associated (myrmecophilous) lycaenid butterflies, and was asked to investigate this population of *O. niobe*, with a view to elucidating some aspects of its biology. The brief was to establish exactly where the butterfly is breeding, the identity of its larval host plant, the identity of its host ant, and to record the development and morphology of its early stages. Martin Krüger and Dave Edge, working at the Brenton locality from 25th October to 3rd November 1995, had established where the insect was flying, and the likely larval host plant. Mark Williams, present from 4–9th November and assisted by the author, followed ovipositing females and identified the larval host plant as *Indigofera porrecta* – Eckl. & Zeyh. (Fabaceae), from an illustration by Moriarty (1982).

Edge & Pringle, 1996

The life history and ecology of the habitat of *Orachrysops niobe* (Trimen) (Lepidoptera: Lycaenidae) was described and illustrated by these LSA experts. Eggs were collected at the BBBR (Fig. 2) and kept in small transparent plastic tubes until the larvae hatched. The tubes were carefully cleaned every second day and freshly cut leaves supplied. Larval instar durations and size were recorded (1st instar – Fig. 3) and the four instars prior to pupation photographed. The emerging imagines were found to be unusually small (dwarfs) (Fig. 4). The distribution of the genus, and its position in the tribe Polyommatini is discussed in the light of this new information. Proposals were made for saving the last known *O. niobe* colony from extinction.

Britton & Silberbauer, 1996

These two well qualified Australian lepidopterists led and coordinated a study at the Brenton habitat from 7–20th December 1996. Their own contribution was a study of adult behaviour, an estimate of adult abundance, and the density and distribution of the host plants and eggs laid. They also made suggestions for future management of the reserve, and the considerable further research required to establish a viable management plan. This study was later published in an Australian journal (Silberbauer & Britton, 1999).

Figure 2 – Eggs laid on underside of leaves.

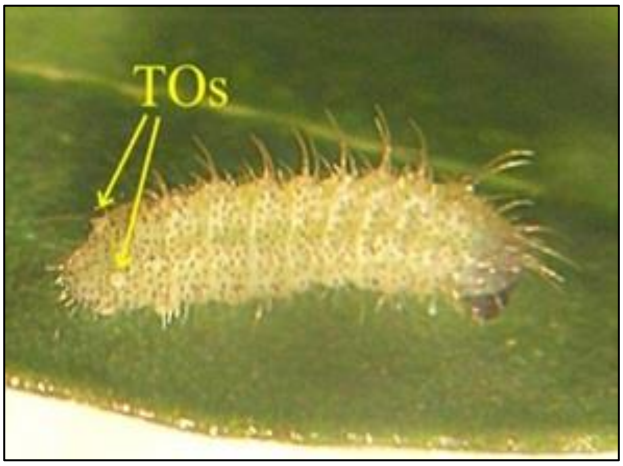

Figure 3 – 1st instar larva (1.5mm).

Figure 4 – Dwarf butterflies (right) – fed leaves; (left) fed live rootstock.

Lubke *et al.*, 1996

A team of botanists from Rhodes University and the University of Pretoria described the vegetation and floristics of the habitat of the Brenton Blue butterfly at Brenton on Sea and Nature's Valley (subsequently published in the SA Journal of Science, 2003). They determined that the host plant was not *I. porrecta*, as provisionally identified by Williams (1996), but *I. erecta* (Thunberg, 1800) discovered by this famous disciple of Linnaeus during his 1772–1775 expedition from Cape Town to the Gamtoos river near present day Port Elizabeth (Gqeberha) and back to Cape Town. They characterised the vegetation as asteraceous coastal fynbos in a mosaic with dune thicket, with over 50% of the species being herbs or graminoids. They recorded 154 species of plants at the two sites investigated.

Robertson, 1996–2000

The ants at Brenton-on-Sea and their possible interactions with the Brenton Blue butterfly were investigated by an ant expert from the Iziko South African Museum in Cape Town, working for the EWT. Several ant species in the genus *Camponotus* were identified as the most likely host ants. Robertson followed up with further investigations in 1998 and 2000. Much of his work guided and informed Edge in his later publications on ants at the BBBR and Nature's Valley.

Ecological factors influencing the survival of the Brenton Blue butterfly Orachrysops niobe (Trimen) (Lepidoptera: Lycaena). (Edge, 2005a)

This research was conducted by the author from 1999 to 2004 under the supervision of the School of Environmental Sciences of North-West University and published as a Doctor of Philosophy thesis in November 2005. The thesis was organised into nine chapters:

General Introduction (Edge, 2005a: 1–6).

Description of the study sites and General Methodology (Edge, 2005a: 7–22)

Three study sites were compared (Brenton on Sea, Nature's Valley and Uitzicht 216 portion 40), which each contained significant populations of the host plant *Indigofera erecta*. Aspects described were the topography, geology, climate, vegetation types and soils. Common features of the sites were location on a fairly steep south facing slopes close to the sea, and substrates of calcareous aeolian sands hosting a vegetation mosaic of sand fynbos and dune thicket.

The life history and myrmecophily of *Orachrysops niobe* (Edge, 2005a: 23–58; Edge & van Hamburg, 2006)

The larval feeding behaviour and myrmecophily of the Brenton Blue *Orachrysops niobe* Trimen, an endangered polyommatine butterfly from Knysna in South Africa, were investigated by field observations and captive larval rearing. The aerial and subterranean parts of the leguminous *Indigofera erecta* host plants were searched for *O. niobe* eggs, larvae and potential host ants. Third and fourth instar larvae and pupae were found in association with *Camponotus baynei* ants on the host plant rootstock. Ant colonies in viewable artificial *C. baynei* nests were sited near host plants bearing multiple *O. niobe* eggs, but no larvae were taken into the nests. Cannibalism was observed between larvae raised in captivity on cut host plant (Fig. 5), and the benefits of such behaviour postulated.

Figure 5 – 3rd inst. larva eating sibling.

Searching for mature *O. niobe* larvae at BBBR

Searching the leaves of host plants *I. erecta* at the BBBR only found 1st & 2nd instar *O. niobe* larvae, mostly on the upperside of the leaflets. 1st instar cut shallow grooves in the upper surface of the leaflet, whereas 2nd instar consumed the whole leaflet. Lu & Samways (2001) found 3rd instar *O. ariadne* larvae at the base of host plants, which gave a clue as to where to look. After several days of systematically searching around the base of *I. erecta* plants, one afternoon Edge found a small hole next to a host plant rootstock (Fig. 6), from which a *Camponotus* ant came out. Hamish Robertson of the Iziko South African Museum identified these ants as *Camponotus baynei* Arnold – which usually nest in dead wood – not soil, and are nocturnal. (Fig. 7).

Figure 6 – Rootstock (15 mm dia) of *I. erecta*.

Looking down the hole with a torch something pale could be seen, and with soft tweezers it was carefully extracted – a final instar larva of O. *niobe.* It was placed back in the hole and a few days later it pupated, still tended by the

Camponotus ants, and later hatched as full size butterfly (Fig. 4 – left side).

Figure 7 – Nest of *C. baynei* with larvae and pupae. (Photo H. Robertson)

Rearing with living host plant and artificial ant nest

Two live mature host plants were dug out of the ground and planted in pots with a fine mesh dome cover. An artificial wooden ant nest was constructed of wood with a red transparent perspex lid (ants can't see red light), and populated with *C. baynei* ants with a source of food (protein and sugar water) in an adjacent exercise and feeding area. Tubes connected the ant nest to the host plant area (Fig. 8).

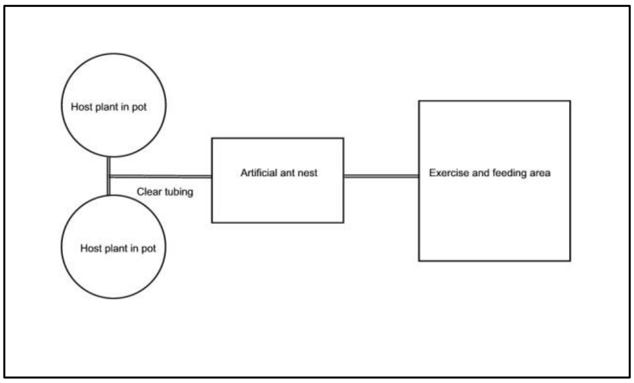

Figure 8 – Experimental set up – rearing larvae on live host plant connected to artificial ant nest with exercise and feeding area.

Orachrysops niobe larvae were reared from eggs collected during February in clear plastic tubes and supplied with fresh cut leaves from *I. erecta* until they reached the third instar, when one larva was placed on the host plant in one of the pots. Within a few days the larva disappeared and could not be found anywhere on the plant, or in the ant nest. The second host plant was isolated and left to grow as a control.

There was no further disturbance of the experiment from March–June but the ants' supply of food and water was maintained, and distilled water mist was sprayed on each host plant every few days. In early July the host plants were examined – the control host plant looked healthy but the leaves of host plant on which the larva had been placed were small and shrivelled. This host plant was loose and could be lifted out with its rootstock, on which there was a fully grown 4th instar larva (Fig. 9). The rootstock had been eaten (Fig. 10). This larva eventually grew to 18mm and pupated, and a fully sized butterfly emerged on 3rd November (Fig. 4 left side).

Figure 9 – Mature 4th instar larva (15–18 mm).

Figure 10 – Rootstock eaten down from 6–3 mm dia.

This feeding behaviour was later confirmed by multiple field observations. *O. niobe*'s ant association is thus inferred to be obligate. Larval growth characteristics were used to compare African polyommatine genera and *Orachrysops* is intermediate between the facultative myrmecophilous genera (e.g, *Euchrysops*) and the predaceous/parasitic *Lepidochrysops* species. A cladistic analysis based on host plants, ant associations and feeding behaviour led to a hypothetical phylogeny of the African myrmecophilous polyommatines.

Why eat the rootstock?

Larvae are vulnerable to being attacked and eaten by their siblings from below (Fig. 5) when feeding on the leaves. When on the rootstock the larva's ventral surface is protected and its dorsal surface has a thick impenetrable skin. Larvae feeding on the rootstock are underground, tended and protected by the host ants from enemies such as parasitoids and spiders, and are also able to survive fires. Chemical analysis comparing the rootstocks with the leaves showed that the leguminous *Indigofera erecta* rootstocks are enriched with essential amino acids (threonine, histidine and allo-isoleucine) needed to produce collagen for forming connective tissue for body and wing structures. Without this diet, dwarf butterflies would result (Fig. 4 right side).

Ant assemblages at three potential breeding sites for *O. niobe* (Edge, 2005a: 61–80; Edge, Robertson & Van Hamburg, 2008)

Ant assemblages were investigated by pitfall and bait trapping to sample the ground foraging ants at the BBBR and two other ecologically similar sites where *I. erecta* also occurred (Nature's Valley Fynbos Reserve – NVFR – and Uitzicht 216/40 on the Brenton peninsula), but *O. niobe* was not present at the latter two sites. The ants collected were identified by a key (Fig. 11) and the second author's expertise (c. 30 species). The ant assemblages found differed significantly, with the host ant of *O. niobe, Camponotus baynei,* only occurring at the Brenton site where the butterfly was breeding. Vegetation composition, structure and microclimate differed at the three sites and these appear to be key factors in determining the ant assemblages that a site will support. The two sites where *C. baynei* was absent had a history of recent fire (stimulating the growth of *I. erecta*) , which contributed to the vegetation changes and deprived the ant of dead wood for nesting. The Argentine ant *Linepithema humile* was not detected at any of the study sites, despite fear that it might take over from indigenous ants. Possible reasons for its absence were the presence of the aggressive indigenous ants *Lepisiota capensis,* which were recorded at the BBBR and NVFR.

Population dynamics of *O. niobe* (Edge, 2005a: 81–91)

Adult butterfly population counts

The method most often used for determining the population sizes of small flying animals is referred to as "mark–release–recapture = MRR". Every individual is captured, an indelible numbered mark made on its wings, and then released. If it is recaptured this is recorded and it is not added to the total count. In the case of the Brenton Blue this method was ruled out, because it could cause trauma to the butterflies, a risk of damage when handling, and the danger of poisoning from the ink used.

Consequently, two other counting methods were employed. It had been observed that patrolling males fly past a fixed point whilst circling the reserve, and that the count per 20 mins is good indicator of the population that day. This method was "calibrated" by first doing the count; then capturing all the butterflies and holding them in a netting cage and releasing them after all had been counted. Repeating this exercise over many days demonstrated that there was a linear relationship between the dynamic count and the actual number of butterflies in the population. The females do not patrol like the males, but fly randomly throughout the reserve, looking for host plants. They were counted by doing a transect of the whole reserve, with same route every time – very similar to a Pollard count. From these counts the total population per brood can be estimated (see below), and we have these records from 2001 to 2017 when the Knysna fire happened (Fig. 12).

Population estimates

A simple model was constructed in order to calculate the basic reproductive rate of *O. niobe* at low densities, and the total population. The model showed that the total population for a brood (N_{total}) was a function of the maximum butterfly count (N_{max}), the brood time from first butterfly emerging to the last butterfly dying (b_t), and the maximum lifespan of a butterfly (λ):

$N_{total} = 2\ N_{max}\ (b_t - \lambda/2)/\lambda$. From this function estimates could be made of the total butterfly population for each brood.

The taxonomy, biology, autecology and population dynamics of *I. erecta* (Edge, 2005a: 105–142)

Taxonomy of *Indigofera erecta* Thunberg, 1800

The genus *Indigofera* was studied, using Schrire (1991), Schrire (2000) and more recently Manning & Goldblatt (2012). Each genus is organised into sections with diagnostic features of the section and of each species (including its distribution and phenology), which was used to construct a key to identify the *Indigofera* species of the Southeast Centre of the Core Cape subregion. *Indigofera erecta* is characterised as having "Leaves digitately 3-foliate, leaflets obovate to oblanceolate, glabrous above, thinly hairy beneath, stipules setaceous, spreading. Flowers in racemes on robust peduncles, orange-red to pink" – which distinguishes it from its closest congeners *heterophylla* Thunb., *meyeriana* Eckl. & Zeyh., *porrecta* Eckl. & Zeyh., and *tomentosa* Eckl. & Zeyh.

Vegetative growth and growth forms

I. erecta leaflets have glabrous (smooth) upper surfaces and are thinly hairy underneath, whereas its congeners listed above have leaflets that are hairy on both sides. The commonest growth form has the stems sprawling across bare ground, but without bare ground the stems are vertical and supported by the surrounding vegetation. At the BBBR the leaflets are thin and soft, but in other habitats where *I. erecta* occurs closer to the sea the leaflets are thicker and succulent to prevent desiccation from strong sunlight and salt spray.

Environmental niche

I. erecta occurs mostly on steep (10º–25º) south facing slopes not far from the sea at altitudes from 60–120m. They prefer partial shade which gives a cool, moist microclimate, and are less successful on level, more open spaces, or places overgrown with other vegetation.

Rootstock morphology, nitrogen fixation and biochemistry

Rootstocks can be as much as 18mm diameter or 15cm in length, and are associated with rhizobial nodules. The rootstocks are thereby enriched with proteins containing essential amino acids which promote growth in lepidopteran larvae (Edge 2005a: 119).

Reproductive ecology

I. erecta flowers from the end of August to late November. The flowers are mostly insect pollinated by a guild of small bees (family Halictidae), although self-pollination does

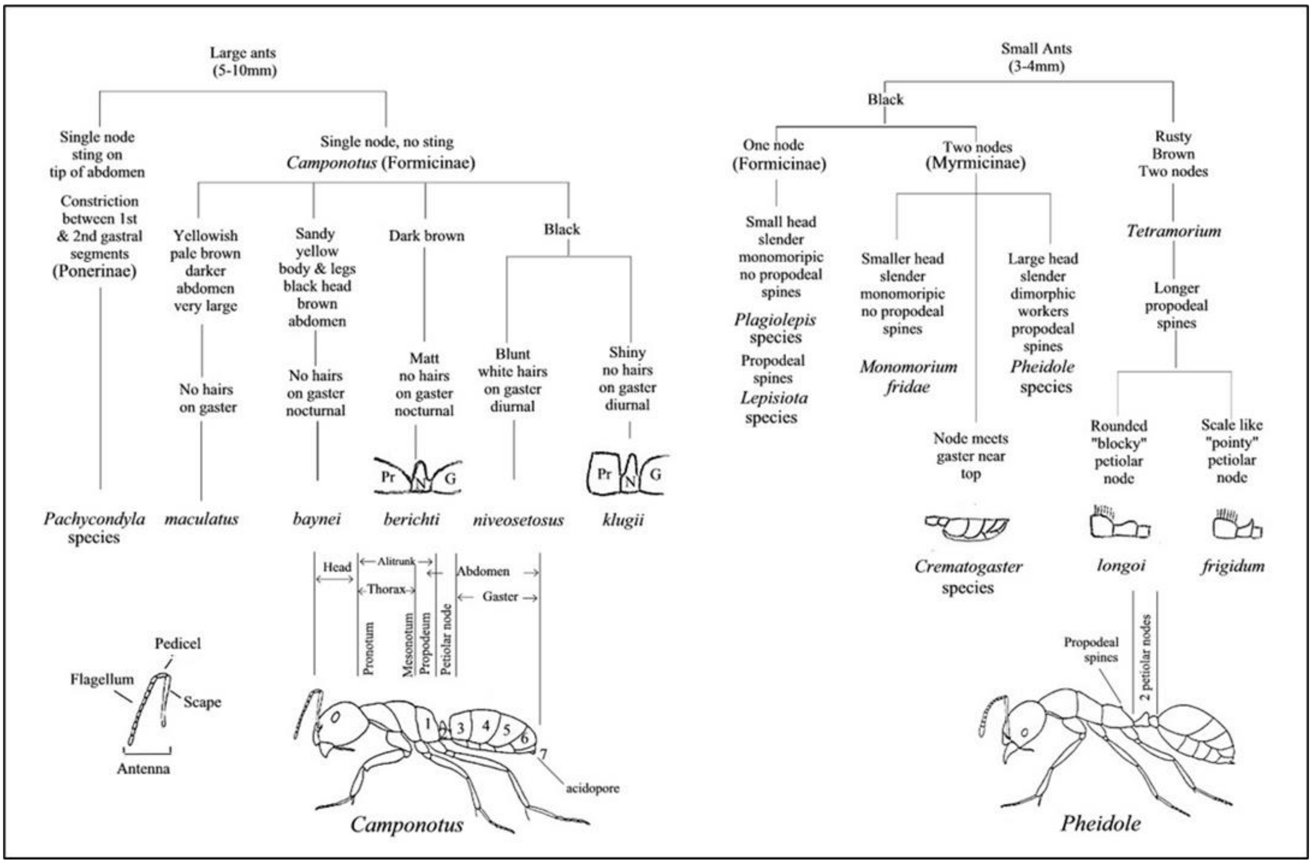

Figure 11 – Key to the ant species recorded at the Brenton Blue butterfly reserve in 2003–2005.

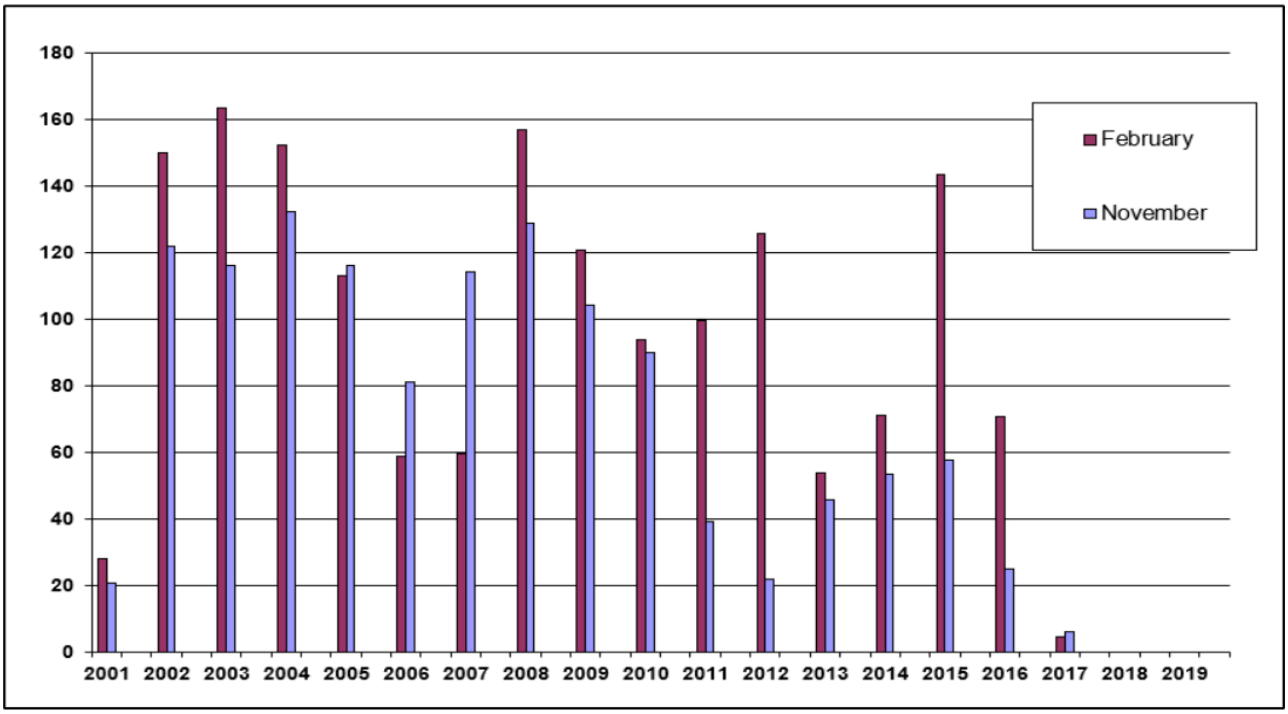

Figure 12 - Number of *O. niobe* per brood, calculated from counts made between the start and finish of each brood.

occur. Seeds are dispersed up to 1m (further downhill) by explosive dehiscence of the legume pods during December to February. Germination of seeds is stimulated by moisture and scarification of the testa.

Response of *I. erecta* to fire

Four fires in places where *I. erecta* was known to occur, but had become very scarce, were investigated. In each case there was a large recruitment of *I. erecta* from about the third month, peaking after a year and then declining. 70–80% of the plants were recruited from resprouting rootstocks, the rest from seedlings.

Population dynamics & distribution

At the BBBR the population of *I. erecta* was tracked from March 2001 to October 2003, in three areas with different characteristics. In an area that was burnt in October 2000 the *I. erecta* density peaked at 39 plants per m^2, whereas along the paths which had plants the density continued to rise until it was 55 plants per m^2 at the end. The third area was along a south facing embankment where the plant density stayed fairly steady at 15 plants per m^2. The recruitment rate along the paths was found to be 1.1 seedlings per plant from c. 1200 seeds average yield per plant. The age structure of the population was estimated from the size of the rootstocks and over 50% of the plants were seedlings <2mm diameter and c. 7% were >7mm and big enough to feed at least one *O. niobe* larva. By comparing the distribution data from 1996 (Britton & Silberbauer, 1997) to the 2003 survey it could be seen that the distribution of *I. erecta* plants had not changed very much.

Vegetation communities at the BBBR (Edge 2005a: 143–173; Edge, Cilliers & Terblanche 2008)

Associations between vegetation types and the presence of *O. niobe*'s only host plant, *Indigofera erecta* (Thunb.) were explored by sampling 32 5mx5m plots. Braun-Blanquet methods were applied to produce a phytosociological table of species v. plots and vegetation classification was accomplished using ordination techniques. Nine distinct plant sub-communities were identified and positive correlations were demonstrated between the occurrence of *I. erecta* and certain thicket vegetation subtypes dominated by *Pterocelastrus tricuspidatus* (candlewood trees). Ordinations using soil analysis and slope data as variables did not detect any significant environmental gradients influencing vegetation types. The high degree of vegetation heterogeneity at the BBBR is driven in part more recently by a variety of disturbance histories. Historical ecological events at the site such as fire and the impacts of plentiful megaherbivores, and their role in sustaining the ideal habitat for *I. erecta* and *O. niobe,* are discussed. Management techniques for the BBBR such as controlled fires or the cutting of paths through the vegetation are evaluated and an optimum future management strategy is recommended. This is the most comprehensive vegetation study ever carried out at the habitat of an endangered butterfly in South Africa, and breaks new ground by using vegetation analysis to enable a well-informed management plan to be prepared for conservation of this species. It also has significance for the management of small sites where many other such endangered butterflies occur.

MANAGEMENT OF THE BRENTON BLUE BUTTERFLY RESERVE

Brenton Blue management committee

This committee was established by the Brenton Blue Trust and held its first meeting in September 1998, chaired by Rhett Hiseman of CapeNature. Committee members were from LepSoc Africa, South Cape Herbarium, locally represented NGOs and the local community in the vicinity of the BBBR. With some gaps during the COVID period this committee continued to function but lack of funding resources from CapeNature has made it difficult to implement the management plans.

Research into the history and ecology of the BBBR

Evidence drawn from archaeological sites, sediments, small mammal indicators and pollen analysis reveals four low sea levels (117ka, 45ka, 16ka and 11ka) when much water was locked up in glaciers in Antarctica and Greenland. Consequently at these times the continental shelf around South Africa was exposed and the coastline was c. 100km to the south. Much of the exposed land contained suitable habitat for *O. niobe*. The present day distribution along the south Cape coast is an interglacial refugium. Rising temperatures and sea level pose existential threats to this butterfly.

Furthermore, whilst early man had little influence on broader ecological processes, over the last two centuries the elimination of megaherbivores, establishment of pine plantations and proliferation of alien plants have dramatically changed the landscape. Suppression of natural fires has also encouraged the dominance of thicket over fynbos vegetation, recently encouraged by higher temperatures and CO_2 levels. In a landscape which originally had many patches of suitable habitat for *O. niobe*, fragmentation and changes of land use have also isolated these patches and smaller ones were unviable to support populations of *O. niobe*.

Management plan for the BBBR (Schutte-Vlok, 2001; Edge 2005a: 174–192; Edge, 2008)

The first management plan for the BBBR was drawn up by CapeNature with inputs from LepSoc Africa (Schutte-Vlok, 2001). Subsequent research described above resulted in a revised management plan (Edge, 2008) and its implementation enabled the butterfly population to be sustained for two decades (Fig. 12). The main guiding principles of the 2008 management plan were to:

- Maintain the BBBR path network, to sustain the *I. erecta* population and prevent it being shaded out by thicket elements.
- Protect candlewoods, which provide the correct level of shade.
- Prevent fire at BBBR – danger to host ants which nest in dead wood on soil surface.
- Increase the size of the BBBR from 1.5 ha. This was achieved in a 2018 agreement between CapeNature

and Knysna Municipality to include 13 ha more adjacent municipal owned land (Uitzicht 216-81 and Erf 542, Brenton on Sea).

Attempts to re-introduce the Brenton Blue to Nature's Valley (Edge, 2005–2006)

The Nature's Valley Trust (NVT) had been working with CapeNature (CN) and Rhodes University to prepare the Nature's Valley (NVFR) for the re-introduction of the Brenton Blue. Since the NVFR was quite overgrown with dune thicket species such as Candlewoods *Pterocelastrus tricuspidatus* it was decided to cut most of the thicket species down and burn the whole reserve in 2003. After the vegetation had recovered and many *I. erecta* plants had emerged the NVT asked the author to assess the feasibility of reintroducing the Brenton Blue to the Fynbos Reserve. All the *I. erecta* plants at the NVFR were marked with numbered flags and counted, and an ant survey was conducted as part of the detailed ant study carried out by Edge *et al.* (2008), summarised above. Despite the poor outcome of these surveys, an *O. niobe* female and a few males were released at the NVFR in February 2006. To enhance the chances of success some captive reared 3rd instar larvae were placed onto *I. erecta* plants in April 2006. In November 2006 intensive searches were conducted for adult butterflies and eggs on *I. erecta* plants but none were found. It was concluded that reintroduction had failed, because there were no *C. baynei* ants and the small number of *I. erecta* plants were in poor condition, lacking shade (Edge 2005c; 2006).

Conservation status of *Orachrysops niobe*

Orachrysops niobe is one of South Africa's most threatened butterfly species, Red Listed as "Endangered" by Henning & Henning (1995), revised to "Critically Endangered" by Henning *et al.* (2009), with this category subsequently confirmed by Mecenero *et al*. (2013 & 2020) using the latest data and threat categories (IUCN, 2017).

The Knysna fire destroys the BBBR (Edge, 2017)

During the Knysna fire in June 2017 the entire butterfly reserve was burnt, and even though some butterflies emerged in November 2017 (probably from underground larvae and pupae protected from the fire), these were the last ones seen. A research programme was initiated to monitor recovery of the host plants, host ants, record the vegetation succession following the fire, and search for other populations of the Brenton Blue. The results of this programme will be presented in a future research article, and the chances of preventing an extinction will be assessed.

CONCLUDING REMARKS

This review has described the efforts made by many parties between 1993 and 2017 to prevent the extinction of the Brenton Blue butterfly. The early years were all about gaining widespread public support, mobilising private companies, NGOs, universities and government departments from local to national level. The environmental protection guaranteed in the 1994 constitution was put to the test and was found visionary enough to even save an insignificant invertebrate organism from extinction. Having won that struggle, much research was needed to make such a small reserve viable. Many scientists from several universities participated in this research, which eventually enabled the most critical ecological factors influencing the breeding success of the Brenton Blue to be determined. This led to a management strategy for the BBBR, implemented by CapeNature and the Lepidopterists' Society of Africa, which increased the population size of the Brenton Blue to a sustainable level. The devastating effects of the 2017 Knysna fire were predicted by the researchers, but no-one could have foreseen that a fire of such magnitude could arise. This was one of the early portents of what could to happen to biodiversity and human populations during the anthropocene – an era of accelerating climate change caused by anthropogenic activities.

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