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Southern African Moths for the Control of British Bracken

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Abstract

Two southern African moths, *Conservula cinisigna* and *Panotima* sp. near *angularis*, are potentially suitable for the control of bracken in Britain. Both species are widely distributed and abundant in the colder, wetter regions of Southern Africa which are climatically similar to the U.K. They are taxonomically and ecologically distinct from any British bracken herbivores, which may reduce the likelihood of them acquiring British parasitoids and other natural enemies. Field observations indicate that the moths are highly damaging to the plant, and starvation trials on both South African and British ferns show that they are host-specific.

Introduction

Bracken (*Pteridium aquilinum* (L.) Kuhn, Dennstaeditiaceae) is a cosmopolitan species which is rapidly becoming one of the worlds most troublesome weeds (Lawton 1985, 1986, Taylor 1985). In Britain, the rate of encroachment of bracken over hill land (up to 3% p.a.) leads to a direct loss of grazing, while the plant itself is toxic to livestock (Watt and Breyer-Brandwijk 1962). Evidence of carcinogenicity to humans via contaminated milk and water is also accumulating (Villalobos Salazar 1987). Recently it was estimated that a conventional bracken control programme in Scotland alone would cost about 80 million pounds (Birnie 1985).

The expense and short-term effectiveness of conventional control measures has led to the investigation of biological control for this native weed. The use of foreign organisms to control a native is an infrequently utilized strategy (Julien 1982), but has been successfully employed against prickly pear on Santa Cruz Island, California (Goeden and Ricker 1980). A similar programme has been proposed for the control of mesquite in the U.S.A. (DeLoach 1985).

Since bracken occurs world wide, supporting a different herbivore fauna in each region (Kirk 1982, Lawton 1982), there is no shortage of potential biological control candidates. Southern Africa is a particularly suitable area in which to search for agents. Firstly, the subspecies and variety of bracken, namely *P. aquilinum*, subspecies *aquilinum*, variety *aquilinum* is taxonomically identical to that found in the U.K. (Page 1976). Secondly, the southern Africa geographic range of bracken includes regions which are climatically similar to the U.K.

Following a general survey of the South African bracken fauna, four arthropods are currently being examined as potential agents. They are: *Panotima* sp. near *angularis* (= *Parthenodes angularis* Hampson; Lepidoptera: Pyralidae) (Lawton 1985), *Conservula cinisigna* de Joannis (= *Appana cinisigna* [de Joannis]) (Lepidoptera: Noctuidae) (Vari and Kroon 1986), *Eupteryx maigudoi* Dworakowska (Hemiptera: Cicadellidae) and *Eriophyes* sp. indesc. near *E. helicantyx*) (Acari: Eriophyidae). This paper examines the merits of the two moths as agents for the biological control of bracken in the U.K.

Methods

Distribution of Bracken and the Two Moths in Southern Africa

Bracken distribution (using a "quarter degree" mapping system) were obtained from various sources, including herbaria, personal communications and observations.

The distribution of *C. cinisigna* and *Panotima* sp. was surveyed throughout the range of bracken in southern Africa. At each sampling site, 20 haphazardly-chosen fronds were examined and moth abundance estimated according to the rating scale few (1 to 5), many (6 to 20) and abundant (>20) individuals/20 frond sample. Other species of fern in the vicinity were also checked for evidence of bracken herbivores. A total of 102 faunal samples from 80 sites in 59 quarter degree squares were taken.

South Africa Bracken and Moth Life Histories

The phenology of the plant was studied in order to compare with frond development in Britain. Bracken was monitored in eight permanent 1 m^2 quadrats at a site near Grahamstown in the eastern Cape Province of South Africa. Frond development was categorised into four stages; crozier (young shoot), unfurling, mature and senescing frond. Numbers of fronds at each stage (excluding dead fronds) were recorded at monthly intervals for one year from March 1986 to February 1987.

Field collected eggs and larvae of both moth species were reared on cut bracken in the laboratory. Any parasites obtained were kept for identification.

Host-specificity of C. cinisigna *and* Panotima *sp.*

Starvation trials. The fern species used in the host-specificity tests were chosen because of their taxonomic relatedness and morphological similarity to bracken. Three of the fifteen species tested (including Bracken) are represented in the British flora, while a further five are in the same genus as British ferns. All plants were grown in identical conditions in a shadehouse and, where possible, several individuals were used for each test.

First instar larvae of each moth species, hatched from eggs that had been removed from bracken, were used in starvation trials. Pieces of young fern were offered to groups of five larvae in petri dishes and checked regularly for evidence of feeding. Trials were conducted at 20 to 23°C (day) and 16 to 19°C (night). Between 20 and 36 larvae were tested on each fern species.

Oviposition trials. Over a period of two months a total of 76 newly emerged *C. cinisigna* adults were released into a cage (57 x cm x 84 cm) containing sugar and a choice of ferns growing in pots. The species offered were *P. aquilinum*, *Hypolepis sparsisora* (Shrad.) Kuhn and *Pellaea viridis* [Forsk.] Prantl (= *Cheilanthes viridis* [Forsk.] Swartz). These species were chosen because *H. sparsisora* is the only other southern African fern in the same family as bracken (Dennstaeditiaceae) and *P. viridis* was the only fern accepted by *C. cinisigna* larvae in starvation trials (other than bracken). The fronds of each fern species were checked daily for eggs.

Results

Distribution of Bracken and the Two Moths in Southern Africa

Distribution of *P. aquilinum* in southern Africa corresponds closely with those areas where annual rainfall is greater than 500 mm, as given by Zietsman and Van Der Merwe (1981)

(Fig. 1). Both species of moths were widely distributed on bracken, with *C. cinisigna* present in 46 of the 59 squares sampled and *Panotima* sp. in 39.

Average monthly maximum and minimum air temperature data for two weather stations close to sample sites in the eastern Cape Province are given in Table 1. These provide a climatic comparison with bracken areas in the U.K. (Climate of South Africa 1984, Thran and Broekhuizen 1985). Balfour represents a mountainous region which has winter conditions comparable to the U.K., experiencing high rainfall, frosts and snow.

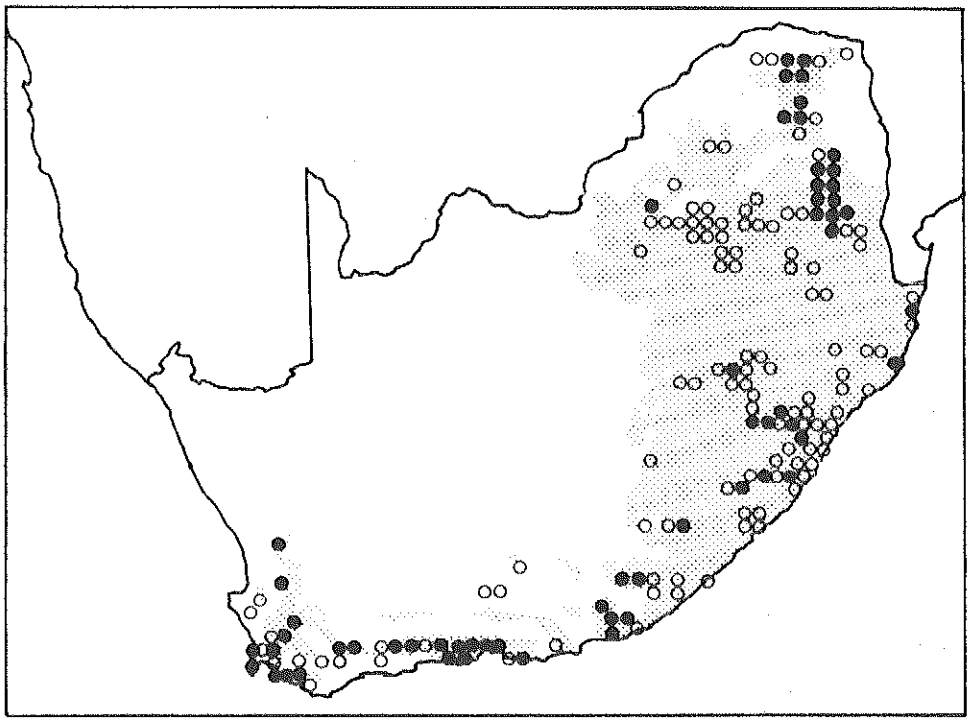

Figure 1. The distribution of bracken in South Africa. Closed and open circles represent quarter degree squares where bracken has been recorded. Sample sites to determine the distribution of the two moth species are shown by the closed circles. Shading indicates areas where rainfall exceeds 500 mm p.a.

Bracken Phenology and Moth Life Histories

Conservula cinisigna. The main period of egg laying and larval development coincided with the emergence of bracken croziers in the spring (August - October) (Fig. 2). Batches of one to nine eggs (mean = 3.1) were laid in the uncurling frond tips. There are five larval instars. Early instars initially fed in the areas where they hatched, then moved around the plant to graze on the underside of the fronds. The larger larvae were voracious feeders, capable of causing extensive damage to the fronds. Pupation occurred in the soil. In addition to the main spring generation there was a partial second generation and low numbers of eggs were found throughout the year. Since the oviposition sites were determined by the frond growth stage, egg laying was restricted to times when young unfurling fronds were available. In South Africa such new growth appeared year round., but was not abundant outside of the spring months (Fig. 2). This is similar to, but less extreme than, the phenology of the plant in Britain where it dies back completely during the winter.

The most widespread parasite of *C. cinisigna* was *Euplectrus? epiblemae* Ferriere (Hymenoptera: Eulophidae), a colonial ectoparasite which attacked the grazing larvae. Parasitism by this chalcid reached high levels at certain sites, affecting 87% of the 62 larvae collected at Grahamstown in February 1986. A solitary, endoparasitic braconid (genus indet.) was also fairly common. Of lesser importance was another unidentified braconid, two ichneumonids and an egg parasite (Trichogrammatidae), all of which were rare.

Table 1. The comparison of mean monthly maximum and minimum temperatures (°C) for a selection of regions where bracken grows in South Africa and Britain.

Month	South Africa				Month	Britain			
	Grahamstown		Balfour			Grampians		South Wales	
	max	min	max	min		max	min	max	min
Jan	26.3	14.2	29.6	14.8	Jul	17.8	8.3	17.2	12.8
Feb	26.6	14.6	29.1	14.8	Aug	16.7	7.8	17.2	13.3
Mar	25.7	13.9	26.7	13.3	Sep	14.4	5.6	16.1	12.2
Apr	23.3	10.7	25.2	9.1	Oct	10.6	3.3	13.9	10.0
May	21.2	7.9	23.5	5.3	Nov	6.7	0.0	10.6	7.2
Jun	19.2	5.4	20.6	3.0	Dec	5.0	-1.1	8.8	5.6
Jul	18.9	4.8	20.1	2.1	Jan	3.9	-1.7	8.3	5.0
Aug	20.2	6.1	22.5	3.8	Feb	4.4	-1.7	7.8	4.4
Sep	21.2	7.9	23.3	6.7	Mar	7.2	-1.1	8.8	4.4
Oct	22.1	9.9	25.1	9.0	Apr	8.8	1.1	10.6	6.2
Nov	23.5	11.8	26.7	11.6	May	12.8	2.8	13.3	8.3
Dec	25.5	12.9	28.7	13.6	Jun	16.1	6.2	15.6	11.1

Panotima *sp. nr.* angularis. Like *C. cinisigna*, this moth had one major generation each spring (Fig. 2). Eggs were laid on the underside of open pinnae and the newly hatched young larvae exhibited several different feeding modes. Most grazed the frond undersurface, while a few fed in the uncurling frond tips, sometimes with *C. cinisigna* larvae. Other individuals destroyed the terminal sections of the pinnae by tunnelling into them before they were fully opened. Irrespective of their previous feeding pattern, all third instar larvae migrated down the plant and tunnelled into the rachis (stem). One larva was found/mine (although smaller larvae occasionally used old larval holes) and the number of mines per rachis was usually between one and three. However, in a sample of 22 stems at a locality near Grahamstown (December 1987), the mean number of mines per rachis was 8.59, with a maximum of 19. Larvae left their mines towards the end of the fifth instar to pupate in the soil.

Panotima sp. was host to a diverse array of parasitoids, but no one species was dominant. *Trichogrammatoidea lutea* Girault (Hymenoptera: Trichogrammatidae) could destroy >50% of the host eggs (Grahamstown 1985). An ectoparasitic wasp, *Elachertus* sp. (Hymenoptera: Eulophidae), and an unidentified ichneumonid were reared from grazing larvae. Two braconid species were commonly found attacking the mining larvae.

Host-specificity of C. cinisigna *and* Panotima *sp.*

Starvation trials. In the field no evidence of eggs, larvae or feeding damage by either moth on other ferns was observed. This was confirmed by the starvation trials (Table 2). *C. cinisigna* completed its development on bracken and one other fern, *Pellaea viridis*. However, only a very small proportion of the larvae on *P. viridis* pupated successfully, and larval growth rates and pupal weights were significantly less than controls (Mann-Whitney U, $P < 0.05$). *Panotima* sp. developed beyond its first instar only on bracken. However, larvae undergo a major change in their feeding behaviour in the third instar and preliminary tests

showed that larvae taken from *P. aquilinum* mines are less discerning and will burrow into suitably thick stems of other ferns.

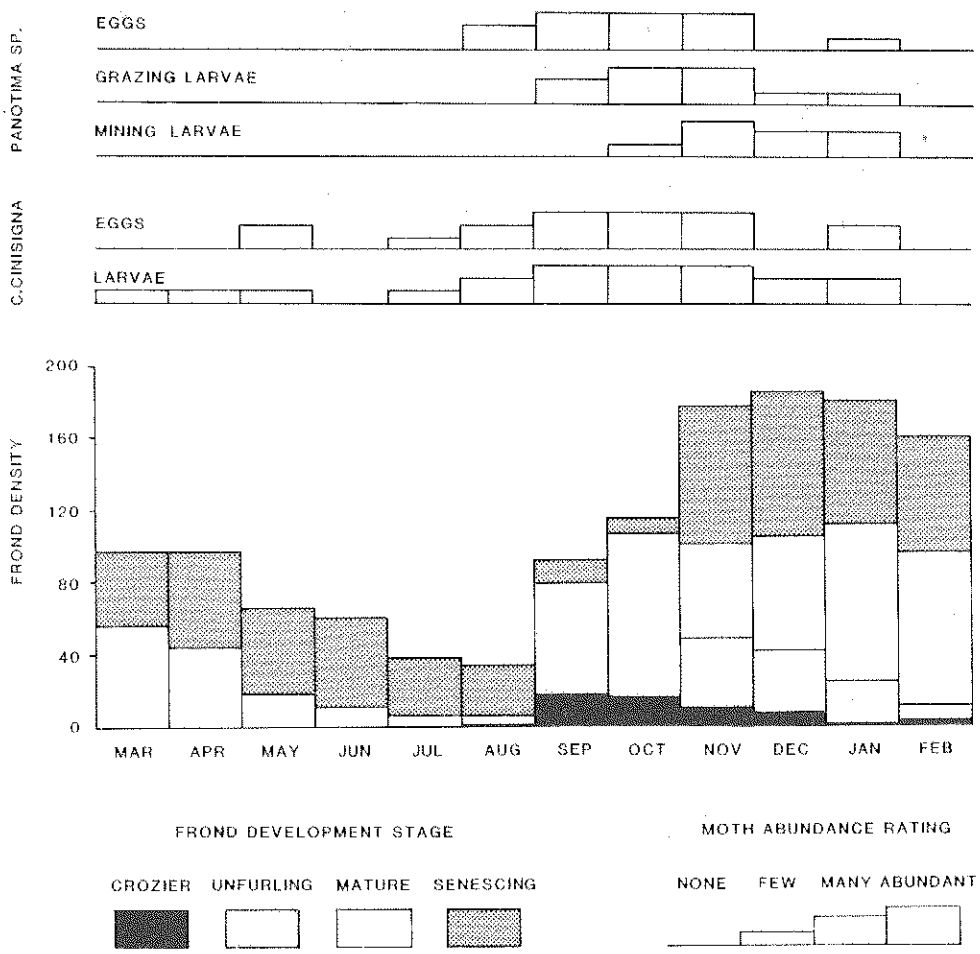

Figure 2. The relationship between bracken phenology and moth life histories. The number of fronds at each plant development stage (ignoring dead fronds) in eight m^2 was recorded at Faraway, near Grahamstown (eastern Cape Province) during 1986 and 1987. Moth abundances were recorded from a number of eastern Cape sites during 1985 and 1986. Few = 1 to 5; many = 6 to 20; abundant = >21 individuals/frond sample.

Similar results using first instar larvae have been obtained from preliminary tests on British ferns conducted under quarantine conditions at the C.A.B. International Institute of Biological Control, U.K. (O'Donnell, D. and Speed, C., pers. comm., 1988). The results indicate that the larvae of both moth species are extremely specific in their food preferences.

Oviposition trials. *C. cinisigna* females laid only on bracken, despite the fact that the other ferns were producing unfurling fronds similar to those utilized on bracken. However, a major difference between egg batches collected in the field and those laid in the laboratory was that the latter were not always confined to the uncurling frond tips. Eggs were also found in scattered groups over the entire unfurling frond, perhaps due to a shortage of suitable oviposition sites on the bracken. A total of 14 egg "batches" were laid during the experimental period, the number of actual eggs found being in excess of 100.

Discussion

Both species of moth were found throughout the full range of habitats occupied by bracken in southern Africa, indicating that they are tolerant of a wide spectrum of environmental conditions. Climatic incompatibility has been responsible for the failure of the only previous biological control study in the U.K. (Baker *et al.* 1972), but it appears that the cool-temperate seasonal climate of Britain may not pose problems for *C. cinisigna* and *Panotima* sp.

Table 2. The survival of *Panotima* sp. and *Conservula cinisigna* de Joannis on various South African and British ferns (* = fern genus represented in Britain; ** British species).

Fern species	*C. cinisigna* no. larvae tested	*C. cinisigna* survival beyond I instar	*Panotima* sp. no. larvae tested	*Panotima* sp. survival beyond I instar
Osmundaceae				
** *Osmunda regalis* L.	22	0	26	0
Schizaeaceae				
Mohria caffrorum (L.) J.E. Sm.	30	0	22	0
Dennstaedtiaceae				
** *Pteridium aquilinum* (L.) Kuhn	31	30	32	29
Hypolepis sparsisora (Shrad.) Kuhn	30	0	30	0
Adiantaceae				
* *Adiantum poiretii* Wikstr.	25	0	27	0
Pteris dentata Forsk.	30	0	30	0
Cheilanthes hirta Sw.	20	0	-	-
Pellaea viridis (Forsk.) Prantl (= *Cheilanthes viridis* [Forsk.] Swartz)	35	7	23	0
Davalliaceae				
Nephrolepis cordifolia (L.) Presl	30	0	27	0
Aspleniaceae				
Asplenium aethiopicum (Burm.f.) Becherer	30	0	24	0
Thelypteridaceae				
* *Amauropelta bergiana* (Schlech) Holtt (= *Thelypteris bergiana* [Schlech.] Ching)	30	0	20	0
Athyriaceae				
** *Cystopteris fragilis* (L.) Bernh.	25	0	-	-
Aspidiaceae				
* *Dryopteris inaequalis* (Schlech.) Kuntze	30	0	20	0
* *Polystichum lucidum* (Burm.) Bech.	30	0	26	0
Rumohra adiantiformis (G. Forst.) Ching	30	0	24	0

The degree of taxonomic and ecological distinctness from British bracken-feeding herbivores may enhance the effectiveness of *C. cinisigna* and *Panotima* sp. once introduced to Britain. Of the 40 herbivorous arthropods found on bracken in the U.K., only 27 are considered to occur commonly and comprise the "key species" associated with the plant (Lawton 1976). There are three species of noctuid, all polyphagous, recorded from bracken in the U.K., but none are included in the list of "key species". The only stem-feeding lepidopteran on bracken in Britain is a gelechiid that occurs in England, but has not been recorded in Scotland or Wales. Goeden and Louda (1976) document examples where shifts by native natural enemies to introduced agents adversely affected the success of biological control. Since lepidopterans are seldom found on bracken in the U.K. the presence of specific lepidopteran parasitoids,

predators and diseases will be considerably reduced. The southern Africa moths should therefore be relatively safe from attack, and this should favour their establishment and spread.

Our observations suggest that, removed from the ecological constraints present in southern Africa, both moths could prove to have a debilitating effect upon bracken in Britain. *C. cinisigna* larvae have the ability to extensively defoliate the fronds, thus directly reducing available photosynthetic area. This attack is prolonged, covering the time when the plant is at its most vulnerable in the spring and early summer, when both southern African and British bracken produce most new frond growth. Noctuids have proved effective control agents in the past, notable examples being *Catabena esula* (Druce) and *Hypena strigata* F., which contributed to the successful biological control of *Lantana camara* L. (Verbenaceae) in Hawaii (Andres, Davis, Harris and Wapshere 1976). *Panotima* sp. displays a multi-faceted attack on bracken, grazing the fronds and mining the stem. The latter form of attack undoubtedly disrupts the plant's vascular system and improves the destructive ability of this agent. A stem-boring pyralid, *Cactoblastis cactorum* (Berg) (Lepidoptera: Pyralidae) proved extremely effective in the well-documented biological control success of *Opuntia stricta* Haw. (Cactaceae) in Australia (Andres *et al.* 1976).

The release of agents to control either exotic or native weeds has not yet been seriously attempted in Britain. Consequently, the legal and political background for biological control is lacking. The demands for safety made by the Department of the Environment will be necessarily stringent and any candidates proposed for introduction must highly host-specific. Both moths appear to satisfy this requirement, although further starvation and oviposition trials on a wider range of British fern species must be made before their eventual release into the U.K. can be considered.

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