The wart-biter, *Decticus verrucivorus* (L.), in the United Kingdom; a comparison of sampling methods

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Summary
The wart-biter, *Decticus verrucivorus* (L.) (Tettigoniidae), is rare in the United Kingdom and has been the subject of field studies to identify its habitat requirements and establish a monitoring programme for remaining populations. The main technique used has been a simple walk-survey method carried out on permanently marked transects. This article summarises the lessons learnt and presents a rationale for using walk-surveys, in combination with a range of alternative methods, as a basis for estimating the distribution, density and size of wart-biter populations. Unpublished data, including from walk-surveys and a preliminary mark-recapture study, are presented. The article concludes with a list of recommendations for the survey of *Decticus* populations which may have relevance to studies of other ground-dwelling Orthoptera.

Samenvatting
De Wrattenbijter, *Decticus verrucivorus* (L.) (Tettigoniidae) is zeldzaam in Groot Brittanië. Met veldstudies is gepoogd vast te stellen wat de habitatseisen van de soort zijn. Daarnaast is er een monitoring programma opgesteld voor de resterende populaties. De belangrijkste gebruikte techniek is een eenvoudige loop-onderzoek langs een permanent gemarkeerd transect. De resultaten van dit onderzoek worden, tesamen en in combinatie met die van andere gebruikte technieken, besproken en geëvalueerd om de betrouwbaarheid aan te tonen van schattingen van de verspreiding, dichtheid en grootte van Wrattenbijter populaties. Nog niet eerder gepubliceerde gegevens van o.a. loop-monitoring en merk-en-terugvang onderzoek worden hierbij gebruikt. Ten slotte wordt er een lijst van aanbevelingen gegeven voor onderzoek aan *Decticus* populaties, die mogelijk ook voor andere grondbewonende soorten hanteerbaar zijn.

Résumé
Le Dectique, *Decticus verrucivorus* (L.) (Tettigoniidae) est une espèce rare en Grande Bretagne. Elle a fait l'objet d'études visant à identifier les besoins en termes d'habitat et à établir un programme de surveillance des populations existantes. La technique utilisé consiste simplement à marcher le long d'un transecte indiqué en permanence. L'article résume les leçons de cette étude et démontre l'intérêt de cette technique, utilisée en combinaison avec d'autres méthodes, pour l'estimation de la distribution, la densité et l'étendue des populations. Des données inédites, provenant d'études basées sur la méthode du transecte, ainsi que sur la capture consécutive d'animaux, sont présentées. Des recommandations sont données concernant l'étude de *Decticus verrucivorus*, qui peuvent également être utiles pour l'études d'autres espèces géophiles.

Introduction

At the Saltabel meeting of 23—25 August 1996, a proposal was made for the monitoring of Orthopteran populations in the Netherlands. The meeting also included presentations and discussions on the habitat requirements and conservation of the wart-biter; a species which would be included within the proposed monitoring scheme. In the United Kingdom work on the habitat requirements of the wart-biter has involved intensive sampling, to estimate changes in the densities and distributions of the nymphal and adult developmental stages within each of three years (1987—1989) (Cherrill & Brown, 1990a, 1990b, 1991, 1992). A longer term monitoring programme is now needed to emphasise changes in population size between years, and this is currently being developed. However, the methods used from 1987 to 1989 are clearly relevant to the development of British and Dutch monitoring schemes and form the focus of the present article.

The main technique used for sampling *Decticus* was a

simple walk-survey method carried out at intervals on permanently marked transects (Cherrill & Brown 1990a). Other approaches were also used and this article summarises the lessons learnt and presents a rationale for using walk-surveys, in combination with a range of alternative methods, as a basis for estimating the density and size of wart-biter populations. The methods reviewed are illustrated using previously unpublished data from the wart-biter population at Castle Hill National Nature Reserve (Sussex, U.K.), during the unusually warm and dry spring and summer of 1989 (Cherrill & Brown, 1991).

Semi-quantitative observations before 1987

The first step in the project was to assess the availability of existing data on the habitat requirements, distribution and abundance of the wart-biter in Britain. There had been no quantitative studies prior to 1987. However, Chris Haes had visited the wart-biter's main British population at Castle Hill National Nature Reserve in East Sussex in twelve of the summers between 1969 and 1987 (Haes et al., 1990). The data, recorded in the form of a field note book, were simply the number of wart-biters seen and adults males heard singing, along with brief notes on the weather. The data were collected from personal interest rather than with the intention of subsequent statistical analysis. Counting only those visits made in weather suitable for detecting wart-biters, the number of visits in each year ranged from one to three. These data were summarised as the average numbers of adults recorded per visit in each year. This figure varied greatly between years and in several none or very few wart-biters were found. In these respects the population appears to be similar to others in Britain. One potential use of such observational data is to show any effects of habitat management on population size. However, this is not possible unless the influence of temporal variation in weather is first taken into account. At Castle Hill, detailed management data were lacking, but the little information available suggested that the vegetation had remained more or less unchanged since 1969. The opportunity was therefore taken to investigate the effects of variations in weather between years (Haes et al., 1990). The most interesting result is shown in Figure 1. The number of adults was positively correlated with the number of sunshine hours in the summer two summers previously. This unexpected

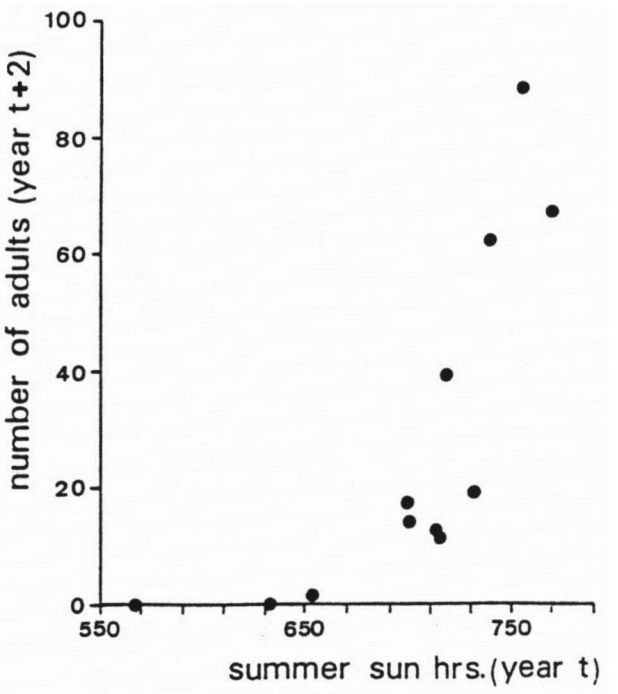

Figure 1: The relationship between the number of hours of sunshine in the summer of year t and the estimated numbers of adult *D. verrucivorus* two years later (in year t+2).

observation is probably due to two factors. First, a dependence of reproductive output on weather, and particularly the amount of sunshine which allows Orthoptera to raise their body temperatures and increase growth, survival and reproductive output (Chappell & Whitman, 1990). Second, the wart-biter's pattern of embryonic development. Eggs can remain viable for at least 6 years, but in the laboratory the modal hatch date is in the second spring after oviposition (Ingrisch, 1986). Thus, the relationship may represent the delayed effects of increased reproductive output on population size two years after eggs were laid. Of course this is a speculative conclusion, but suggests a hypothesis to be tested when more rigorously collected data become available.

Quantitative studies 1987—1990

Work funded by the Nature Conservancy Council (now English Nature) from 1987 to 1990 involved a three year descriptive investigation into the habitat requirements of the wart-biter; again primarily at the Castle Hill National Nature Reserve (Cherrill & Brown, 1990b, 1992). Sampling of juvenile and adult stages was centred upon five transects on east and south facing grassland slopes. The distribution and density of the

early instars was estimated by repeatedly placing a 1 m² box-quadrat with transparent side walls on the transects at randomly selected coordinates. This approach was necessary for the first and second instars, because they could be located reliably only by conducting a painstaking fingertip search of the vegetation. The side walls of the box-quadrat prevented the insects from escaping. Use of the box-quadrat was time consuming and could only be undertaken on one of the two slopes. Even so, population density fell rapidly to the extent that use of the box-quadrat was no longer realistic from the fourth instar onwards. To overcome this problem, the larger more readily detected later instars from the fourth onwards were sampled using another method.

The walk-survey method involved slowly walking across each 5 m wide transect at intervals of 0.75 m along (and at right angles) to its main axis. Surveying was done first by moving down the transect in one direction and then repeated moving in the opposite direction. All specimens were temporarily placed in individual containers, to avoid over-estimation by counting a single specimen more than once. To restrict the chance of undetected individuals moving on or off the transects between upward and downward searches, the transects were surveyed in lengths of 30 m. Tussocks within the transect were searched carefully from their edges without damaging the structure of the vegetation. The predominantly short vegetation and topography of the study site was such that wart-biters leaving the transect ahead of the surveyor were visible. Survey of a 60 m transect typically took approximately 1.5 to 2 hours. The total length of transects included in the study was 400 m and each was surveyed at approximately two week intervals. Walk-surveys were conducted only when the grasshoppers, *Chorthippus brunneus*, *C. parallelus* and *Omocestus viridulus*, were singing. These grasshoppers sing at temperatures below those at which male wart-biters fall silent. Providing conditions are suitable for grasshopper stridulation, wart-biters are still sufficiently active to be located by the walk-survey method. In cooler conditions walk-surveying should not be attempted. Any data collected would be unreliable and there would be a risk of treading on immobile insects.

The results of the surveys in 1989 are shown in Table 1 and Figure 2. A number of points can be made. First, a striking feature of the data is that population densities of all stages are low (note that Figure 1 is reproduced from Cherrill & Brown, 1991 with corrections). Second, the last estimates of population density based on the box-quadrats are similar to the first estimates made using the walk-survey technique, suggesting that the two methods are of comparable accuracy. Third, adult densities on east and south facing slopes were similar suggesting that box-quadrating was not a cause of significant mortality on the east facing slope. Fourth, while mortality rates during the early instars appeared to be very high, densities of adults were relatively stable suggesting high survivorship in that stage. Fifth, nymphal development in 1989 was unusually rapid (Cherrill & Brown, 1991), but in other respects the results were similar to those obtained in 1988 (Cherrill & Brown, 1990a).

In addition to the basic data on population densities, the surveys also yielded information on the microhabitat preferences of each stage of the wart-biter (Cherrill & Brown, 1990b, 1992). Oviposition was in areas of short turf and patches of bare soil. First and second instars were associated with these vegetation types, but subsequent instars up to the fifth were randomly distributed with regard to vegetation structure. The sixth instars, however, showed a clear preference for grass tussocks which are relatively scarce at the study site. This preference was maintained into the adult stage. The switch from open turf to tussocks reflected a marked change in the wart-biter's behaviour. Up to the fifth instar, the wart-biters were relatively "naive" in their response to the surveyor and were easily seen and captured. From the sixth instar onwards, however, they were more wary, elusive and difficult to catch.

Alternative quantitative sampling methods

Weidemann et al. (1990) used a mark-recapture technique to assess the size and density of a wart-biter population in Bavaria, Germany. The Lincoln Index was used to derive an estimate of 173 adults within an area of approximately 5500 m², giving an estimated density of 0.031 adults per m². This figure is 3 to 4 times greater than recorded on the transects at Castle Hill in the three years 1987 to 1989 (Table 1, Figure 2) (Cherrill & Brown, 1990a).

A small scale pilot study using the Lincoln Index to check the accuracy of the walk-survey method was undertaken on the east facing slope at Castle Hill in July

Table 1. The seasonal occurrence and maximum densities (number per m^2) of wart-biters on three transects on an east facing slope at Castle Hill National Nature Reserve, Sussex, England in 1989

Stage*	Period of recorded occurrence	Maximum recorded density on transect: 1 $\bar{x}$	sd	2 $\bar{x}$	sd	3 $\bar{x}$	sd
I	15iv-26iv	0.000	-	0.100	0.305	0.133	0.346
II	5v	0.000	-	0.075	0.267	0.025	0.158
III	16v	0.000	-	0.067	0.254	0.033	0.183
IV	25v	0.000	-	0.004	-	0.010	-
V	25v	0.003	-	0.036	-	0.023	-
VI	25v-14vi	0.000	-	0.007	-	0.003	-
VII	14vi	0.003	-	0.022	-	0.013	-
Adult	28vi-10x	0.003	-	0.015	-	0.023	-

*estimates of density for instars I, II and III are based on box-quadrat samples (n=30-40 per transect)

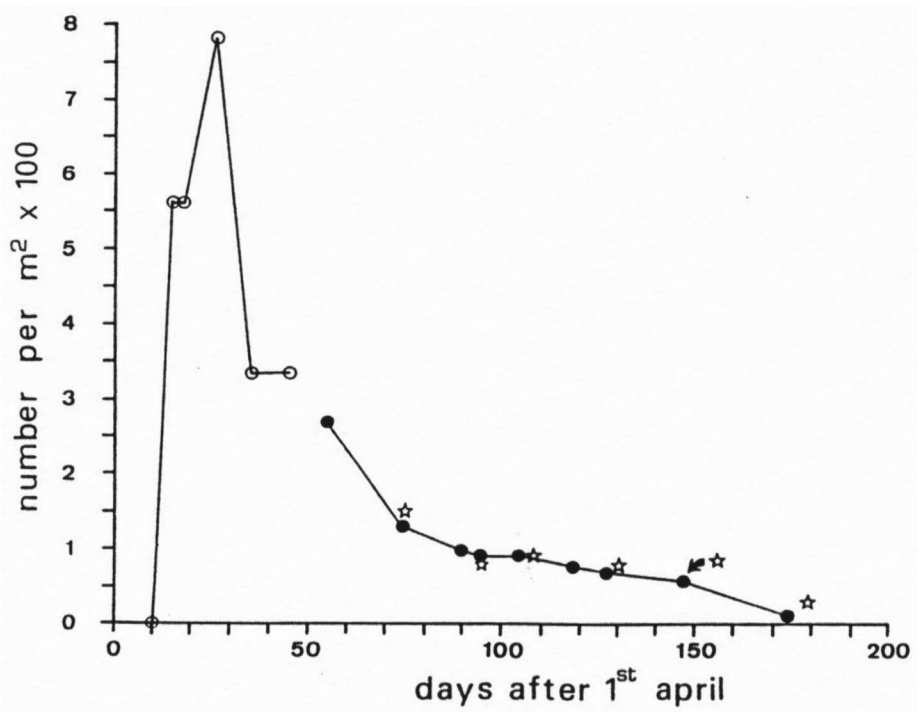

Figure 2: Temporal variation in mean densities of *D. verrucivorus* on a south facing slope (stars) (walk-survey estimates) and an east facing slope (open circles, box-quadrat estimates; closed circles, walk-survey estimates) in 1989. The arrow indicates a date when estimated densities on east and south facing slopes were identical.

and August 1989 by which time all animals were adults. The grassland slope between two adjacent transects was selected for the study. The two transects were parallel, 55 m apart and were 55 m and 60 m in length respectively. On each of three pairs of consecutive days, the slope (area 3162.5 m^2) was searched. On the first day of each pair, all wart-biters found were marked on the pronotum using a black permanent marker pen (a different mark being used for each pair of days). Individuals were released at their point of capture. On the days immediately after marks were made, the search was repeated and the numbers of marked and unmarked individuals were recorded. The results are shown in Table 2. Over the period when these data were being collected, the two transects were also surveyed using the walk-survey method as part of the on-going habitat study. Estimates of population size and density derived from each method are shown in Table 3. For both methods, averaging over the three dates, a mean population size of approximately 33 adults was obtained. This is equivalent to a density of 0.01 adults per m^2. The agreement between techniques is encouraging, nonetheless a number of assumptions are implicit in the use of the Lincoln Index (Southwood, 1978, Weidemann et al., 1990). It is assumed that marked animals are not lost due to mortality, emigration or moulting and that there is no immigration of animals from outside of the study area. Consequently, mark-recapture cannot be used to estimate the numbers of juveniles and care should be taken to ensure that marks do not make individuals more conspicuous to vertebrate predators. It is also important that the second sample is taken shortly after the first, to ensure that immigration and emigration are minimal.

Constraints on quantitative sampling

A sustainable monitoring scheme must yield reliable data yet must utilise the resources of time and manpower available. A long-term scheme should also employ a simple methodology such that the work can be readily replicated without the need for excessive training of personnel. This is especially important if volunteers are to carry out the bulk of the field work. With these points in mind and considering the results summarised above, a number of recommendations are made for the survey and monitoring of wart-biter populations.

Monitoring involves the repeat survey of the same population using a standard method. However, before this can be done effectively the spatial extent of the population needs to be defined. When population size (and density) are low, knowing where to concentrate monitoring effort can be a difficult problem. Walking of the areas surrounding sites of known sightings, whilst listening for singing males and looking for animals disturbed by the passage of the surveyor, is a useful approach. Obviously, the former is possible only when adults are present. However, conducting a wide ranging search in late May and early June before adults are typically present also has advantages. The early instars are more numerous and prior to the sixth instar make little attempt to avoid detection. The first and second instars are not readily seen, but the third, fourth and fifth instars are quite conspicuous. The distribution of these instars could therefore be used to locate the area to be included in the quantitative monitoring scheme. In addition, once transects for monitoring have been established, it will remain important to search in the surrounding areas to detect any contraction, expansion or change in the population's distribution (as opposed to changes in the density of wart-biters within the 'core' area occupied, i.e. that within which the species is most abundant). Searching for juveniles early in the year could be a useful method of mapping the distribution of the population, because the time taken would not impinge on that available for transect surveys later in the year.

When the spatial limits of the population are known, the most appropriate method for monitoring is to focus on the adult stage and use the walk-survey technique. There are two main reasons for this. First, owing to the rapid decline in population density, the box-quadrat is practical for the first and second instars only. Second, the density of the adults changes relatively slowly, such that estimates are not dependent on date to the same extent as for the instars (Figure 2). As few as three or four visits to carry out walk-surveys, at one or two week intervals, may be sufficient to obtain a reliable estimate of adult population density on the transects.

Estimation of absolute population size using the walk-survey data relies on the transects being representative of the site and the total area occupied by the population being known. In reality, populations do not occupy clear limits and density is variable within a site (Cherrill & Brown 1990a, Weidemann et al. 1990) (Table 1).

Table 2. Numbers of wart-biters captured during estimation of the total numbers of wart-biters in the study area using the Lincoln Index* mark-recapture method

Dates 1989 (day1/day2)	No. marked (day 1)	No. captured (day 2) marked	unmarked	Population estimate
	a	r	b	N
19/20 July	19	9	8	35.9
25/26 August	11	7	10	26.7
31 July/ 1 August	16	7	8	34.3

* Estimate of population size, $N = a(b+r)/r$

Table 3. Estimates of the number of wart-biters based on mark-recapture and transect survey methods

	Method	
Date (1989)	mark recapture	transect*
13 July	-	38.5
19/20 July	35.9	-
25/26 July	26.7	-
28 July	-	33.0
31 July/1 August	34.3	-
5 August	-	27.5
Mean	32.3	33.0

*estimates based on mean density recorded on transects extrapolated to the study area

Estimates of the total numbers of adults may therefore be possible only for the core area of a site. At Castle Hill the number of adults in the core area was estimated as being 290 in 1987, 190 in 1988 (Cherrill & Brown, 1990a) and 300 in 1989 (unpublished), but an unknown number were present at much lower densities in peripheral areas not adequately sampled by the transects. Notwithstanding the importance of knowing the spatial extent of the population, it may be best to use estimates of population density on the transects as a simple index of relative population size.

At sites where population sizes are thought to be low the choice of monitoring approach is particularly problematic. There is always the feeling that time spent in a fruitless search of a transect might have been better spent on a more subjective but wider ranging survey. A monitoring programme for these sites might therefore include a greater emphasis on rapid semi-quantitative searches for juveniles and singing adults (in June and July/August respectively) compared to sites with large well-known populations. However, while a range of methods may be appropriate, it is important that at least one method is applied uniformly across all sites to allow comparisons to be made. For this reason it is suggested that permanently marked walk-survey transects should be established and monitored at all sites, while other methods are used to provide complementary data. Within this arrangement, the overall balance between methods could vary according to population density, the area occupied and time constraints.

Considerations for the development of a monitoring programme

1. Owing to the species protracted embryonic phase, the full value of any quantitative monitoring will not be realised for at least the five to ten years of the project.
2. Population sizes vary greatly from year to year and much of this variation appears to be caused by the weather in addition to the vagaries of the life cycle. Effects of habitat management may be difficult to identify unless meteorological effects are taken into account.
3. The spatial extent of the population should be monitored to detect expansion, contraction or directional change in the area occupied. The limits to the population can be determined by rapid wide ranging searches listening for singing males, but can also include searches for the less elusive, and more abundant, third, fourth and fifth instars.
4. The density of first, second and third instars can be estimated using a box-quadrat. A disadvantage is that the technique is laborious, time consuming and not suitable for later instars. In addition, juvenile densities change rapidly and consequently cannot provide a reliable index of population size.
5. For the long-term monitoring of abundance it is recommended that adults are surveyed using a walk-survey method on permanently marked transects. The method yields estimates of adult density. Provided the area occupied and location of the population remain stable, adult density on transects is likely to be a suitable relative index of population size.
6. Monitoring of the wart-biter population should be accompanied by monitoring of vegetation structure, species composition and management, such that, in combination with meteorological data, the causes of changes in population density can be identified.
7. The walk-surveys should only be conducted when weather conditions are sufficiently warm for wart-biters to be active.
8. Semi-quantitative observations recorded by amateur entomologists often provide the only data on the past distribution and abundance of rare species. Such information should not be neglected, but amateur entomologists should also be encouraged to make brief notes on the weather and state of the vegetation at the time their observations are made.

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Photo 9: One of the wart-biters found along the Drongelen Canal on 24.VIII.1996 during the Saltabel weekend, predominantly olive-green coloured, marbled with grey, edge of elytra on analis-cubitalis field light brown fringed. Photo by Rene Krekels, 1.4x