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A Quick Method for Estimating Butterfly Numbers During Surveys

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ABSTRACT

This paper describes how the size of butterfly populations may be quickly assessed during surveys. The method is a development of Pollard's transect technique, which measures changes in adult numbers in time on fixed sites. In this development, comparability between counts made in the same season on different sites is achieved by ensuring that the transect representatively samples each population, and that the results take account of the length of transect, size of site, and the recording date. The accuracy and usefulness of the method are assessed, using examples taken from six recent surveys. It is concluded that the method gives an accurate measurement of numbers for species that fly freely in open habitats, and an adequate, but less accurate, estimate for species that aggregate or fly in heterogeneous habitats.

INTRODUCTION

Changes in the status and distribution of British butterflies are currently being monitored through three projects: the national mapping scheme of the Biological Records Centre (BRC) (Heath & Harding, 1979); more detailed local mapping schemes (e.g., Smith & Brown, 1979; Edwards & Edwards, 1980; Gower, 1980); and ITE's Butterfly Monitoring Scheme (BMS) (Pollard, 1977, 1979). By combining the results, it is now possible to identify endangered species at an early stage in their decline. But before

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any action is taken, it is usually desirable to have more details than are provided by these methods. There have therefore been several intensive surveys of individual rarities, aimed at discovering the exact numbers, location and size of all surviving colonies. The earliest surveys were of *Maculinea arion* L. (Hunt, 1965; Muggleton, 1973), *Mellicta athalia* Rott. (R. M. Pyle, pers. comm.), *Lysandra bellargus* Rott. (Buxton & Connolly, 1973), *Strymonidia pruni* L. (Thomas, 1974), and *Carterocephalus palaemon* Pallas (Farrell, 1975).

A drawback of the early surveys was that only subjective assessments were made of the sizes of most colonies, due to the long time needed to estimate numbers by traditional capture-mark-recapture methods. This was a serious deficiency if (as was usual) several independent recorders were used. In 1972, an objective method using transects was devised for quickly monitoring changes in butterfly numbers on fixed sites (Pollard *et al.*, 1975). This proved to be fairly accurate (Pollard, 1977), and was developed in 1978 to obtain quick estimates of the relative sizes of colonies on particular sites. This development is described and evaluated in this paper, using examples from recent surveys of six species of butterfly.

METHOD

General

Surveys were made of *Euphydryas aurinia* Rott., *Melitaea cinxia* L., *Cupido minimus* Fuessly, *Lysandra bellargus* L., *Thymelicus acteon* Rott., and *Hesperia comma* L. All inhabit open grassland, except *C. minimus* which prefers scrubbier areas and a broken terrain.

Most surveys were undertaken by three full-time or professional entomologists who recruited another 20 to 30 voluntary helpers to work part-time. They first compiled a list of potential sites by consulting record centres, the literature, and local entomologists. Then a pre-season survey was made to see which former sites still survived, and whether other suitable-looking localities occurred in the neighbourhood. All potential sites were then visited in the first third of the flight period, to discover whether a colony existed.

Before the season started, each main surveyor also selected one colony on a known site for more intensive study. These were used as reference sites during the survey, and each was visited every fifth day or so

throughout the adult period. Mark-recapture experiments were made on every visit to discover the population structure and behaviour of the species; to calibrate transect counts that were also made there; and to monitor changes in numbers during the season, so that estimates obtained from single visits to other sites could be related to the likely population on the day of peak numbers. Between these visits a quick transect estimate was made of adult numbers on every other site that had been found during the survey. These transect counts were restricted to a period of about 20 days spanning the peak day.

Intensive studies

A map was drawn of each reference site, which was stratified into sub-areas if the terrain was heterogeneous, or the adults were aggregated in certain parts. This was usually necessary for *C. minimus* (Fig. 1), but often unnecessary for other species, especially *L. bellargus* (e.g. Fig. 2). On each visit, adults were caught, individually marked, and immediately released at the place of capture. The exact location of each was plotted (Figs 1, 2) and a record was made of the time, sex, amount of wing wear (subjectively scored as well worn (1), poor (2), fine (3), or perfect (4)), and of the butterfly's behaviour before capture.

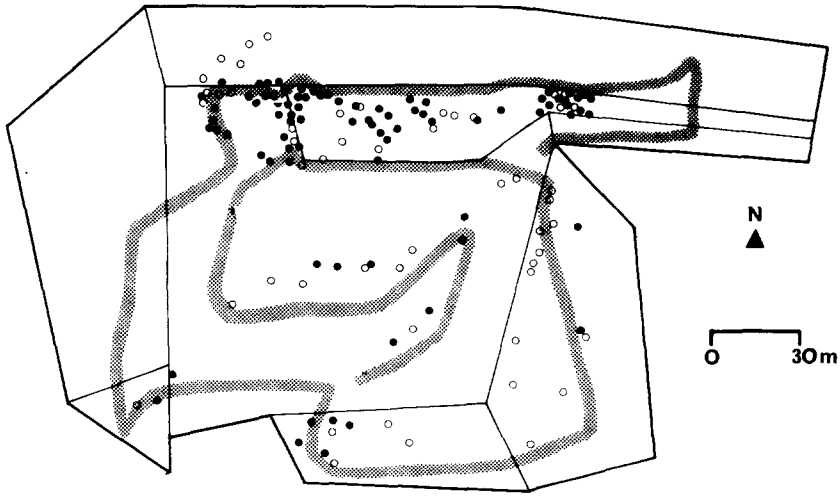

Fig. 1. The distribution of male (●) and female (○) *C. minimus* adults on 29, 30 May and 1, 8 June 1978 in eight sub-areas of a reference site. All captures are shown. The dotted strip represents the first transect route.

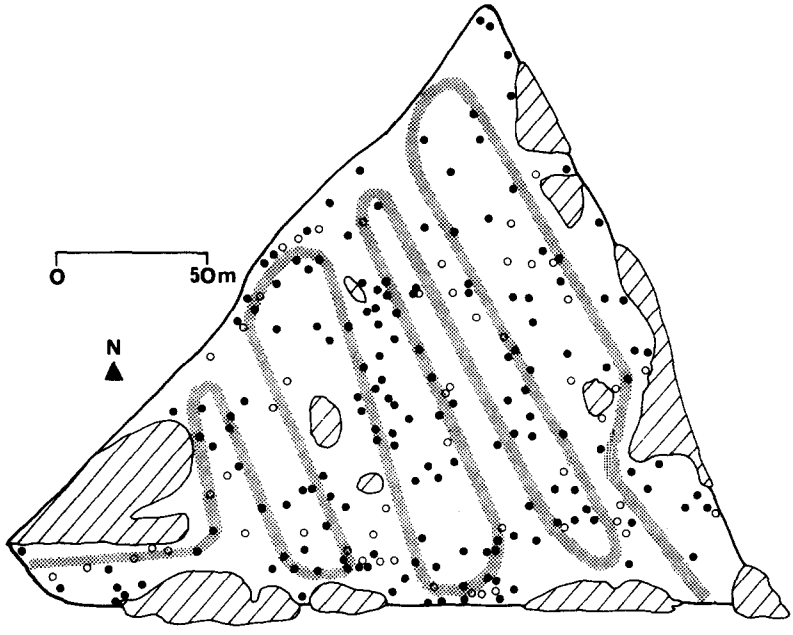

Fig. 2. A *L. bellargus* site showing the distribution of adults found by walking systematically over the whole area on 29 May 1982. The previously determined transect is also shown. Symbols as in Fig. 1, with shrubs as diagonal shading.

An estimate of adult numbers, based on the frequency of capture of individuals (Craig, 1953; Pollard, 1977), was obtained for each site on the day of every visit. The results were compared with transect counts.

The definition of a colony

All the species surveyed except *T. acteon* had discrete and obvious colony boundaries, but it was important to discover if these represented closed populations that could be supported, in isolation, by the land that had been mapped, regardless of other sites nearby. Alternatively, each 'colony' might merely be part of a larger open population whose mobile adults bred over wide areas on scattered fragments of habitat. This was determined by plotting progressive estimates of numbers made during the day against time (Pollard, 1977; pers. comm.). Continued sampling in a closed population results in similar and increasingly accurate estimates through the day, once a certain level of accuracy has been achieved. Open populations are revealed by estimates that become progressively higher

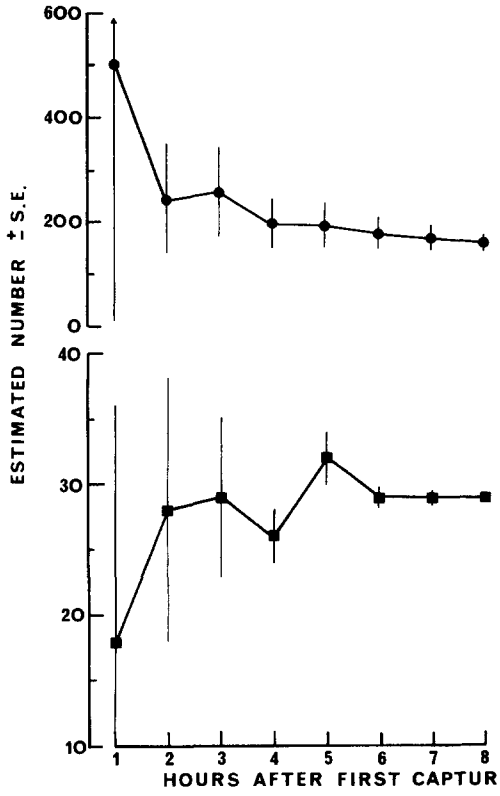

Fig. 3. Two examples of progressive frequency of capture estimates plotted against time to determine whether populations are open or closed. (●) *E. aurinia* (11 June 1978); (■) *C. minimus* (1 June 1978).

(and are meaningless) as marked adults emigrate and, perhaps, fresh ones immigrate.

All the species studied formed closed populations (e.g. Fig. 3). *M. cinxia* alone possibly forms looser colonies, for, in a separate experiment involving simultaneous marking on two sites, three out of 31 recaptured adults crossed 500 m of unoccupied land during one day. However, no movement was detected between *M. cinxia* colonies on two other occasions. Similar experiments on the other butterflies revealed no mixing between nearby sites (Thomas, 1983).

The distribution of adults within a colony

Before comparable transect routes can be chosen on unfamiliar sites, the surveyor must discover whether the butterfly tends to congregate in

particular places, or is evenly or randomly distributed. Both sexes of *M. cinxia*, *E. aurinia*, *H. comma*, *T. acteon* and especially *L. bellargus* (Fig. 2) flew fairly randomly throughout their intensive study sites. However, males of *C. minimus* aggregated in gullies and around shrubs (Fig. 1), although individual males mixed freely between their favourite areas. The females were more evenly distributed.

Transect estimates on unfamiliar sites

The main modification of Pollard's (1977) transect method was to ensure that the route representatively sampled the whole flight area or (less satisfactorily) was biased to the same extent on each site. Account was also made of the length of the transect, the size of the flight area, and the date of recording. The following procedure was adopted on each new site.

Definition of the boundaries
Each flight area was identified by wandering through the colony, plotting the distribution of adults on a sketch map. This was redrawn with more precision later; either out of season or during unsuitable weather for transect recording. The size of the flight area (A; ha) was measured by pacing. *T. acteon* occurred continuously in certain regions, and the drawing of some colony boundaries was rather subjective. The other butterflies occupied discrete and obvious areas that could be defined and sketched in 10 to 60 min.

Choice of transect route
For most species, a route was chosen that zig-zagged through the whole flight area (e.g. Fig. 2). The general course was selected to include all parts or sub-areas, but the precise route was chosen at random on the map, then translated to the field. Efforts were made to ensure that routes on *C. minimus* sites included the congregation areas of males, but did not sample them unduly. This was only partly successful; the example shown was later found to have missed one concentration, but was otherwise satisfactory (Fig. 1).

The length of route depended on the size of the site and the density of adults, but should usually either exceed 1000 m or be long enough to contain more than forty adults. The good example shown (Fig. 2) fulfils both criteria: 43 *L. bellargus* adults were counted along its 1140 m. This distance (L; metres) was measured by pacing.

Transect count

The surveyor walked along the chosen route counting all the butterflies seen within an imaginary box 5 m ahead of him. The width varied according to the species, but was constant once it had been chosen: a 6 m wide transect was used for *M. cinxia* because the butterfly was both conspicuous and flew at low densities; a 4 m wide transect was used for the other species. Recording was restricted to the times of day and weather conditions suggested by Pollard (1977), unless the intensive studies had shown that greater latitude was possible. For example, on warm summer days, *T. acteon* could be sampled as early as 0930 h and as late as 1700 h.

The sex ratio and wing-wear of adults (1–4) was also recorded if more than twenty individuals were present, either during the count or afterwards.

Standardisation of counts

The butterfly count (N) on each transect was expressed as numbers per 100 m to give a standard measure of the density of adults on each site. This was then multiplied by the flight area to give an index (P) of the population size of each colony:

$$\text{Population Index } P = \frac{100\,NA}{L}$$

The reliability of this method was tested by comparing Population Indices from reference sites with estimates of absolute numbers obtained on the same day (Fig. 4). Regression equations are given in Table 1. Very close correlations were found between the two sets of figures for species that were both randomly distributed within their sites and were conspicuous enough for mark-recapture estimates of numbers to be accurate (*L. bellargus*, *M. cinxia*, *E. aurinia*); indeed, indices for *L. bellargus* reflected differences in absolute numbers even in very small populations (Fig. 4, Table 1). Counts and estimates of *C. minimus* were less closely correlated, probably because its aggregated adults were inconsistently sampled by transects on different sites. The poorer correlations of *T. acteon* and *H. comma* may merely be a reflection of the inaccuracy of mark-recapture estimates (Fig. 4), for Hesperiinae fly infrequently and are rarely recaught. However, repeated transect counts of these (and the other) butterflies gave reassuringly similar results (Fig. 5).

The Population Indices from different sites were converted to estimates

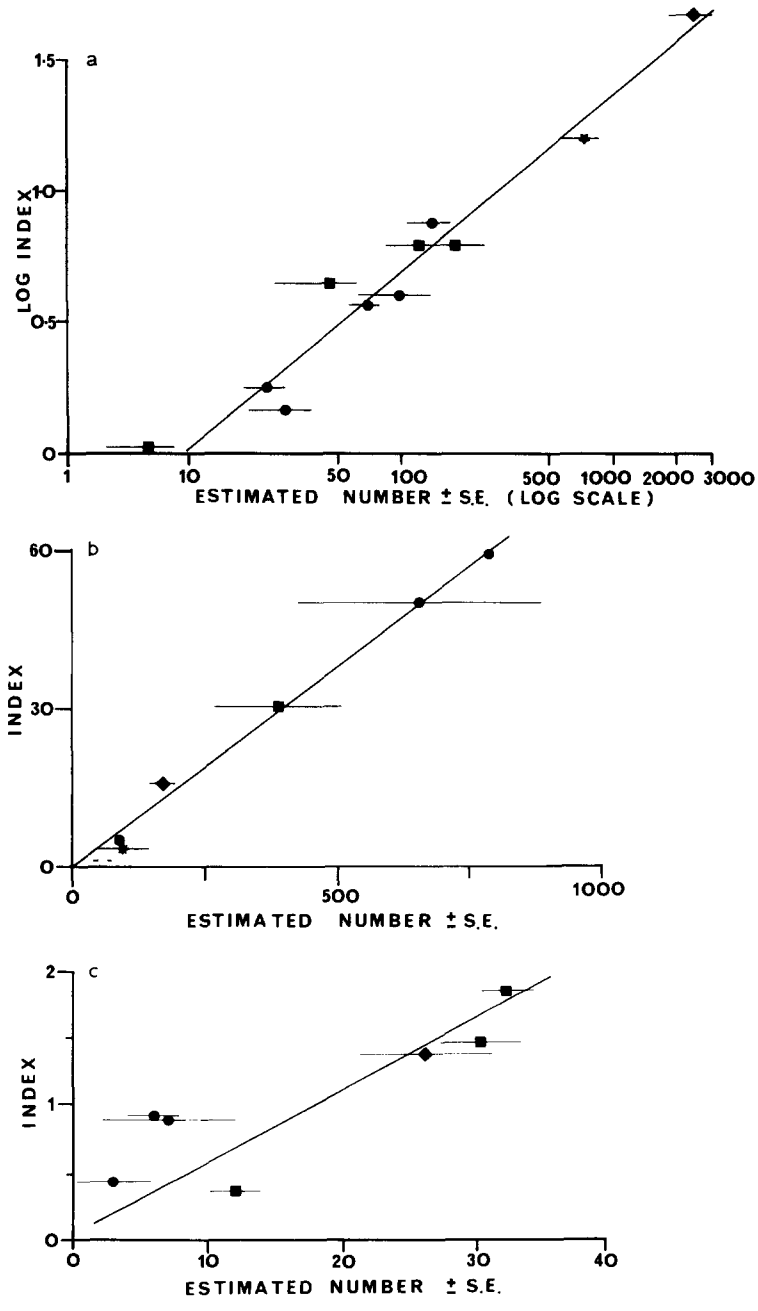

Fig. 4. Examples of the relationship between Population Indices (Y) and estimates of absolute numbers (X) made on the same day on intensive study sites (See Table 1). (a) *L. bellargus* (1978–81); (b) *M. cinxia* (1979–82); (c) *C. minimus* (1978); (d) *H. comma* (1978). (Different symbols indicate different sites for each species.)

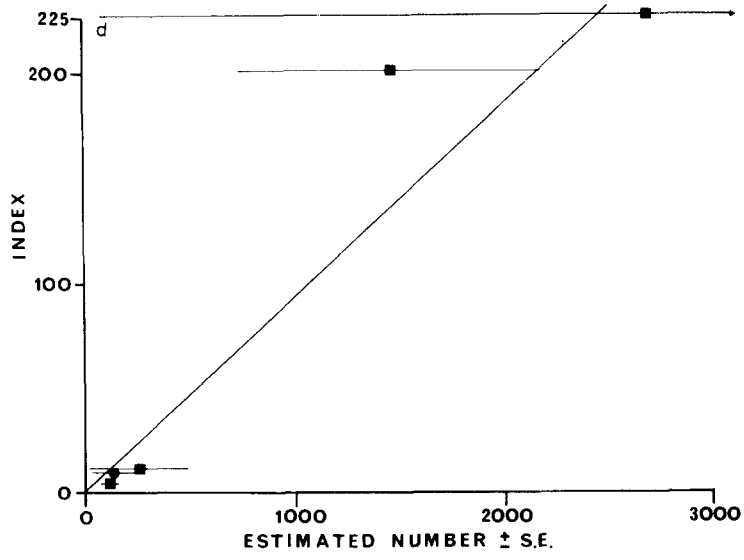

Fig. 4—*contd.*

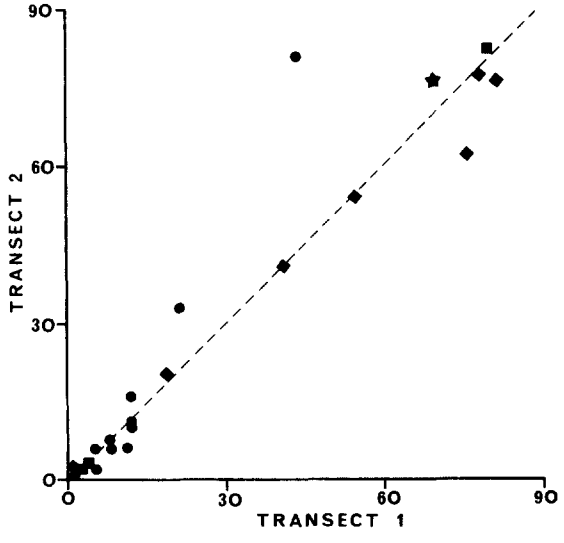

Fig. 5. A comparison of transect counts when the same route was re-walked on the same day (★) *L. bellargus*; (○) *E. aurinia*; (◆) *M. cinxia*; (■) *H. comma*; (●) *T. acteon*.

TABLE 1

Linear Regressions between Population Indices obtained from Transect Counts and Estimates of Absolute Numbers made on the Same Day (See Fig. 4)

Species	*Sample size*		*Equation*	*r*	*p*
	No. of estimates	*No. of sites*			
L. bellargus	11	4	$y = 0{\cdot}018x + 2{\cdot}688$	0·995	$<0{\cdot}001$
L. bellargus populations of under 150 adults	8	2	$y = 0{\cdot}048x + 0{\cdot}941$	0·911	$<0{\cdot}01$
C. minimus	7	3	$y = 0{\cdot}039x + 0{\cdot}395$	0·872	$<0{\cdot}02$
E. aurinia	3	3	$y = 0{\cdot}118x - 5{\cdot}258$	0·999	$<0{\cdot}05$
M. cinxia	7	5	$y = 0{\cdot}077x - 1{\cdot}409$	0·996	$<0{\cdot}001$
H. comma	5	2	$y = 0{\cdot}047x + 4{\cdot}378$	0·948	$<0{\cdot}02$
T. acteon	11	3	$y = 0{\cdot}013x + 5{\cdot}394$	0·786	$<0{\cdot}01$

of actual numbers present when surveyed, using the regression equation for that species (Table 1).

Correction for seasonality

The main adult period of each butterfly lasted for about five weeks, during which numbers gradually increased and then declined (e.g. Fig. 6). At their peak, populations of *L. bellargus* and butterflies with similar lifespans have about one third of the entire emergence alive on the same day (Thomas, 1983).

The emergence of most species differed by a few days on some sites, probably due to variation in the local climate. Not all Population Indices could be obtained on the same date or at the same stage in the season, so a correction was made to convert numbers to the figure assumed to be present on the day of peak numbers. This was done by a comparison with the proportion of adults that were flying on the reference sites at the equivalent date (Fig. 6a). This actual date used for the correction was obtained from the mean of the calendar date on which the transect had been made and (if available) two physiological dates corresponding to the days when the same sex-ratio and degree of wing-wear occurred on the reference sites (Fig. 6b). For example, supposing a transect count of *T.*

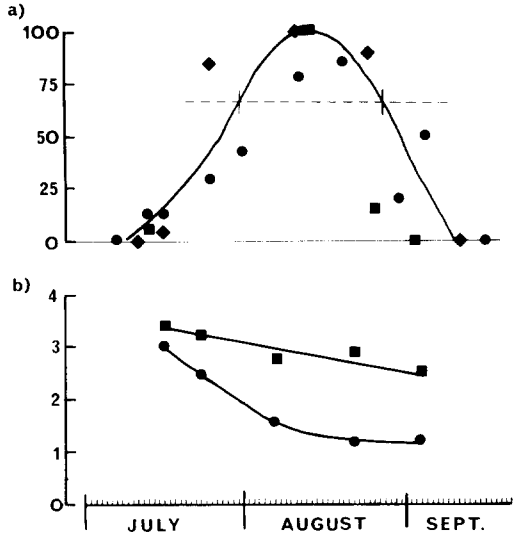

Fig. 6. Mean changes in *T. acteon* during the adult period on three reference sites in 1978. (a) Changes in numbers expressed as percentage of the peak. Dashes indicate the period in which the survey had to be made. (b) The sex ratio (●) and wing wear (■).

acteon was made on 10 August, but there was a ratio of 1·3 males per female and the mean wing-wear was 2·8, that would give respective physiological dates of 6 and 9 August, and a mean correction date of 8 August. From Fig. 6a, that estimate would be assumed to be 95 % of the numbers present on the peak day, and would be corrected accordingly.

The accuracy of this correction was not tested, so for the present no estimate has been accepted that required a correction factor of more than 1·5.

EXAMPLES OF RESULTS

Full results of the surveys will be published separately. The following brief extracts are given to illustrate the usefulness of the method.

Thymelicus acteon

Forty-one colonies of this skipper had been recorded before the survey, mainly in SE Dorset. During a wet summer (1978), three surveyors found 83 colonies and estimated the sizes of 77 of them; each could manage four or five sites on a fine day. Some worked examples are given in Table 2. In addition, a map similar to Figs. 1 and 2 was drawn of each site, with the transect route marked for future repetition.

Not only were more colonies of this butterfly found than had been known previously, but many were extremely large: about 10^6 adults were estimated to have emerged on the Army ranges near Lulworth (this figure is very rough since it is based on a considerable extrapolation of the regression equation; Table 1). Crude habitat analyses showed that large populations invariably occurred on south-facing downs that had been abandoned for agriculture. This had allowed the larval foodplant, *Brachypodium pinnatum* L., both to dominate the sward and to grow into the tall clumps chosen for egglaying (Frohawk, 1934). Since myxomatosis, this butterfly seems to have increased greatly in numbers and local distribution within its restricted range, and was shown from the survey to be in no need of special conservation measures (Thomas, in prep.).

Lysandra bellargus

This butterfly was once widespread and locally common on most south-facing calcareous hillsides in Dorset, but the 1978 survey revealed that

TABLE 2
Examples of Transect Counts and Population Indices of *T. acteon* on Four Sites in 1978

Site	*Map no.*	*Area (ha) A*	*Transect count length (m) N/L*	*Population index 100 NA L*	*Estimated number*	*Correction date*	*Correction factor*	*Estimated no. on peak day*
Mupe Bay	1	35·0	643/1 513	1 487·4	115 226	10 Aug.	1·05	121 431
Ridgeway Hill	8	62·0	37/3 000	76·4	5 390	12 Aug.	1·05	5 670
Bindon (South Hill)	12	5·0	127/1 250	50·8	3 683	7 Aug.	1·15	4 253
New Swanage (1)	41	0·4	5/400	0·5	36	21 Aug.	1·17	42

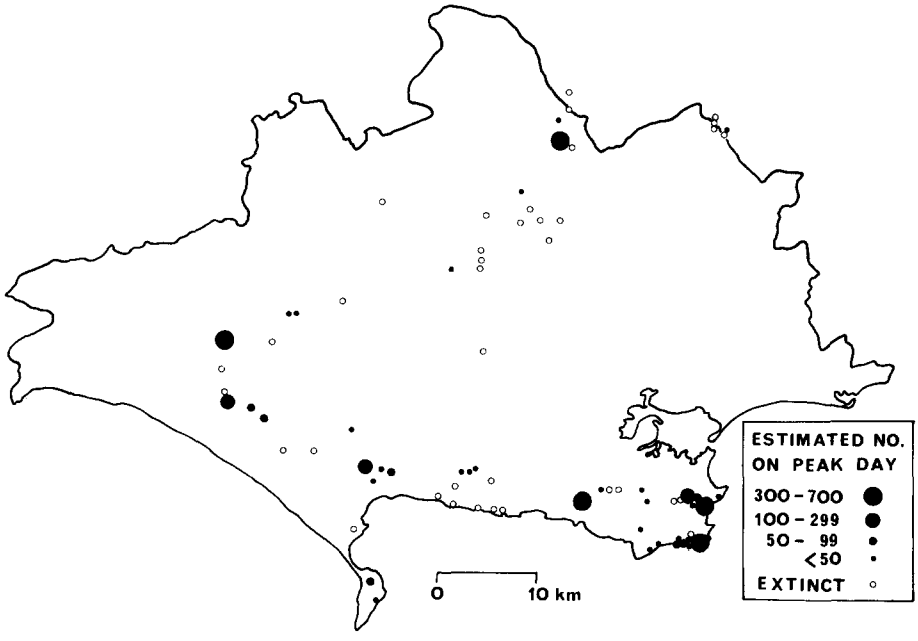

Fig. 7. The distribution and size of *L. bellargus* colonies in Dorset in 1978.

only 39 colonies survived, of which 23 consisted of fewer than 50 adults on the day of peak numbers in the second generation (Fig. 7). Numbers were even lower in the first generation. At least two of the smallest populations have become extinct since 1978. The Dorset colonies are thought to represent about half the remaining populations in Britain, and specific measures must soon be taken if this butterfly is to survive (Thomas, 1983). As with *T. acteon*, a rough assessment of this species' habitat requirements was made during the survey by comparing the conditions found on good, medium and poor sites with those on sites that had lost their colony. Subsequent research has confirmed that this butterfly needs open areas of close-cropped natural grassland, and has declined greatly due to the agricultural improvement of some sites and to the abandonment of grazing on others (Thomas, 1983).

DISCUSSION

On earlier surveys it was usually possible for a recorder to cover six to eight sites in a day, depending on the intervening distances. Objective

population estimates were rarely made, because these took at least one day on each site when traditional mark-recapture methods were used. By the transect method, each surveyor recorded 4–5 sites in a day, but also had to spend every fifth day on his reference site. It usually proved possible to estimate the size of most, if not all, the colonies that were found in one season, using transects.

The techniques of transect recording were quickly acquired by the main surveyors (usually zoology students), but there was some improvement in their performance over the first few days, especially in choosing comparable transect routes. The accuracy and general applicability of the results have yet to be fully evaluated, but such tests as have been made suggest that estimates based on transect counts are much more accurate than had been envisaged, and provide an adequate basis for assessing a butterfly's status and needs. Indeed, less accurate estimates would have been adequate, since the range in population size of all the species tested was very great. It may even transpire that transect recording is a more accurate way of estimating the numbers of a species that flies infrequently or has very large populations, for the recapture rate of marked individuals is then so low that traditional methods yield very poor results. However, the most accurate transect estimates were obtained of conspicuous species that flew readily and randomly throughout discrete open sites (*L. bellargus*, *M. cinxia*, *E. aurinia*). Casual helpers would probably have obtained acceptable estimates of these. Greater skill and experience were needed in setting transects of *C. minimus*, due to the uneven terrain and the aggregation of the males. Thus, this technique may be of less use in estimating populations of woodland butterflies, although it has been successfully used on *Mellicta athalia* by experienced practitioners (Warren *et al.*, 1981). Perhaps the greatest reservation about the method, at present, is the correction of estimates to account for different recording dates. Further research is needed on this aspect, and probably better use could be made of voluntary helpers to obtain regular counts along fixed transects on certain sites.

Despite these reservations, the benefits of having accurate information on colony boundaries and reasonable estimates of numbers have been considerable when the results of surveys have been applied to practical conservation measures, such as the selection of sites for nature reserves. In addition, much was learned of the habitat requirements of each species, both from the intensive studies made on reference sites and from a comparison of the conditions found on a range of sites that had either lost

their colony or supported large, medium or small populations. Finally, once boundaries have been identified and a transect chosen, it takes little effort to walk the same route in later years to see how the butterfly has fared on any site. This has already been done on some *T. acteon* and *M. cinxia* sites, and has revealed striking changes in relative numbers in certain localities where the vegetation has changed.

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