Journal of the Lepidopterists' Society
45(3), 1991, 241–243

A COMPARISON OF FOUR METHODS TO EVALUATE BUTTERFLY ABUNDANCE, USING A TROPICAL COMMUNITY

Additional key words: neotropics, Costa Rica, line-transect method, relative abundance.

In recent years, several transect methods to evaluate the abundance of butterflies have been proposed (Pollard, E. 1977, Biol. Conserv. 12:115–134; Feltwell, J. 1982, Proc. Trans. Br. Entomol. Nat. Hist. Soc. 15:17–24), but to our knowledge there has been no attempt to compare experimentally their usefulness in relation to the availability of time and resources. Herein, we present the results of an experiment in which modifications of four of those methods were applied, simultaneously, to a community of neotropical butterflies.

The study area was a 30-year old secondary forest (Moist Premontane Tropical Forest in the Holdridge System; Holdridge, L. R. 1974, Life zone ecology. Tropical Science Center, San José, Costa Rica, 206 pp.) located in San Pedro de Montes de Oca, Costa Rica (elevation 1200 m, annual precipitation 2000 mm, mean annual temperature 20.5°C). Censuses were taken from 0900 h to 1100 h on sunny mornings during the dry season of 1989, a time selected because weather conditions were excellent for butterfly activity. The experiment was replicated 13 times (13–25 February 1989).

Transect censuses involve counting butterflies while walking, usually along a trail (90 m long, in our case). For all the methods mentioned below, a steady walking speed is assumed, although occasional stops to take notes or to corroborate taxonomic identifications are allowed. We found that a small tape recorder is better than the usual note pad, as it eliminates the need to stop for writing and allows the observer to look constantly for butterflies.

We used the following methods (details in Pollard *op. cit.*; Feltwell *op. cit.*; Southwood, T. R. E. 1978, Ecological methods, Chapman and Hall, London, 524 pp.): **(1) King:** all individuals seen are counted and the distance at which each individual is first seen is recorded; for butterflies, identification beyond 5 m is unreliable and thus we used that distance as a maximum; **(2) Sides:** all individuals seen within a pre-defined distance but only at both sides of the observer are counted (we selected a predefined distance of 5 m and counted butterflies on both sides of the trail); **(3) Pollard:** all individuals seen in front of the observer at a range of 5 m or less are counted; **(4) Dowes:** all individuals seen to the right of the observer within a range of 5 m are counted.

Note that the last three methods actually are variants of the classical method of King. By applying the King method along with recording both the distance and the direction of the observation, one person can obtain simultaneously the kind of data required by all four methods. Nevertheless, the methods may be somewhat different due to non-independence, and for that reason method names appear in quotes in Table 4. To maximize consistency V.N. made all counts in our study. Density (individuals/m^2) was calculated independently according to the area actually covered by each method (Table 4). Family identifications were based on field guides of B. D'Abrera (1984, Butterflies of South America, Hill Press, Victoria, Australia, 256 pp.) and P. J. DeVries (1989, The butterflies of Costa Rica, Princeton Univ. Press, 327 pp.). Although we were primarily interested in comparing methods and not in species determinations (or in measuring actual population sizes), we collected vouchers which we deposited in the Natural History Museum (London).

The distance at which butterflies were first seen varied by taxon (family or subfamily) (Kruskal-Wallis AOV, $P < 0.01$; Table 1). Taxon was not correlated with frequency of identification according to the relative position of the observer (Contingency Chi-square = 9.9, $P > 0.05$; Table 2). More individuals were seen in front of the observer than on either side (Chi-square, $P < 0.01$; Table 3).

The method of King produced significantly higher counts than the other methods (Kruskal-Wallis AOV, $P < 0.01$; Table 4), which in turn did not differ significantly among themselves (Tukey Non Parametric Test). Although the King method apparently samples

TABLE 1. Distances (m) at which individuals were first seen according to taxon. Distance values for all families range from 0.25 to 5 m.

Family/subfamily	Mean	SD
Nymphalinae	1.1	0.9
Satyrinae	1.2	1.0
Ithomiinae	1.3	1.1
Pieridae	1.9	1.3
Heliconiinae	2.1	1.5

TABLE 2. Relation between taxon and direction in which individuals were first seen (left, front, or right of the observer) for all observations.

Family/subfamily	Left	Front	Right
Ithomiinae	53	77	46
Satyrinae	32	75	44
Pieridae	19	18	16
Heliconiinae	10	14	9
Nymphalinae	4	2	5
Total	118	186	120

TABLE 3. Relation between distance (m) and direction in which individuals were first seen, in number of cases.

Distance	Left	Front	Right
1	20	79	29
1–1.9	46	68	50
2–2.9	23	15	12
3–3.9	21	15	18
4–5	8	10	11
Total	118	187	120

TABLE 4. Density of butterflies in a neotropical secondary forest (individuals/m^2) × 100 according to four methods. Each row represents one day.

King	"Sides"	"Pollard"	"Dowes"
1.4	1.4	2.9	1.3
20	1.6	4	2
19.2	2.7	4	3.1
21.7	3.8	5.6	4
13.3	2.7	3.9	3.1
16.2	3	5.2	2.9
12.1	2.1	4	2.7
14.9	2	4	2
20	2	4.1	1.6
9	1.8	3.9	0.9
10.1	0.9	2.1	0
14	3.1	4.7	2.9
3.1	0.9	1.6	0.9

more of the population, it may have more error (e.g., counting individuals multiple times). When the sampling time is limited, the method of Dowes is recommended because it is simpler and its results are similar to those of the "sides" and Pollard methods. Future work should (1) test the effect of non-independence of methods applied simultaneously and (2) use a population of known size to evaluate the accuracy of each method.

We thank T. C. Emmel, J. Feltwell, P. Hanson, L. F. Jirón, and one anonymous reviewer for comments on the manuscript.

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Received for publication 18 March 1991; revised and accepted 28 June 1991.

BOOK REVIEW

Journal of the Lepidopterists' Society
45(3), 1991, 243–244

PRIMITIVE GHOST MOTHS. Morphology and Taxonomy of the Australian Genus *Fraus* Walker (Lepidoptera: Hepialidae *s. lat.*) (Monographs on Australian Lepidoptera, Volume 1), by Ebbe S. Nielsen and Niels P. Kristensen. 1989. CSIRO, East Melbourne, Victoria, Australia. Distributed by Apollo Books, Lundbyvej 36, DK-5700 Svendborg, Denmark. xii + 206 pp. with 435 figures. Hard cover, 17.5 × 25.5 cm, ISBN-0-643-04999-1; DKK 378 (about. $57 U.S.)

The Hepialidae are phylogenetically and biologically distinct outliers that sit near the very base of the evolutionary tree that has at its tips some 150,000 species of butterflies and moths. Hepialids are arguably the most interesting and popular of the ancient lepidopteran lineages, being noteworthy for their diversity, often beautiful coloration, and comparatively enormous size (at least one of these "microleps" has a wingspan that may exceed 250 mm!). Their peculiar flight and courtship habits—from which their common name the "ghost moths" obtains—also have garnered them a great deal of attention from a range of naturalists. Further, they stand as biological record holders in being among the most fecund non-social herbivores as well as candidates for the most polyphagous (even omnivorous!) Lepidoptera.

Primitive Ghost Moths is the first volume in a new monographic series on the Australian Lepidoptera recently initiated by E. S. Nielsen. In this work Nielsen and Kristensen revise what is believed to be the most primitive hepialid genus, *Fraus* Walker (hence the book's title), a genus of 25 species endemic to Australia and Tasmania. The authors review thoroughly the morphology and taxonomy of the genus and survey all available biological data.

The first 100 pages are given to a morphological review that is exceptionally detailed and will be of use to all entomologists concerned with lepidopteran anatomy. Emphasis is placed on the skeletal structure, visceral anatomy, and musculature of the head, thoraco-abdominal articulation, and genitalia segments. This first chapter is generously supplied with 222 line drawings and photomicrographs. The tissue sections are very clearly stained. Even more impressive are the electron scanning micrographs of sections that have secondarily had the embedding material (paraplast) dissolved away. The numerous scanning electron micrographs of the external anatomy are used effectively throughout. The first 85 pages treat the structure of adults, with the remainder given to the egg, larval, and pupal stages. One cannot help but be struck by the fact that there is perhaps more information on moth morphology here than in John L. Eaton's mistitled book *Lepidop-*