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Modified Pollard transects for assessing tropical butterfly abundance and diversity

Astrid Caldas[a,b,*], Robert K. Robbins[b]

[a] *UERJ-Dept. Biologia Animal e Vegetal, 20550-900 Rio de Janeiro, Brazil*
[b] *Department of Systematic Biology, Section of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0127, USA*

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Abstract

This paper introduces and discusses the consistency and effectiveness of an inexpensive modification of Pollard transects for assessing the diversity and abundance of tropical butterfly communities in two national parks in Rio de Janeiro, Brazil. To measure butterfly abundance, students walked simultaneous timed transects at the interface of forest and cleared areas. They either counted the number of individuals observed or tabulated the number of specimens collected with nets. After a short training period, the number of butterflies observed or collected on simultaneous transects was statistically indistinguishable among student groups, and there was a significant positive correlation between observation counts and collected number of individuals. As a measure of species richness, the number of butterfly species sampled on each simultaneous transect was tabulated and did not differ statistically. To measure diversity, alpha of the logseries model was calculated for each collected sample, and statistical fit to a logseries model was determined. Although virtually all daily samples and the year's accumulated sample at one park fit the logseries model, about 35% of the daily samples and the entire year's sample did not fit at the other park. Despite these differences between the two parks, values for alpha from daily samples at both parks varied similarly (from 15 to 50 in almost all cases), and values from the entire year's samples were statistically indistinguishable. The repeatability of results among novices, such as students, suggests that timed transects have great promise for furthering our understanding of butterfly community demographics.
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Keywords: Butterfly abundance; Butterfly diversity; Transects; Pollard; Tropics

1. Introduction

Butterflies are possibly the best group for assessing and monitoring patterns of terrestrial arthropod diversity (Kremen, 1992, 1994). Butterfly biology and taxonomy are well known (e.g. Gilbert and Singer, 1975; Vane-Wright and Ackery, 1984), and an estimated 90% of species are described (Robbins et al., 1996). Butterflies as a group eat a wide array of Angiosperms and occasionally other plants or animals (e.g. Ehrlich and Raven, 1964; Singer et al., 1971; Cottrell, 1984; Singer and Mallet, 1986) and occur in many habitats, ranging from disturbed to pristine areas (e.g. Thomas, 1991; Kremen et al., 1993; Brown, 1996; Brown and Hutchings, 1997). Butterflies are a large group, with twice as many species as terrestrial birds and about three times the number of mammals, reptiles, dragonflies, mosquitoes, termites, or tiger beetles (Robbins and Opler, 1997). The use of butterflies as indicators in conservation planning has been the focus of authors for several years (e.g. Ehrlich and Murphy, 1987; Brown, 1991; Kremen et al., 1993; Nelson and Andersen, 1994; DeVries et al., 1997), and many of the a priori advantages of butterflies as biodiversity indicators are summarized in McGeoch (1998).

Despite these potential advantages, assessing tropical butterfly diversity by directly sampling and identifying a large proportion of the species at a tropical site has been difficult. Identification requires the preparation of thousands of specimens and genitalic dissection of hundreds of abdomens by highly trained taxonomists (e.g.

* Corresponding author. Present address: Department of Entomology, University of Maryland, College Park, MD 20742-4454, USA. Fax: +1-301-314-6334.

E-mail address: ac182@umail.umd.edu (A. Caldas).

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Robbins et al., 1996). Expensive drawers and cabinets are necessary to store these specimens as vouchers. Further, because net-collected samples are questionably random (a statement that might actually apply to most methods of sampling insects), data analysis can be problematic (cf. Lamas et al., 1991). As a consequence of these difficulties, for example, the entire butterfly fauna of only four Neotropical sites have been well-inventoried and vouchered (Robbins and Opler, 1997).

Practical methods used to assess tropical butterfly diversity usually focus on an ecological or taxonomic part of a butterfly community. Perhaps the best ecological example is the butterfly species that are attracted to traps baited with decaying fruit (e.g. DeVries, 1994; DeVries et al., 1997, 1999). This group comprises about 10% of the butterfly community, at least in the Neotropics (Robbins et al., 1996) and avoids the biases of netting. Another advantage is that diversity in different forest strata can be assessed. A disadvantage is that the "attractiveness" of trap bait—and the resulting sample—may be affected by variation in the availability of naturally occurring fruits. For example, in this paper we report no success in trapping butterflies at our study sites in southern Brazil using decaying fruit baits, despite the presence of species attracted to these same baits at other southeastern Brazil sites (Caldas, 1995). Focusing on a taxonomic group, such as the Ithomiinae (Nymphalidae) (Beccaloni and Gaston 1994), may incur similar disadvantages. About 95% of all ithomiine species have larvae that eat plants in the Solanaceae, and the diversity and abundance of these butterflies may mirror those of Solanaceae rather than those of the butterfly community as a whole.

The Pollard Technique, in which butterflies belonging to a limited number of species are counted along transects that are walked in a given amount of time, has been developed over the last 25 years in England (Pollard et al., 1975; Pollard, 1977, 1979; Thomas, 1983; Pollard and Yates, 1993). These observation counts are a measure of abundance because they are positively correlated with the abundances of individual species as estimated by mark-recapture studies (Pollard, 1979). At most tropical sites, however, the vast majority of butterfly species cannot be easily identified "on the wing." To deal with this problem in Costa Rica, Sparrow et al. (1994) combined Pollard Transects with trapping and netting of the more conspicuous, but less diverse, butterfly families (Papilionidae, Pieridae, and Nymphalidae), but their methods do not seem to have been adopted by others or expanded upon.

We propose in this paper a modification of the Pollard Technique similar to that introduced by Sparrow et al. (1994) to monitor the overall abundance of butterflies at diverse tropical study sites. The first modification was to combine timed observation transects with timed collection transects, in which the sampled specimens were later identified by experts. The second modification was to develop a protocol by which workers with limited training, such as undergraduate students, could learn to perform observation and collection transects relatively rapidly and with results that were repeatable. As with other methods for sampling rich tropical butterfly communities, our modification of Pollard's technique samples only a portion of the butterfly community and contains biases. However, it can be potentially useful when used in conjunction with other methods, such as bait-trapping, because the biases of these methods are different. Also, when other methods do not work, such as trapping with decaying fruit baits at our study sites, it provides a viable alternative for assessing and monitoring diversity.

2. Methods

2.1. Study sites

The project was developed and tested in two Brazilian National Parks. Itatiaia National Park (hereafter Itatiaia) is a 30,000 ha reserve in the southeastern states of Rio de Janeiro, São Paulo, and Minas Gerais. Most of this park is montane (> 500 m) Atlantic rain forest. Serra dos Órgãos National Park (hereafter Serra dos Órgãos) is a 10,000 ha reserve in Rio de Janeiro state, about 200 km east-northeast of Itatiaia. This is also a montane park (> 500 m) covered mostly by primary Atlantic rainforest, but with a slightly different climatic regimen, being locally called an "altitude slope rainforest."

2.2. Sampling method

We first tried to monitor abundance and diversity using traps baited with either rotting fish or decaying bananas, a technique that is often successful. However, 16.5 days of trapping (September 1994 to January 1995) yielded a total of three individuals, even though butterflies attracted to fruit baits at other sites in southern Brazil were common during this period. It is unclear why this method failed, but perhaps the butterflies had too many alternative food sources. Consequently, we revised the protocol and developed a modified Pollard transect methodology, described below.

2.3. Student training

Field training was conducted between September 1994 and March 1995, when five undergraduate students from the Universidade do Estado do Rio de Janeiro made 19 field-trips to Itatiaia, Serra dos Órgãos, and Tijuca National Park (a park in the city of Rio de Janeiro) for a total of 49.5 student-days of field work with butterflies. The students received information on collecting techniques and on recognizing the major butterfly groups in the field. The sampling protocol was worked out on trips with Caldas or Robbins. On the others, the students gained experience netting butterflies. At the university, the students were shown entomological techniques and were lectured on butterfly taxonomy, behavior, and ecology, including analysis of butterfly abundance and diversity.

2.4. Transects

Transects were selected at Serra dos Órgãos (1100 m) and at Itatiaia (800 m) along small park roads and paths (3–4 m wide) at the interface of forest and cleared areas (the roads and paths themselves and some clearings), where we found the greatest abundance and diversity of species. Transects through totally shaded areas tended to have few butterflies whereas those only in cleared areas tended to lack forest species. Although transects in other habitats would be desirable for obtaining a more complete picture of butterfly demographics at a site, our primary purpose for this project was to test the feasibility of these sampling methods. The data presented below were collected from April 1995 through March 1996, with at least one monthly trip to each of the parks.

2.5. Analysis of abundance

We first asked whether observation counts of butterfly abundance by students along timed transects were repeatable. To answer this question, two student teams walked the same 1 km transect in 15 min, but each team started at the opposite end of the transect. Each team had the same number of students (one or two), so that the same number of students counted butterflies along the same transect at the same time and over a sufficiently short time period that changing weather was unlikely to be a factor (see below). All butterflies seen were counted. We tested whether each pair of simultaneous transect counts was statistically the same by using a standard chi-square test with a continuity correction factor (Microstat commercial software) and combining the results with a combined probability test of significance (Sokal and Rohlf, 1969). We used a 5% significance level for rejecting the null hypotheses for all statistical tests in this paper.

The second question was whether the number of butterfly specimens collected along transects was repeatable. To answer this, two student teams collected along the same transect from opposite ends, as with the observation counts. Students sampled butterflies along 0.5 km transects in 30 min, which means that they walked the sampling transects about four times slower than the observation transects. We tested the repeatability of the number of collected specimens using the statistical method described above.

The third question was whether the number of butterflies that students collected was positively correlated with observation counts. If there were a strong positive correlation, then the collected specimens, which are needed to monitor diversity (below), might also be used as a measure of abundance. To test this, one student team collected along a 0.5 km transect for 30 min. Simultaneously, another student team walked the transect about four times counting the number of butterflies until the end of the 30 min period. We calculated a standard correlation coefficient between the number of individuals observed and collected, and tested whether it differed significantly from zero.

The fourth question was whether collecting significantly decreased the number of butterflies observed. For each 30-min simultaneous collection and observation transect, we tabulated the number of butterflies observed during the first and final 10 min. We compared these counts using a standard chi-square test with a continuity correction factor.

The three preceding protocols were performed at approximately the same time each day (within a half hour), depending on weather (rain usually falls in early or mid-afternoon). The transects were sufficiently short (none more than 30 min) that it was usually possible to complete a transect without the weather changing significantly. However, if it was not sunny for 90% of the time or if the temperature fell below 18 °C, then the data from that transect were discarded. Bad weather is the reason why there are no data for one of the months at Serra dos Órgãos and why occasionally not all transects were performed on a given day. On days with sustained good weather, the three protocols were repeated.

2.6. Identification

The butterflies of these parks are exceedingly diverse, with 912 species recorded so far at Itatiaia in over a half century of collecting (Zikán and Zikán, 1968, modified slightly in Robbins and Opler, 1997). In addition to some undescribed species among butterfly groups containing smaller, dull-colored individuals, there are some very complex (presumably) mimetic groups. Consequently, systematist Olaf H.H. Mielke at Universidade Federal do Paraná (Curitiba, UFPR) identified specimens in the families Hesperiidae, Papilionidae, Pieridae, and Nymphalidae, and Robbins and D.H. Harvey (Smithsonian Institution, USNM) identified the Lycaenidae and Riodinidae. Out of 1597 specimens collected, only 31 could not be identified, usually because the specimen was too worn. These unidentified specimens were included in the data on abundance, but were omitted from the data below on species richness and diversity. All specimens are deposited in UFPR or USNM.

2.7. Analysis of species richness

The first species richness question that we addressed was whether the number of species that students collected was repeatable. We recorded the number of species that each student team sampled on the simultaneous collecting transects and analyzed these data as was done for the number of collected specimens (above). The second addressed question on species richness was what proportion of the butterfly fauna was sampled by the students, which was directly calculated for Itatiaia whose butterfly fauna is well-known (Zikán and Zikán, 1968). The third species richness question was whether the efficiency of student sampling approximated that of experts. We compared the number of butterfly species collected by students with the number collected by experts at Pakitza, Peru, in an equivalent number of person-hours (Lamas et al., 1991). The fourth species richness question was whether student collecting over-sampled the larger and more conspicuous butterfly species at the cost of under-sampling the richer groups of smaller and less conspicuous species. This kind of bias is difficult to measure, but we compared the proportion of each butterfly family in the Itatiaia sample with Itatiaia's known fauna (Zikán and Zikán, 1968). Generally, the Hesperiidae (skippers), Lycaenidae (blues), and Riodinidae (metalmarks) tend to be smaller and less conspicuous than the Papilionidae (swallowtails), Pieridae (sulfurs/whites), and Nymphalidae (brushfoots).

2.8. Analysis of species diversity

The logseries distribution is probably the most widely used model of insect diversity (Southwood, 1978; Magurran, 1988). It usually fits insect diversity data well, and its parameter alpha, which is an index of diversity, is relatively independent of sample size and has been shown in many cases to be the best measure of diversity (Taylor et al., 1976; Southwood, 1978; Wolda, 1981, but see the balanced discussions in Krebs, 1989, and Magurran, 1988). The wide use of the logseries distribution allows results to be compared among studies of insect communities. We used the software package accompanying Krebs (1989) to calculate the logseries alpha and its variance. Goodness of fit was tested using a standard chi-square test (Magurran, 1988) except that expected values less than five were pooled.

The first diversity question that we addressed was whether students with limited training in butterfly taxonomy could tabulate diversity data sufficiently well to obviate the need for professional taxonomists. We had three students and one taxonomist (Robbins) identify species from a Itatiaia sample in February 1995 and tabulate rank abundance data (i.e. how many species with one individual, how many with two individuals, etc.). For the expert's tabulation, a 95% confidence interval was calculated for the corresponding value of alpha to see if the values of alpha from the student tabulations were significantly different. The second diversity question was whether the student samples fit the logseries distribution. We tabulated diversity data for the individuals from the simultaneous collection transects and the simultaneous collection and observation transects. We also tabulated data from the entire project for each park.

3. Results

3.1. Abundance

Observation counts on timed transects were consistent between student teams (Table 1). Of 33 pairs of simultaneous transects, the number of butterflies observed by each team differed significantly once, and the combined probability was not significant ($P=0.2437$). Number of individuals sampled with nets on timed transects were also consistent between student teams (Table 1). In none of the 33 simultaneous sampling transects were the number of butterflies collected by each team significantly different, and the combined probability was not significant ($P=0.8161$). The number of butterflies collected by one team was positively correlated ($r=0.7825$, $N=33$, $P<0.001$) with the number observed by a second team during simultaneous collecting/observing transects (Fig. 1). About 3.1 butterflies were observed for each one collected during these simultaneous transects, calculated as the slope of a regression line through the origin. The number of butterflies observed during the first 10 min of the transect was higher than the number observed during the final 10 min in 19 transects, lower in 12 transects, and the same in two transects. The hypothesis that collecting decreased observation counts was not significant ($\chi^2=1.161$, df$=1$, $P=0.2812$).

3.2. Species richness

Species richness as measured by number of species collected during simultaneous sampling transects was exceedingly consistent between student teams (Table 2). None of the 31 simultaneous transects differed significantly from each other (sample size for two others were too small to be tested), and the combined probability was not significant ($P=0.9656$). Species accumulation curves show no signs of leveling off (Fig. 2), which is expected since the 189 species collected by the student teams at Itatiaia in 43.5 person-hours is 20.7% of the 912 species that have been recorded at Itatiaia. At Serra dos Órgãos, 170 species were sampled in 46.5 person-hours. In comparison, experienced lepidopterists

Table 1
Butterfly abundance as measured on simultaneous timed transects

Date	Park	Observed specimens teams 1,2	Collected specimens teams 1,2
7/APR/95	Itatiaia	26,39	17,19
27/APR/95	Serra dos Órgãos	14,14	3,11
5/MAY/95	Itatiaia	48,65	25,41
8/JUN/95	Serra dos Órgãos	6,8	4, 5
9/JUN/95	Itatiaia	12,21	6, 7
17/JUL/95	Itatiaia	25,27	9,16
24/JUL/95	Serra dos Órgãos	6,13	9,13
18/AUG/95	Itatiaia	50,52	19,30
25/AUG/95	Serra dos Órgãos	16,16	11,13
25/AUG/95	Serra dos Órgãos	8,17	6,15
1/SEP/95	Itatiaia	53,57	22,26
11/SEP/95	Serra dos Órgãos	27,35	19,24
2/OCT/95	Itatiaia	36,49	20,25
27/OCT/95	Serra dos Órgãos	3,14*	4,7
6/NOV/95	Serra dos Órgãos	5,14	7,10
6/NOV/95	Serra dos Órgãos	7,7	4,5
17/NOV/95	Itatiaia	26,38	18,24
27/NOV/95	Serra dos Órgãos	12,19	7,13
27/NOV/95	Serra dos Órgãos	9,11	7,9
8/DEC/95	Serra dos Órgãos	17,21	14,14
18/DEC/95	Itatiaia	24,37	13,18
18/DEC/95	Itatiaia	28,34	19,19
5/JAN/96	Serra dos Órgãos	15,16	14,23
5/JAN/96	Serra dos Órgãos	17,27	20,30
8/JAN/96	Itatiaia	24,31	11,20
8/JAN/96	Itatiaia	22,31	19,21
15/JAN/96	Itatiaia	33,38	17,17
26/JAN/96	Itatiaia	36,41	16,25
29/JAN/96	Serra dos Órgãos	15,19	14,20
5/FEB/96	Itatiaia	30,44	30,34
12/FEB/96	Serra dos Órgãos	17,23	8,10
28/FEB/96	Serra dos Órgãos	20,28	9,14
28/FEB/96	Serra dos Órgãos	16,18	8,8

Number of specimens recorded on observation and collecting transects. See text for further explanation of transect types.
* $P<0.05$.

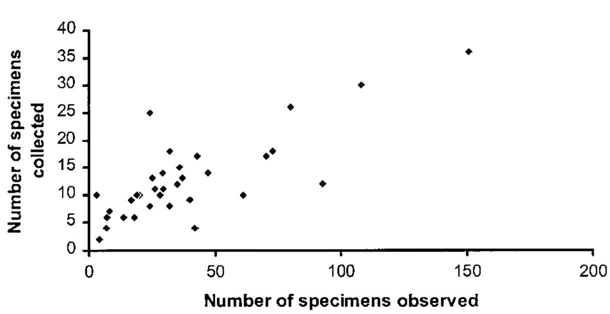

Fig. 1. Positive correlation ($r=0.7825$, $N=33$, $P<0.001$) between number of butterfly specimens observed by one team and number collected simultaneously by another team on the same transect.

at species-rich Pakitza, Manu National Park, Peru, caught 222 species in 40 person-hours (Lamas et al., 1991). A comparison of butterfly family composition of the student Itatiaia sample with Itatiaia's total fauna (Table 5) shows that the students over-sampled the Papilionidae, Pieridae, and Nymphalidae and under-sampled the Lycaenidae, Riodinidae, and Hesperiidae. The composition of the Itatiaia sample was similar to that at Serra dos Órgãos (Table 5).

Table 2
Butterfly species richness as measured on simultaneous timed collecting transects

Date	Park	Collected no. of species teams 1,2
7/APR/95	Itatiaia	12,15
27/APR/95	Serra dos Órgãos	3,11
5/MAY/95	Itatiaia	17,30
8/JUN/95	Serra dos Órgãos	3,4
9/JUN/95	Itatiaia	6,6
17/JUL/95	Itatiaia	8,11
24/JUL/95	Serra dos Órgãos	7,12
18/AUG/95	Itatiaia	16,22
25/AUG/95	Serra dos Órgãos	9,12
25/AUG/95	Serra dos Órgãos	4,10
1/SEP/95	Itatiaia	13,18
11/SEP/95	Serra dos Órgãos	16,18
2/OCT/95	Itatiaia	14,15
27/OCT/95	Serra dos Órgãos	3,7
6/NOV/95	Serra dos Órgãos	5,9
6/NOV/95	Serra dos Órgãos	3,4
17/NOV/95	Itatiaia	15,17
27/NOV/95	Serra dos Órgãos	7,9
27/NOV/95	Serra dos Órgãos	7,7
8/DEC/95	Serra dos Órgãos	11,11
18/DEC/95	Itatiaia	9,14
18/DEC/95	Itatiaia	12,15
5/JAN/96	Serra dos Órgãos	10,20
5/JAN/96	Serra dos Órgãos	14,18
8/JAN/96	Itatiaia	9,17
8/JAN/96	Itatiaia	15,19
15/JAN/96	Itatiaia	12,13
26/JAN/96	Itatiaia	12,18
29/JAN/96	Serra dos Órgãos	10,14
5/FEB/96	Itatiaia	18,20
12/FEB/96	Serra dos Órgãos	7,8
28/FEB/96	Serra dos Órgãos	9,12
28/FEB/96	Serra dos Órgãos	8,8

3.3. Species diversity

Diversity data are presented as rank-abundance plots for each park (Fig. 3). In our preliminary trial, student tabulation of diversity data was similar to that of a professional, but contained too many species. Robbins recognized 61 species in the 145 specimen sample from Itatiaia on 22 February 1995. Tabulations of three students (63, 65, and 71 species) were too high. The value of alpha with 61 species was 39.6 with a 95% confidence interval from 29.6 to 49.7. The values of alpha from the students' tabulations (42.4, 45.3, 55.0) fell within the confidence interval twice and outside of it once.

The logseries model fit 15 of 17 samples from Itatiaia as well as the total Itatiaia sample (Table 3). Values of alpha for the daily samples ranged from 20.8 to 47.7,

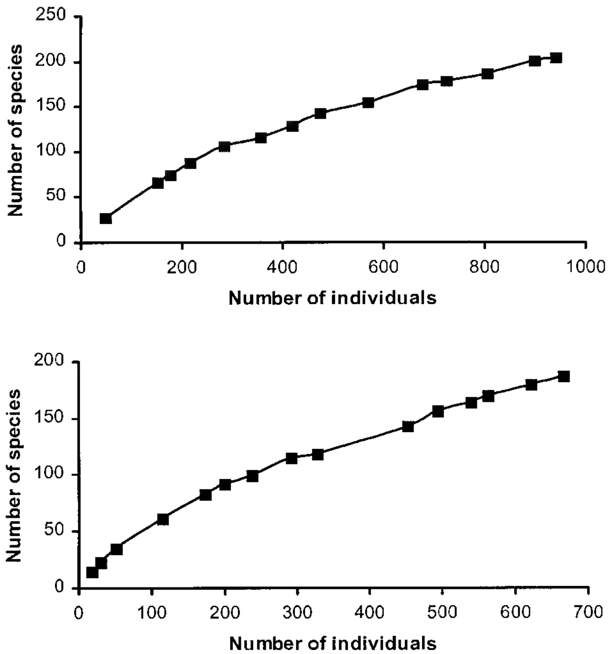

Fig. 2. Species accumulation curve for Itatiaia National Park (top) and Serra dos Órgãos National Park (bottom).

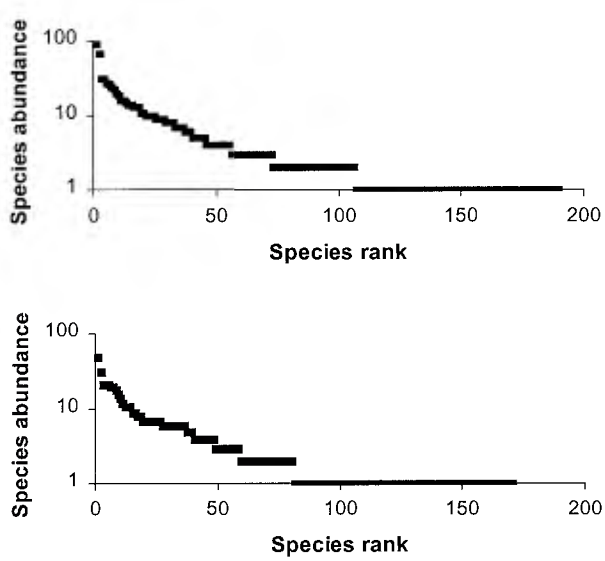

Fig. 3. Rank abundance plots for species collected at Itatiaia National Park (top) and Serra dos Órgãos National Park (bottom).

but there were no clear seasonal trends (Table 3). The value of alpha for the entire sample was considerably greater (80.2) than that for the daily samples, indicating a not unexpected significant seasonal component to the species diversity of this park. The two daily samples that differed statistically from a logseries model had more species with a single individual than predicted by the model.

The logseries model fit 11 of 21 samples from Serra dos Órgãos, with six samples being statistically different

Table 3
Diversity samples for the Itatiaia National Park

Date	No. of Specimens	No. of Species	Alpha	95% Confidence interval
7/Apr/95	48	27	25.5	16–35
5/May/95	102	52	42.5	31–54
9/Jun/95	26	17	21.3	11–32
17/Jul/95	39	26	34.1	21–47
18/Aug/95	67	41	44.9	31–59
1/Sep/95	74	35	26.0	17–35
2/Oct/95	62	37	38.7	26–51
17/Nov/95	56	33	33.7	22–45
18/Dec/95#1	56	32	29.4	19–40
18/Dec/95#2	41	28	36.5	23–50*
8/Jan/96#1	65	41	47.7	33–62
8/Jan/96#2	43	30	43.0	27–59
15/Jan/96	47	26	24.0	15–33
26/Jan/96#1	51	26	21.2	13–29
26/Jan/96#2	30	24	30.0	17–43*
5/Feb/96	94	52	47.8	15–61
18/Mar/96	42	23	20.8	12–29
Total	941	204	80.2	69–91

* Significant ($P<0.05$) deviation from a logseries model.

Table 4
Diversity samples for the Serra dos Órgãos National Park

Date	No. of Specimens	No. of Species	Alpha	95% Confidence interval
27/Apr/95	18	15	18.0	8–28
8/Jun/95	11	9	11.0	3–19[a]
24/Jul/95	22	16	22.0	11–33
25/Aug/95#1	35	26	35.0	21–49
25/Aug/95#2	28	17	18.3	10–27*
11/Sep/95	58	39	52.2	36–69
27/Oct/95#1	12	10	12.0	4–20[a]
27/Oct/95#2	15	13	15.0	6–24*
6/Nov/95#1	23	16	23.0	12–34[a]
6/Nov/95#2	15	10	13.1	5–21[a]
27/Nov/95#1	30	24	30.0	17–43*
27/Nov/95#2	24	22	24.0	12–36*
8/Dec/95	36	22	24.0	14–34
5/Jan/96#1	60	36	38.0	25–51
5/Jan/96#2	55	34	38.0	25–51
22/Jan/96	42	36	42.0	27–57*
29/Jan/96	45	26	25.7	16–36
12/Feb/96	24	15	17.1	8–26
28/Feb/96#1	32	23	32.0	19–45
28/Feb/96#2	26	23	26.0	14–38*
25/Mar/96	45	25	23.2	14–32
Total	657	186	86.5	74–99

[a] Sample was too small to test fit to a logseries model.
* Significant ($P<0.05$) deviation from a logseries model.

and four being too small for statistical comparison (Table 4). Values of alpha had a wider range than for the Itatiaia samples (11.0–52.2), but again, there was no evident seasonal pattern. The entire Serra dos Órgãos sample was significantly different from a logseries model, but the value of alpha (86.5) was similar to and not statistically different from that at Itatiaia. In all daily Serra dos Órgãos samples where the data were significantly different from a logseries model, including the entire Serra dos Órgãos sample, there were more species with one individual than predicted by the model.

4. Discussion

Pollard and his collaborators (Pollard et al., 1975; Pollard, 1977; Pollard and Yates, 1993) formalized the concept of timed transects as a framework for quantitatively sampling butterfly communities. With only minimal training in this technique, novices made observation counts along simultaneous timed transects that were highly repeatable (Table 1). To the extent that these counts are strongly correlated with overall abundance, as demonstrated by Pollard (1979), this result means that variation over time in observation counts reflects variation in the abundance of butterflies. Our results suggest that this method is an effective, low cost means of monitoring butterfly abundance in tropical communities.

Our study may be the first formal attempt to sample butterfly abundance quantitatively by student collecting along timed transects. Although there appeared to be considerable variation among students in their physical ability to collect butterflies with a net, the number of specimens collected along simultaneous timed collecting transects was highly repeatable (Table 1) and correlated with counts during simultaneous timed observation transects (Fig. 1). Timed collecting transects appeared to be an effective means of monitoring butterfly abundance and providing a quantitative sample for assessing species richness and diversity. Collection transects depressed simultaneous observation counts in a statistically non-significant number of cases.

Student collecting along timed transects proved to be a reasonable method for quantitatively sampling species richness. The number of species collected by students along timed transects was repeatable (Table 2). The students sampled 20.7% (189 species) of the 912 species that are known to occur at Itatiaia, despite collecting along a transect with an area of less than a half hectare in a 30,000 ha park with elevations ranging from 500 to 2200 m. The students sampled species at a rate roughly comparable with that of experts in Peru's Parque Manu. Although Itatiaia and Serra dos Órgãos have lower species richness than Parque Manu, the samples in these parks were collected all year while that in Peru was restricted to 3 weeks. Students appeared to under-sample the more obscure species belonging to the Lycaenidae, Riodinidae, and Hesperiidae (Table 5). However, their sampling may correctly represent the fauna along the transects because many species belonging to these families are usually found only on hilltops or at certain times of year on flowers that did not occur along the transects (Robbins unpublished data).

Table 5
Number of species (and percentage of the fauna) in each butterfly family at Itatiaia (Zikán and Zikán, 1968, modified slightly in Robbins and Opler, 1997) and in the collected samples at Itatiaia and Serra dos Órgãos

Family	Itatiaia	Itatiaia sample	Serra dos Órgãos sample
Papilionidae	21 (2.3%)	11 (5.8%)	11 (6.5%)
Pieridae	45 (4.9%)	18 (9.5%)	20 (11.8%)
Lycaenidae	170 (18.6%)	15 (7.9%)	14 (8.2%)
Riodinidae	111 (12.2%)	15 (7.9%)	14 (8.2%)
Nymphalidae	225 (24.7%)	76 (40.2%)	52 (30.6%)
Hesperiidae	340 (37.3%)	54 (28.6%)	59 (34.7%)
Totals	912	189	170

The collected diversity samples fit the logseries model well for Itatiaia and not so well at Serra dos Órgãos. In all cases at both sites of statistically significant deviation from the logseries model, there were more species with one individual than expected. This result suggests that either the students tended to collect individuals that "looked" different from those previously collected, or butterfly relative abundances, especially at Serra dos Órgãos, were comprised of more rare species than predicted by the logseries model, as appears to occur in many tropical herbivores (Novotný and Basset, 2000). Although students were instructed to collect as objectively as possible, we cannot distinguish these possibilities at present.

The value of alpha for daily samples varied (with rare exceptions) between 15 and 50, and the values for the entire year at each park (80.2 and 86.5) were not significantly different. The values of alpha for daily samples are in accord with those for butterfly and moth samples in other tropical areas and are generally higher than those for temperate areas (Fisher et al., 1943; Williams, 1964).

The one preliminary experiment with student taxonomy indicated that students tend to recognize too many species because of sexual dimorphism and other variation. The differences were not great, but appeared to be consistent. We suspect that students could be taught to recognize intraspecific variation among butterfly species at a particular site, but did not pursue this task during the project.

Some differences between the butterfly communities at Itatiaia and Serra dos Órgãos were apparent. Daily observation counts, collected number of individuals, and species diversity were generally higher at Itatiaia (Tables 1 and 2). Despite these results, the total number of species sampled at both parks was about the same (170 species at Serra dos Órgãos versus 189 at Itatiaia, 318 species together) and the values for alpha at Serra dos Órgãos (86.5) and Itatiaia (80.2) were not significantly different. Further study would be needed to determine whether the differences in daily samples of abundance and species richness were due to the specific transect sites or to general differences between the butterfly communities at the two parks.

Timed transects and fruit-bait trapping are the two ways that butterflies have been quantitatively sampled in the Neotropics. The first method samples the butterfly community that occurs at the transect site while the latter method samples those adult butterflies that are attracted to decaying fruit. Not surprisingly, there are clear differences between our monthly timed transect samples and the monthly trap samples at two Ecuadorian rainforest localities (DeVries et al., 1997, 1999). The Itatiaia and Serra dos Órgãos samples had greater species richness (189 and 170 species versus 130 and 91 species) and greater values of alpha (86.5 and 80.2 versus 25.5 and 22.9) than the Ecuadorian samples, but a much lesser percentage of the community was sampled (20.7% of the entire butterfly fauna at Itatiaia versus 91.2 and 90.3% of the fruit-feeding butterfly community at the Ecuadorian sites as estimated from a lognormal model). In brief, the timed transects sampled a larger and ecologically more varied butterfly community, but at only one site at each park in contrast to bait traps in different areas and at different heights in the forest. If timed transects were set up in different habitats, then presumably it would be possible to greatly increase the percentage of the fauna sampled at a park using timed transects.

The long term goal of assessing butterfly communities is to understand how abundance, richness, and diversity varies seasonally and annually among ecological sites. Repeatable, quantitative sampling is essential in attaining this goal. DeVries and colleagues (1997, 1999) have made great headway in this direction by assessing the fruit-feeding portion of tropical butterfly communities in different forest habitats. Given the effectiveness and low cost of timed transects, we envision that timed transects in carefully chosen habitats (as detailed in Sparrow et al., 1994) could likewise add to our knowledge of butterfly community demographics. And as we better understand these factors, we will be able to more effectively monitor changes in butterfly communities due to habitat changes, whether natural or caused by man.

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