BEETLES FROM PITFALL-TRAPPING IN A CALEDONIAN PINEWOOD AT LOCH GARTEN, INVERNESS-SHIRE

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As part of a survey of the beetles of the Loch Garten RSPB. Reserve undertaken during the period 1978–1987 (Owen, 1989), a pitfall-trapping exercise was carried out between April 1983 and March 1984. This paper presents the results of this trapping, in part as an exercise helping to define the beetle fauna of the area and in part as a study in its own right.

Methods

The RSPB Reserve at Loch Garten is geographically part of Abernethy Forest, one of the largest remaining tracts of the Caledonian Forest. The trapping was carried out in a part of the Reserve which had probably had Scots pine (*Pinus sylvestris* L.) cover more or less continuously since pre-historic times.

Trapping was carried out in four different pine-wood habitats, all within a circle of about 1000 m diameter. The first site (grid ref. NH 979175) comprised fairly close canopy mature pine forest on a poorly drained site with good ground cover mostly of thick mosses with some *Vaccinium* spp. The second site (NH 976186) comprised more open mature pine forest with juniper and ground cover likewise mainly of moss and *Vaccinium* spp. The third site (NH 968178) was an area with about 20-year-old Scots pine, well spaced out with various grasses between the trees and the fourth (NH 965176) was an area which had been clear felled some years previously, with patches of vegetation between old pine stumps and a few self-sown young pine trees.

The traps were slightly tapered, plastic drinking cups (diameter at mouth 7 cm, capacity 200 ml) set into the ground with their rims flush with the ground level. Each cup had a cut 2–3 cm long vertically in the wall just below the rim to allow excess fluid from rain to escape without loss of beetles. The cups were charged initially and on emptying with about 80 ml of 10% (v/v) aqueous ethylene glycol as a preservative and each was loosely covered with a piece of pine bark set 1–2 cm above the rim to make them less obvious and to reduce entry of rain. The ground immediately around the sunken cups was not cleared.

Initially 18 traps were set out at each site in three circles (diameter about 3 m) of six traps but, during the study period, some traps were found to have been damaged or disturbed (probably by deer) and these were not replaced. By the end of the survey, about one trap in six had been put out of action. The traps were set out at the beginning of April 1983. Because of the distance of Loch Garten from Epsom, it was only possible to service the traps at 3 months (end of June), 6 months (end of September) and 12 months (end of March 1984). In presenting the results, the collecting periods are described as 'early summer', 'late summer' and 'winter'.

All species trapped were identified and counted. The relation between numbers of species and their relative abundances was expressed by plotting species *count* (number of species with a particular abundance i.e. 1, 2, 3 . . . examples) against their *abundance*. Details of the procedure are given in the legend to the figure.

In many studies on samples of trapped insects, the numbers of species with a particular abundance has been found to conform more or less to a log-series (Williams, 1964). In such a series, the numbers of species of which there are respectively 1, 2, 3, 4 . . . examples are given by the terms:

$$\alpha x,\ \alpha x^2/2,\ \alpha x^3/3,\ \alpha x^4/4 \ldots \text{ and so on.}$$

α is a parameter related to the population from which the sample is obtained and has the characteristic of a diversity index; the greater the diversity of insects (in terms of number of species and their relative abundances), the higher the value of α. An estimate of α can be obtained from the number of species and number of beetles in the sample (Williams, 1964). x is a parameter related to the size of the sample and can be calculated similarly from the total number of species and the total number of beetles.

To see how well the observed data conformed to a log-series, the parameters α and x were first determined for the beetles trapped and the expected number of species with 1, 2, 3, . . . examples (assuming a log-series) then calculated. To allow comparison between observed and expected species counts, the latter were plotted in the same way as was the observed data.

Finally, Simpson's index of diversity (Simpson, 1949) was calculated in the form of its reciprocal (Hill, 1973) and Brillouin's index as described by Morris & Lakhani (1979). The latter indices are likewise higher in instances of greater species diversity. They have the attraction that they make no assumption about the relation between numbers of species and their respective abundances.

Results

A summary of the results of this exercise is presented in Table 1 and a list of the species caught is given in the appendix. The open canopy pine forest produced the most beetles and the most species; the young pine forest produced the least beetles and the least species. There were more beetles and species in late summer and, as might be expected, least numbers of both in the winter. There were 17 species (see appendix) each represented by two or more examples (in one case 32 examples) which were trapped in only one habitat and 18 species represented by two or more examples which were restricted to one season.

Table 1. Summarized results of pitfall-trapping at Loch Garten

	Total beetles	Trap-days (approx.)	Beetles per 100 trap-days	Total species	Exclusive* species
By habitat					
Closed canopy pine forest	393	5400	7	48	4
Open canopy pine forest	778	5400	14	67	4
Young pine forest	280	5400	5	36	1
Cleared area	490	5400	9	52	7
By season					
April–June	800	5400	15	57	5
July–September	938	5400	17	68	8
October–March	203	10 800	2	37	5
All data	1941	21 600	9	117	

*Species represented by at least two examples but restricted to one habitat or one season.

At the time, 20 of the species taken were not among the 600 species already recorded from the Reserve. Some of these 20 species were found by other means later in the survey but, by the end of 1987, there were still 12 species (see appendix) recorded in this exercise which were not found by any means other than pitfall-trapping.

As indicated in the appendix, the numbers of examples of individual species

(species-abundance) varied widely. The number of species with one example was greatest, with a progressive diminution in the numbers of species with more examples. As an expression of this, a plot of species-abundance (the *number of examples* of a species caught) against the species count (the *number of species* with that particular abundance) is given in Fig. 1 for which a full explanation is provided in the legend. The plot of data appears to comprise two approximately linear sections, one covering abundances from 1 to 5, the other covering higher abundances but this apparent discontinuity may simply represent an effect of sampling. Similar plots for data from each habitat have not been included in the figure for the sake of clarity but all four were similar in shape to that for all the data combined.

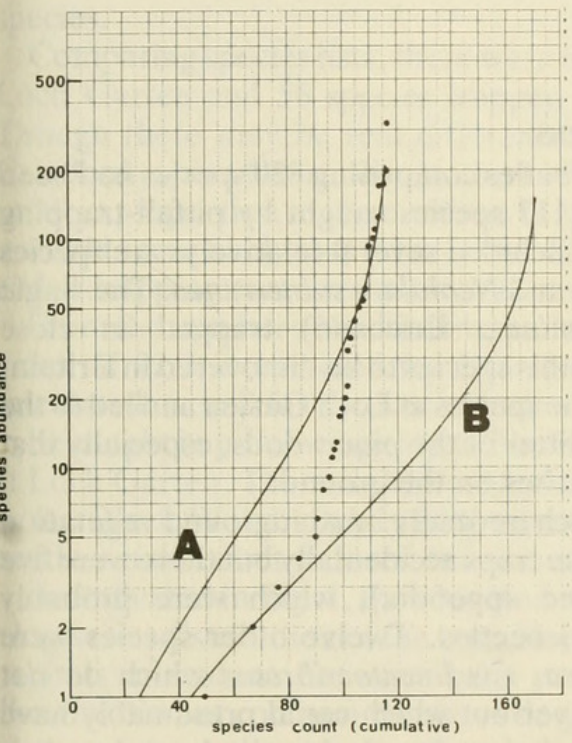

Fig. 1. Species-abundance plotted against species count. Species abundance (no. of examples of a species) is expressed as usual (Southwood, 1978) on a log-scale. Species counts (numbers of species with a particular abundance) have been plotted cumulatively to allow comparison with theoretical log-series plots, with rarer species (low species-abundance) on the left to give a positive slope. Dots represent observed data. Thus, there were 49 species of which only single examples were trapped (species-abundance = 1). There were *further* 18 species of which two examples each were trapped, giving a cumulative species count of 67 against a species abundance of 2. The cumulative plot continues up to the 117th species, of which 319 specimens were collected. Curve A is a theoretical curve derived from a log-series with diversity index $\alpha = 27.3$, as calculated from the observed data; total beetles = 1941. Curve B is a theoretical curve derived from a log-series with an arbitrary diversity index $\alpha = 45$; total beetles = 1941.

The theoretical curve which would have been obtained had the species-abundances conformed exactly to a log-series is also plotted (curve A). The α index for this curve (27.3) is that calculated from the number of beetles and number of species obtained as described by Williams (1964). The curve approximates to the plot of observed data only in the region covering common species (high species-abundance).

A curve (B) represents the theoretical curve conforming to a higher α value selected to give a curve fitting better the region of rarer beetles (low species-abundance). This curve, however, deviates considerably from the plot of observed data in the region of common species.

Table 2 presents indices of species-diversity. There is obvious correlation between the different diversity indices for a particular habitat or season and very little evidence of superiority of one over another. All measures of species-diversity indicated that this was highest in the open canopy pine forest and lowest in the young forest. Overall, more than a third of the 117 species recorded were represented by single examples and this relatively high number of singleton species occurred in all habitats and at all seasons.

Table 2. Analysis of species-diversity by habitat and by season

	Total species	William's α index	Simpson's index	Brillouin's index	No. of singleton species predicted*	observed
By habitat						
Closed canopy pine forest	48	14.3	8.3	3.6	14	25
Open canopy pine forest	67	17.6	13.8	4.2	17	33
Young pine forest	36	11.0	6.7	3.4	11	28
Cleared area	52	14.7	11.5	3.9	14	28
By season						
April–June	57	14.0	11.7	4.0	14	24
July–September	68	16.8	11.6	4.0	17	26
October–March	37	13.2	5.4	3.2	12	18
All results	117	27.3	14.4	4.5	27	49

*From the α index and the number of beetles.

Discussion

By the end of 1987, approximately 12 000 beetles comprising 820 species had been recorded from the Reserve. Only 12 of the 117 species caught by pitfall-trapping were not found by any other means but they included several relatively rare species such as *Acidota cruentata*, *Quedius fulvicollis* and *Neohilara subterranea*. The single specimen of *Atomaria ornata* (= *contaminata* Erichson) trapped in close canopy forest was only the second example of this species to be discovered in Britain. Its capture drew attention to the presence of the species at Loch Garten and led to the discovery of many more examples in ground litter of the pine woods, especially that accumulating beneath fallen or cut pine branches on the ground.

Most of the species trapped were those which normally inhabit ground vegetation or soil and which had presumably fallen into the traps accidentally but there were five species (four silphids and a *Geotrupes*—see appendix), which were probably attracted to the traps by the odour of dead beetles. Twelve other species were trapped, e.g. *Cetonia cuprea*, *Triplax russica*, *Cis lineatocribratus* which do not ordinarily spend much time in the ground layer but which could presumably have been accidentally trapped without necessarily being attracted to the traps.

The rate of capture of species (Table 1) was surprisingly low, with an overall average of about nine beetles per 100 trap-days. Even in the warmest season—late summer—the capture-rate reached an average of only 17 beetles per 100 trap-days, i.e. just over one beetle per trap per week. This rate of capture was approximately the same as that achieved (Owen, unpublished observations) by pitfall-trapping during the same time of year on two very exposed sites on the summit of Beinn Macdhui (altitude ca 1300 m).

At the start of this exercise, it was thought that the findings might reveal differences in the beetle faunas of the four habitats examined. A few species were only trapped in one of the habitats (see appendix). Thus *Cicindela campestris* was trapped only in the open area (habitat 4), which is in keeping with the habits of this species. Overall, however, the number of species showing apparent habitat preferences was small. Much larger samples would have been required to be sure that the differences were significant. Identification of seasonal difference presented a similar problem. The trapping of some species such as *Acidota crenata* and *A. cruentata* only in the winter is in keeping with the known habits of this group but again the number of species showing apparent seasonal trends was small. Species-diversity, however measured, was highest in the open canopy pine forest probably

because this site held the greatest number of different microhabitats. It was lowest among the young pine trees, perhaps because the young trees with grass between them formed the most uniform area.

Dobson (1978) has presented the results of a similar pitfall-trapping exercise carried out in the Black Wood, Rannoch, another area of old Caledonian forest. He used 74 traps continuously over a period of 14 months and caught approximately 5900 beetles of 126 species. This gives an average capture-rate of about 24 beetles per 100 trap-days which is appreciably higher than the average rate at Loch Garten. The difference could have been due to there being a higher density of beetles in the Black Wood than at Loch Garten or it may have been due to differences, such as have been described by Greenslade (1964) and Luff (1968, 1975), in the efficiency of the trapping techniques used at the two sites. For example, formalin was used in the traps at Rannoch as a preservative and Luff (1968) has shown that this attracts some species.

Comparing species lists, there were 69 species trapped at Loch Rannoch but not at Loch Garten and 56 species trapped at Loch Garten but not at Loch Rannoch. Though there may be real differences in the beetle faunas of these two areas of Caledonian pine forest, the numbers of species trapped at the two site were relatively small in proportion to the numbers of species known respectively from the areas and it would seem likely that most of the differences in species lists obtained in these two pitfall-trapping exercises were due to sampling.

From the number of beetles trapped and the number of species found, a Williams α index of 22.5 is obtained for Dobson's Black Wood data. This is less than that calculated overall for the Loch Garten data (27.3) which suggests that beetles liable to be caught in pitfall-traps in the Black Wood at Rannoch are less diverse than those at Loch Garten. There is, however, also the possibility that the formalin in the traps in the Black Wood attracted selectively some species which would have increased beetle numbers but reduced the diversity 'score' of the species trapped.

As indicated in Fig. 1, the observed species-abundances for all data did not fit well a log-series distribution of the type described by Williams. Plots of data for individual habitats or seasons have not been presented but they were similarly shaped and likewise did not conform to curves derived from a log-series distribution. The shape of the plot relating species-abundance to species count (Fig. 1) is perhaps more suggestive of a log-normal relationship (Whittaker, 1972).

The lack of close conformity of species abundance to a log-series is further illustrated (Table 2) by the numbers of singleton species observed being in every case higher than those predicted respectively from the calculated α index and the number of beetles. The same was true for the findings at Rannoch reported by Dobson—observed number of singleton species 27, predicted 22. A similar under-estimate of singleton species expected was noted by Williams (1964) in analysing data obtained by Easton (1947) relating to a sample of beetles in flood refuse. Whether these discrepancies reflect the underlying distribution of species-abundances in the population sampled or are an effect of sampling procedures remains to be determined.

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Appendix

List of species caught by pitfall trapping at Loch Garten 1983–1984

Cicindela campestris Linnaeus	32 H4 **	Catops fuliginosus Erichson	2
Cychrus caraboides (Linneaus)	44	C. nigrita Erichson	1
Carabus arvensis Herbst*	1	C. tristis (Panzer)	1
C. glabratus Paykull	172	Nicrophorus investigator Zetterstedt	101
C. problematicus Herbst	169	N. vespilloides Herbst	1
C. violaceus Linnaeus	60 S2	Thanatophilus rugosus (Linnaeus)	2 H4
Leistus rufescens (Fabricius)	5	Oiceoptoma thoracicum (Linnaeus)	8 H4
Notiophilus aquaticus (Linnaeus)	1	Silpha atrata Linnaeus	55
N. biguttatus (Fabricius)	6	Stenichnus collaris (Muller & Kunze)	1
Trechus obtusus Erichson	11	Proteinus brachypterus (Fabricius)	20 S3
Pterostichus melanarius (Illiger)	108	P. crenulatus Pandelle	2 H1
P. nigrita aggr.	1	P. ovalis Stephens	2
P. oblongopunctatus (Fabricius)	123	Anthobium unicolor (Marsham)	319
P. versicolor (Sturm)*	5 H4	Olophrum fuscum (Gravenhorst)*	2
Calathus erratus (Sahlberg, C. R.)	1	O. piceum (Gyllenhal)	12
C. micropterus (Duftschmid)	50	Acidota crenata (Fabricius)	1 S3
C. piceus (Marsham)	2	A. cruentata Mannerheim	5 S3
Harpalus latus (Linnaeus)	2 H4	Omalium rugatum Mulsant & Rey	3
Bradycellus harpalinus (Serville)	1	Stenus impressus Germar	2
B. ruficollis (Stephens)	1	Lathrobium brunnipes (Fabricius)	2 H1 S3
Megasternum obscurum (Marsham)	17	Othius laeviusculus Stephens	1
Sphaerites glabratus (Fabricius)	2	O. myrmecophilus Kiensenwetter	3 H2
Leiodes obesa (Schmidt, W.L.E.)	1	O. punctulatus (Goeze)	23
Agathidium convexum Sharp	4	Xantholinus laevigatus Jacobsen*	9
A. laevigatum Erichson	3	X. linearis (Oliver)	2 S3
A. rotundatum Gyllenhal	4	Philonthus decorus (Gravenhorst)	18
Nargus wilkini (Spence)	4 H2 S2	P. fimetarius (Gravenhorst)	1
Choleva glauca Britten*	1	P. marginatus (Strom)	1
Sciodrepoides watsoni (Spence)	4 S2		

P. puella von Nordmann	5 S2	Cetonia cuprea Fabricius	1
P. splendens (Fabricius)	1	Byrrhus fasciatus (Forster)*	4
Platydracus stercorarius (Oliver)*	1	B. pilula (Linnaeus)	2 H3 S1
Staphylinus brunnipes Fabricius	13	Melanotus erythropus (Gmelin)	4
S. erythropterus Linnaeus	34	Selatosomus impressus (Fabricius)	1
Quedius curtipennis Bernhauer	1	Dalopius marginatus (Linnaeus)	3
Q. fuliginosus (Gravenhorst)	1	Epuraea pusilla (Illiger)	1
Q. fulvicollis (Stephens)*	1	E. thoracica Tournier	1
Q. mesomelinus (Marsham)	1	Rhizophagus depressus (Fabricius)	4
Q. molochinus (Gravenhorst)	9 S2	R. dispar (Paykull)	5
Q. nigriceps Kraatz	1	Cryptophagus scanicus (Linnaeus)	2
Q. tristis (Gravenhorst)	2	C. setulosus Sturm	54
Mycetoporus rufescens (Stephens)	2	Antherophagus nigricornis (Fabricius)*	1
M. splendidus (Gravenhorst)	1	Atomaria contaminata Erichson	1
Lordithon thoracicus (Fabricius)	1	A. bella Reitter	1
Tachinus elongatus Gyllenhal	1	Triplax russica (Linnaeus)	3 H2 S2
T. marginellus (Fabricius)	2	Coccinella hieroglyphica Linnaeus	1
T. pallipes (Gravenhorst)	1	Dienerella elongata (Curtis)	3 H2
T. proximus Kraatz	1	Corticaria linearis (Paykull)	1
T. signatus Gravenhorst	94	Cis lineatocribratus Mellie*	1
Autalia impressa (Olivier)	4 S2	Lochmaea suturalis (Thomson, C. G.)	5 H4 S1
Neohilara subterranea (Mulsant & Rey)*	2 H2	Otiorhynchus nodosus (Muller, O. F.)	1
Geostiba circellaris (Gravenhorst)	1	O. scaber (Linnaeus)	2 H2 S1
Atheta harwoodi Williams	1	Strophosomus melanogrammus (Forster)	1
A. aquatica (Thomson, C. G.)	1	Hylobius abietis (Linnaeus)	3 S1
A. oblita (Erichson)	1	Pissodes pini (Linnaeus)	1
A. repanda (Mulsant & Rey)	1	Hylurgops palliatus (Gyllenhal)	8 H1 S1
Drusilla canaliculata (Fabricius)	1	Hylastes brunneus (Erichson)	3 H1 S1
Zyras humeralis (Gravenhorst)	1		
Oxypoda spectabilis Markel*	1		
Geotrupes stercorosus (Scriba)	198		
Aphodius ater (Degeer)	1		

*Species not found at Loch Garten except by pitfall trapping; **no. of examples trapped. Hn species trapped more than once but only in habitat n; Sn species trapped more than once but only in season n.