The effect of deciduous afforestation on carabid ground beetle communities on a coal mine spoil heap near Cannock, Staffordshire, England

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SUMMARY

A 50 ha mine spoil heap was flattened, covered with top-soil, and re-seeded, subsequently native deciduous trees were planted in 1990, 1994 and 1996. Carabid beetle species richness and diversity tended to increase with time after planting. The species composition of the ground flora appeared to have little effect on carabid distribution, at least in the early years of monitoring.

BACKGROUND

Derelict land is potentially a valuable conservation resource and the restoration of these degraded or man-made habitats is currently a subject of much interest. Designing management strategies to maximise the biodiversity of such sites is an important conservation goal.

Afforestation is considered to be one method of improving such sites' conservation value and nationwide projects such as the Community Forests scheme have been implemented to help achieve this. Community Forests were initiated in 1989 by the Countryside Commission, the Forestry Commission and Local Authorities as a response to a national need to diversify land-use. The Forest of Mercia is one of 12 'community forests' being developed across England. It currently covers 23,800 ha of southern Staffordshire and parts of the West Midlands. It aims to use multi-purpose forestry to improve the countryside around urban areas and restore sites scarred by industrial dereliction. This work has included the re-afforestation of exhausted mine sites on the semi-rural Midlands coalfield. Although tree-planting on degraded sites is widely assumed to benefit wildlife, there have been few scientific investigations to quantify this in biodiversity terms. In terms of invertebrates, many previous studies have concentrated on the invertebrate communities of wasteland undergoing primary succession, such as reclaimed coal waste, strip mines, urban wasteland, landfills and polders.

The Carabidae is one of the most species of beetle families with approximately 352 species occurring in the British Isles. They are also relatively easily identifiable and may be effectively investigated using short sampling periods. This makes the group a valuable indicator of biological diversity. This study investigated the effect of planting deciduous trees on an old mine site upon the carabid beetle community. The findings relate to management issues concerning the development and restoration of derelict land through forestry and the usefulness of using the Carabidae as biodiversity indicators.

ACTION

Study site: The study was conducted on the spoil heap of Wyrley No.3 colliery, near Cannock, Staffordshire in the summer of 1997. The site covers an area of approximately 50 ha and is surrounded by agricultural land. Coal extraction ceased in 1962. The spoil heap was subsequently flattened, covered with top-soil and re-seeded. The area was allowed to regenerate naturally into ruderal grassland before the first planting of mixed deciduous trees in 1990. At this time, around a quarter of the total area was afforested. Further planting of similarly sized areas was undertaken in 1994 and 1996. The remaining area of the site has been allowed to regenerate naturally.

Table 1a. Tree species recorded in the six planted 100m² plots in years 1, 3 and 7 after planting, two replicates (A/B) each.

Plot:	1 A	1 B	3 A	3 B	7 A	7 B	Plot occurrence
Species							
Oak *Quercus robur*	2				11		2
Ash *Fraxinus excelsior*	6	5	6	1			4
Field maple *Acer campestre*		4	3	2		12	4
Willow *Salix spp.*			1	4			2
Whitebeam *Sorbus aria*			1				1
Alder *Alnus glutinosa*				4	5	2	3
Hazel *Corylus avellana*				1		1	2
Birch *Betula spp.*					1	6	2
Hawthorn *Crataegus monogyna*					2	2	2
Total	8	9	11	12	19	23	

Table 1b. Ground flora recorded in the eight plots. Plots in four age classes: no trees (0), 1-, 3- and 7-year old trees, 2 replicates (A/B) each. Individual species scored out of 250 (10 x score/25).

Plot:	0A	0B	1A	1B	3A	3B	7A	7B	Plot occurrence
Species									
False oat grass *Arrhenatherum elatius*	0	0	0	0	0	9	14	0	2
Tufted hair-grass *Deschampsia cespitosa*	30	23	14	0	15	18	70	32	7
Sweet vernal *Anthoxanthum odoratum*	29	16	0	0	0	0	0	0	2
Cock's-foot *Dactylis glomerata*	0	0	0	0	0	15	0	3	2
Tall fescue *Fesctuca arundinacea*	83	33	81	83	21	28	40	48	8
Red fescue *F. rubra*	164	198	141	120	108	102	36	57	8
Common couch *Elymus repens*	10	1	0	0	11	8	7	7	6
Fat hen *Chenopodium album*	0	0	0	0	0	0	1	0	1
Spear thistle *Cirsium vulgare*	3	0	0	0	0	0	11	0	2
Tufted vetch *Vicia cracca*	1	4	12	5	1	21	28	5	8
Yellow vetch *V. lutea*	37	61	61	79	82	51	0	0	6
Hairy tare *V. hirsuta*	0	0	0	0	3	0	0	0	1
Hogweed *Heracleum sphondylium*	0	0	0	0	0	0	1	1	2
Black knapweed *Centaurea nigra*	6	0	0	0	0	0	6	8	3
Ribwort plantain *Plantago lanceolata*	23	1	0	0	0	0	2	0	3
Greater stichwort *Stellaria holostea*	0	0	0	0	9	0	3	4	3
Meadow buttercup *Ranunculus acris*	0	0	0	0	0	0	0	2	1
Creeping buttercup *R. repens*	12	0	3	0	2	5	0	11	5
Broad-leaved dock *Rumex obtusifolius*	0	2	0	1	0	1	1	0	4
Hairy St. John's wort *Hypericum hirsutum*	0	0	0	42	0	0	0	7	2
White clover *Trifolium repens*	54	59	37	0	73	82	0	0	5
Red clover *T. pratense*	0	7	0	0	0	0	0	0	1
Goosegrass *Galium aparine*	0	0	0	0	0	0	1	0	1
Ox-eye daisy *Leucanthemum vulgare*	0	0	0	0	0	0	0	20	1
Common sorrel *Rumex acetosa*	1	0	0	0	0	0	0	1	2
Black medick *Medicago lupulina*	35	12	5	0	0	0	0	0	3
Dandelion *Taraxacum agg.*	3	0	0	0	0	0	0	0	1
Coltsfoot *Tussilago farfara*	3	0	0	0	0	0	0	0	1
Yarrow *Achillea millefolium*	10	0	0	0	0	0	0	0	1
BARE GROUND	0	2	12	16	17	7	0	0	6

Table 2a. Species and numbers of carabids caught by hand searching. Plots in four age classes: no trees (0), 1-, 3- and 7-year old trees, 2 replicates (A/B) each (total search time = 13.3 hours).

Plot:	0A	0B	1A	1B	3A	3B	7A	7B	Total
Species									
Demetrias atricapillus	0	1	4	3	8	7	16	21	60
Bradycellus verbasci	0	0	1	1	3	5	10	11	31
Pterostichus strenuus	1	2	1		5	3	3	6	21
P. nigrita								1	1
P. madidus									
P. melanarius									
P. niger									
P. macer	1		1	1	7	5	6	8	29
Bembidion obtusum						1			1
Acupalpus consputus							1	2	3
Leistus rufescens							2	1	3
L. ferrugineus				1					1
L. rufomarginatus					1	1		1	3
Harpalus aeneus									
H. rufipes									
Calathus melanocephalus									
C. fuscipes						2			2
Dromius melanocephalus				1					1
Amara familiaris									
A. aulica					1				1
A. similata					1				1
Notiophilus bigattatus		1		1	1		1	1	5
Badister bipustulatus	2		3		2	2	1		10
Trechus quadristriatus									
Carabus violaceus									
Cychrus caraboides									
Total									**173**

Study plots: A total of eight study plots were selected, two in each of the four age-classes present (unplanted, one-year-old trees, three-year-old trees and seven-year-old trees). The eight plots were spread about evenly across the site (each separated by a gap of approximately 200 m). Each plot measured 10 x 10 m. In each plot, the number and species of tree was recorded and the ground flora surveyed. Some environmental variables (soil pH, soil organic matter content and canopy cover) were also recorded.

The carabid community was sampled over a 6 week period using a combination of pitfall trapping and hand searching.

CONSEQUENCES

This study illustrates that carabid communities change across a successional gradient during the early stages of woodland development. The results of the plant surveys are summarised in Tables 1a and 1b, and the carabid beetle surveys in Tables 2a and 2b. Carabid beetle species richness and diversity tended to increase with time after planting (Table 3). Environmental gradients in the study were short as topographic and abiotic variation was low (Table 4). This low level of variation in physical conditions might imply that species would not be restricted to local patches and could potentially occur anywhere in the study area.

Table 2b. Species and numbers of carabids caught by pitfall traps. Plots in four age classes: no trees (0), 1-, 3- and 7-year old trees, 2 replicates (A/B) each.

Plot:	0A	0B	1A	1B	3A	3B	7A	7B	Total
Species									
Demetrias atricapillus			1						1
Bradycellus verbasci			1				8	5	14
Pterostichus strenuus	1		1		1	3	4	3	18
P. nigrita		1				1			2
P. madidus	5	1	23	6	5	4	5	23	73
P. melanarius	3	1	9		2	5	6	5	31
P. niger	18	28	69	29	20	26	22	26	238
P. macer		1					4	1	6
Bembidion obtusum							2		2
Acupalpus consputus									
Leistus rufescens				1		1			2
L. ferrugineus							1		1
L. rufomarginatus						1			1
Harpalus aeneus	2		1	3	5			2	16
H. rufipes							1		1
Calathus melanocephalus		1			1	1			3
C. fuscipes	2	3	1	2	7	12		2	29
Dromius melanocephalus									
Amara familiaris	1	1							2
A. aulica								1	1
A. similata									
Notiophilus bigattatus									
Badister bipustulatus		1				1			2
Trechus quadristriatus	1						3	6	10
Carabus violaceus	1								1
Cychrus caraboides	1						1	2	3
Total									**454**

Effect of tree cover: Afforestation significantly increased carabid species richness. The quadrat-searched sample showed significantly higher richness in planted areas than unplanted ones and richness increased with age after planting (Table 3). The pitfall-trapped sample failed to replicate this result but some of this disparity may be attributed to an increased propensity of pitfall-trapped species to aggregate. However, the diversity of the pitfall samples does significantly increase with age after planting, older areas being more diverse. Considering these two factors in combination, it can be concluded that the planting of native deciduous trees on the site has had the positive effect of increasing the richness and diversity of the carabid fauna.

Ground flora: The species composition of the ground flora appeared to have little effect on carabid distribution. This is perhaps not surprising as the ground flora was relatively species poor and dominant species e.g. red fescue *Festuca rubra*, consistently occurred across much of the site.

Environmental conditions: Environment changes were led by the changing physiognomy of the developing woodland. As trees age, conditions appear to become more favourable for a number of carabid species. Such conditions may include increased structural complexity, increased soil organic matter/plant litter and increased canopy cover leading to a more favourable microclimate (Table 4). Increased cover is important for diurnal carabids (which formed a large

Table 3. Species richness and Shannon's diversity indices for the eight study plots. QS = quadrat search, PT = pitfall traps, Total = pooled data.

Plot	QS richness	QS diversity	PT richness	PT diversity	Total richness	Total diversity
0A	3	2.36	10	1.67	11	1.85
0B	3	2.36	9	1.10	11	1.23
1A	5	1.42	8	1.04	10	1.32
1B	6	1.64	6	1.10	12	1.69
3A	9	1.91	7	1.54	14	2.26
3B	7	1.77	10	1.62	16	2.09
7A	9	1.74	12	2.00	16	2.36
7B	9	1.67	10	1.80	15	2.24

proportion of the hand-collected sample) as they may otherwise be vulnerable to predation, particularly by birds. The increased depth of leaf litter also benefited some woodland species that habitually forage in leaf litter.

Carabids and ecological site evaluation: Applied research has advocated the use of invertebrates in ecological site evaluation. This study supports this approach and an additional benefit was that the methods employed were considered cost-effective. The study however questions the relevance of carabid research that employs a single sampling technique as the species caught varied significantly between the two methods employed (Figure 1). A combination of both is required to effectively monitor high and low density species. A standard sampling technique would help to minimise the variation imposed by pitfall trapping.

Table 4. Environmental variables recorded in the eight study plots.

Plot	Soil organic matter (% +/- sd)	Canopy cover (%)	pH
0A	2.10 +/- 0.89	0	7.1 - 7.4
0B	1.86 +/- 1.02	0	7.1 - 7.4
1A	3.21 +/- 1.19	7	7.1 - 7.4
1B	2.79 +/- 0.97	5	7.4 - 7.7
3A	4.58 +/- 2.05	12	7.4 - 7.7
3B	4.30 +/- 1.45	14	7.1 - 7.4
7A	6.89 +/- 2.37	24	6.8 - 7.1
7B	6.56 +/- 2.90	27	7.1 - 7.4

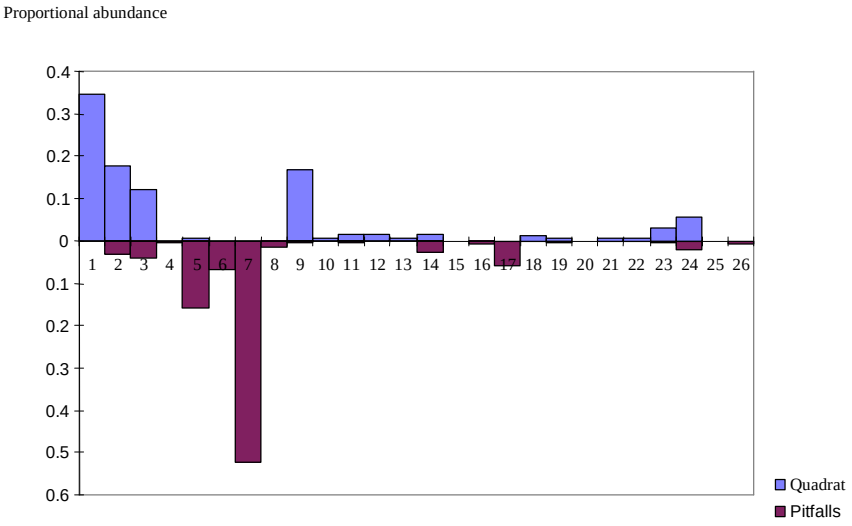

Figure 1. Comparison of sampling methods. Each bar represents the proportion of an individual species (number 1 to 26) in each sample.

Conclusions: The results of this study illustrate that the carabid diversity of degraded areas, and biodiversity as a whole, may be improved by deciduous afforestation using native trees and shrubs. Afforestation increases the structural complexity of the landscape, increases microsite variation and produces a greater degree of spatial heterogeneity. However, when drawing up management plans due regard should be taken for species of conservation interest already on site and their habitat requirements.