Significantly Higher Carabid Beetle (Coleoptera: Carabidae) Catch in Conventionally than in Organically Managed Christmas Tree Plantations[1]

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Abstract Carabid beetles play an important role as consumers of pest organisms in forestry and agriculture. Application of pesticides may negatively affect abundance and activity of carabid beetles, thus reducing their potential beneficial effect. We investigated how abundance and diversity of pitfall trapped carabid beetles (Coleoptera, Carabidae) varied between conventionally and organically managed Caucasian Fir (*Abies nordmanniana* (Stev.)) plantations, in northern Zealand, Denmark. We recorded significantly higher numbers of carabid beetle specimens and species at conventionally than at organically managed sites. Carabid beetle abundance and richness did not decline more between two sampling periods at sites with pesticide application than at unamended sites. Apparently, the amount of bare ground, which dominated in the conventionally managed, herbicide treated sites, correlated closely with the number of recorded carabid beetle specimens. Thus we attribute the higher catch at the conventionally managed sites to a higher activity at bare ground due to lack of food and a larger potential for invasion at the bare ground sites of opportunistic species from surrounding arable areas.

Key words Christmas trees, *Abies nordmanniana* (Stev.), organic management, conventional management, pesticides

Carabid beetles are beneficial as they consume significant amounts of pest organisms, most species are generalists, though some are specialists, e.g. *Loricera pilicornis* (F.) feeding on microarthropods and *Cychrus caraboides* (L.) feeding on snails. In collaboration with other generalist arthropods, e.g. wolf spiders, they keep pest organism levels tolerable in organic farming and forestry (Sunderland et al. 1997, Kromp 1999). Thus, potential negative effects on the carabid beetles are important to consider when choosing management strategies in forestry and agriculture. Field application of insecticides may reduce carabid beetle numbers seriously, though the effects vary greatly between species (Vickerman and Sunderland 1977, Navntoft et al. 2006). Apart from direct effects, carabid beetles may be intoxicated from eating other animals poisoned by insecticides (Mauchline et al. 2004). According to Taylor et al.

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(2006), herbicides indirectly affect carabid beetles negatively, since a low diversity of plants often leads to a low diversity of carabid beetles.

Agriculture and forestry has a major impact on landscapes and biodiversity in Europe. Intensive land management leads to loss of habitats and application of pesticides may directly affect survival of e.g. terrestrial arthropods in the affected areas (Moreby et al. 2006). An anecdotal assumption supports the view that organically managed areas generally harbor a richer biodiversity than conventionally managed. Nevertheless, systematic, statistically founded studies on this matter are sparse and have reached contradictory conclusions (Hole et al. 2005).

In Scandinavian Christmas tree plantations, weeds are usually controlled with herbicides. However leaching of herbicides into the environment is a serious problem (Sæbø et al. 2009), and in recent years the public demand for organically grown products has increased (Gunnersen and Bisgaard 2010). Denmark has the second largest production of Christmas trees in Europe with *Abies nordmanniana* (Steven) (Caucasian Fir) and *Abies procera* Rehder (Noble Fir) as the dominant species. Denmark produces approx. 10 million Christmas trees annually, and about 1% of these are grown organically. There are very few studies dealing with the effect of conventional and organic management on biodiversity in coniferous plantations.

Carabid beetles are well suited organisms for biodiversity analyses (Rainio and Niemela 2003). Thus, their species composition depends strongly on ecological/environmental factors; as most carabid beetle species are predators, their occurrence will reflect the organisms present at lower trophic levels. Furthermore, they are relatively easy to catch and identify, and many habitats are rich in both specimens and species (Thiele 1977). There is much information on the effects of different agricultural practices on ground beetles (Dennis et al. 1997, Thomas and Marshall 1999, Cole et al. 2002, Döring et al. 2003, Irmler 2003). Also, several studies have used carabid beetles as bio-indicators to compare biodiversity on organic and conventional farmland (see Holland 2002). However, these studies have reached contradictory conclusions. Shah et al. (2003) found higher specimen numbers in organically managed farmland than in conventional fields, whereas species numbers were virtually identical. By contrast, a Swedish study suggested a larger number of carabid beetle species in conventionally managed than in organically managed fields (Weibull and Ostman 2003). Purtauf et al. (2005) found that landscape characteristics were more important than management type for the diversity of carabid beetles. Despite the apparently contradictory findings, it is generally assumed that organically managed fields contain the larger number of both species and specimens (Döring and Kromp 2003, Hole et al. 2005). Differences in carabid diversity between organically and conventionally managed coniferous plantations are virtually unexplored, although some studies concerning arthropods in general have been conducted. Thus, Ravn and Nielsen (2006) found that organically grown trees harbored more different groups of arthropods than did conventionally grown trees, possibly because the organically raised trees were more vulnerable to pests.

Conventional Christmas tree production is extremely pesticide demanding, and, thus, potentially, has strong negative effects on the environment. Here, we used carabid beetles as biological indicators of impacts and report results from an investigation of their diversity and abundance in organically and conventionally managed plantations of Caucasian Fir (*A. nordmanniana*). We sampled twice, once in spring and once in summer. Between the samplings the conventionally managed plantations were sprayed with pesticides. We hypothesized (1) that organically managed plantations contain the largest number of both species and specimens, and (2) that there would be a greater relative difference between spring and summer samples on conventional sites as a result of intervening pesticide treatment.

Materials and Methods

Locations. We carried out the investigation in four organically and four conventionally managed Caucasian Fir (*A. nordmanniana*) plantations located in Northern Zealand, Denmark (Table 1). We selected plantations as close to each other as possible as to minimize the influence of geography and weather. Consumers want perfectly proportioned, symmetrical trees. Hence, trees are planted with a distance of approx. 120 cm to facilitate weed- and pest-control and to avoid disturbance from neighbor trees. The conventionally managed locations received herbicides, insecticides and fertilizers, except location E that received no insecticides, whereas the organically managed locations received no chemical amendments, but manual pest- and weed-control. The major visible difference between the two management types is the much more developed herbal layer in the organically managed plantations. To attain similarity between the plantations (Day and Carthy 1988), we selected plantations which only contained 5 - 12 year old trees; none of the plantations had any grazing animals. The exact position of each location was determined using GPS. The sizes of the plantations were calculated using the website "arealinfo.dk" that provides satellite photographs and an area measuring tool. We also used satellite photographs to determine the landscape-structure (the percentage of forests, fields and garden areas) in the surrounding landscape within a 400 m radius from the center of each plantation.

Pitfall traps. At each of the eight locations, we selected three sample areas. We placed five pitfall traps in each sample area at each sampling, that is, 15 pitfall traps per location, per sampling. To optimize the catch and to ensure sampling homogeneity, we placed the sampling areas at least ten meters from each other, evenly spread across the particular plantation. In each sample area, we placed the five pitfall traps between 2 and 2.5 m from each other. Each trap was placed exactly at the periphery of a tree crown. We sampled in two periods, spring and summer. Spring sampling took place from May 15 to May 22, 2008, and summer sampling from July 22 to July 29, 2008. Between the sampling periods pesticides were applied to the conventionally managed plantations. The pitfall traps were cylindrical plastic containers with a diameter of 9.3 cm and a depth of 7.0 cm. We filled the traps with 150 mL of a mixture of water (30%) and ethylene glycol (70%) as to preserve the catch and minimize vaporization. Further, we added a few drops of detergent to reduce the surface tension of the mixture, to ensure that small sized beetles did not escape. We carefully ensured that the top of the pitfall traps were in level with the ground. At harvest, the beetles were sorted out and placed in 70% alcohol until identification was performed. The beetles were identified using Hansen (1968) and Lindroth (1985, 1986).

Vegetation. We used the "Raunkiær circle method" for vegetation analysis (Raunkiær 1910). A circle (0.1 m^2) was positioned randomly 10 times, at each sample area, at each sampling, and the percentages of vascular plants, mosses, bare ground and dead plant material in the circle was estimated, we then calculated the average of the replicates for each plantation.

Data analysis. The carabid beetles from the five pitfall traps at each sample area were merged and each of the merged samples was considered a replicate. Thus, we

Table 1. Basic ecological and geographical data four organically and four conventionally managed Christmas tree plantations, where Carabid beetles were collected.

Location	Management*	Geodetic coordinates**	Plantation size (ha)	Landscape in a 400 m radius (%)		
				Forest	Field	Garden
A (Egelund)	Organic	55°57.542' N, 12°21.116' E	1.2	71	23	6
B (Solskinbakker)	Organic	55°54.007' N, 12°22.249' E	0.3	84	12	4
C (Brødeskov)	Organic	55°53.071' N, 12°18.486' E	1.6	74	25	1
D (Uggerløse)	Organic	55°50.114' N, 12°14.153' E	2.8	76	23	1
E (Hornbæk)	Conventional	56°04.473' N, 12°26.254' E	0.5	66	30	4
F (Hillerød)	Conventional	55°56.110' N, 12°22.099' E	0.5	63	30	7
G (Lynge)	Conventional	55°51.174' N, 12°15.565' E	0.4	21	75	4
H (Slangerup)	Conventional	55°50.968' N, 12°08.705' E	2.1	18	73	9

* The conventionally managed locations received herbicides, insecticides and fertilizers, except location E that received no insecticides, whereas the organically managed locations received no chemical amendments, but manual pest- and weed-control.

** The datum for the geodetic coordinates is WGS84.

obtained three replicates from each plantation from each period, i.e. 48 replicates in total. We compared the number of specimens and species as well as Simpson's index of diversity ($1-\Sigma\{n_i[n_i - 1]\}/\{N[N-1]\}$), where n_i is the total number of individuals of species "i", and N is the total number of individuals (Magurran 2004) using the SAS Enterprise Guide 4.1 interface to the SAS 9.1 package (SAS 2002). Data for beetle abundance were log-transformed before analysis to obtain variance homogeneity. The effect of management type (organic versus conventional) and season (spring versus summer) was analyzed by applying a mixed model ANOVA with season as the repeated variable and each of the 24 replicates as subjects. We calculated the Product-Moment Correlation Coefficients (Fowler and Cohen 1990) to find possible significant correlations between beetle abundance and diversity and environmental parameters vegetation data, distance to nearest plantation edge, plantation size, and landscape-structure.

Results

We caught and identified 1140 carabid beetle specimens representing 54 species (Table 2). Significantly more carabid beetle specimens were collected from the conventionally managed plantations than from the organically managed ($F = 20.12$; $df = 1, 20$; $P = 0.0002$). The total number of specimens found at the spring sampling was significantly higher than the total number found at the summer sampling ($F = 18.51$; $df = 1, 20$; $P = 0.0003$). Likewise, significantly more species were found in the conventionally managed plantations than in the organically managed ($F = 14.93$; $df = 1, 20$; $P = 0.0008$), and in the spring sampling than in the summer sampling ($F = 13.14$; $df = 1, 20$; $P = 0.0015$). Contrary to our expectations, we found no significant interaction between cultivation method and season regarding neither specimen ($F = 1.65$; $df = 1, 20$; $P = 0.21$) nor species number ($F = 0.56$; $df = 1, 20$; $P = 0.46$).

We recorded the highest number of specimens at the conventionally managed plantation H (Table 3). The conventionally managed plantation E, that received no insecticides, yielded the highest total number of species, 30, and second highest number of individuals (Table 3). The lowest total number of species, 6, and specimens were recorded at the organically managed plantation D.

The most abundant species was *Harpalus rufipes* (De Geer), with 273 specimens, which were, however, almost exclusively found at the conventionally managed sites, with only five specimens from the organically managed sites. The second most abundant species, *Bembidion lampros* (Herbst), with 155 specimens, was also almost exclusively found at the conventionally managed sites. *Nebria brevicollis* (F.) was also very abundant in the conventionally managed sites (97 specimens) and was apparently absent at the organically managed sites. The genera *Agonum* and *Notiophilus* were also found exclusively at the conventionally managed sites, except for three specimens of *Notiophilus* spp. recorded from plantation C. Plantation E with no insecticide amendment differed somewhat from the other conventionally managed plantations; it harbored several species of *Amara* spp. and *Carabus* spp. The vast majority of *H. tardus* (Panzer) was also collected from plantation E.

The organically managed plantations had a different distribution of carabid beetles than did the conventionally managed; most importantly, no species had any profound dominance. However, *Harpalus latus* (L.) and *Poecilus versicolor* (Leske) were predominantly found on the organic plantations. Examples of species only found at

Table 2. Total list of carabid beetle species collected from four organically and four conventionally managed Christmas tree plantations.

Species*	Organic spring	Organic summer	Conventional spring	Conventional summer
Abax parallelepipedus (Piller and Mitterpacher, 1783)	1	0	0	0
Agonum fuliginosum (Panzer, 1809)	0	0	1	0
Agonum muelleri (Herbst, 1784)	0	0	4	0
Amara aenea (De Geer, 1774)	0	0	1	2
Amara aulica (Panzer, 1797)	0	0	0	1
Amara bifrons (Gyllenhal, 1810)	0	0	0	6
Amara communis (Panzer, 1797)	2	0	0	0
Amara consularis (Duftschmid, 1812)	0	0	2	1
Amara fulva (Müller, 1776)	0	0	0	1
Amara plebeja (Gyllenhal, 1810)	0	0	1	0
Amara spreta Dejean, 1831	0	7	0	0
Anchomenus dorsalis (Pontoppidan, 1763)	0	0	3	0
Asaphidion pallipes (Duftschmid, 1812)	0	0	1	2
Badister lacertosus Sturm, 1815	1	0	0	0
***Bembidion lampros* (Herbst, 1784)**	**3**	**0**	**152**	**0**
Bembidion quadrimaculatum (Linnaeus 1761)	1	0	2	1
Bradycellus verbasci (Duftschmid, 1812)	0	1	2	4

Table 2. Continued

Species*	Organic spring	Organic summer	Conventional spring	Conventional summer
Calathus erratus (Sahlberg, 1827)	0	0	3	2
Calathus fuscipes (Goeze, 1777)	0	0	3	1
Calathus melanocephalus (Linnaeus, 1758)	1	2	0	4
Calathus rotundicollis Dejean, 1831	0	0	0	1
Carabus coriaceus Linnaeus, 1758	0	0	0	3
Carabus hortensis Linnaeus, 1758	2	0	6	2
Carabus nemoralis **Müller, 1764**	**1**	**0**	**22**	**5**
Carabus violaceus Linnaeus 1758	1	0	0	3
Clivina fossor **(Linnaeus 1758)**	**8**	**0**	**16**	**0**
Dyschirius globosus (Herbst, 1784)	0	0	3	0
Epaphius secalis (Paykull, 1790)	0	1	0	1
Harpalus affinis **(Schrank, 1781)**	**0**	**0**	**54**	**18**
Harpalus latus **(Linnaeus, 1758)**	**21**	**7**	**6**	**2**
Harpalus laevipes Zetterstedt, 1828	2	0	2	0
Harpalus rubripes (Duftschmid, 1812)	1	0	5	0
Harpalus rufipes **(De Geer, 1774)**	**4**	**1**	**121**	**147**
Harpalus tardus **(Panzer, 1797)**	**2**	**0**	**43**	**4**
Leïstus ferrugineus (Linnaeus, 1758)	0	1	6	0

Table 2. Continued

Species*	Organic spring	Organic summer	Conventional spring	Conventional summer
Loricera pilicornis (Fabricius, 1775)	0	0	2	1
***Nebria brevicollis* (Fabricius, 1792)**	**0**	**0**	**96**	**1**
Notiophilus aquaticus (Linnaeus, 1758)	0	1	4	2
Notiophilus biguttatus (Fabricius, 1779)	0	0	3	0
Notiophilus germinyi Fauvel, 1863	0	0	0	2
Notiophilus palustris (Duftschmid, 1812)	2	0	0	0
Ophonus rufibarbis (Fabricius, 1792)	0	0	0	1
Panagaeus cruxmajor (Linnaeus, 1758)	0	0	1	0
Poecilus lepidus (Leske, 1785)	0	0	2	0
***Poecilus versicolor* (Sturm, 1824)**	**60**	**0**	**9**	**0**
***Pterostichus melanarius* (Illiger, 1798)**	**18**	**26**	**5**	**33**
***Pterostichus niger* (Schaller, 1783)**	**2**	**21**	**0**	**74**
Pterostichus oblongopunctatus (Fabricius, 1787)	5	3	1	0
Pterostichus strenuus (Panzer, 1796)	2	0	4	0
Stomis pumicatus (Panzer, 1796)	4	1	0	0
Syntomus truncatellus (Linnaeus, 1761)	0	0	1	0
Synuchus nivalis (Panzer, 1797)	0	1	0	6
Trichocellus placidus (Gyllenhal, 1827)	5	0	0	0

Table 2. Continued

Species*	Organic spring	Organic summer	Conventional spring	Conventional summer
Total number of specimens	149	73	587	331
Total number of species	23	13	33	29

* Species for which criteria for comparing numbers in the four situations using a Chi-square test are fulfilled (i.e. expected frequencies for the four situations > 5) are marked with bold. For all these species Chi-square analysis showed significant differences between situations with $P < 0.0001$.

the organically managed sites, but only in small numbers, are *Trichocellus placidus* (Gyllenhal), *A. spreta* Dejean and *Stomis pumicatus* (Panzer).

The average Simpson's diversity index (Table 4) was not significantly affected by management ($F = 0.02$; $df = 1, 12$; $P = 0.88$). The diversity found in the summer samplings was significantly lower ($F = 8.98$; $df = 1, 12$; $P = 0.02$) than in the spring samplings. There was no significant interaction in Simpson's diversity indices between cultivation method and season ($F = 1.45$; $df = 1, 12$; $P = 0.27$).

The conventionally managed, herbicide treated sites had a sparse cover of vascular plants (Table 3), though some mosses occurred. The greater part of sites F and G were covered by withered plant material. At locations G and H, pine branches had been placed on the ground to inhibit weed growth, and thus these plantations had the smallest percentage of vascular plants. The organically managed plantations were predominantly and densely covered with grasses. A major difference between the conventionally managed and the organically managed sites was that the percentage of bare ground was very small at the organically managed plantations as compared with the conventional plantations. Among the Product-Moment Correlation Coefficients (Table 5), the percentage of bare ground by far had the most significant effect. Thus, percentage of bare ground explained 69% of the variation in beetle abundance (Fig. 1).

Discussion

We found significantly higher numbers of both carabid beetle species and specimens at the conventionally managed sites than at the organically managed. To discuss occurrence of particular species, and its significance, we selected the species from Table 2 for which a Chi-square-comparison was meaningful (i.e. expected frequencies for the four situations > 5, Fowler and Cohen, 1990). For all these species Chi-square analysis showed significant differences between situations with $P < 0.0001$ (see Table 2). The two most abundant species in our study, *H. rufipes* and *B. lampros*, occurred in high numbers at the conventionally managed sites. These are common species in agricultural fields and prefer open areas with a relatively high amount of light (Lindroth 1985, 1986). *H. rufipes* is omnivorous and a facultative seed eater (Lindroth 1986), whereas *B. lampros* is an obligate carnivore (Lindroth 1985). Other species that occurred significantly more often in the conventional fields were *Carabus nemoralis* Müller, *Clivina fossor* (L.), *H. affinis* (Schrank), *H. tardus* (Panzer),

Table 3. Basic parameters at four organically managed (A-D) and four conventionally managed (E-H) Christmas tree plantations where Carabid beetles were collected.

	Carabid beetle species*		Carabid beetle specimens*		Vegetation data (%)			
Location	Location	Sample area**	Location	Sample area**	Vascular plants	Mosses	Bare ground	Withered plants
A (Egelund)	11	5.3 (2.3)	28	9.3 (5.6)	38.7	32.0	3.3	26.0
B (Solskinbakker)	14	9.3 (1.9)	89	29.7 (7.8)	19.4	22.6	4.6	53.5
C (Brødeskov)	16	11.0 (1.2)	79	26.3 (2.6)	26.1	20.5	2.3	51.2
D (Uggerløse)	6	4.3 (0.7)	25	8.3 (3.2)	20.0	23.1	1.0	55.9
E (Hornbæk)	30	22.0 (4.6)	317	105.7 (20.8)	26.6	37.6	21.2	14.7
F (Hillerød)	24	10.7 (0.9)	85	28.3 (4.4)	11.3	27.4	19.3	42.0
G (Lynge)	23	13.7 (0.7)	173	57.7 (8.4)	6.8	2.6	18.4	72.2
H (Slangerup)	18	14.3 (0.7)	343	114.3 (7.0)	6.3	0.0	50.4	43.4

* The numbers of carabid beetle species and carabid beetle specimens are given both as total numbers per location and as average number per sample area ($n = 3$) within the location.

** Each sample area contained five individual pitfall traps, Numbers in brackets are standard errors.

Table 4. Simpson diversity indexes of carabid beetles from organic and conventionally managed Christmas tree plantations.

Location	Management*	Season**	Simpson's index+
A (Egelund)	Organic	spring	0.84
		summer	0.83
B (Solskinbakker)	Organic	spring	0.69
		summer	0.63
C (Brødeskov)	Organic	spring	0.86
		summer	0.74
D (Uggerløse)	Organic	spring	0.58
		summer	0.58
E (Hornbæk)	Conventional	spring	0.83
		summer	0.77
F (Hillerød)	Conventional	spring	0.80
		summer	0.75
G (Lynge)	Conventional	spring	0.76
		summer	0.52
H (Slangerup)	Conventional	spring	0.76
		summer	0.65

* The conventionally managed locations received herbicides, insecticides and fertilizers, except location E that received no insecticides, whereas the organically managed locations received no chemical amendments.
** Spring sampling took place from May 15 to May 22, 2008, and summer sampling from July 22 to July 29, 2008.
+ Simpson's index was calculated as $(1-\Sigma\{n_i[n_i-1]\}/\{N[N-1]\})$, where n_i is the total number of specimens of the particular species "i", and N is the total number of specimens of all species.

and *N. brevicollis* (F.). All these are eurytopic species that often occur in open land, except *N. brevicollis* which is a eurytopic woodland species (Lindroth 1985, 1986).

Only two species, *H. latus* (L.) and *P. versicolor* (Sturm), occurred significantly more abundantly in the organic plantations. Both are also eurytopic species that can occur on open, cultivated ground. *Pterostichus melanarius* (Illiger) and *P. niger* (Schaller) occurred abundantly in both organic and conventional plantations, and were both significantly more abundant in summer than in the spring in accordance with their late propagation in August-September (Lindroth 1986). We finally notice that *Stomis pumicatus* (Panzer) and *T. placidus* (Gyllenhal), which are common woodland species (Thiele 1977), only were found at the organically managed sites. Hence, in general, the conventionally managed sites seem to be more dominated by species that prefer open habitats and often occur in agricultural land compared with the organically managed sites.

The correlation analyses (Table 5) can help us to explain the higher abundance and diversity at the conventional plantations. A large fraction of the carabid beetles in both plantation types are incidental opportunistic migrants from surrounding areas. This is supported by the significantly negative correlation between distance to nearest plantation edge and species number, and by the significantly negative correlation

Table 5. Product-Moment Correlation Coefficients (r), between numbers of carabid beetle specimens and species and different environmental parameters compiled from four organically managed and four conventionally managed Christmas tree plantations.

	Specimens		Species	
	r	*P**	r	*P**
Ground cover (%)**				
Vascular plants	- 0.35	0.09	- 0.17	0.44
Mosses	- 0.29	0.17	- 0.07	0.76
Bare ground	+ 0.83	**$< 10^{-7}$**	+ 0.53	**0.007**
Dead plant material	- 0.29	0.16	- 0.32	0.13
Plantation size	- 0.11	0.62	- 0.38	0.07
Landscape structure (%)+				
Forest	- 0.60	**0.003**	- 0.34	0.10
Field	+ 0.59	**0.003**	+ 0.34	0.10
Garden	+ 0.45	**0.03**	+ 0.19	0.39
Distance to nearest plantation edge	- 0.37	0.08	- 0.45	**0.03**

* *P* values ($n = 24$) indicating significant Correlation Coefficients are shown in bold.
** The percentage composition of ground cover at sample areas.
+ The percentage composition of landscape structure in a 400 m radius from the center of each plantation.

between amount of surrounding forest and carabid numbers, whereas sources of opportunistic species, i.e. fields and gardens, correlate positively with carabid abundance. The most abundant species found in this study are all common to cultivated fields. Further, in *Harpalus* spp. that made up a large fraction of the collected specimens, the food of the adults consists to a great extent of seeds (Tooley and Brust 2002). This indicates that small invertebrates may be relatively sparse in the plantations. Thus, this study suggests that Christmas tree plantations generally are poor habitats for carabid beetles; irrespective of whether they are organically or conventionally managed.

The average cover of vascular plants was higher at the organically managed sites (26%) than on the conventionally managed (13%). Complementary, the percentage of bare ground was higher at the conventionally managed sites (27%) than on the organically (3%). We found a particularly high significant correlation between percentage of bare ground at the sampling sites and number of specimens recorded (Fig. 1), whereas vegetation (vascular plants, mosses, dead plant material) correlated negatively (Table 5). We suggest that this is due to a higher activity on bare ground because of lack of food and shelter. Carabid beetles display strong habitat preferences, and are selective with regard to the amount of light and moisture. Furthermore, different species exhibit different types of behavior regarding mobility; hence, the catch of carabid beetles tends to be biased toward more active species (Lövei and Sunderland 1996).

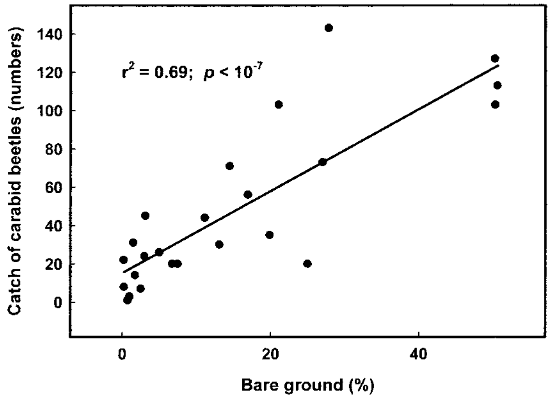

Fig. 1. The relationship between number of carabid beetles specimens caught in pitfall traps and percentage of bare ground at the individual sample sites. The solid line represents the linear regression. Percentage of bare ground was the measured environmental parameter that showed the highest Product-Moment Correlation Coefficients with beetle catch (Table 5).

Additionally, dense undergrowth will impede the mobility of the carabid beetles and thus reduce the number of individuals caught by the traps (Greenslade 1964). Thus there is a larger potential for invasion at the bare ground sites of opportunistic species from surrounding areas.

We expected a decline in numbers of species and specimens at the conventionally managed sites relative to the organically managed at the summer sampling due to the in-between pesticide amendment (Navntoft et al. 2006, van Toor 2006), but we did not observe such a decline. The effect of pesticide application in a complex environment is, however, unpredictable as vegetation-cover and animals at other trophic levels of the food chain are affected. Moreover, if most of the beetles in the plantations are actually migrants and not residents, then an intervening pesticide application will have little effect.

In conclusion, we found significantly higher numbers of both species and specimens of carabid beetles in conventionally than in organically managed plantations. We observed no effect of an intervening pesticide amendment between our two samplings. The study suggests that Christmas tree plantations generally are poor habitats for carabid beetles. Percentage of bare ground was a major explanatory factor for beetle distribution; likely because bare ground facilitates migration by stimulating beetle activity, hence the higher numbers caught probably reflect a higher migration activity rather than a higher abundance. Moreover, bare ground favors species with a preference for open areas and a high amount of light (Lindroth 1985, 1986), which we observed in the conventionally managed sites.

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