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R. A. Byers
USDA

G. M. Barker
LandCare Research

R. L. Davidson
Carnegie Museum of Natural History

E. R. Hoebeke
Cornell University

M A. Sanderson
USDA

RICHNESS AND ABUNDANCE OF CARABIDAE AND STAPHYLINIDAE (COLEOPTERA), IN NORTHEASTERN DAIRY PASTURES UNDER INTENSIVE GRAZING

R. A. Byers[1], G. M. Barker[2], R. L. Davidson[3], E. R. Hoebeke[4] and M. A. Sanderson[1]

ABSTRACT

Dairy cattle grazing has become popular to dairy farmers in the Northeast looking for management schemes to cut production costs. Carabidae (ground beetles) and Staphylinidae (rove beetles) are indicators of habitat disturbances, such as drainage of wetlands, or grassland for grazing animals, and their monitoring could provide one measure of ecosystem sustainability if intensive grazing management systems expand or intensify in the future. Our objective was to assess the abundance and species richness of these two beetle families under intensive grazing throughout Pennsylvania, southern New York and Vermont. We collected 4365 ground beetles (83 species) and 4,027 rove beetles (79 species) by pitfall traps in three years in Pennsylvania. Nine ground beetle species, *Amara aenea, Poecilus chalcites, Pterostichus melanarius*, *Bembidion quadrimaculatum oppositum*, *Amara familiaris, Poecilus lucublandus, Agonum muelleri, Bembidion obtusum* and *Bembidion mimus* represented 80% of the Carabidae collected.

Five other species were new to Pennsylvania. Four rove beetle species, *Philonthus cognatus, Meronera venustula, Amischa analis,* and *Philonthus various* = (*carbonarius*), comprised 74% of the total Staphylinidae collected. Yearly distributions of the dominant species did not change significantly in the three years with *A. aenea* and *P. cognatus* being most abundant every year. A parasitic rove beetle, *Aleochara tristis,* was recovered for the first time in Pennsylvania and Vermont since its release in the 1960's to control face fly, *Musca autumnalis*.

Similar results were found in New York and Vermont. We collected 1,984 ground beetles (68 species). *Pterostichus melanarius* was most abundant. *Pterostichus vernalis* was detected for the first time in the United States (Vermont). It was previously reported from Montreal, Canada. We collected 843 rove beetles (45 species). *Philonthus cognatus* was the most abundant rove beetle. In addition, *Tachinus corticinus*, previously known only from Canada, was discovered for the first time in the United States in Vermont.

Pastures in Pennsylvania were diverse, containing 14 species of forage plants and 17 weed species. Botanical composition was similar in New York and Vermont. Sixteen species of grasses and legumes made up 90% of the plant composition and 36 species of weeds made up the remainder. This diverse plant ecosystem may explain the richness of ground and rove beetles in

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[1]USDA, ARS Pasture Systems and Watershed Management Research Unit,Univ. Park, PA 16801.

[2]LandCare Research, Private Bag 3127, Hamilton, New Zealand.

[3]Carnegie Museum of Natural History, Pittsburgh, PA 15213.

[4]Department of Entomology, Cornell University, Ithaca, NY 14853.

northeastern U.S. pastures because the heterogeneity in the plant population provided additional resources which can support a rich assemblage of beetles. Monitoring richness and abundance of Carabidae and Staphylinidae over three years in Pennsylvania suggests intensive grazing systems are ecologically sustainable.

Carabidae and Staphylinidae have been extensively studied in disturbed environments because they are numerous, sensitive to ecological change, and easily collected by pitfall traps. A decline in species diversity or richness and abundance indicates a disturbed, unstable environment while an increase indicates a stable and diverse environment (Eyre et al. 1989). Luff (1990) found a gradual decline in species richness because of changes to habitats surrounding the experimental area, which included drainage of wetlands and cutting of forests. Both studies underscore the value of carabids as indicators of changes to habitats.

Many dairy farmers in the northeastern U.S. have adopted or increased intensive grazing technology to cut production costs (Ford 1996, Ford and Hansen 1994). Abundance of Carabidae and Staphylinidae has been studied in agroecosystems such as alfalfa (Lester and Morrill 1989, Los and Allan 1983), raspberry plantations (Levesque and Levesque 1995), soybean fields (Ferguson and McPherson 1985) and grasslands (Luff 1990) including turf (Bramen and Pendley 1993). However, no studies have examined abundance and richness of Carabidae and Staphylinidae under intensive grazing in the northeastern U.S.

Carabids and staphylinids abundance can be positively or adversely affected by grazing. Dennis et al. (1997) found five of the 32 most abundant species of Carabidae and Staphylinidae correlated with the effects of different grazing regimes imposed on a *Nardus* grassland in England. The rove beetles, *Othius angustus* Stephens, *Xantholinus linearis* (Olivier), *Olophrum piceum* (Gyllenhal) and the ground beetle, *Carabus violaceus* L. (Carabidae) were more abundant in ungrazed or lightly grazed treatments. The ground beetle, *Pterostichus strenuus* Panzer was more abundant where sheep and cattle with sheep grazed with greater intensity.

Carabids and staphylinids patrolling the soil surface for prey have an influence on soil fertility. Kajak (1997) found where macro-arthropods (including predatory Carabidae and Staphylinidae) had access to an open meadow microcosm (steel net enclosure with openings cut at soil surface), the proportion of detritus below ground, and animal feces above ground, was significantly higher than in a closed microcosm. He concluded that too little attention has been paid to the influence of carabids and staphylinids on soil fertility.

Our objective was to provide baseline information on the relative abundance and species diversity of these two families in several rotational cattle grazing systems of different intensity over a wide range of environments in Pennsylvania, New York and Vermont.

MATERIALS AND METHODS

Five dairy farms that used intensive grazing were selected representing several physiogeographic regions of Pennsylvania from a 21 farm ecological study (Byers and Barker 2000). Four paddocks (subdivided pastures used in rotational grazing systems) were chosen from each farm for a total of 20 pad-

Table 1. Location and attributes of farms sampled for carabids and staphylinids.

Farm	County and State	Grazing period (Years)	Stocking rates (cows/ha/day for each grazing event)	Soil series
2	Berks, PA	1	152	Weikert
8	Tioga, PA	4–14	114	Oguaga, Valousia
13	Juniata, PA	3–13	38–51	Edom
15	Venango, PA	2	64	Wharton, Brinkerton
18	Westmoreland, PA	9	68	Upshur-Gilpin, Weikert
22	Chemung, NY	30	55–60	Nardin, Valois
23	Tompkins, NY	9	45–50	Howard
25	Grand Isle, VT	5	65	Benson
26	Franklin, VT	1–10	50	Marlow
27	Washington, VT	10	20	Cabot
28	Chenango, NY	9	100–120	Volusia

docks. They were selected to provide a range in slope, aspect, and elevation that represented the topographic variation of the farm. Insect sampling was by pitfall traps (six per paddock placed randomly ca 20–100 m apart) operated for one week in late May, mid-July and early September 1994–1996. In 1997, three New York farms were sampled in May, July and September, and three Vermont farms in June and August. Four paddocks were sampled with six pitfall traps in each paddock on each farm. The location and attributes of each farm are presented in Table 1.

Pitfall traps consisted of 12 cm diameter tapering to a 9 cm diameter bottom plastic food containers (Grocery Wholesale Supply, State College, PA), placed in PVC sewer pipe connectors (10.2 cm diameter by 10 cm tall) buried flush with the soil surface. A hole (8 mm diameter) was punched near the upper lip of each cup and covered with plastic screen (100/cm^2 mesh) to allow rainwater to escape but retaining any trapped insects. Each cup contained 250 ml of Galt's solution (Barber 1930) as a killing and preserving agent. A screen (1-cm mesh) of galvanized steel was positioned over each trap and held in place with spikes and metal washers to exclude cattle. Insects were removed at the end of the 7-day trapping period and transferred to 70% ethanol until mounting and identification

We sampled the botanical composition of the paddocks by harvesting four, 0.093 m^2 quadrants within 1 m of each trap site in the spring of each year. Samples were sorted into grasses, legumes and weeds. Grasses and legumes were identified to species and recorded. We lumped weed species together for Pennsylvania, but identified to species for New York and Vermont. After identification, plants were dried and weighed for estimates of standing biomass, or yield (kg/ha).

We made estimates of grazing intensity (amount of forage removed) near the pitfall traps at the end of each trapping period. A 1–5 scale was employed with 1 = no grazing, 2 = light, tops of some plants eaten, 3 = medium, most plants grazed to some extent, 4 = heavy, all plants grazed to low heights (5–10 cm), and 5 = severe grazing, most forage removed, stubble remaining very short (5 cm or less).

The percent slope and compass direction or aspect was recorded for each paddock. Mean monthly maximum and minimum temperatures, monthly rainfall from January until time of sampling, and elevation were obtained from nearest National Weather Service stations. Four soil samples (ca 30 g wet weight) taken near each pitfall trap were weighed and oven dried and percent moisture determined.

Correlation (r) of the most abundant Carabidae and Staphylinidae with grazing management, biomass, weather data, soil moisture, and botanical composition were made using PROC CORR (SAS 1985). Regression analysis (PROC REG, SAS 1985) was used to examine linear relationships between the nine most abundant carabids, and four most abundant staphylinids and grazing management intensity, soil moisture and biomass. We used a confidence level of $\alpha = 0.05$ for all statistical tests.

RESULTS

Abundance. We collected 4,365 ground beetles represented by 83 species in Pennsylvania dairy pastures in three years (Table 2). *Amara aenea* (DeGeer) comprised 42.8 % of the total number collected. Eight additional species, *Poecilus chalcites* (Say), *Pterostichus melanarius* (Illiger), *Bembidion quadrimaculatum oppositum* Say, *Amara familiaris* (Duftschmid), *Poecilus lucublandus* (Say), *Agonum muelleri* (Herbst), *Bembidion obtusum* Serville and *Bembidion mimus* Hayward made up 80.4% of the specimens trapped.

Six species were not listed in a recent catalog (Bousquet and Larochelle 1993) and are new records for Pennsylvania: *Bembidion obtusum* Serville, *Trechus quadristriatus* (Schrank), *Bradycellus nigriceps* LeConte, *Acupalpus pumilis* Lindroth, and *Stenolophus rotundus* LeConte. *T. quadristriatus* and *B. obtusum* are recent introductions to the U.S., which have been gradually spreading through the northeastern U.S. The other three species have been found in the surrounding states but not in Pennsylvania.

We collected 1,984 ground beetles on NewYork. and Vermont farms in 1997 (Table 3). *P. melanarius* made up 20.1% of the total sample. Six additional species, *Carabus auratus* L., *Amara aenea*, *B. q. oppositum*, *Clivina fossor* (L.), *P. lucublandus*, and *A. muelleri* made up 80.2% of the specimens trapped. We discovered *Pterostichus vernalis* (Panzer) for the first time in the U.S. on a farm located in Vermont on the Canadian border. The only other North American record of this species is one specimen from Montreal which Bousquet and Larochelle (1993) claim to be mislabeled. We also discovered *Carabus auratus* L. on a farm near Montpelier, VT, a new state record. This species had been released in the 1960's in Mass. to control the gypsy moth and is spreading westward.

We collected 4,027 rove beetles represented by 79 species in Pennsylvania in three years (Table 4). *Philonthus cognatus* Stephens was the most abundant species (52.9% of the total collected). Five species, *P. cognatus* Stephens, *Meronera venustula* Erichson, *Amischa analis* (Gravenhorst), and *Philonthus varius* Gravenhorst (=*carbonarius*), and *Anotylus tetracarinatus* comprised 77.3% of the total specimens trapped. We collected one adult *Aleochara tristis* Gravenhorst on farm 8 in Tioga County in May 1994. We also collected a second adult from a farm in Lehigh County, PA which was not included in this study. This staphylinid was introduced to control face fly, *Musca autumnalis* DeGeer (Drea 1966), but was never recovered in the Northeast. This represents the first detection of this insect since its release over 30 years ago (W. H. Day, pers. comm.). *Aleochara. tristis* has also been found in Quebec Province, Canada and California.

We collected 843 rove beetles (45 species) in New York and Vermont in 1997 (Table 5). *Philonthus cognatus* was the most abundant species (17.2% of the total collected). Eleven other species and one undetermined Alleochari-

Table 2. Abundance of Carabidae in grazed dairy pastures in Pennsylvania for three years.

Species arranged in order of abundance	1994	1995	1996	3 yr. Total	Percent	Cumulative Percent
Amara aenea (DeGeer)	643	518	708	1869	42.82	42.82
Poecilus chalcites (Say)	138	73	144	355	8.13	50.95
Pterostichus (Morphnosoma) melanarius (Illiger)	128	138	20	286	6.55	57.50
Bembidion (Bembidion) quadrimaculatum oppositum Say	97	90	74	261	5.98	63.48
Amara familiaris (Duftschmid)	70	14	114	198	4.54	68.02
Poecilus lucublandus (Say)	77	49	46	172	3.94	71.96
Agonum muelleri (Herbst)	31	55	47	133	3.05	75.01
Bembidion (Phyla) obtusum Serville	86	20	18	124	2.84	77.85
Bembidion (Furcacampa) mimus Hayward	59	17	35	111	2.54	80.39
Harpalus (Pseudoophonus) pensylvanicus (DeGeer)	57	24	6	87	1.99	82.38
Cyclotrachelus sodalis sodalis (LeConte)	12	36	5	53	1.21	83.60
Agonum punctiforme (Say)	10	20	16	46	1.05	84.65
Chlaenius (Chlaeniellus) tricolor tricolor Say	16	20	10	46	1.05	85.70
Harpalus affinis (Schrank)	15	17	11	43	0.99	86.69
Patrobus longicornis (Say)	15	7	18	40	0.92	87.61
Anisodactylus sanctaecrucis (Fabricius)	25	10	4	39	0.89	88.50
Agonum cupripenne (Say)	2	17	17	36	0.82	89.32
Anisodactylus rusticus (Say)	8	13	9	30	0.69	90.01
Harpalus herbivagus Say	7	6	12	25	0.57	90.58
Bembidion (Notaphus) rapidum (LeConte)	4	10	10	24	0.55	91.13
Pterostichus (Abacidus) permundus (Say)	1	0	22	23	0.53	91.66
Dyschirius globulosus (Say)	1	9	12	22	0.50	92.16
Pterostichus (Abacidus) atratus (Newman)	8	6	7	21	0.48	92.65
Amara impuncticollis (Say)	9	2	9	20	0.46	93.10
Agonum octopunctatum (Fabricius)	6	2	9	17	0.39	93.49
Patrobus sp.	17	0	0	17	0.39	93.88
Clivina impressefrons (LeConte)	6	3	7	16	0.37	94.25
Chlaenius (Eurydactylus) tomentosus (Say)	14	1	0	15	0.34	94.59
Agonum sp.	14	0	0	14	0.32	94.91
Agonum placidum (Say)	5	5	2	12	0.27	95.19
Scarites subterraneus Fabricius	0	2	10	12	0.27	95.46

Continued

Table 2. Continued

Species arranged in order of abundance	1994	1995	1996	3 yr. Total	Percent	Cumulative Percent
Bradycellus nigriceps LeConte*	5	4	2	11	0.25	95.72
Clivina bipustulata (Fabricius)	5	4	2	11	0.25	96.12
Bembidion (Furcacampa) affine Say	0	0	9	9	0.21	95.97
Amara sp.	8	0	0	8	0.18	96.36
Anisodactylus sp.	8	0	0	8	0.18	96.54
Scarites quadriceps Chaudoir	5	3	0	8	0.18	96.72
Amara apricaria (Paykull)	1	1	5	7	0.16	96.88
Badister notatus Haldeman	6	1	0	7	0.16	97.04
Colliuris pensylvanica (L.)	4	2	1	7	0.16	97.21
Microlestes pusio (LeConte)	7	0	0	7	0.16	97.37
Elaphropus xanthopus (Dejean)	4	0	2	6	0.14	97.50
Undetermined sp.	4	2	0	6	0.14	97.64
Bradycellus rupestris (Say)	4	0	1	5	0.11	97.75
Cyclotrachelus convivus (LeConte)	0	2	3	5	0.11	97.87
Harpalus fulgens Csiki	2	2	1	5	0.11	97.98
Harpalus somnulentus Dejean	2	3	0	5	0.11	98.10
Stenolophus (Agonoderus) comma (Fabricius)	5	0	0	5	0.11	98.21
Anisodactylus nigerrimus (Dejean)	3	0	1	4	0.09	98.30
Chlaenius sp.	4	0	0	4	0.09	98.40
Harpalus (Pseudoophonus) compar LeConte	1	3	0	4	0.09	98.49
Harpalus caliginosus (Fabricius)	3	1	0	4	0.09	98.58
Loricera pilicornis (Fabricius)	2	1	1	4	0.09	98.67
Pterostichus (Morphnosoma) stygicus (Say)	1	1	2	4	0.09	98.76
Syntomus americanus (Dejean)	0	2	2	4	0.09	98.85
Amara angustata (Say)	1	1	1	3	0.07	98.92
Amara cupreolata (Putzeys)	0	0	3	3	0.07	98.99
Calathus gregarius (Say)	3	0	0	3	0.07	99.06
Chlaenius (Brachylobus) lithophilus Say	2	0	1	3	0.07	99.13

Dicaelus elongatus Bonelli	2	1	0	3	0.07	99.20
Platynus hypolithos (Say)	1	1	1	3	0.07	99.27
Trechus quadristriatus (Schrank)*	0	2	1	3	0.07	99.34
Anisodactylus ovularis (Casey)	1	1	0	2	0.05	99.38
Elaphropus incurvus (Say)	0	2	0	2	0.05	99.43
Notiophilus semistriatus Say	2	0	0	2	0.05	99.47
Probably *Harpalus* sp. (teneral)	2	0	0	2	0.05	99.52
Pterostichus (Morphnosoma) novus Straneo	0	2	0	2	0.05	99.56
Stenolophus (Agonoderus) conjunctus (Say)	0	1	1	2	0.05	99.61
Acupalpus pumilus Lindroth*	0	1	0	1	0.02	99.63
Agonum melanarium Dejean	0	1	0	1	0.02	99.66
Amara littoralis Mannerheim	1	0	0	1	0.02	99.68
Amara lunicollis Schiødte	0	0	1	1	0.02	99.70
Anisodactylus harrisii LeConte	0	1	0	1	0.02	99.73
Bradycellus tantillus (Dejean)	1	0	0	1	0.02	99.75
Calathus opaculus LeConte	0	1	0	1	0.02	99.77
Chlaenius (Chlaeniellus) nemoralis Say	0	1	0	1	0.02	99.79
Diplocheila obtusa (LeConte)	1	0	0	1	0.02	99.82
Elaphropus vernicatus (Casey)	0	1	0	1	0.02	99.84
Galerita janus (Fabricius)	0	1	0	1	0.02	99.86
Platynus angustatus Dejean	1	0	0	1	0.02	99.89
Polyderis laevis (Say)	1	0	0	1	0.02	99.91
Pterostichus (Bothriopterus) mutus (Say)	0	0	1	1	0.02	99.93
Stenolophus (Agonoderus) rotundatus LeConte*	0	1	0	1	0.02	99.95
Stenolophus (Stenolophus) ochropezus (Say)	0	1	0	1	0.02	99.98
Stenolophus sp.	1	0	0	1	0.02	100.00
Grand total 83 species	1685	1236	1444	4365		

*New PA record.

Table 3. Abundance of Carabidae in Grazed Dairy Pastures in New York and Vermont in 1997.

Species arranged in order of abundance	New York	Vermont	Total	Percent	Cumulative Percent
Pterostichus (Morphnosoma) melanarius (Illiger)	117	282	399	20.11	20.11
Carabus (Autocarabus) auratus L.*	0	310	310	15.63	35.74
Amara aenea (DeGeer)	130	196	326	16.43	52.17
Bembidion (Bembidion) quadrimaculatum oppositum Say	95	118	213	10.74	62.90
Clivina fossor (L.)	24	141	165	8.32	71.22
Poecilus lucublandus (Say)	59	67	126	6.35	77.57
Agonum muelleri (Herbst)	17	35	52	2.62	80.19
Bembidion (Furcacampa) mimus Hayward	17	17	34	1.71	81.91
Poecilus chalcites (Say)	2	30	32	1.61	83.52
Harpalus (Pseudoophonus) pensylvanicus (DeGeer)	22	5	27	1.36	84.88
Anisodactylus sanctaecrucis (Fabricius)	9	13	22	1.11	85.99
Harpalus rufipes (DeGeer)	0	21	21	1.06	87.05
Agonum cupripenne (Say)	7	13	20	1.01	88.05
Dyschirius globulosus (Say)	8	10	18	0.91	88.96
Amara angustata (Say)	13	5	18	0.91	89.87
Bembidion (Phyla) obtusum Serville	15	1	16	0.81	90.68
Harpalus affinis (Schrank)	9	7	16	0.81	91.48
Pterostichus (Morphnosoma) novus Straneo	13	0	13	0.66	92.14
Agonum octopunctatum (Fabricius)	0	13	13	0.66	92.79
Chlaenius (Chlaenius) sericeus sericeus (Forster)	0	12	12	0.60	93.40
Loricera pilicornis (Fabricius)	7	5	12	0.60	94.00
Amara lunicollis Schiødte	9	2	11	0.55	94.56
Amara familiaris (Duftschmid)	7	3	10	0.50	95.06
Chlaenius (Chlaeniellus) tricolor tricolor Dejean	4	3	7	0.35	95.41
Amara littoralis Mannerheim	1	5	6	0.30	95.72
Amara impuncticollis (Say)	0	5	5	0.25	95.97
Elaphropus incurvus (Say)	0	5	5	0.25	96.22
Patrobus longicornis (Say)	1	4	5	0.25	96.47
Agonum melanarium Dejean	0	4	4	0.20	96.67
Anisodactylus rusticus (Say)	4	0	4	0.20	96.88
Pterostichus (Lagarus) commutabilis (Motschulsky)	0	4	4	0.20	97.08
Trechus quadristriatus (Schrank)	4	0	4	0.20	97.28
Bradycellus nigriceps LeConte	2	1	3	0.15	97.43
Carabus (Archicarabus) nemoralis O. F. Müller	2	1	3	0.15	97.58

Harpalus herbivagus Say	2	1	3	0.15	97.73
Harpalus somnulentus Dejean	1	2	3	0.15	97.88
Platynus hypolithos (Say)	3	0	3	0.15	98.03
Amara cupreolata (Putzeys)	0	2	2	0.10	98.14
Blemus discus (Fabricius)	0	2	2	0.10	98.24
Elaphropus granarius (Dejean)	2	0	2	0.10	98.34
Platynus angustatus Dejean	2	0	2	0.10	98.44
Pterostichus (Melanius) corvinus (Dejean)	1	1	2	0.10	98.54
Pterostichus (Pseudomaseus) luctuosus (Dejean)	0	2	2	0.10	98.64
Pterostichus (Argutor) patruelis (DeJean)	2	0	2	0.10	98.74
Pterostichus (Lagarus) vernalis (Panzer)**	0	2	2	0.10	98.84
Acupalpus hydropicus (LeConte)	0	1	1	0.05	98.89
Agonum affine (Kirby)	0	1	1	0.05	98.94
Agonum (Europhilus) gratiosum Mannerheim	0	1	1	0.05	98.99
Agonum placidum (Say)	0	1	1	0.05	99.04
Amara apricaria (Paykull)	0	1	1	0.05	99.09
Amara pallipes (Kirby)	0	1	1	0.05	99.14
Amphasia interstitialis (Say)	1	0	1	0.05	99.19
Bembidion (Furcacampa) versicolor LeConte	0	1	1	0.05	99.24
Bradycellus kirbyi (Horn)	1	0	1	0.05	99.29
Calathus gregarius (Say)	1	0	1	0.05	99.34
Carabus (Homoecarabus) maeander Fischer von Waldheim	0	1	1	0.05	99.40
Chlaenius (Chlaeniellus) impunctifrons Say	0	1	1	0.05	99.45
Diplocheila obtusa (LeConte)	0	1	1	0.05	99.50
Elaphrus olivaceus LeConte	0	1	1	0.05	99.55
Harpalus erythropus Dejean	0	1	1	0.05	99.60
Harpalus longicollis LeConte	1	0	1	0.05	99.65
Harpalus rubripes Duftschmid	0	1	1	0.05	99.70
Harpalus puncticeps (Stephens)	0	1	1	0.05	99.75
Lebia fuscata (Dejean)	1	0	1	0.05	99.80
Scarites subterraneus Fabricius	1	0	1	0.05	99.85
Stenolophus (Agonoderus) conjunctus (Say)	1	0	1	0.05	99.90
Stenolophus (Stenolophus) ochropezus (Say)	0	1	1	0.05	99.95
Syntomus americanus (Dejean)	0	1	1	0.05	100.00
Number of Species 41	618	1366	1984		

*New VT record.
**New U. S. record.

Table 4. Abundance of Staphylinidae in Grazed Dairy Pastures in Pennsylvania for Three Years.

Species arranged in order of abundance	1994	1995	1996	3 yr. Total	Percent	Cumulative Percent
Philonthus cognatus Stephens	1181	634	462	2277	52.92	52.92
Meronera venustula Erichson	132	253	198	583	13.55	66.47
Amischa analis (Gravenhorst)	56	32	77	165	3.83	70.30
Philonthus varius Gravenhorst =(*carbonarius*)	43	77	39	159	3.70	73.99
Anotylus tetracarinatus (Block)	83	40	21	144	3.35	77.34
Tachyporus nitidulus (F.)	89	9	12	110	2.56	79.90
Stenus sp.	12	17	49	78	1.81	81.71
Euaesthestus sp.	3	25	42	70	1.63	83.34
Apocellus sphaericollis (Say)	1	57	8	66	1.53	84.87
Anotylus sp.	13	8	42	63	1.46	86.34
undet. Aleocharinae	26	17	18	61	1.42	87.75
Falagria dissecta Erichson	28	11	19	58	1.35	89.10
Trichiusa sp.	5	15	29	49	1.14	90.24
Lordithon facilis (Casey)	36	0	0	36	0.84	91.08
Neohypnus sp. (obscurus group)	19	4	12	35	0.81	91.89
Tinotus sp.	10	10	2	22	0.51	92.40
Mycetoporus inquisitus Casey	2	16	0	18	0.42	92.82
Euaesthestus americanus Erichson	6	9	2	17	0.40	93.21
Gyrohypnus fracticornis (Müller)	0	10	5	15	0.35	93.56
Platydracus maculosus (L.)	10	4	1	15	0.35	93.91
Tachyporus jocosus Say	4	7	3	14	0.33	94.24
Anotylus rugosus (Fabricius)	4	8	0	12	0.28	94.52
Oxypoda sp.	4	2	6	12	0.28	94.79
Aleochara (Xenochara) lanuginosa Gravenhorst	6	0	4	10	0.23	95.03
Aleochara (Xenochara) sp.	5	2	3	10	0.23	95.26
Dinaraea sp.	9	0	0	9	0.21	95.47
Ephelinus notatus LeConte	2	6	1	9	0.21	95.68
Philonthus cruentatus (Gmelin)	3	6	0	9	0.21	95.89

Astenus sp.	2	4	2	8	0.19	96.07
Autalia rivularis (Gravenhorst)	4	2	2	8	0.19	96.26
Oxypoda opaca (Gravenhorst)	5	2	1	8	0.19	96.44
Callicerus sp.	6	1	0	7	0.16	96.61
Philonthus sp.	0	2	5	7	0.16	96.77
Platydracus vulpinus Nordman	4	1	2	7	0.16	96.93
Amischa sp.	1	3	2	6	0.14	97.07
Bryoporus rufescens LeConte	3	0	3	6	0.14	97.21
Neobisnius sp.	1	5	0	6	0.14	97.35
Paederus sp.	0	0	6	6	0.14	97.49
Scopaeus sp.	1	3	2	6	0.14	97.63
Tachyporus flavipennis Campbell	2	4	0	6	0.14	97.77
Apocellus sp.	0	0	5	5	0.12	97.89
Lathrobium sp.	2	2	1	5	0.12	98.00
Platystethus sp.	0	4	1	5	0.12	98.12
Tachyporus canadensis Campbell	4	1	0	5	0.12	98.23
Bryoporus testaceus LeConte	0	4	0	4	0.09	98.33
Euplectus sp.	4	0	0	4	0.09	98.42
Hoplandria sp.	4	0	0	4	0.09	98.51
Mycetoporus sp.	2	1	1	4	0.09	98.61
Mycetoporus triangulatis Campbell	2	2	0	4	0.09	98.70
Oligota sp.	4	0	0	4	0.09	98.79
Acrotona sp.	3	0	0	3	0.07	98.86
Omalium sp.	2	1	0	3	0.07	98.93
Platydracus mysticus Erichson	3	0	0	3	0.07	99.00
Tachyporus rulomoides Campbell	1	0	2	3	0.07	99.07
Aleochara (Coprochara) bimaculata Gravenhorst	2	0	0	2	0.05	99.12
Aleochara lata Gravenhorst	0	1	1	2	0.05	99.16
Carpelimus sp.	0	2	0	2	0.05	99.21
Corproporus laevis LeConte	0	2	0	2	0.05	99.26
Lestiva pallipes LeConte	2	0	0	2	0.05	99.30

(Continued)

Table 4. Continued.

Species arranged in order of abundance	1994	1995	1996	3 yr. Total	Percent	Cumulative Percent
Lithocharis sp., pb. ochracea Gravenhorst	2	0	0	2	0.05	99.35
Olophrum sp.	0	2	0	2	0.05	99.40
Rhexius sp. pb. insculptus LeConte	2	0	0	2	0.05	99.44
Rugilus orbiculatus (Paykull)	2	0	0	2	0.05	99.49
Rugilus sp.	1	0	1	2	0.05	99.54
Stenistoderus rubripennis (LeConte)	2	0	0	2	0.05	99.58
Tachyporus sp.	2	0	0	2	0.05	99.63
Undetermined Staphylinidae	0	1	1	2	0.05	99.67
Acidota subcarinatus Erichson	1	0	0	1	0.02	99.70
Aleochara (Xenochara) fumata Gravenhorst	0	0	1	1	0.02	99.72
Aleochara tristis Gravenhorst*	1	0	0	1	0.02	99.74
Bledius sp.	0	0	1	1	0.02	99.77
Bryoporus sp.	0	1	0	1	0.02	99.79
Ischnosoma sp.	1	0	0	1	0.02	99.81
Lathrobium pallidulum (LeConte)	1	0	0	1	0.02	99.84
Leptacinus sp. pb. intermedius Donisthorpe	1	0	0	1	0.02	99.86
Omalium rivulare Paykull	0	1	0	1	0.02	99.88
Ontholestes cingulatus Gravenhorst.	0	1	0	1	0.02	99.91
Rugilus dentatus (Say)	1	0	0	1	0.02	99.93
Sunius melanocephalus (Fabricius)	1	0	0	1	0.02	99.95
Tachinus corticinus Gravenhorst	0	0	1	1	0.02	99.98
Tachyporus inornatus Campbell	1	0	0	1	0.02	100.00
Grand Total 79 species	1768	1171	1088	4027		

*New PA record.

nae comprised 80.2% of the total. We discovered *Tachinus corticinus* Gravenhorst for the first time in the U.S. in Vermont. It had previously only been reported from the St. Lawrence Valley in the Ontario and Quebec Provinces of Canada. We also collected *A. tristis*, the parasitic species mentioned earlier, for the first time in Vermont in 1997.

Botanical composition of pastures. Of 13 grass species, Kentucky bluegrass, *Poa pratensis*, averaged 25% of the plant species composition in Pennsylvania dairy pastures over three years and orchardgrass, *Dactylis glomerata*, averaged 19%. Other grasses were tall fescue, *Festuca arundinacea*, 5.6%; quackgrass, *Elytrigia repens*, 4.8%; and timothy, *Phleum pratense*, 3.7%. Most other grasses and one forb (chicory, *Cichorium intybus)* were < 1% (sweetvernal grass, *Anthoxanthum odoratum*; smooth bromegrass, *Bromis inermis*; chess, *Bromis secalinus*; creeping bentgrass, *Agrostris stolonifera* var. *palustris*; colonial bentgrass, *Agrostris tenuis*; reed canarygrass, *Phalaris arundinacea*; slender rush, *Juncus tenuis*; and povertygrass, *Danthonia spicata*. White clover, *Trifolium repens*, was the dominant of the four legumes, averaging 12% of the total plant species. Red clover, *Trifolium pratense*, averaged 2.3%; alfalfa, *Medicago sativa*, 1.9%; and birdsfoot trefoil, *Lotus corniculatus*, < 1%. Over 12 percent of plants in pastures were 17 species of weeds as follows: Curly dock, *Rumus crispus*; prostrate pigweed, *Amaranthus blitoides*; mouse-eared chickweed, *Cerastium vulgatum*; tall buttercup, *Ranunculus acris*; shepherd's purse, *Capsella bursa-pastoris*; black medic, *Medicago lupulina*; carolina geranium, *Geranium carolinianum*; common mallow, *Malva neglecta*; wild carrot, *Daucus carota*; field bindweed, *Convolvulus arvensis*; jimsonweed, *Datura stramonium*; buckhorn plantain, *Plantago lanceolata*; blackseed plantain, *Plantago rugelli*; Canada thistle, *Cirsium arvense*; rough fleabane, *Erigeron strigosus*; common dandelion, *Taraxacum officinale*; and common cocklebur, *Xanthium strumarium*.

The plant composition of New York and Vermont dairy pastures was 81.3% grasses, 9.6 % legumes and 9.1% weeds. *Poa pratensis* averaged 47.7 % of the plant species in 1997 and *Dactylis glomerata* averaged 16.4%. Other grasses and percentage composition were as follows: *Elytrigia repens* 4.9%, *Festuca arundinacea* 4.7%, *Bromis inermis* 3.0 %, *Phalaris arundinacea* 1.5%, *Poa pratense* 1.2% and ryegrass, *Lolium perenne* 0.8%. Most of the other forbes and grasses were less than 1%: (Canadian bluegrass, *Poa compréssa*; bentgrass, *Agrostis stolonifera*, *Juncus tenuis*, crabgrass, *Digitaria sanguinalis*; witchgrass, *Panicum capillare*; chicory, *Cichorium intybus*; and *Danthonia spicata*. *Trifolium repens* was the dominant legume averaging 8.0 % of the plant composition. Other legumes were *Medicago sativa* 0.9%, *Trifolium pratense* 0.3%, *Lotus corniculatus* 0.2%, and narrow-leafed vetch, *Vicia angustifolia*, 0.06%.

Taraxacum officinale (3.75%) was the most common weed found in every pasture. Other weeds and their percent composition are as follows: poorjoe, *Diodia teres*, 1.1%; *Cerastium vulgatum*,0.9%; yellow nutsedge, *Cyperus esculentus*, 0.9%; black-seeded plantain, *Plantago rugelli*, 0.6%; common burdock, *Arctium minus*, 0.3%; *Cirsium arvense*, 0.2%; bedstraw catchweed, *Gallium mollugo*, 0.2%; *Ranunculus acris* 0.2%, and yellow toadflax, *Linaria vulgaris*, 0.2%. The following weeds each made up less than 0.1% of the species composition: small flowered buttercup, *Ranunculus arbortivus*; bull thistle, *Cirsium vulgare*; hop sedge, *Carex lupulina*; oxeye daisy, *Chrysanthemum leucanthemum*; wild radish, *Raphanus raphanistrum*; common chickweed, *Stellaria media*; wild strawberry, *Fragaria virginiana*; yellow thistle, *Cirsium horridulum*; yellow rocket, *Barbarea vulgaris*; evening primrose, *Oenothera biennis*; *Amaranthus albus*, common ragweed, *Ambrosia artemisiifolia*; wild carrot, *Daucus carota*; white heather aster, *Aster pilosus*; pasture

Table 5. Abundance of Staphylinidae in Grazed Dairy Pastures in New York and Vermont in 1997.

Species arranged in order of abundance	New York	Vermont	Total	Percent	Cumulative Percent
Philonthus cognatus Stephens	90	55	145	17.20	17.20
Philonthus varius (Gravenhorst) = (*carbonarius*)	82	36	118	14.00	31.20
Meronera venustula Erichson	80	16	96	11.39	42.59
Amischa analis (Gravenhorst)	43	18	61	7.24	49.82
Stenus sp.	14	31	45	5.34	55.16
Anotylus tetracarinatus (Block)	39	0	39	4.63	59.79
Trichiusa sp.	30	5	35	4.15	63.94
Oxypoda spp.	30	3	33	3.91	67.85
Amischa sp.	29	0	29	3.44	71.29
undet. Aleocharinae	23	0	23	2.73	74.02
Euaesthestus sp.	10	9	19	2.25	76.28
Apocellus sphaericollis (Say)	1	16	17	2.02	78.29
Anotylus sp.	13	3	16	1.90	80.19
Drusilla canaliculata (Fabricius)	7	19	26	3.08	83.27
Autalia rivularis (Gravenhorst)	11	3	14	1.66	84.93
Neohypnus sp. (obscurus group)	9	2	11	1.30	86.24
Falagria dissecta Erichson	10	0	10	1.19	87.43
Tachyporus jocosus Say	6	4	10	1.19	88.61
Tinotus sp.	6	3	9	1.07	89.68
Gyrohypnus fracticornis (Müller)	8	0	8	0.95	90.63
Tachyporus canadensis Campbell	2	6	8	0.95	91.58
Tachyporus nitidulus (Fabricius)	4	4	8	0.95	92.53
Mycetoporus sp.	3	4	7	0.83	93.36
Tachyporus flavipennis Campbell	3	3	6	0.71	94.07
Aleochara (Xenochara) lanuginosa Gravenhorst	4	0	4	0.47	94.54
Aleochara (Xenochara) sp.	0	4	4	0.47	95.02
Oligota sp.	3	1	4	0.47	95.49
Platydracus mysticus Erichson	3	1	4	0.47	95.97

Platystethus sp.	4	0	4	0.47	96.44
Tachinus limbatus Melsheimer	3	1	4	0.47	96.92
Lordithon facilis (Casey)	3	0	3	0.36	97.27
Mycetoporus inquisitus Casey	2	1	3	0.36	97.63
Philonthus cruentatus (Gmelin)	2	1	3	0.36	97.98
Astenus sp.	1	0	1	0.12	98.10
Hoplandria sp	0	2	2	0.24	98.34
Paederus sp.	1	1	2	0.24	98.58
Undetermined Philonthina	0	2	2	0.24	98.81
Aleochara tristis Gravenhorst*	0	1	1	0.12	98.93
Anotylus rugosus (Fabricius)	0	1	1	0.12	99.05
Bryoporus rufescens LeConte	0	1	1	0.12	99.17
Platydracus maculosus (L.)	1	0	1	0.12	99.29
Scopaeus sp.	1	0	1	0.12	99.41
Aleochara (Coprochara) sp.	1	0	1	0.12	99.53
Bledius sp.	0	1	1	0.12	99.64
Tachinus corticinus Gravenhorst**	0	1	1	0.12	99.76
Neobisnius sp.	1	0	1	0.12	99.88
Sunius melanocephalus (Fabricius)	0	1	1	0.12	100.00
Totals Species 45	583	260	843		

*New VT record.
**New U. S. Record.

thistle, *Cirsium pumilum*; sow thistle, *Sonchus oleraceus*; rough cinquefoil, *Potentilla novegia*; sulphur cinquefoil, *Potentilla recta*; fool's parsley, *Aethusa cynapium*; yellow wood sorrel, *Oxalis stricta*; and wild parsnip, *Pastinaca sativa*.

Regression analysis of the four most abundant carabids. Grazing management intensity (GMI = 1 to 5 scale) had a negative effect on pitfall collections of four of the nine most abundant carabid species (Fig. 1). Grazing management had no significant effect ($P < 0.05$) on catches of *B. q. oppositum, P. chalcites, A. muelleri, B. mimus* and *P. melanarius.*

Soil moisture (SM=%) had a positive effect on catches of six of nine carabids (Fig. 2). (Soil moisture data not shown in Fig.2 for *B. obtusum* and *B. mimus* because there were less than 10 in any trap). Soil moisture had no significant effect on catches of *B. q. oppositum, P. lucublandus* or *P. melanarius*.

Biomass (BM = yield of forage kg/ha) had a positive effect on catches five of the nine most abundant carabid species (Fig. 3). (Data not shown in Fig.3 for *P. lucublandus* because there were less than 10 per trap). Biomass had no significant effect on catches of *P. chalcites, B. quadrimaculatum oppositum, P. melanarius* and *A. muelleri.*

Regression analysis of the four most abundant staphylinids. Grazing management intensity had a negative effect on collections of two of the four staphylinids (Fig. 4). There was no effect of grazing intensity on *M. venustula* and *P. varius*.

Soil moisture had a positive effect on catches of the two of the abundant staphylinids Fig. 5). Soil moisture had no significant effect on catches of *M. venustula* and *P. varius.*

Biomass had a positive effect on catches of two staphylinid species (Fig. 6) Biomass had no significant effect on catches of *M. venustula* and *P. varius*.

DISCUSSION

Species richness of ground and rove beetles in northeastern farms and paddocks indicate the pasture environment is at least as diverse as most crop agroecosystems. Considerably fewer species of ground beetles were found in soybeans, (Ferguson and McPherson 1985, 39 species), and alfalfa, (Los and Allen 1983, 49 species) than we found in pastures (83 species) but we sampled on a larger scale. Comparable numbers to what we found were collected by Esau and Peters (1975) in cornfields, fencerows and prairies in Iowa (94 carabid species). Rushton et al. (1990) found 90 carabid species in grassland in the UK, and Luff (1990), found 59 species in a mosaic of grass and arable plots also in the UK.

We found a few species to be dominant and represent most of the total specimens collected. In general, it is not unusual for a few species to be dominant and represent 80–90% of the species trapped. Ecologists have found most measures of species diversity to follow a log normal curve with a few species very abundant, most at moderate densities and the remainder rare (May 1975). No community consists of equal abundance of species. Instead it is normally the case that the majority of species are rare, while a number are moderately common with the remaining few being very abundant (Magurran 1988). Evenness is known as a measure how equally abundant the species are. High evenness is usually equated with high diversity and vice versa. Therefore, our data showed low diversity of ground and rove beetles in traps because of low evenness. Barney and Pass (1986) found Kentucky alfalfa fields were rich in ground beetle species (40 species) and numbers of

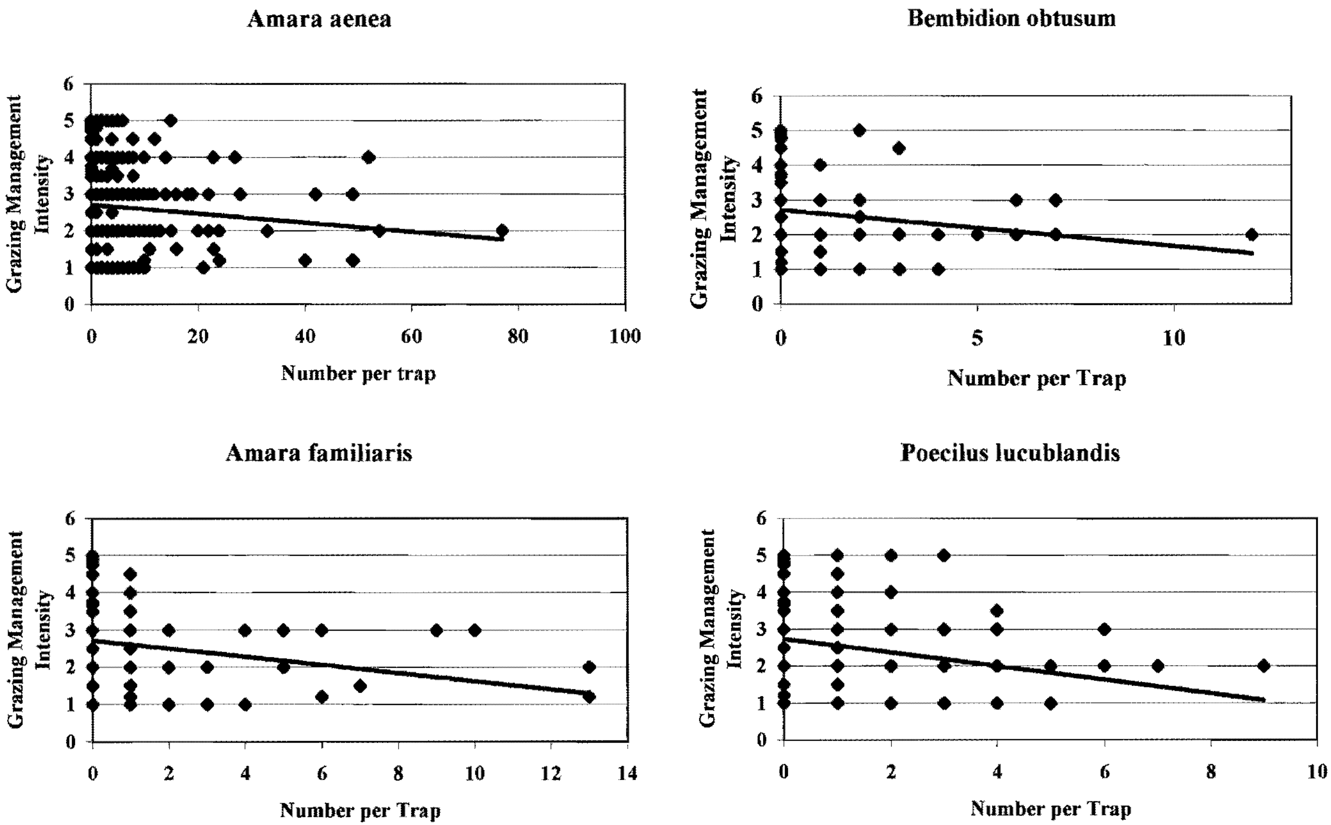


Figure 1. Effect of Grazing Management Intensity (GMI) on the four of the most abundantly collected carabid beetles (GMI = 2.71–0.01 *A. aenea*, $F = 3.63$, $P = 0.057$; GMI = 2.70–0.10 *B. obtusum*, $F = 4.52$, $P = 0.033$; GMI = 2.7–0.11 *A. familiaris*, $F = 9.04$, $P = 0.003$; and GMI = 2.72–0.18 *P. lucublandus*, $F = 17.05$, $P < 0.0001$).

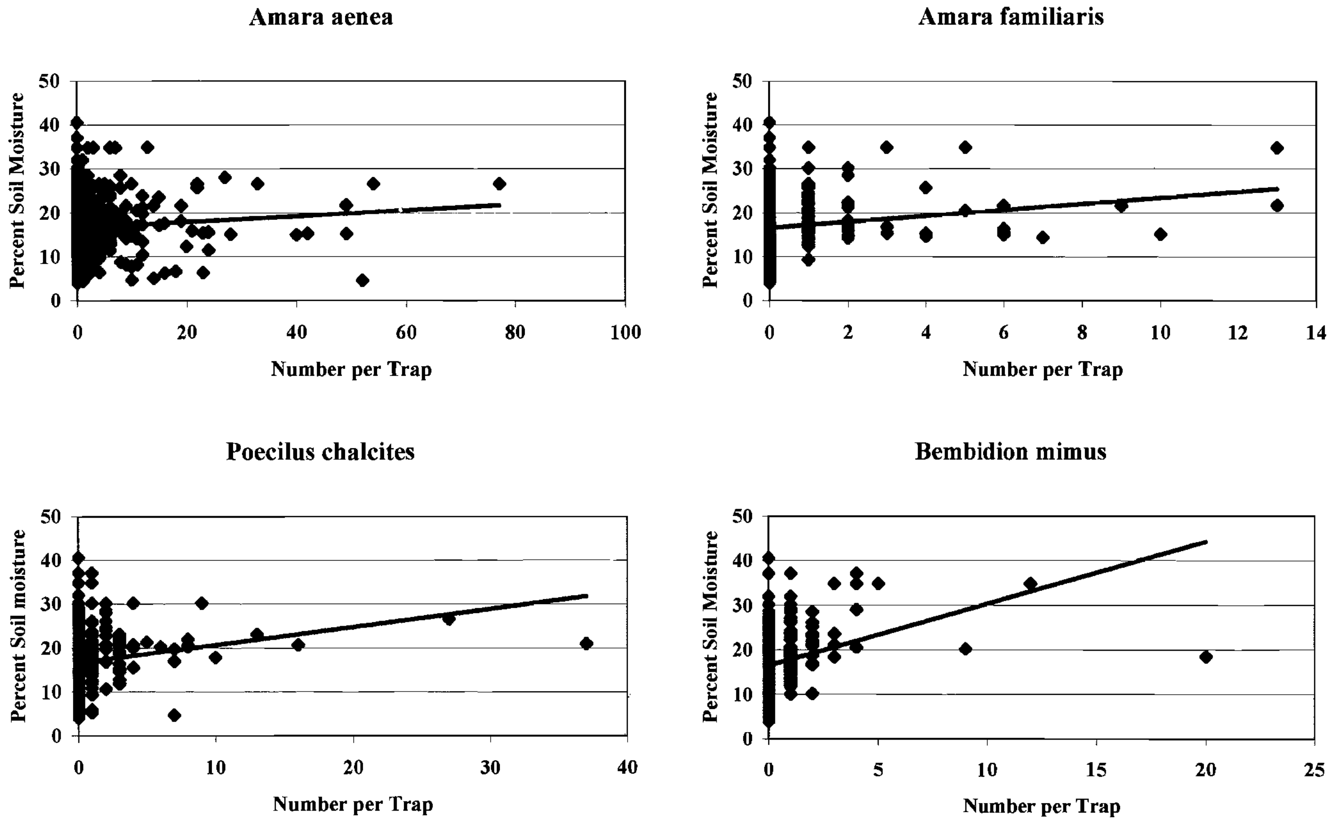


Figure 2. Effect of Soil Moisture on the four of the most abundantly collected carabid beetles (SM = 16.50 + 0.07 *A. aenea*, $F = 5.59$, $P = 0.02$; SM = 16.49 + 0.70 *A. familiaris*, $F = 17.85$, $P < 0.0001$; SM = 16.50 + 0.42 *P. chalcites*, $F = 20.76$, $P < 0.0001$; SM = 16.42 + 1.26 *A. muelleri* $F = 24.46$, $P = 0.0001$; SM = 16.32 + 2.49 *B. obtusum*, $F = 137.9$, $P = 0.0001$; and SM = 16.43 + 1.37 *B. mimus*, $F = 60.28$, $P < 0.0001$).

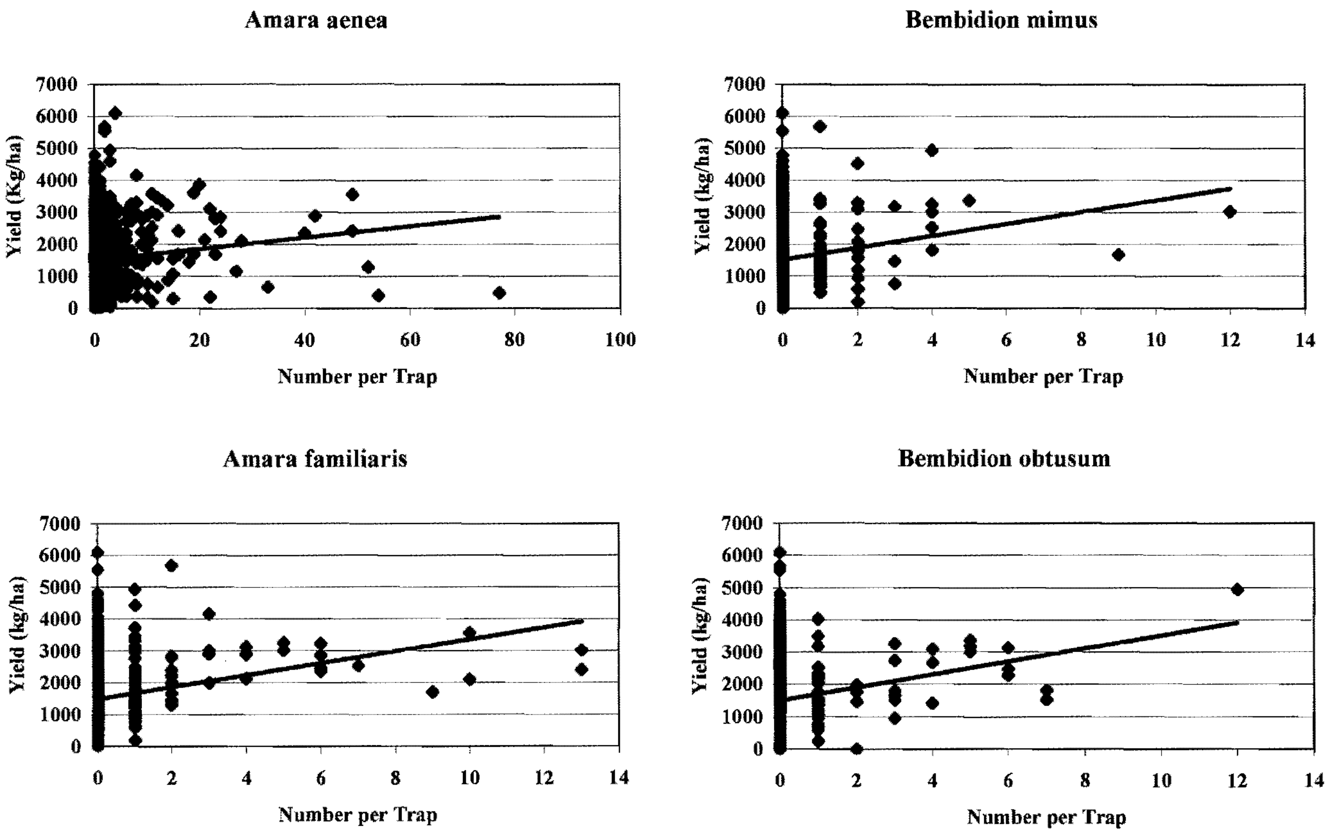
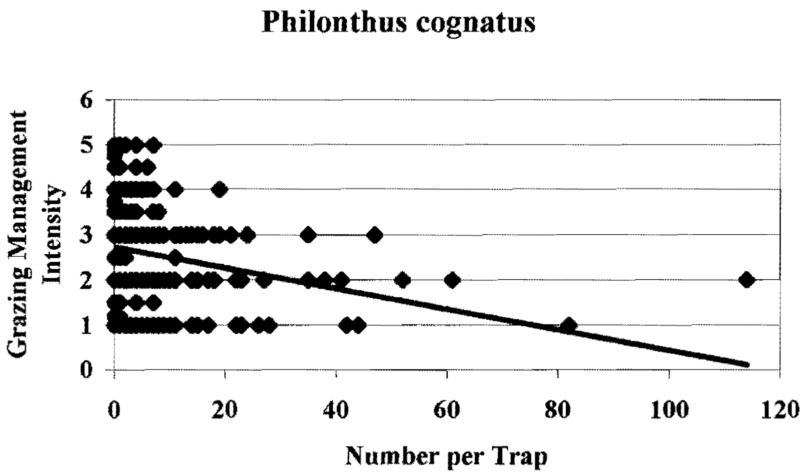


Figure 3. Effect of Biomass (kg/ha) on the four of the most abundantly collected carabid beetles (BM = 1488.9 + 17.7 *A. aenea*, F = 8.34, P = 0.004; BM = 1480 + 187.2 *A. familiaris*, F = 31.43, P < 0.0001; BM = 1500.4 + 186.4 *B. mimus*, F = 12.75, P = 0.0004; BM = 1495.7 + 200.4 *B .obtusum*, F = 19.49, P = 0.0001; and BM = 1499.0 + 191.4 *P. lucublandus*, F = 7.0, P = 0.008).



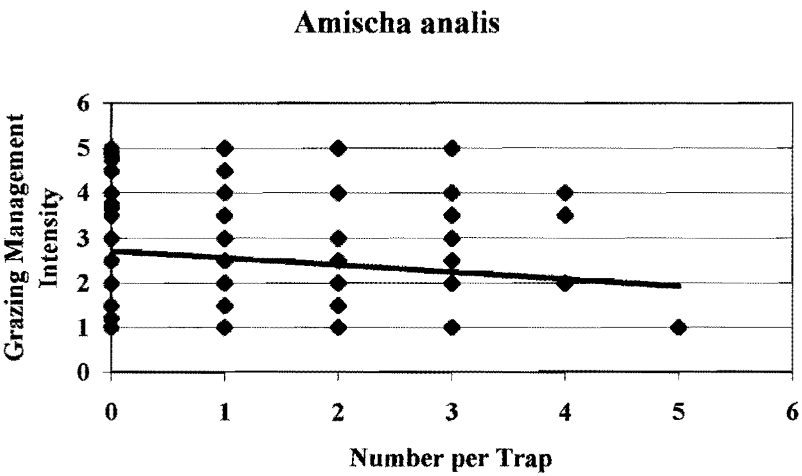
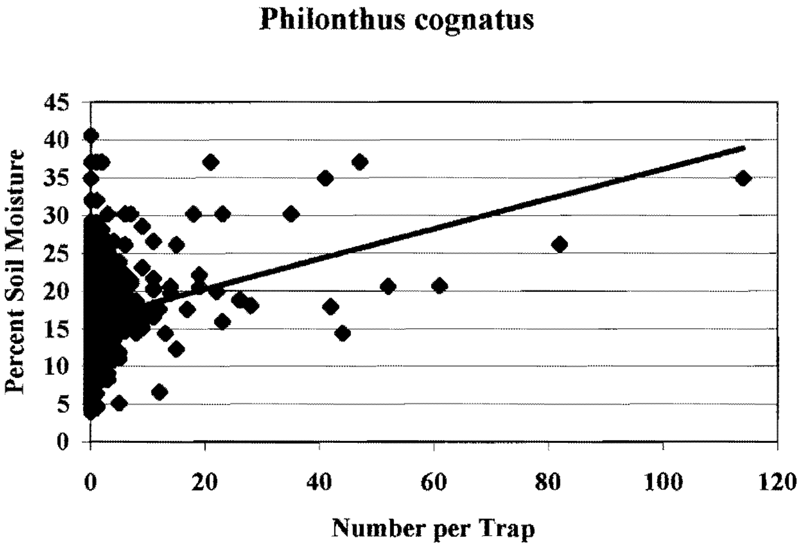


Figure 4. Effect of Grazing Management Intensity on two of the most abundantly collected staphylinid beetles (GM = 2.72–0.02 *P. cognatus*, $F = 20.31$, $P < 0.0001$ and GM = 2.71–0.16 *A. analis*, $F = 7.61$, $P = 0.006$).



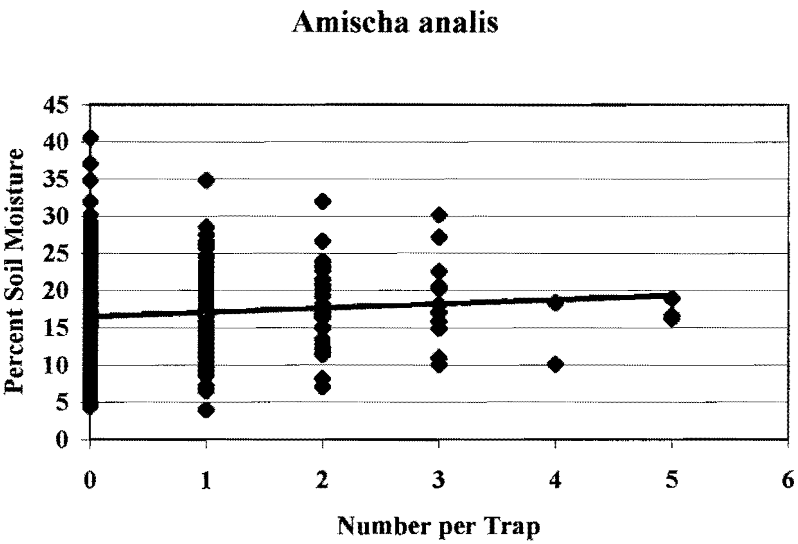
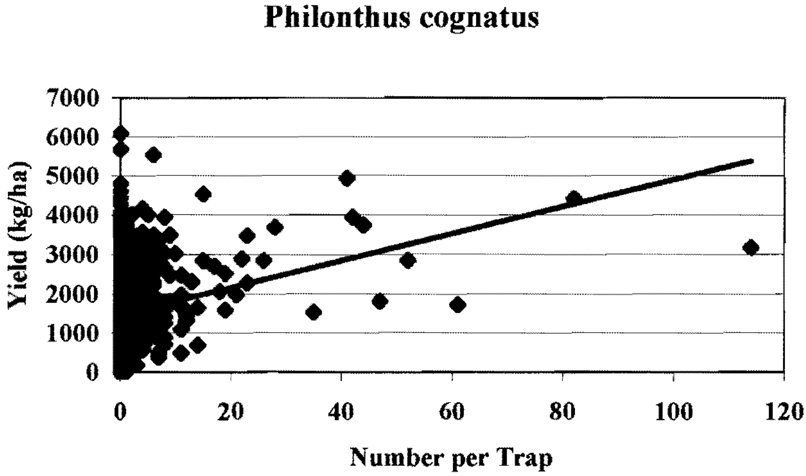


Figure 5. Effect of soil moisture on the two of the most abundantly collected staphylinid beetles (SM = 16.33 + 0.20 *P. cognatus*, $F = 61.35$, $P < 0.001$; and SM = 16.51 + 0.56 *A. analis*, $F = 4.27$, $P = 0.04$).



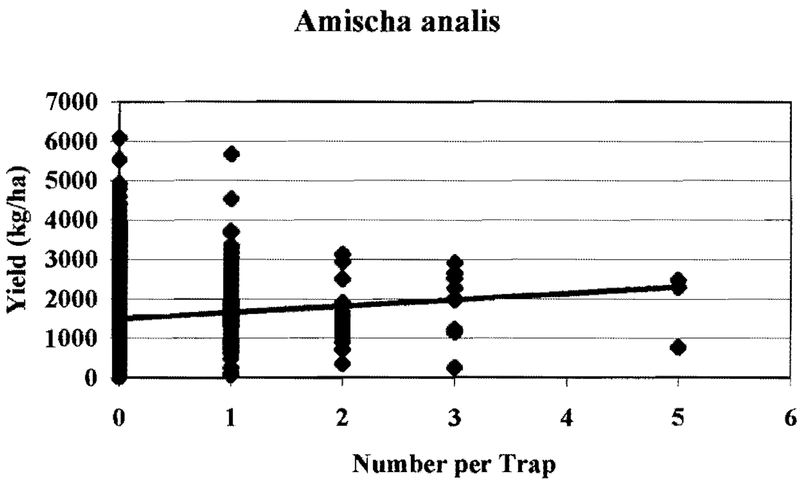


Figure 6. Effect of biomass (kg/ha) on the two of the most abundantly collected carabid beetles (BM = 1458 + 34.26 *P. cognatus*, $F = 44.87$, $P < 0.0001$; and BM = 1496.0 + 159.1 *A. analis*, $F = 5.90$, $P = 0.02$).

individuals (11,895 in two years) but diversity was low in traps due to the overwhelming abundance of a three species (*Evarthus sodalis* LeConte, *Harpalus pensylvanicus* DeGeer and *Amara cupreolata* Putzeys). Other surveys of Carabidae have shown similar results. Levesque and Levesque (1995) found that *Gyrohypnus angustatus* Stephens and *Tachinus corticinus*

Gravenhorst were the dominant rove beetle species from 181 taxa collected in rows of old and young raspberry plantations. These two species and 15 others represented 98% of the annual catch. Morris and Rispin (1987) found 3063 individuals of a small rove beetle, *A. analis*, represented 31% of the total beetle fauna of grassland at a site in the UK. Braman and Pendley (1993) collected 21 ground beetle species and 16 rove beetle species with seven species representing 93% and 87% of the total catch at two centipedegrass turf plots in Georgia. *Agonum punctiform* (Say) was most abundant at one site and *H. pensylvanicus* at the other. Lester and Morrill (1989) found 90% of 7,759 ground beetles trapped in sainfoin and alfalfa were six species: *P. melanarius*, *Harpalus amputatus* Say, *Amara farcta* LeConte, *Stenolophus comma* Fabricius, *Bembidion lampros* Herbst and *Agonum dorsale* Pontoppidan. Ellsbury et al. (1998) also found several dominant ground beetle species in several cropping systems in the northern Great Plains. Dennis et al. (1997) collected 36,176 ground and rove beetles of 68 species in 1993 and 1994 from upland semi-natural grassland in the UK. Eighty four percent of the catch consisted of five species: *Calathus melanocephalus* L., *Tachinus signatus* Gravenhorst, *Pterostichus madidus* Fabricius, *Carabus problematicus* Herbst, and *Carabus violaceus* L.

The botanical composition of northeastern U.S. pastures was quite diverse with many species of forage plants and weeds. This complex mix of species could explain the large number of carabids and staphylinids we encountered because the heterogeneity of pastures provides more resources for these insect species than perhaps would be found in more homogenous systems.

The abundance of certain ground and rove beetles were significantly correlated with some environmental and management variables and botanical composition but the r-values were < 0.30 and are not meaningful. Most of the abundant ground and rove beetles correlated positively with plant biomass but r-values were < 0.13 and no conclusions were made. Soil moisture was an important factor in catches of *P. cognatus* and *A. aenea*, the two most abundant beetles. Perhaps this factor would have been as important to other species if more individuals of other species had been collected, but very few individuals represented some species. The weak correlations of some ground and rove beetles to specific plant species are unexplained. Many predators may be eating prey associated with a particular plant. Some species such as the *Amara* group are seed feeders (Zetto 1990). *A. aenea* is phytophagous and feeds on seeds (Johnson and Cameron 1979). *Poecilus* and *Bembidion* species are also phytophagous (Johnson and Cameron 1979). Other species are saprophytes and may be feeding on decaying plants of a particular plant species. Many of the rove beetles are predacious on insects associated with dung, but also feed on fungi associated with decaying organic matter, and seeds (Levesque and Levesque 1995). Other species are both predatory and phytophagous. *P. melanarius* was the most abundant predator we collected, but also feeds on seeds. However, *P. melanarius* preferred immature *Hyperodes* spp. to grass seeds in the laboratory (Johnson and Cameron 1969). *Harpalus* species eat seeds but *Harpalus compar* LeConte act as predators under duress (Johnson and Cameron 1979).

Grazing management negatively affected several carabid and two staphylinid species. Most of these species were more prevalent in areas of high biomass (ungrazed). Most species responded positively to soil moisture, which usually relates to areas of high biomass. If grazing management increases in intensity in the future these species may not be as abundant in pastures.

The richness and abundance of Carabidae and Staphylinidae in northeastern U.S. pastures indicates the ecosystem is stable and in equilibrium. Some species were abundant year after year in Pennsylvania and the same species occurred in New York and Vermont in 1997. Grazing systems in the Northeast may become more intensively managed in the future with greater inputs of improved plant species through renovation and increases in soil fertility. Monitoring of richness and abundance of Carabidae and Staphylinidae could indicate faunal changes associated with more intensive management in the future. The challenge will be to keep the insect population as diverse as possible to safeguard against pest outbreaks common to monocultures of food crops.

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