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Functional species traits of carabid beetles living in two riparian alder forests of the Sila plateau subject to different disturbance factors (Coleoptera: Carabidae)

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Abstract
We studied carabid beetle assemblages found in riparian black alder forests in the Sila plateau (Southern Apennines). These carabid assemblages are characterized by a high incidence of endemic small-sized, low dispersal, highly stenotopic (hygrophilic), and trophically specialized species. To evaluate the influence of anthropogenic disturbance on these insects, we compared carabid assemblage of an old undisturbed forest (65-170y, wilderness landscape) with that of a younger, partly grazed stand (40-60y, cropland landscape). The carabid assemblage of the disturbed stand was characterized by a higher number of species, but showed a lower incidence of zoophagous specialists and brachypterous beetles, with many species probably coming from an adjacent cropland. However, the disturbed stand maintains almost 80% of the core species found in the older forest, which suggests that these insects are not particularly sensitive to disturbance factors represented by periodic wood harvesting and extensive cattle grazing.

Key words: ground beetles, *Alnus glutinosa*, ecological traits, Calabria, Sila National Park.

Introduction

Community structure of carabid beetles of riparian forests has been widely investigated in Central Europe and Northern Italy (e.g., Franz et al. 1959; Thiele & Weiss 1976; Thiele 1977; Obrtel 1971; Brandmayr & Brunello Zanitti 1982; Allegro & Correggia 2010). By contrast, little is known for southern Italy. The only remarkable exception is a study of the carabid beetles inhabiting a black alder site in the Aspromonte massif (Brandmayr et al. 1996). This carabid assemblage included 21 species, 23% of which Italian endemic. In this paper, we present an analysis of ground beetle assemblages found in two riparian sites in another locality in south Italian massif, the Sila Plateau.

The ground beetles living in riparian forests are mainly characterized by high dispersal power (macropterous) elements, and include several hygrophilic components belonging to waterside dwelling genera like *Platynus* Bonelli 1810, *Agonum* Bonelli 1810, *Bembidion* Latreille 1802, *Asaphidion* Gozis 1886, *Elaphrus* Fabricius 1775. Moreover, moving to Southern Italy, the frequency of relictual species and of highly sensitive or endemic taxa appears progressively increasing. Carabid beetles are widely used as biological indicators in studies on biodiversity or on environmental quality (Rainio & Niemelä 2003; Kotze et al. 2011). They seem well suited as ecological indicators on a small, local scale (single habitat type or biotope), and are frequently used to detect the changes induced by anthropogenic impacts or biota management on the ecosystem and its animal community (Brandmayr et al. 2005, Gobbi & Fontaneto 2008).

The Sila plateau is a granite bedrock upland with a rich hydrographic net marked by a highly diversified complex of hydro- and hygrophilic vegetation communities that intersects the dominant forest vegetation. More or less swampy black alder forests (*Alnus glutinosa* Gaertner) grow most along the water courses, on alluvial soils often marked by a high subsoil water level. These forests have been framed in the Euphorbio-Alnetum glutinosae Brullo & Furnari 1982, in its turn enclosed in the phytosociological class of Salici purpureae-Populetea nigrae Rivas-Martínez & Cantó ex Rivas-Martínez, Báscones, T.E. Díaz, Fernández-González & Loidi 1991. Because of severe human pressure, these riparian forests are often reduced to narrow stripes or gallery forests. However, around lentic or less sloping waters the soil becomes marshy and under natural conditions a wide black alder swamp forest can be still found. The black alder woods that develop in the numerous hydrographic basins of the Sila are all classified under the Natura 2000 Habitat code 91E0 "Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*", a priority habitat also listed in the Annex I of the EU 92/43 Habitats Directive.

To detect possible effects of human pressures on carabid assemblages of the Sila riparian forest, we compared the species composition and abundance of two large-sized alder woods subject to different levels of disturbance: one was in contact with cropland (potato fields) and pastures, the other was surrounded only by different forest types or pasturelands. We hypothesized that higher disturbance conditions in the first site should affect carabid beetles by favouring species with higher dispersal power, lower body size, wider geographic range and more opportunistic feeding habits.

STUDY AREA

The Sila upland (partially included in the territory of Sila National Park) forms a large, approximately rectangular plateau covering about 170,000 hectares at altitudes ranging from 1100 to 1800 m a. s. l., which belongs to the granite outcrop of the Calabrian Arc, a geologic domain that interrupts the calcareous sequence of southern Italian Apennines and reaches Sicily in the Peloritani Mounts. The area belongs to the oceanic temperate bioclimate. Precipitations increase with altitude (Camigliatello Silano: 1636 mm/y) and the winters are cold, with average monthly below zero minimum temperatures that give rise to abundant and long lasting snow covers (Uzunov et al. 2013). More information on the climate of the Sila upland can be found in Pesaresi et al. (2014). Sampling was done in two alder woods, identified by the acronyms Fa_On and Sb_On, respectively.

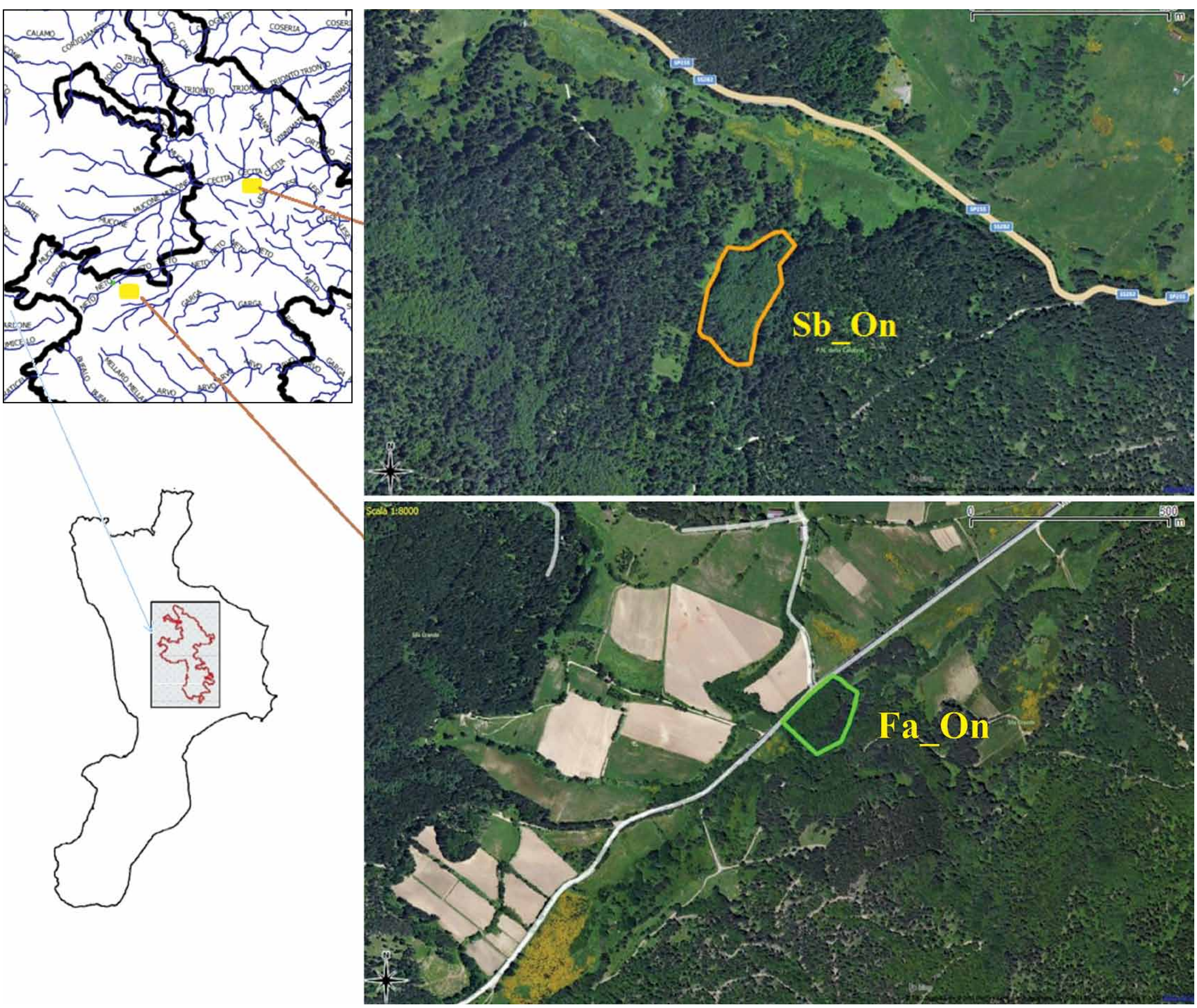

Fig. 1 – Geographic location of the study sites in the Sila National Park.

Fa_On (UTM 33 S 626657.44 m E 4353306.81 m N) is placed in the Neto river basin, Fallistro, Spezzano della Sila municipality, and presents the following main characteristics: altitude 1400m, aspect NE, slope 2°, tree covering 70%, age of trees: 40-60 y. This site is surrounded by pine forest, potato cropland and wide areas of pasturelands. During the summer, cows are often resting in the alder wood.

Sb_On (UTM 33 S 638101.69 m E 4361306.81 m N) lies in the Cecita river basin, near the Sbanditi arboretum (Fossiata, Longobucco municipality), and present the following main characteristics: altitude 1340m, aspect N, slope 2°, tree covering 80-90%, age of trees 65-170y. The wood is surrounded by pine forest and wide grasslands where grazing ceased after 2011. This less disturbed forest stand is perhaps the oldest black alder site in the whole Sila plateau. Location of the two sampled alder woods is shown in Figure 1.

METHODS

Ground beetles were collected in 2013 during their entire activity season, from April to October, with pitfall-traps emptied every 20 days, to obtain a conspicuous "year sample". In each sampling site a number of 7 or 8 traps were set up to compensate trampling by cows or running waters and to ensure at least 5 undamaged traps per time. Traps were given by plastic vessels with an upper diameter of 9.2 cm and a depth of 11 cm and provided with a small hole to avoid water filling and "aquaplaning" of beetles. Traps were filled up to two thirds of their depth with a commercial wine vinegar saturated by sodium chloride as further preservation measure and buried at least 10 meters from each other on a straight line. Wine vinegar is known to attract preferentially some larger Carabinae or the Sphodrines, such as *Calathus* spp. but not phytophagous carabids (*Amara*, *Harpalus*). Nevertheless, vinegar has been

Fig. 2 – A ♀ of *Carabus* (*Chaetocarabus*) *lefebvrei bayardi* (Sila National Park, Sbanditi-Fossiata, November 20th, 2011; photo by Antonio Mazzei).

demonstrated to be a better collecting fluid than other commonly used solution, such as propylene glycol, if used in large mouth traps (90 mm, Koivula et al. 2003). Moreover, if compared to pure water, vinegar allows a collection of larger numbers of species and individuals by keeping the species structure very similar (Allegro & Dulla 2008). In our experience, wine vinegar favors the capture of large, rare species like *Carabus* or *Cychrus* especially under dense vegetation conditions. Species abundance has been calculated as individuals/trap in a standard period of 10 days (annual activity density: aAD) as in most year sampling studies conducted in Italy (e.g.: Brandmayr et al. 2005, Pizzolotto et al. 2014). To evaluate the differences in species composition and abundance between the two stands, we analyzed a set of species traits selected among the best reflecting functional characteristics related to habitat preferences or species' history (Cole et al. 2002; 2012; Kotze et al. 2003; Ribera et al. 2001; Taboada et al. 2006; Mazzei et al. 2012; Homburg et al. 2013): size, food preferences of adults, wing status for dispersal power, distributional range, habitat affinity and reproduction rhythm). We extracted size measures as total body length from Porta (1923 -1934). We did not distinguish between males and females and when minimum and maximum values were given in Porta, we calculated their arithmetic mean. Then, based on these body size values, species were classified into dimensional classes using a five mm scale. Habitat affinity was derived by already published literature (Brandmayr et al. 2005) on the Italian fauna or from our unpublished databases.

Abax parallelepipedus, a species with unstable overwintering conditions (Thiele 1977), has been provisionally classified under the autumn breeders, because probably a large part of the larval population is overwintering (winter larvae).

Taxonomy and nomenclature of Italian Carabidae follow Vigna Taglianti (2004, 2005), with a few recent updates.

RESULTS

We collected 1231 individuals belonging to 36 carabid species (Table 1). For each trait, Table 2 shows the number and percentage of species that present that trait in the two assemblages. In Sb_On, we found 17 ground beetle species, several of which are characteristic of hygrophilic riparian wood communities or of swampy, high subsoil water forests. In Fa_On we collected S = 32. The total annual activity density (taAD) of carabid beetles is three times higher in Fa_On than in Sb_On. The species that contribute to this noticeable difference of ground beetle activity density are three generalist predators: *Pterostichus nigrita*, *Calathus rotundicollis* and *Nebria brevicollis*. The last one is very abundant in Sila croplands. Among the 13 species that were found in both sites, at least five are associated with or frequent in black alder woods of the Sila landscape: *Loricera pilicornis pilicornis*, *Elaphrus* (*Neoelaphrus*) *uliginosus*, *Pterostichus ruffoi*, a Calabrian endemic vicariant of *P. micans* Heer 1841, *Bembidion* (*Philochthus*) *demartini*, an Italian endemic that inhabits forested and open watersides of the Southern Apennine (Neri & Gudenzi 2011), and *Calathus* (*Amphyginus*) *rotundicollis*. Four species, among which the forest dwellers *Cychrus italicus, Calathus montivagus* and *Carabus* (*Chaetocarabus*) *lefebvrei bayardi* (Fig. 2), were captured only in the Sb_On site.

Focusing on species traits (Tab. 2), small-sized taxa dominated in the old undisturbed forest Sb_On, where 70% of the species have a body length < 10 mm. In Fa_On 34% of the species had a body size between 10 and 20 mm. The Fa_On assemblage was also characterized by a high percentage of opportunistic omnivorous and granivorous species (20% of the species). Ground beetle species able to fly (i.e. with high dispersal power) are better represented in the Fa_On assemblage (72%) than in the Sb_On assemblage (59%). Endemics were much more represented in the Sb_On assemblage (41%) than in the Fa_On assemblage (16%.). Stenotopic forest dwellers were largely prevailing in the Sb_On assemblage (59%), whereas they represented 41% of the species of the Fa_On assemblage. Spring or summer breeders (with summer larvae) are largely prevailing in both sites, but in Fa_On the number of autumn breeders is higher, probably an indication of a lower subsoil water level in the late summer/fall months.

DISCUSSION

Black alder forests of Southern Italy are subject to severe harvesting and forms of disturbance due to cattle grazing, especially in late summer, when open areas around forests are too arid (Pesaresi et al. 2014). Black alder forests of the Sila plateau host a highly diversified hygrophilic assemblages of species favored by the impermeable granite rock substrate and the related capillary net of brooks and streams that permeates the plateau (Bonacci et al. 2012; Mazzei et al. 2010) as well as for plants (Gangale et al. 2011; Gangale & Uzunov 2013). Moreover, black alder forests might represent an important biotope for the conservation of the saproxylic beetle *Cucujus cinnaberinus* (Scopoli 1763), an umbrella species listed in Annex II of the Habitats Directive (Mazzei et al. 2011). Our comparison of the carabid beetles inhabiting an undisturbed, mature black alder forest with those occurring in younger forest surrounded by a managed landscape, highlighted important differences in species composition and traits. The old stand showed a lower number of species, most of which are less than 10 mm long, higher percentages of endemic predator, spring breeder and stenotopic forest dwellers, and a lower proportion of species able to fly. Although the younger stand had a larger number of species, out of the 19

Table 1 – Carabid species included in the analysis and their ecological attributes. **I**, Size (body length); **II**, Food of the adult; **III**, dispersal power (wing morphology); **IV**, geographical range (chorotype); **V**, habitat association of the species; **VI**, reproduction rhythm. Numeric codes of species traits as in Table 2. Ecological traits here used have been identified and reported by many authors (see Cole et al. 2002; 2012; Kotze et al. 2003; Ribera et al. 2001; Taboada et al. 2006; Homburg et al. 2013).

		Sb_On	Fa_On	*I*	*II*	*III*	*IV*	*V*	*VI*
1	*Pterostichus* (*Platysma*) *niger* (Schaller, 1783)	1.25	0.20	4	2	3	5	2	3
2	*Pterostichus* (*Pseudomaseus*) *nigrita* (Paykull, 1790)	0.73	2.66	3	2	3	6	2	3
3	*Trichotichnus* (*Trichotichnus*) *nitens* (Heer, 1838)	0.52	0.49	2	4	2	3	1	1
4	*Pterostichus* (*Phonias*) *strenuus* (Panzer, 1796)	0.42	0.82	2	2	3	5	1	3
5	*Bembidion* (*Philochthus*) *demartini* Neri & Gudenzi, 2011	0.38	0.37	1	2	3	2	1	3
6	*Trechus* (*Trechus*) *obtusus lucanus* Focarile, 1949	0.35	0.27	1	2	3	2	1	2
7	*Amara* (*Amara*) *anthobia* A. Villa & G.B. Villa, 1833	0.14	0.56	2	4	3	3	2	3
8	*Loricera pilicornis pilicornis* (Fabricius, 1775)	0.12	1.02	2	1	3	6	2	3
9	*Notiophilus rufipes* Curtis, 1829	0.06	0.10	1	1	3	3	1	3
10	*Elaphrus* (*Neoelaphrus*) *uliginosus* Fabricius, 1792	0.01	0.06	2	1	3	5	1	3
11	*Metallina* (*Metallina*) *lampros* (Herbst, 1784)	0.01	0.19	1	2	2	6	2	3
12	*Calathus* (*Amphiginus*) *rotundicollis* Dejean, 1828	0.01	1.86	2	2	1	2	1	2
13	*Pterostichus* (*Pterostichus*) *ruffoi* Sciaky, 1986	0.01	0.13	3	2	1	1	1	1
14	*Cychrus italicus* Bonelli, 1810	0.05		5	1	1	2	1	2
15	*Badister* (*Badister*) *bullatus* (Schrank, 1798)	0.06		1	1	3	6	2	3
16	*Carabus* (*Chaetocarabus*) *lefebvrei bayardi* Solier, 1835	0.02		6	2	1	2	1	3
17	*Calathus* (*Calathus*) *montivagus* Dejean, 1831	0.02		2	2	1	2	2	2
18	*Nebria* (*Nebria*) *brevicollis* (Fabricius, 1792)		2.46	3	2	3	5	2	2
19	*Carabus* (*Oreocarabus*) *preslii neumeyeri* Schaum, 1856		0.63	5	2	1	3	1	2
20	*Anchomenus* (*Anchomenus*) *dorsalis* (Pontoppidan, 1763)		0.19	2	2	3	6	2	3
21	*Nebria* (*Nebria*) *kratteri* Dejean & Boisduval, 1830		0.14	4	2	1	4	1	2
22	*Agonum* (*Melanagonum*) *permoestum* Puel, 1938		0.12	3	2	3	5	2	3
23	*Poecilus* (*Poecilus*) *cupreus* (Linné, 1758)		0.09	3	2	3	5	3	3
24	*Amara* (*Amara*) *aenea* (De Geer, 1774)		0.09	2	4	3	6	3	3
25	*Clivina* (*Clivina*) *collaris* (Herbst, 1784)		0.07	2	2	3	5	2	2
26	*Anisodactylus* (*Anisodactylus*) *binotatus* (Fabricius, 1787)		0.06	3	4	3	5	2	3
27	*Syntomus obscuroguttatus* (Duftschmid, 1812)		0.06	1	2	3	4	3	3
28	*Calathus* (*Calathus*) *fuscipes graecus* Dejean, 1831		0.04	3	2	2	4	3	2
29	*Leistus* (*Leistus*) *fulvibarbis fulvibarbis* Dejean, 1826		0.03	2	1	3	4	2	2
30	*Ophonus* (*Metophonus*) *rufibarbis* (Fabricius, 1792)		0.03	2	3	3	5	3	3
31	*Amara* (*Amara*) *eurynota* (Panzer, 1796)		0.03	3	4	3	5	3	3
32	*Synuchus vivalis vivalis* (Illiger, 1798)		0.01	2	2	3	5	2	2
33	*Abax* (*Abax*) *parallelepipedus curtulus* Fairmaire, 1856		0.01	4	2	1	3	1	2
34	*Asaphidion stierlini* (Heyden, 1880)		0.01	1	2	3	4	1	3
35	*Harpalus* (*Harpalus*) *rubripes* (Duftschmid, 1812)		0.01	2	4	3	5	3	3
36	*Platyderus neapolitanus neapolitanus* Reiche, 1855		0.01	2	2	1	2	1	1

species found here and not in the older stand, three (*Abax parallelepipedus curtulus*, *Nebria kratteri*, *Carabus preslii*) are strictly associated with forests (Brandmayr & Zetto Brandmayr 1987) and one (*Asaphidion stierlini)* is a visual predator (Ribera et al. 1999) associated with more or less shaded waterside sandbanks (Brandmayr & Brunello Zanitti 1982). Almost all the other species are associated with open biotopes (*Calathus fuscipes graecus*, *Syntomus obscuroguttatus*, *Ophonus rufibarbis*, *Harpalus rubripes*), are eurytopic (*Platyderus neapolitanus*, *Synuchus vivalis)* or are associated with cultivated fields (*Anchomenus dorsalis, Anisodactylus binotatus, Poecilus cupreus, Amara aenea, A. eurynota* and *Clivina fossor)* (Jeannel 1941-42; Lindroth 1945; Thiele 1977; Vigna Taglianti 2000; Mazzei et al. 2010; Bonacci et al. 2011). Species traits suggest that, in comparison with the older stand, the younger one is a less stable environment (fewer endemic and brachypterous species), has a lower prey diversity (fewer

Table 2 – Summary of species traits for the carabid species inhabiting black alder forests in the Sila National Park. **Sb_On**, old black alder forest in the "Sbanditi arboretum"; **Fa_On**, young alder wood near "Fallistro" in the Neto river basin. **S - %**, species number represented by the trait code and the corresponding percentage.

Ecological trait	Categories of trait	Numerical code	Sb_On N°	%	Fa_On N°	%
I= Size (length)						
	≤ 5 mm	1	**5**	29%	**6**	19%
	> 5 - ≤ 10	2	**7**	41%	**14**	44%
	> 10 - ≤ 15	3	**2**	12%	**8**	25%
	> 15 - ≤ 20	4	**1**	6%	**3**	9%
	> 20 - ≤ 25	5	**1**	6%	**1**	3%
	> 25 - ≤ 30	6	**1**	6%	**0**	0%
	> 30 mm	7	**0**	0%	**0**	0%
II = Food of the adult						
	Specialist predators	1	**5**	29%	**4**	13%
	Generalist predators	2	**10**	59%	**21**	66%
	Phytophagous	3	**0**	0%	**1**	3%
	Mixed diet (polyphagous)	4	**2**	12%	**6**	19%
III = Wing morphology						
	brachypterous	1	**5**	29%	**6**	19%
	dimorphic	2	**2**	12%	**3**	9%
	macropterous	3	**10**	59%	**23**	72%
IV = Chorology						
	Calabrian endemics	1	**1**	6%	**1**	3%
	Italian endemics	2	**6**	35%	**4**	13%
	European	3	**3**	18%	**5**	16%
	Mediterranean	4	**0**	0%	**5**	16%
	Eurasiatic/Eurosiberian	5	**3**	18%	**12**	38%
	Palearctic	6	**4**	24%	**5**	16%
V = habitat association of the species	forest	1	**10**	59%	**13**	41%
	generalist	2	**7**	41%	**12**	38%
	open habitat species	3	**0**	0%	**7**	22%
VI = Reproduction rhythm						
	Two years life cycle	1	**2**	11,8%	**3**	9,4%
	Autumn (winter larvae)	2	**4**	23,5%	**10**	31,3%
	Spring/summer (summer larvae)	3	**11**	64,7%	**19**	59,4%

specialized predators), a higher prey density (larger mean size of species), and a more favorable subsoil water level in autumn and winter (presence of several autumn breeders). These results are in line with previous studies indicating that in a fragmented forest landscape even interior assemblages are altered by the invasion of numerous stragglers from neighboring open (e.g. cropland) biotopes (Noreika & Kotze 2012; Halme & Niemelä 1993; Niemelä 1996).The thirteen species found in both forest stands are all more or less strictly associated to the black alder forests, and, in some cases, with population densities even higher in the disturbed stand than in the older one (*Loricera pilicornis, Elaphrus uliginosus, Pterostichus rufoi*). Only few species strictly associated with forests, such as *Carabus lefebvrei* and *Cychrus italicus* (Brandmayr et al. 2005), are missing in the disturbed stand, where, however, other species typical of mesic forests, such as *Abax parallelepipedus* and *Nebria kratteri* (Brandmayr & Zetto Brandmayr 1987), were found. Presence in the disturbed stand of *Asaphidion stierlini*, an inhabitant of lower altitude riparian forests (Brandmayr & Brunello Zanitti 1982), associated with bare sand or loam flats, is consistent with the "riparian character" of the assemblage, but is also a possible reflection of a lighter canopy and of soil trampling. The species belonging to this Bembidiine genus are known to be visual hunters (Bauer & Kredler 1983) that search for their prey on fine grained, spoiled and wet surfaces, as often produced by resting livestock (Brandmayr and co-workers unpublished data). On the whole, the young managed forest conserves 13 (76%) of the 17 species found in the old stand, which suggests that opportunistic species found in the disturbed stand were unable to compete and exclude those typical of mature forests.

CONCLUSIONS

This paper presents a first study of carabid assemblages of the black alder riparian forests of the Sila plateau, a biotope so far almost unknown as regards its soil invertebrates. A comparison of species composition of a mature, relatively undisturbed forest with that of young, disturbed forest suggests a relatively good resilience of most carabid species against low to medium intensity disturbance such as extensive grazing. As recently reviewed by Fountain-Jones et al. (2015), species traits allow us to extend a framework of eco-functional responses of a guild (e.g.: ground beetles) from a local to a global scale, thus avoiding a merely taxonomic approach based on regional species pools. The same concept from local to global has been outlined by Pizzolotto et al. (2014) for chorological traits only, by proposing a new index of biogeographical peculiarity (IBP), that emphasizes the value of endemic species for different habitat types. The use of species traits for terrestrial habitats seems to give us an interesting new chance in evaluating habitat disturbance, provided that species' ecology, morphology, physiology and life cycles are well known in the taxon studied.

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