Ground beetles (Coleoptera Carabidae) in the wall park of the city of Ferrara (Emilia-Romagna, Italy)

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Abstract

In 2019, the carabid beetles of the semi-circular park organized around the ancient walls of the city of Ferrara were studied with pitfall sampling. Data were used to calculate the Index of Natural Value of the entire park and of each sampling site. They were compared with a previous list of species collected between 1964 and 1990 by the entomologist Giorgio Grillenzoni. The restoration works that took place in 1988-89 deeply changed the ecosystem, reducing the forested areas and increasing the anthropic uses of the park. Twenty-two new species were added to the theoretical pool of the park but, as a whole, the list of the species shortened. The largest species (*Calosoma sycophanta*, *C. auropunctata*, *Carabus coriaceus*, *C. granulatus interstitialis*) disappeared, but two species added to the list of the endemic ones, now composed by *Abax contractus*, *Platyderus neapolitanus* and *Trechus binotatus*. The xero-thermophilous and Mediterranean in a broad sense species increased their presence, reaching 35% of the list as a probable consequence of both ecosystem changes and climate change. The INV pointed to an intermediate level of natural conservation in comparison with other regional ecosystems. The highest score was reached by a not managed portion of the park with many fallen trees. Some management suggestions are given.

Key words: Carabidae, Index of Natural Value, urban heat islands, Climate Change, Po Valley

Riassunto

Coleotteri Carabidi (Coleoptera Carabidae) nel parco delle Mura di Ferrara (Emilia-Romagna, Italy)
Nel 2019 sono stati studiati con trappole a caduta i Coleotteri Carabidi del parco semicircolare organizzato intorno alle antiche mura della città di Ferrara. I dati sono stati utilizzati per calcolare l'Indice di Pregio Naturalistico dell'intero parco e di ciascun sito di campionamento e sono stati confrontati con un precedente elenco di specie raccolto tra il 1964 e il 1990 dall'entomologo Giorgio Grillenzoni. I lavori di restauro avvenuti nel 1988-89 hanno profondamente modificato l'ecosistema, riducendo le aree boschive e aumentando gli usi antropici del parco. Ventidue nuove specie sono state aggiunte al pool teorico del parco ma, nel complesso, l'elenco delle specie si è accorciato. Le specie di taglia maggiore (*Calosoma sycophanta*, *C. auropunctata*, *Carabus coriaceus*, *C. granulatus interstitialis*) sono scomparse, ma due specie si sono aggiunte all'elenco di quelle endemiche, ora composte da *Abax contractus*, *Platyderus neapolitanus* e *Trechus binotatus*. Le specie xerotermofile e mediterranee in senso lato hanno aumentato la loro presenza, raggiungendo il 35% dell'elenco. L'IPN ha indicato un livello intermedio di conservazione della natura rispetto ad altri ecosistemi regionali. Il punteggio più alto è stato raggiunto da una porzione non gestita del parco con molti alberi caduti. Vengono forniti alcuni suggerimenti gestionali.

Key words: Carabidae, Indice di Pregio Naturalistico, Isole di calore urbano, Cambiamento climatico, Pianura Padana.

Introduction

Carabidae are Adephaga beetles present in Italy with over 1600 known species (Casale *et al.*, 2021). They often turn out to be useful as bioindicators of the conservation status of the natural and semi-natural environment (Brandmayr *et al.*, 2005): that is possible since, particularly in European countries, they are well-known taxonomically and ecologically, have a high diversity of species, efficiently reflect biotic and abiotic conditions, they are relevant at different spatial scales and it is easy to collect them in large enough numbers to allow statistical analysis (Koivula, 2011).
Ground beetles also are beneficial insects in agriculture, since both larvae and adults of most carabid species predate many invertebrate pests such as aphids, lepidopteran larvae and slugs (Rouabah *et al.*, 2015). Several other species can be important predators of weed seeds. Moreover, they are often used as ecological model organisms, for instance to test the effects of pesticides (Giglio *et al.*, 2017) or to elaborate general ecological theories (Kotze *et al.*, 2011).
In the past, numerous studies have been conducted on Carabidae of the Ferrara area, concentrated on the ecosystems with the highest degree of naturalness, such as the Po River floodplains, other sites of the Po Delta Regional Park and some Natura 2000 sites (e.g. Contarini, 1988; Contarini & Garagnani, 1981; Fabbri, 1996; Fabbri & Pesarini, 1996; Fabbri & De Giovanni, 1997; Fabbri *et al.*, 2005; Fabbri & Corazza, 2009; Boscolo *et al.*, 2013; Maccapani *et al.*,

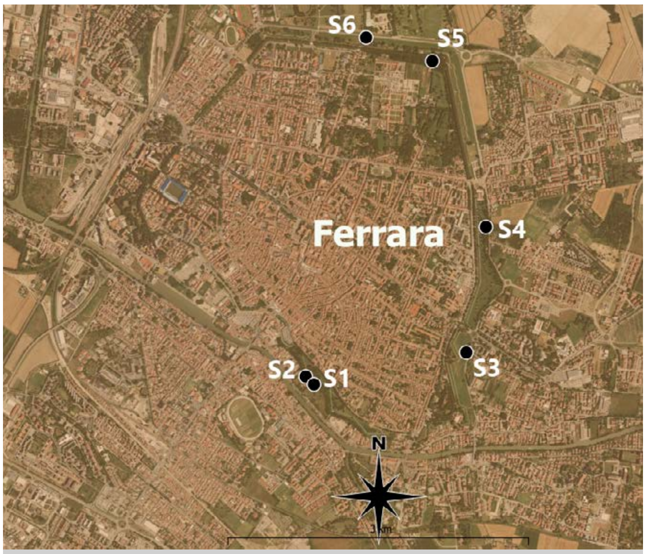

Fig. 1. The wall park surrounding the ancient quarters of the city of Ferrara with our 6 sampling sites.

2015). In recent years, Corazza & Fabbri (2017) studied the ground beetles along the shores of the artificial ponds, typical of the agricultural landscape of Ferrara, used in the past centuries to process textile hemp. In the period 1964-1997, a survey involved some ecosystems of the Ferrara municipality, including the ancient wall complex that encircles the historical centre of the city (Sciaky & Grillenzoni, 1990).

In the present paper, we report the results of a new study carried out in 2019 on the fauna of the ground beetles living in the park of the ancient walls that surround the historic centre of the city of Ferrara. Results have been compared with a similar study carried on by Sciaky & Grillenzoni (1990) some decades before.

Study area

Ferrara is a city located in the eastern Po Valley, one of the most anthropized areas in Italy and Europe. The city originated in the Middle Ages, favoured by the presence of two important branches of the Po River, fundamental for commercial traffic between the interior of the Po Valley and the coasts of the Adriatic Sea. Today the historic centre of the city of Ferrara is almost completely surrounded by 9 km of mediaeval terracotta brick walls, about 6 metres high. The walls are coupled with a clay embankment, about 3 metres high. A fortification moat accompanies the external profile of the walls, about 80 metres wide and 2 metres deep. The three structures together surround the oldest districts of the north, east and south-east parts of the city: the south-western corner of the walls was destroyed due to historical events in the centuries following the decline of the Este family (1598) that had governed the city. The current wall complex (moat, walls and embankments) forms a semicircular urban park with a surface of about 150 ha.

In the Middle Ages, the walls of the northern part of the city were related to a large wooded hunting reserve of the Este family. Some aerial photographs taken in the Thirties of the XX century (Geoportale Emilia Romagna, 2022) show that the moat was occupied by bushes. Later, during the Fifties, it was almost entirely cultivated with regular lines of trees, maybe poplars (*Populus nigra* var. *italica*) perpendicular to the fortification walls. Other photographs show that a dense tree cover was still present in 1982, a few years before an extensive restoration work that took place in 1988-89.

Today, the moat houses permanent meadows and scattered trees (Fig. 2). Part of the meadows is managed for haymaking, whilst other meadows are regularly mowed, and cut grass is left in situ. Cyclable tracks encircle all the walls and run along the top of the embankment, creating paths largely used by the citizens. Some remnants of the wild vegetation with trees

Fig. 2. The wall park around the historical center of the city of Ferrara (photos by Giulia Finotti).

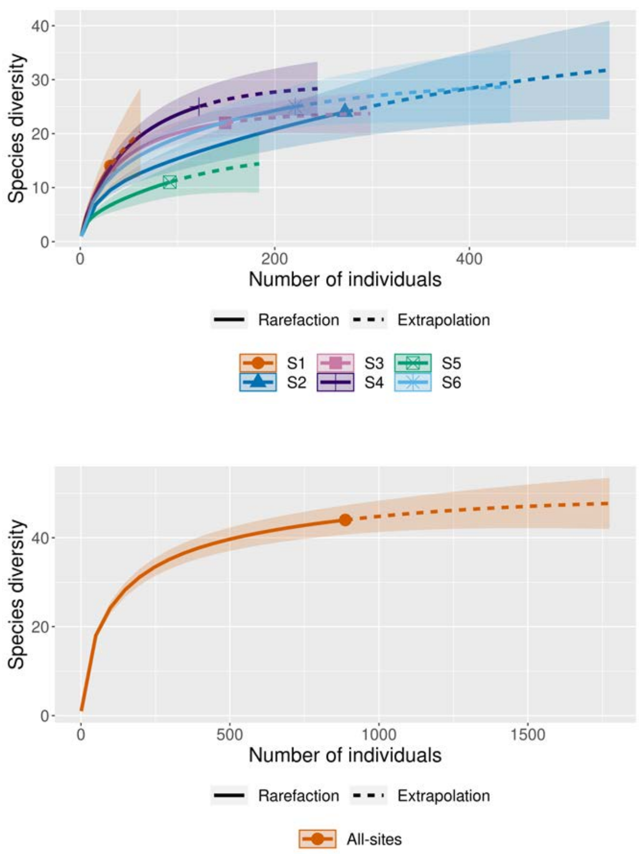

Fig. 3. Rarefaction curves for each single sampling site and for the entire wall park. Shaded areas draw the 95% confidence limits.

and bushes are still present along some ditches that border the outer profile of the moat and, in the north-eastern corner of the walled complex, along the bank escarpment.

Due to its circular structure, the wall park has many orientations with respect to sunlight. At the same time, the moat has irregular depths and the slow degradation of the terracotta bricks enriches the soil of mineral components. As a consequence, the park encompasses numerous habitats and microhabitats with different levels of temperature and humidity whose effects are evident, for instance, observing the high botanical diversity, the highest inside the city of Ferrara, with some interesting presences (Piccoli & Pellizzari, 2003).

Sampling technique

In 2019, the ground beetle community was sampled in 6 locations along the wall park (Fig. 1), for a total of 27 traps: three locations had 3 traps and three locations had 6. The traps were active from March 21st to October 4th, 2019.

Sampling station 1 was at the top of the walls, on an enlarged, not managed, and south-oriented bulwark, rich in herbs, small trees, and bushes. Station 2 was in the southern part of the park, in the moat with lawns and bushes, and nearby the raised embankment covered with trees and bushes. Stations 3 and 4 were in the Eastern part of the park, not far from a small peripheral canal covered by a gallery of trees that runs alongside the external border of the moat. Station 5 was in a sheltered part of the wall embankment without human trampling, with many fallen trunks and an important presence of young laurel trees (*Laurus nobilis*). Station 6 was in the northern portion of the moat, an area with scattered trees, large managed lawns, and small ditches; the area is partly flooded in case of intense rain.

The ground beetles were collected with attractive plastic pitfall traps 12 cm deep with an upper diameter of 9 cm. Inside each trap, we poured about 250 ml of a saturated solution of NaCl in vinegar (Allegro & Dulla, 2008). Each trap was protected from rain, evaporation, and debris by a transparent plastic cup or by pieces of bark, leaving a space of about 2 cm over the ground to allow the insects to walk into the trap. In every sampling location, each trap was at least 6 meters apart from the others, a distance that fall in the range adopted in many studies (Woodcock, 2021).

Statistical analyses

The original, not standardized species counts were used to draw the rarefaction curves that analyse species diversity and the completeness of the sampling. We adopted the online tool supplied by Chao *et al.* (2016) with 95% confidence limits.

In order to compensate for the different operational times and for differences in the number of traps, due to both disturbances or different installation schemes, we standardised the abundances of the caught carabid beetles as Annual activity Density (AaD) (Brandmayr *et al.*, 2005; Pizzolotto *et al.*, 2018). Annual activity density is preferred in the studies on Carabid communities because pitfall trap catches depend on the walking activity of the beetles and they are not directly related to the population size of the species captured (Niemela & Kotze, 2009). AaD was calculated as the total number of collected carabids divided by the total sampling effort:

AaD = Total number of individuals/Σ su

where su (sampling unit) is equal to the number of active traps multiplied by the number of days of activity in each sampling span of time and divided by 10.

The standardised counts were used to calculate the Pielou's Equitability index E, needed in the calculation of the Index of Natural Value, and to perform a cluster analysis (UPGMA algorithm performed on Bray-Curtis similarity metrics), in both Q and R modes, with the Past 4.11 software (Hammer *et al.*, 2001), to highlight similarity and differences in the community composition of the different sites.

Index of Natural Value

The index proposed by Brandmayr *et al.* (2005) was calculated for each sampling site and for the entire wall park, in order to achieve information about the role of the park in preserving species with high ecological requirements. The morphology of the wing was analyzed on each specimen collected; the information on nutrition came from the various bibliographic sources cited below and from the direct observation of the authors. The INV index was calculated following the same approach used in past papers (Fabbri & Corazza, 2009) by adding up: the percentages of species with reduced functional wings; the percentages of individuals with reduced functional wings; the percentages of species with specialized predatory habits; the percentages of individuals with specialized predatory habits. We then added the Pielou index E of each sampled community, to introduce a parameter that summarises the structure of the community, not only with reference to the number of species but also taking into account the dominant relationships among the species.

Comparisons with previous faunistic studies

The Museum of Ferrara preserves the Carabidae collected by Giovanni Grillenzoni in the wall park between 1964 and 1997. The largest number of specimens was collected before 1989, in particular between 1978 and 1983, i.e. before the restoration of the fortification. These data were published in 1990 by Sciaky & Grillenzoni and we used them for some comparisons. The catching techniques adopted by Grillenzoni included attractive pitfall traps and collection by hand: the comparisons considered only the presence/absence of the species and not the number of individuals.

The chorology of the different carabid species, the feeding habits, the wing morphologies, the body size of the species, and the preferences in terms of temperature and humidity were analysed, using different bibliographic resources (Agosti & Sciaky, 1995; Allegro, 1997, 2005; Allegro & Burlisch, 2012; Allegro & Correggia, 2010; Allegro & Dulla, 2008; Allegro *et al.* 2016; Brandmayr *et al.*, 2005; Della Rocca *et al.*, 2021; Delunas & Cillo, 2020; Facchini & Sciaky, 1999; Grottolo *et al.*, 2016; Negro *et al.*, 2020; Neri *et al.* 2011, Pesarini & Monzini, 2010, 2011; Pilon *et al.*, 2013; Sciaky & Grillenzoni, 1990; Zanella, 2010; Zanella & Uliana, 2022), personal observations of the authors and some suggestions by the entomologists R. Fabbri and F. Pesarini.

Results

In 2019, a total of 887 individuals, 24 genera and 43 species of Carabidae were collected, listed in Appendix A. All the sampled beetles are stored in the collections of the Museum of Natural History of Ferrara. Only three females belonging to the genus *Agonum* were not identified at the species level. The most abundant species were *Pseudoophonus rufipes* and *Trechus quadristriatus*, with 132 and 129 individuals, respectively.

The rarefaction curves (Fig. 3) and the SC estimator (Tab. 1) indicated that the sampling was incomplete in site 1 but acceptable in the other sites. Overall, the collection was able to detect almost all the species living in the park: we collected 44 entities and the maximum number of species estimated from the curves remained below 50, with SC = 0.99, being 1 the upper limit for the SC estimator.

The curves also provide some information about the diversity model of each sampled community: the upper curves indicate more diverse communities and the shaded areas represent the 95% confidence limits: if overlapped, they indicate that the differences are not significant. Thus, based on the raw data, we can argue that site 4 had the highest diversity, site 5 the lowest, and sites 2, 3, and 6 were quite similar; almost nothing we can say about site 1, although it could promise high diversity.

The community of site 5 numbered only 11 species and was dominated by *Abax contractus*: with its 42 individuals and an activity density of 0.743, *A. contractus* had there the second highest AaD recorded, after *Pseudoophonus rufipes* at site 2 (AaD = 1.08).

Only 3 species (7%) were collected at all sampling sites and even 14 (32%) were found at only one of the 6 sites, indicating strong differences between the six sampling stations. Cluster analysis (Fig. 4) grouped S2 and S5. S3, S4 and S6 formed a distinguished cluster, while S1 resulted isolated.

The high activity density of *Abax contractus* was primarily responsible for the strong differences between site 5 and the other sampling stations, although that species was not exclusive to site 5. Site 2 was different from the others due to the highest activity densities of the very common *Pseudoophonus rufipe*s, the exclusive presence of *Brachinus sclopeta*, *Pterostichus strenuus*, *Olistophus fuscatus*, *Harpalus affinis,* and the relatively high densities of species linked to forest habitats, in particular of the Apennines, such as *Platyderus neapolitanus* and *Leistus fulvibarbis*. The link between S2 and S5 was established through the high densities in both sites of *Calathus fuscipes graecus.*

Sites S3, S4, S6 were mainly characterised by grassland-related species, with unspecialized zoophagous or mixed diets. S4 and S6 also housed some wet habitat entities, such as *Asaphidion stierlinii* and *Paranchus albipes. Pterostichus melas italicus* was highly represented in S6.

Index of natural value

In our samples, 84% of the species had well-developed functional wings and 89% were not specialized predators, being zoospermophagous or strictly granivorous entities. Therefore, the species considered for the calculation of the INV were seven entities with reduced functional wings (*Leistus ferrugineus*,

	S1	S2	S3	S4	S5	S6	All sites
N. individuals	31	272	149	122	92	221	887
Species observed	14	24	22	25	11	25	44
SC	0.75	0.96	0.97	0.94	0.95	0.97	0.99
E	0.88	0.64	0.85	0.78	0.65	0.76	0.77

Tab. 1. Basic statistical information about the rarefaction curves and diversity. Pielou's E is calculated on the AaD basis. SC: sampling coverage estimator.

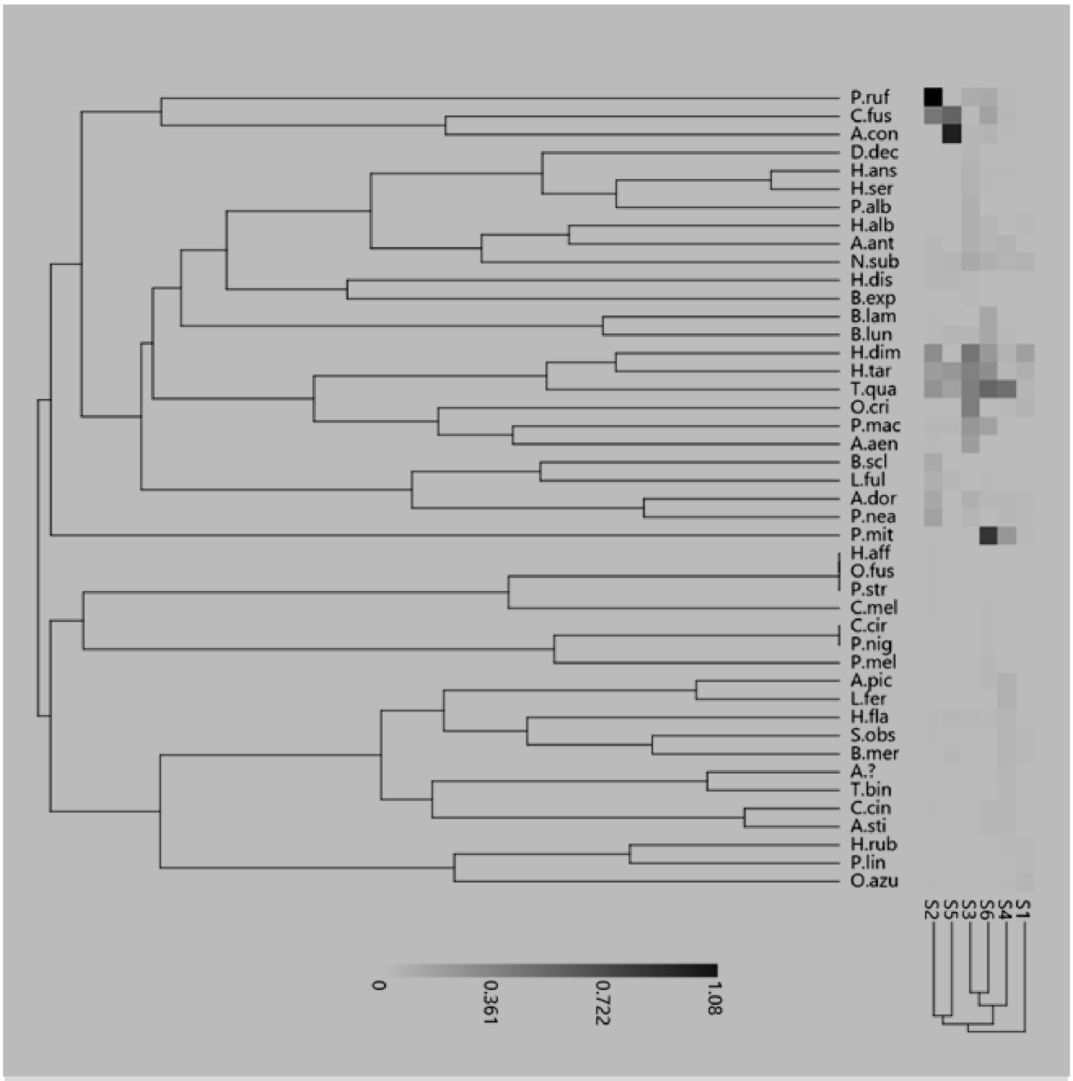

Fig. 4. Cluster analysis performed with the UPGMA method and the Bray-Curtis similarity metric.

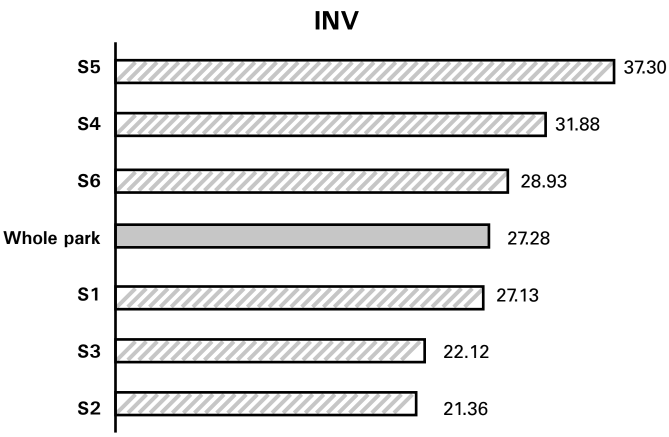

Fig. 5. Scores of the Index of Natural Value.

Trechus binotatus, *Pterostichus melas italicus*, *Abax contractus*, *Calathus fuscipes graecus*, *Platyderus neapolitanus* and *Calathus melanocephalus*) and five specialised predators (*Leistus ferrugineus*, *L. fulvibarbis*, *Notiophilus substriatus*, *Badister meridionalis*). *Calathus cinctus*, often referred to as brachypterous, in our samples was dimorphic.

The best performing sites were S4 and S5, the worst S3 and S2 (Fig. 5). The S5 sampling site, with its almost impenetrable tangle of branches and fallen trees, housed a fairly stable ground beetle community, while S2 and S3 were characterized by intense trampling activity and S3 also hid a lot of waste among trees and bushes.

The park taken as a whole had INV = 27.28, a value that resulted better than that obtained for some comparable ecosystems, such as the parks of some historical villas in the Ferrara province (INV = 23,69) and the hedges along the fields of some organic farms (INV=22,95) (Fabbri & Corazza, 2009).

Comparison with the previous studies

Sciaky & Grillenzoni (1990) listed 69 species from the wall park, of which 22 are in common with our study (Appendix A). Forty-seven species were collected exclusively before the wall restoration and in 2019 we found further 22 species not listed in 1990. Thus, the theoretical pool of ground beetle species in the park is composed by 91 species.

We noticed a change in the chorology (Fig. 6): wide holarctic species dominated in both collections but their importance reduced from 74% to 67%, in favour of the wide European species that in 2019 reached 26%. Wide Mediterranean species increased by 1% between the studies, reaching 7%, the Euro-Mediterranean doubled from 8% to 16% and were the richest category in 2019.

In 1990, among the endemic species only *Abax contractus* was found, an entity from the southern Alps and common in the western Po Valley (Pesarini & Monzini, 2011), while in 2019 we also found *Platyderus neapolitanus*, endemic to the forest and mountains of the Apennines (Pesarini & Monzini, 2011), and *Trechus binotatus*, an entity endemic to both the Alps and the Apennines.

The observed species were divided into four size categories (Fig. 7, Appendix A). In 1990, four species with large body size (*Calosoma sycophanta*, *C. auropunctata*, *Carabus coriaceus, C. granulatus interstitialis*) were present but they disappeared in 2019. The number of medium-sized species dropped from 18 to 15 but their relative abundances grew from 26% to 35%. We assisted in a change of the overall preferences in terms of temperature and humidity: thermophilic species passed from 35% to 58% and xerophilous entities doubled from 14% to 28% (Fig. 8).

Discussion

As shown by the rarefaction curves, the 2019 sampling campaign was comprehensive of the carabid beetle community of the entire park, providing us with a solid foundation for quality assessment and historical comparisons.

The faunal communities of the urban park organised around the ancient walls of the city of Ferrara have undoubtedly been modified by the restoration work that took place at the end of the 1980s when much of the spontaneous vegetation was

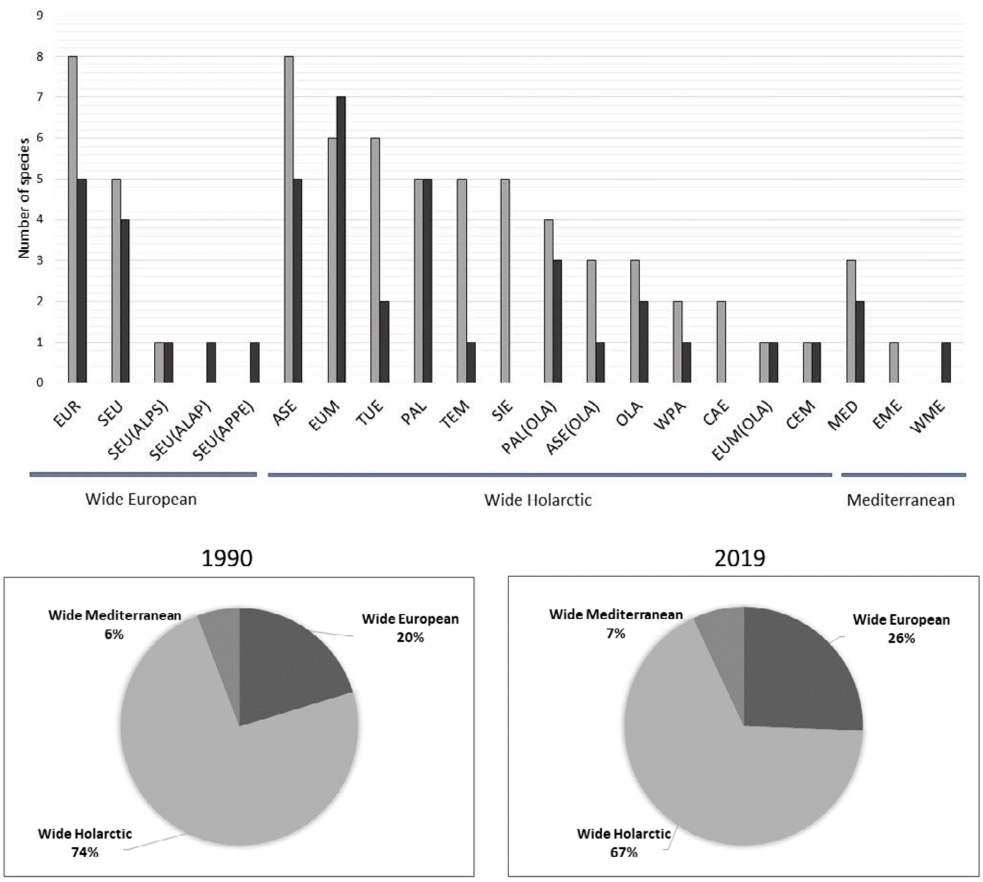

Fig. 6. Chorology of the species. EUR: European; SEU: south European; ALPS: endemic to the Alps; ALAP: endemic to both Alps and Apennines; APPE: endemic to the Apennines; ASE: Asian-European; EUM: euro-mediterranean; TUE: turanic-european; PAL: Palearctic; OLA: Holarctic; WPA: western-Palearctic; CAE: center-Asian-European; EUM: euro-mediterranean; CEM: Middle-Mediterranean; EME: eastern Mediterranean; WME: western-Mediterranean. (OLA): coming from the Holarctic.

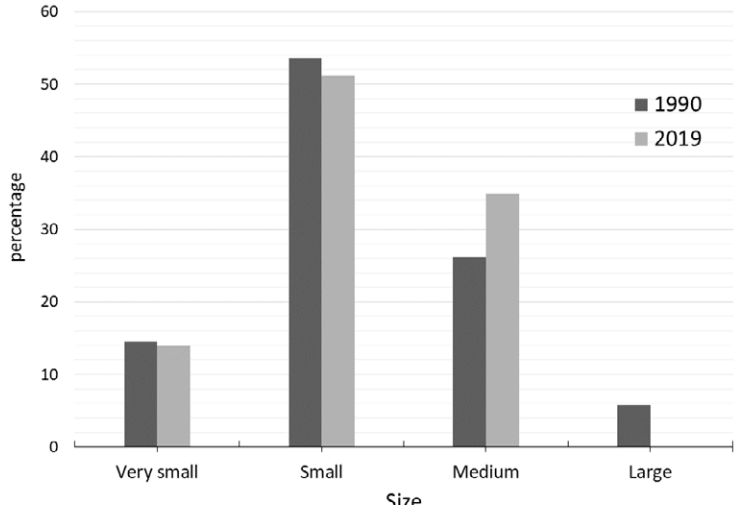

Fig. 7. Size spectrum of the species. Very small: body length <5 mm; small (5-10 mm), medium (10-20 mm), and large (>20mm).

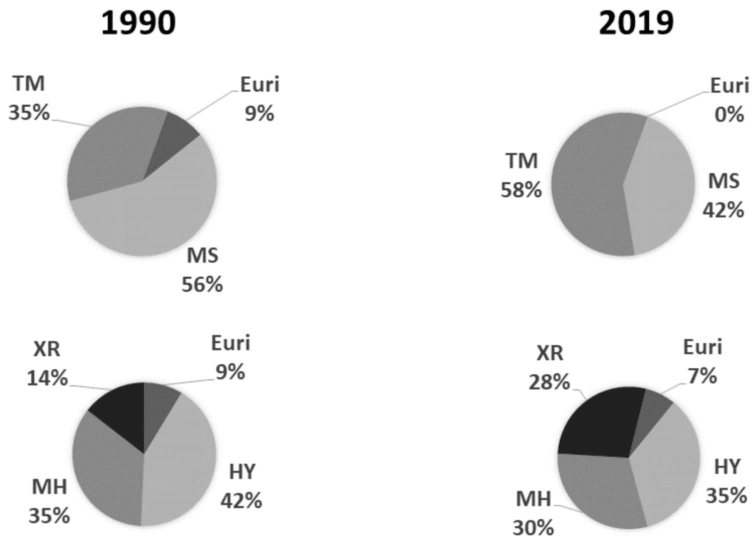

Fig. 8 - Temperature and humidity preferences of the species. TM: thermophilic; MS: mesophilic; Euri: euriecious; XR: xerophilic; MH: meso-hygrophilous; HY: hygrophilous.

removed and the undisturbed habitats were strongly reduced. We detected a partial turnover between species: 47 species were no longer found, 22 new entities were added to the previous list, while the other 22 species stayed in common among studies. As a whole, the number of species decreased by one-third, from 69 to 44.

Among the lost species, we underline the disappearance of the most conspicuous in size, that are *Calosoma auropunctatum*, *C. sycophanta*, *Carabus coriaceus*, *C. granulatus interstitialis*, the only ones that we assigned to the large size category: thus, the "large" category was not present in 2019 samples. The former three species have not been recently reported from other ecosystems of the municipality, while *C. granulatus interstitialis* is still present in the Po River floodplain (Fabbri & Corazza, 2009; Corazza & Fabbri, 2017).

In relative terms, medium-sized species became prevailing. A similar change in species size spectrum was quite expected due to the loss of naturalness in the park caused by the restoration works: in general, the proportion of small sized carabid beetles tends to increase from a rural environment to a city (Niemelä & Kotze, 2009).

However, no exotic species was found, although they are sometimes present in urban areas (Niemelä & Kotze, 2009).

Among the new entities reported in 2019 we have identified two endemic species, *Platyderus neapolitanus* and *Trechus binotatus*, both forest beetles in some way linked to the Apennine biocoenosis (Vigna Taglianti, 2005): they have joined the other endemic *Abax contractus*, a medium-sized species from the southern Alps, already present in the wall park in the 1980s. Recently, *A. contractus* has been also found in other forest ecosystems of the municipality, from the large floodplain forest ecosystem of the Po River to some small forest remains and hedges (Fabbri & Corazza, 2009; Corazza & Fabbri, 2017).

The chorology of the species changed: in the new wall park assemblage, the species with wide Holarctic distribution dropped from 74% to 67%, in favour of the wide European species that, in 2019, went from a fifth to a quarter. In particular, the reduction involved species with a geographical distribution tending to the East: Sibirico-European, Central Asian-European and Eastern Mediterranean species disappeared, while those of the western Mediterranean made their appearance. As a whole, strictly Mediterranean species passed from 6% to 7% and the role of the entities more or less attributable to the Mediterranean area (EUM, CEM, EME, MED, TEM, WME) passed from 25% to 30%.

We found a change in the proportion of thermophilic and mesophilic species and between hygrophilous and xerophilic species: in 2019, entities that prefer warm and dry places were more represented, but that was not unexpected, as the restoration work strongly reduced the forest, shaded habitats. The roles of the thermophilic and xerophilic species have increased: it could confirm that the removal of a dense green belt around the historic centre of the city has leaded to an intensification of the urban heat island effect. The cluster analysis and the Index of Natural Value shortly described the updated situation of the Carabidae community of the wall park.

Site 5 housed an unmanaged forest habitat, rich in fallen trunks: there, *Abax contractus* reached its maximum abundance and density of activity. The S2 sampling site, located in the moat of the southern part of the park, was also clearly distinguished from the others: together with the high density or the exclusive presence of otherwise common species (*Pseudoophonus rufipes, Brachinus sclopeta, Pterostichus strenuus, Olistophus fuscatus, Harpalus affinis*), S2 hosted the highest density of two small-sized species linked to the forest habitats of the Apennines, precisely *Leistus fulvibarbis* and the endemic, brachypterous *Platyderus neapolitanus*. *L. ferrugineus* was collected from 3 other sampling sites and *P. neapolitanus* from 4 others. By that way, *L. ferrugineus,* found also in the Po floodplain and along the shores of some ponds (Fabbri & Corazza, 2009; Corazza & Fabbri, 2017), confirmed to be a species largely present in the Eastern Po valley. The remaining 4 sampling sites were mainly characterised by grassland-related species, with unspecialized zoophagous or mixed diets. The contemporary presence of species related to wet habitats in stations 3, 4 and 6, such as *Asaphidion stierlinii* and *Paranchus albipes,* may be explained by the existence of ditches and floodable areas in the wall moat, particularly in the eastern and northern parts of it.

The different sampling stations of the wall-park had different INV scores. The worst situation was found in Stations 2 and 3: those sampling stations had evident signs of a frequent anthropic presence, and trampling activity in station 2 left a large portion with bare soil. On the contrary, stations 4 and 5 had the highest INV scores, in particular in site 5, which was undoubtedly related to the greatest AaD there recorded of the brachypterous *Abax contractus* and *Calathus fuscipes graecus*.

Conclusions

The ecosystem of the park of the walls of Ferrara deeply changed after the restoration works started at the end of the 1980s: the forest-shaded habitats, along the moat and the embankment, were strongly reduced and the anthropic uses of the park increased.

The modified conditions caused changes in the community of carabid beetles, partly in an expected way: the largest body-sized entities disappeared, while medium-sized species increased their relative importance. Hygrophilous and meso-thermophilic species left room for the xero-thermophilic ones.

Other changes involved the species chorology, which shifted toward European and western entities, reducing the role of species with a north-eastern geographic range. The importance of Mediterranean species in a broad sense increased, even if not in a dramatic way. A couple of endemism related to the Apennines mountains, located south of Ferrara, joined the community. Thus, the results suggested that some changes in the structure of the ground beetle community are not related only to the obvious reduction of the naturalness in the park but probably climate change could have played a role.

The Index of Natural Value pointed to an overall acceptable condition for an urban park, where some endemic, brachypterous, and specialized predator species can thrive. No alien species was found.

It is important to preserve all the habitats where the most ecologically requiring species can survive, and it is necessary to improve all the other ones. The management of the meadows should avoid intensive grass mowing in the lawns and along the ditches in the moat, and the release of large amounts of cut grass (a nitrifying agent) on the soil. Another priority is contrasting the exceeding trampling activities as well as the improper use as a rubbish dump in the marginal areas along the moat. Two ongoing projects already go in those directions: the project "Microcosmi", involving the Natural History Museum of Ferrara for its technical expertise (Martinelli *et al.*, in press) and the activity of Difesa Ambientale Estense (Fb: @difesaambientaleestense), a group of volunteers that acts against improper waste disposal.

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Appendix A. List of the species 1990-2019 with the codes adopted for the cluster analysis. Names as Check List of the Italian Fauna by Casale *et al.*, 2021. *: Brachypterous species and/or specialized predators considered for calculating the Index of Natural Value. Sizes classes: Very small = body length <5 mm; small: 5-10 mm; medium: 10-20 mm; large >20mm. Chorological categories following Vigna Taglianti, 2005. Euri: euriecious; MS: meso-thermophilic; TM: thermophilic; XR: xerophilic; HY: hygrophilic; MH: meso-hygrophilic

CA **Code**	**Species in common between 1990 and 2019**	**Chorology**	**Humidity preferences**	**Temperature preferences**	**Size**
A.con	**Abax contractus contractus* (Heer, 1841)	SEU(alps)	Euri	MS	medium
A.pic	*Acinopus* (*Acinopus*) *picipes* (Olivier, 1795)	TUE	XR	TM	medium
A.dor	*Anchomenus (Anchomenus) dorsalis* (Pontoppidan, 1763)	PAL	MH	MS	small
A.sti	*Asaphidion stierlini* (Linné, 1761)	MED	HY	MS	very small
B.lam	*Bembidion (Metallina) lampros* (Herbst, 1784)	PAL(OLA)	MH	TM	very small
B.lun	*Brachinus (Brachynidius) explodens* Duftschmid, 1812	ASE	HY	MS	small
B.scl	*Brachinus (Brachynidius) sclopeta* (Fabricius, 1792)	EUM	HY	MS	small
C.fus	**Calathus (Calathus) fuscipes graecus* Dejean, 1831	EUM	MH	TM	medium
C.mel	**Calathus (Neocalathus) melanocephalus* (Linné, 1758)	PAL	MH	TM	small
H.aff	*Harpalus (Harpalus) affinis* (Schrank, 1781)	ASE(OLA)	XR	TM	medium
H.dim	*Harpalus (Harpalus) dimidiatus* (P. Rossi, 1790)	EUR	XR	TM	medium
H.rub	*Harpalus (Harpalus) rubripes* (Duftschmid, 1812)	ASE	MH	MS	medium
H.tar	*Harpalus (Harpalus) tardus* (Panzer, 1797)	ASE	MH	TM	medium
N.sub	**Notiophilus substriatus* G.R. Waterhouse, 1833	EUR	HY	MS	small
P.lin	*Paradromius (Manodromius) linearis* (Olivier, 1795)	EUM	HY	TM	very small
P.alb	*Paranchus albipes* (Fabricius, 1796)	EUM(OLA)	HY	MS	small
P.mac	*Parophonus (Parophonus) maculicornis* (Duftschmid, 1812)	SEU	MH	TM	small
P.ruf	*Pseudoophonus (Pseudoophonus) rufipes* (De Geer, 1774)	PAL(OLA)	MH	TM	medium
P.str	*Pterosticus (Phonias) strenuus* (Panzer, 1796)	ASE	HY	MS	small
P.nig	*Pterosticus (Platysma) niger niger* (Schaller, 1783)	ASE	HY	MS	medium
S.obs	*Syntomus obscuroguttatus* (Duftschmid, 1812)	EUM	MH	MS	very small
T.qua	*Trechus (Trechus) quadristriatus* (Schrank, 1781)	TEM	Euri	MS	small
	TOTAL S	**22**			

	Species collected only in 2019	**Chorology**	**Humidity preferences**	**Temperature preferences**	**Size**
A.?	*Agonum* sp.	-	-	-	-
A.aen	*Amara (Amara) aenea* (De Geer, 1774)	PAL(OLA)	Euri	TM	small
A.ant	*Amara (Amara) anthobia* A. Villa & G.B. Villa, 1833	EUR	HY	TM	small
B.mer	**Badister (Badister) meridionalis* Puel, 1925	OLA	HY	MS	small
B.lun	*Bembidion (Philochthus) lunulatus* (Geffroy in Fourcroy, 1785)	EUM	HY	MS	very small
C.cir	*Calathus (Bedelinus) circumseptus* Germar, 1824	WME	XR	TM	medium
C.cin	*Calathus (Neocalathus) cinctus* Motschulsky, 1850	WPA	MH	TM	small
D.dec	*Dinodes (Dinodes) decipiens* (L. Dufour, 1820)	EUM	Euri	MS	medium
H.alb	*Harpalus (Harpalus) albanicus* Reitter, 1900	SEU	XR	TM	small
H.anx	*Harpalus (Harpalus) anxius* (Duftschmid, 1812)	PAL	XR	TM	small
H.dis	*Harpalus (Harpalus) distinguendus distinguendus* (Duftschmid, 1812)	PAL	MH	TM	medium
H.fla	*Harpalus (Harpalus) flavicornis flavicornis* Dejean, 1829	SEU	XR	TM	small
H.ser	*Harpalus (Harpalus) serripes serripes* (Quensel in Schonherr, 1806)	PAL	XR	TM	medium
L.fer	**Leistus (Leistus) ferrugineus* (Linné, 1758)	EUR	HY	MS	small
L.ful	**Leistus (Leistus) fulvibarbis fulvibarbis* Dejean, 1826	EUM	HY	MS	small
O.fus	*Olisthopus fuscatus* Dejean, 1828	MED	XR	TM	small
O.azu	*Ophonus (Hesperophonus) azureus* (Fabricius, 1775)	CEM	XR	TM	small
O.cri	*Ophonus (Hesperophonus) cribricollis* (Dejean, 1829)	TUE	XR	TM	small
P.nea	**Platyderus (Platyderus) neapolitanus* (Reiche, 1855)	SEU(APPE)	MH	TM	small
P.mit	**Pterostichus (Feronidius) melas italicus* (Dejean, 1828)	EUR	XR	TM	medium
P.mel	*Pterostichus (Morphnosoma) melanarius* (Illiger, 1798)	OLA	MH	TM	medium
T.bin	**Trechus binotatus* Putzeys, 1870	SEU(ALAP)	HY	MS	very small
	TOTAL S	**22**			

	Species listed only in Sciaky & Grillenzoni, 1990	**Chorology**	**Humidity preferences**	**Temperature preferences**	**Size**
-	*Acupalpus (Acupalpus) meridianus* (Linné, 1761)	EUR	HY	MS	very small
-	*Agonum (Agonum) nigrum* Dejean, 1828	TEM	HY	Euri	small
-	*Amara (Amara) familiaris* (Duftschmid, 1812)	SIE	MH	MS	small
-	*Amara (Amara) similata* (Gyllenhal, 1810)	ASE	MH	TM	small
-	*Anisodactylus (Anisodactylus) binotatus* (Fabricius, 1787)	ASE	HY	MS	medium
-	*Badister (Badister) bullatus* (Schrank, 1798)	OLA	HY	TM	small
-	*Bembidion (Bembidion) quadrimaculatum quadrimaculatum* (Linné, 1761)	OLA	HY	Euri	very small
-	*Bembidion (Bembidion) quadripustulatum quadripustulatum* Audinet-Serville, 1821	cem	HY	MS	very small
-	*Brachinus (Brachinus) crepitans* (Linné, 1758)	PAL	MH	TM	small
-	*Brachinus (Brachinus) elegans* Chaudoir, 1842	MED	HY	MS	small
-	*Bradycellus (Bradycellus) caucasicus* (Chaudoir, 1846)	SIE	HY	MS	small
-	*Bradycellus (Bradycellus) verbasci* (Duftschmid, 1812)	TUE	MH	MS	very small
-	*Calathus (Neocalathus) mollis* (Marsham, 1802)	WPA	MH	TM	small
-	*Callistus lunatus lunatus* (Fabricius, 1775)	TUE	XR	MS	small
-	*Calosoma (Campalita) auropunctatum auropunctatum* (Herbst, 1784)	CAE	XR	MS	large
-	*Calosoma (Calosoma) sycophanta* (Linné, 1758)	PAL(OLA)	XR	TM	large
-	*Carabus (Procrustes) coriaceus coriaceus* Linné, 1758	EUR	Euri	Euri	large
-	*Carabus (Carabus) granulatus interstitialis* Duftschmid, 1812	ASE(OLA)	HY	MS	large
-	*Chlaenius (Chlaeniellus) vestitus* (Paykull, 1790)	EUM	HY	MS	small
-	*Cicindela (Cicindela) campestris campestris* Linné, 1758	PAL	MH	MS	medium
-	*Clivina (Clivina) collaris* (Herbst, 1784)	TUE	HY	MS	small
-	*Clivina (Clivina) fossor fossor* (Linné, 1758)	ASE(OLA)	HY	MS	small
-	*Demetrias (Demetrias) atricapillus* (Linné, 1758)	EUM	HY	TM	small
-	*Diachromus germanus* (Linné, 1758)	TEM	MH	Euri	small
-	*Dromius (Dromius) meridionalis* Dejean, 1825	SIE	MH	MS	small
-	*Dromius (Dromius) quadrimaculatus* (Linné, 1758)	EUR	HY	MS	small
-	*Gynandromorphus etruscus* (Quensel in Schonherr, 1806)	SEU	XR	TM	medium
-	*Harpalus (Harpalus) oblitus oblitus* Dejean, 1829	TEM	HY	TM	medium
-	*Harpalus (Harpalus) pygmaeus* Dejean, 1829	SEU	Euri	MS	small
-	*Lebia (Lebia) scapularis* (Geoffroy in Fourcroy, 1785)	SEU	MH	MS	small
-	*Leistus (Pogonophorus) rufomarginatus* (Duftschmid, 1812)	EUR	MH	MS	small
-	*Microlestes maurus* (Sturm, 1827)	TUE	MH	MS	very small
-	*Microlestes minutulus* (Goeze, 1777)	OLA	MH	MS	very small
-	*Bembidion (Peryphus) tetracolum tetracolum* Say, 1823	PAL(OLA)	Euri	Euri	small
-	*Ocys quinquestriatus quinquestriatus* (Gyllenhal, 1810)	EUR	HY	MS	small
-	*Oodes helopioides* (Fabricius, 1792)	SIE	HY	MS	small
-	*Ophonus (Metophonus) schaubergerianus* (Puel, 1937)	EUR	MH	MS	small
-	*Ophonus (Metophonus) puncticeps* Stephens, 1828	TUE	XR	TM	small
-	*Panagaeus (Panagaeus) cruxmajor* (Linné, 1758)	SIE	HY	MS	small

-	*Paratachys bistriatus* (Duftschmid, 1812)	WPA	HY	TM	small
-	*Parophonus (Parophonus) mendax* (P. Rossi, 1790)	SEU	MH	TM	small
-	*Parophonus (Parophonus) planicollis* (Dejean, 1829)	EME	MH	TM	small
-	*Poecilus (Poecilus) cupreus cupreus* (Linné, 1758)	ASE	Euri	Euri	medium
-	*Pseudoophonus (Pseudoophonus) griseus* (Panzer, 1796)	PAL	XR	TM	medium
-	*Pterostichus (Pseudomaseus) anthracinus hespericus* (Bucciarelli & Sopracordevole, 1958)	CAE	HY	MS	medium
-	*Scybalicus oblongiusculus* (Dejean, 1829)	MED	XR	TM	medium
-	*Stenolophus (Stenolophus) teutonus* (Schrank, 1781)	TEM	HY	MS	medium
-	**TOTAL S**	**47**			