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Habitat preferences and diversity of butterflies associated with small, fragmented urban vegetation patches

Preferencje siedliskowe i różnorodność motyli związanych z niewielkimi fragmentami miejskiej roślinności

The doctoral thesis

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Table of contents

Introduction

Progressing biodiversity crisis is becoming evident in all types of ecosystems and on all continents (Pimm and Raven 2000, Diaz et al. 2019, Sánchez-Bayo and Wyckhuysb 2019, Chase et al. 2020, Fenoglio et al. 2021, Warren et al. 2021), although declining trends are especially pronounced in Europe and North America (van Klink et al. 2020). Therefore, we came to the point where not even the slightest manifestation of biodiversity can be ignored, especially in highly unstable and disturbed ecosystems like cities (Dearborn and Kark 2010). Habitat loss is amongst the most important threats for entomofauna. Recent review by Sánchez-Bayo and Wyckhuys (2019) demonstrated that about half of analysed papers pointed at urbanization as main disturbance agent for insects. Pollution was mentioned in about 25% of studies. Urbanization is one of the factors contributing to habitat loss as a result of permanent altering of land i.e.: increasing area of impermeable surface as well as fragmentation associated with roads, streets and buildings. Moreover, the density of human population in urban areas is strengthening anthropopression effect (McKinney 2002, Alberti 2005, McKinney 2006, Sánchez-Bayoa and Wyckhuysb 2019, Kuussaari et al. 2020). Other changes are associated with heat island effect, disturbance in water cycle and pollution of air, water and soil. All those factors results not only in biodiversity loss but also in progressing functional and taxonomic homogenization of biological communities (Alberti 2005, McKinney 2006, Wittig and Becker 2010, Jogan et al. 2021).

Ramírez-Restrepo and MacGregor-Fors (2017) reviewed main study directions in the analysis of urban butterfly fauna. Despite the fact that ecological studies dominate, authors pointed at numerous lacks in our knowledge, especially when we consider conservation problems, management practice, and detailed understanding of habitat related processes or functional aspects. The generalisations about functional characteristics of urban butterflies are often very superficial and not based on comprehensive analysis (Ramírez-Restrepo and MacGregor-Fors 2017). Therefore, they might result in serious biases in our knowledge, not only, in understanding of ecological processes and interactions but also in analysis of extinction risk or true reasons of population decline of particular species (Thomas 2000, Kotiaho et al. 2005, Bartonova et al. 2014, Rochat et al. 2017) including taxa that are considered generally common, abundant and resistant to changes (Dennis et al. 2003, van Dyck et al. 2009, Bartonova et al. 2014, Van Strien et al. 2019, Warren et al. 2021). For example, Netherlands population of *Gonopteryx rhamni* and *Lasiommata megera* were continuously decreasing during 1992 – 2007 period to the point of reaching criteria of endangered status according to Dutch Red List (van Dyck et al. 2009). At the same time

Aglais io and *Thymelicus lineola* fullfiled requirements for being described as vulnerable (van Dyck et al. 2009). Available long-term monitoring data showed significant decrease not only in Netherlands, but also in Belgium and United Kingdom. Overall abundance of butterflies in the United Kingdom declined by 50% since 1976, while in the Flanders by 50 % since 1990 (Warren et al. 2021). Those warning numbers can be seen as a prediction for similar changes in other parts of the continent (Warren et al. 2021). Central Europe avoided some of the most devastating anthropogenic changes in natural and semi-natural ecosystems as a result of historical and political processes during the long period of the XX century. Therefore this region can be treated as a model for studies of insects dynamics, ecological processes or influence of anthropogenic factors. At the same time we may still avoid the mistakes that led to changes observed today in the Western Europe. On the other hand we almost completely lack long term monitoring data and ecological studies except of some of the most vulnerable and threatened species often characterized by specialized ecological requirements or very narrow niche (e.g. Sielezniew and Rutkowski 2012, Sielezniew and Nowicki 2017, Sielezniew and Dziekańska et al. 2019, Kajzer-Bonk and Nowicki 2022, Kajzer-Bonk and Nowicki 2023) or areas that are protected as nature reserves or national parks (Dziekańska et al. 2020).

Cities are certainly not the first choice habitats for butterflies but while the urbanized area is expanding there is a great need to answer many questions associated with those ecosystems (Parker 2015, United Nations 2018). On the other hand it was already demonstrated that some pollinators might benefit from urban habitats (Banaszak-Cibicka and Zmichorski 2012, Dylewski et al. 2019) and the web of mutual interactions is much more complicated than we thought. Butterflies are strongly dependent on plant communities as primary source of nutrition needed for development and maintaining adult vitality as well as for providing them appropriate habitat structure for courtship and oviposition (Dennis et al. 2003, Dennis et al. 2008). Therefore, their distribution in the cities is associated also with factors structuring plant communities. Effective urban space management may theoretically preserve favourable habitats allowing to sustain high diversity, but we still lack a strong base knowledge for such actions, especially on a larger regional scale (Alberti 2005). For example, more detailed data about species richness of European urban butterfly fauna are available for only a few cities. Lists of species are very important preliminary information (Ramírez-Restrepo and MacGregor-Fors 2017), allowing, for example to select the most common urban dwellers on a scale of the whole continent or in the particular regions. Nevertheless, even this basic task is difficult to achieve More comprehensive, and what is more important publicly available species lists can be found for only 24 cities including Manchester (Hardy 1998, Hardy and Dennis 1999), –, Vienna (Höttinger 2000, Höttinger 2013), Bydgoszcz (Machnikowski 1999), –, Warsaw (Winiarska 2003) –, Kraków (Palik et al. 2005), Pamplona (Baquero et al. 2011) –, Paris (Bergerot et al. 2011), Marseille (Lizée et al. 2011) –, Prague (Konvicka and Kadlec 2011), Zagreb (Koren et al. 2013), Gdynia –(Senn 2015), Berlin (Gelbrecht et al. 2016, , Łódź (Sobczyk et al. 2018), Patras (Tzortzakaki et al. 2019), Helsinki (Kuussaari et al. 2020), London (Saville 2020, Butterfly Conservation, LNHS), Podgorica – (Pietrzak 2021) – Podgorica, Madrit (uBMS Spain), Barcelona (Pla-Narbona et al. 2022), Glasgow (Butterfly Conservation Scotland) and Białystok(Sielezniew and Dziekańska 2019). One may also suspect that some other data are probably published in local journals which makes them uneasy to access for the international community. The problem is becoming more pronounced when we are trying to focus our attention on relatively up to date literature. The problem of highly scattered information about urban biodiversity was addressed by Kelcey (2014) who compiled comprehensive reference list of publications describing flora and fauna of European cities. A chapter dedicated to butterflies demonstrated that majority of studies were older than 1990. Such old datasets have a great historic value but can not provide meaningful information about ecosystems that were so strongly affected by global changes. Dynamic modifications are typical for urban environment but also for surrounding natural or semi-natural ecosystem that might function as species repositories supporting urban fauna.

How to categorize butterflies inhabiting cities?

Rare attempts to characterized urban lepidopterofauna usually include functional traits like mobility and dispersal abilities (including size and wing shape), larval diet, overwintering stage and voltinism (Shreeve et al. 2001). The concept of specialist-generalist was also used to place particular species on a spectrum according to the range of use of different habitat resources (Clark et al. 2007, Bartonova et al. 2014, Pla-Narbona 2022). A large number of urban butterflies are assumed to be generalists, but rarely in all possible aspects of life cycle and ecological requirements. For example, adult *Aglais io* is not a fastidious nectar consumer, but during larval stage is a specialist bound to *Urtica* It is one of the examples that strict categorization do not allow for comprehensive description of complexity of butterfly requirements. Problems arising from the blurriness of terms specialist and generalist were discussed widely by Dennis et al. (2011). Author of the resource-based habitat approach recommend to apply those terms according to specific resources. It is also worth mentioning, that we do not know details of habitat preferences, resistance to pollution, and tolerance limits for majority of common European butterflies, which makes final conclusions and interpretations difficult and uncertain. It is especially visible in the cities, areas influenced by complex set of dynamically changing factors, not only on habitat or landscape level (e.g. fragmentation) but also different physical (e.g. heat island effect, water ballance) and chemical (e.g. pollution) factors. Those factors, coupled with dynamic changes in mutual interactions between butterflies and other organisms, including plants, predators, parasites and various possible competitors makes the studies of urban entomofauna particularly demanding and often difficult. Moreover, all those factors might dynamically interchange or demonstrate synergistic effects, that are very difficult to describe and are probably strongly site dependant and not universal for different cities, even in the same region. We also can not forget that interspecific interactions involving butterflies are poorly described even in natural conditions (Nakadai et al. 2018, Toro-Delgado et al. 2022).

Butterflies vs habitat fragmentation

Habitat fragmentation is amongst the most important reasons of insect decline and it is undeniably linked with urbanization (McKinney 2008, Fenoglio et al. 2021, Rega-Brodsky et al. 2022). Streats, railroads, pavements and buildings may divide natural or seminatural urban habitats into small patches. Larger urban green spaces like parks and gardens are also isolated from each other and from other habitats resulting in difficulties in dispersal or searching for resources (Sobczyk et al. 2017, Lin et al. 2023). Butterflies are relatively mobile invertebrates mostly characterized by good or even excellent dispersal abilities (Sekar 2012). Nevertheless, majority of earlier studies demonstrated influence of fragmentation on butterfly population size, species composition of particular habitat patchess and even restriction in gene flow or reduced genetic diversity (Takami et al. 2004, Öckinger et al. 2009, Lee et al. 2015, Kalarus and Nowicki 2015, Rochat et al. 2017), although it is worth mentioning that quality of habitat and size of the patch is also very important (Maes and van Dyck 2005, Öckinger et al. 2009, Warren et al. 2020). On the other hand effects of fragmentation might be diminished by presence of ecological corridors, which may include large rivers, green areas under powerlines, wastelands or even railroads (Berg et al. 2016, Garfinkel et al. 2022, Zellmer and Goto 2022).

Fragmentation might result in various, sometimes surprising reactions of insects. Some studies showed that it may cause changes in body mass and wing surface of butterflies (Thomas et al. 1998). Studies of common woodland species *Pararge aegeria* demonstrated that populations associated with fragmented landscape have lower moving abilities, and that both sexes may respond differently (Bergerot et al. 2012), moreover fragmented landscape is affecting ability of finding appropriate habitat (Merckx and van Dyck 2007). Dispersal abilities in the fragmented landscape may differ depending on other functional traits of particular butterfly, including caterpillar host plants and voltinism (Soga and Koike 2011). It is very difficult to avoid fragmentation of the urban ecosystem, although some mangement guidlines are pointing at various ways of landscape restoration (Marzluff and Ewing 2008), however such actions should be accompanied by studies of ecological processes structuring plant and animal communities of the particular city.

Butterflies vs pollution

Studies analysing influence of chemicals on insects were mostly focused on practical aspects associated with pest control (Jiang et al. 2020, Hierlmeier et al. 2022). Overrepresentation of pests in the urban environment is worth to emphasise, because pests are more likely resistant to chemicals as a result of long term selection in the agricultural areas or gardens (Manchikatla et al. 2023). The biodiversity risk context of anthropogenic toxins and their persistence in the environment is often studied nowadays and butterflies are useful models for such studies as insects being usually enough resistant to survive but at the same time presenting semilethal, possibly measurable effects of exposure (Azam et al. 2015).

Urban areas accumulate a wide range of contaminants like heavy metals (i.e. Pb, Mn, Zn, Cu, Cd, As, Sb, Hg) insecticides, plastic particles, persistent bioaccumulative toxic chemicals (PTBs), persistent organic pollutants (POPs) and polychlorinated biphenyls (PCBs) (Gromaire-Mertz et al. 1999, Morillo et al. 2007, Simon et al. 2013, Brown et al. 2016, Kobiela and Snell-Rood 2018, Oliveira et al. 2019, Monchanin 2021, Shepard et al. 2021, Hierlmeier et al. 2022). Traffic, industry and municipal waste are one of the main sources of urban pollution (Simon et al. 2013, Polyclinic 1999). Numerous terrestrial invertebrates spend their lives in a close proximity to dangerous substances, but we lack specific information about their vulnerability or resistance, especially on a larger geographic and taxonomic scale (Lange et al. 2009, Monchanin 2021). Many studies demonstrated that insects accumulate heavy metals and effectively reflect pollution gradients which makes them potentially good bioindicators, however, studies of different taxonomic groups are inconsistent (Cribb et al. 2008, Azam et al. 2015, Phillips et al. 2021), while responses are highly dependent on particular substance, its concentration and exposure time but also life stage, type of host plant or details of the biology and life cycle (Gintenreiter et al. 1993, Lindqvist 1992, Lange 2009).

Influence of toxic substanes is also uneven during different life stages. Butterflies larvae and pupae are often associated with soil and vegetation where pollution accumulates, therefore are considered the most vulnerable (Lange et al. 2009), but at the same time concentrations of some substances (like Cd or Pb) per mass unit can be higher in imagines as an effect of mass drop after eclosion (Gintenreiter et al. 1993).

Sometimes the effects of pollution might be surprising. For example, caterpillars of *Pieris rapae* reared on plants contaminated with Pb developed faster and were more active in adult stage (observed during cognition test) (Philips et al. 2017). It was interpreted as over-reactiveness associated with higher demands for resources to maintain the individuals metabolic processes. However, in laboratory conditions, a lead-enriched artificial larval diet did not caused higher mortality, nor lower success in cognition tests (Philips et al. 2017). Grow acceleration is considered as method for shortening exposition to adverse factors or an exemple of hormetic effect, when a small amount of dangerous substance works stimulating instead of impairing (Constanti 2014, Kobiela and Snell-Rood 2018, Philips et al. 2017). Observed over-reactivness is worth further studies in the urban context, where being more eager to explore and disperse may turn out beneficial, especially in highly fragmented habitat patchess. Studies of other, especially less ubiquitous species, would help clarify whether lead tolerance is specific to *P. rapae* and how much it contributes to urban persistence. Crucifer host plants are known to accumulate metal pollution and *P.rapae* might be more resistant to contamination even in previously non-polluted habitats (Kobiela and Snell-Rood 2018).

Kobiela and Snell-Rood (2018) demonstrated that nickel contaminated larval diet of *Pieris rapae* can cause not only semilethal effects like impairing reproductive efficiency, but may also influence the metal content in offspring. Effects were not the same for the two investigated populations what suggests differences in nickel vulnerability and overall fitness. First-generation of Californian butterflies showed higher mortality than the Minnesota population, moreover indivuduals collected in Minnesota had higher rate of survival and growed bigger with nickel in their food, while Californian individuals were smaller but still characterized by high survival capabilities. Kobiela and Snell-Rood (2018) observed that size of *P.rapae* offspring is associated with their parent's diet, demonstrating very interesting mechanism leading to advantage in polluted areas, including cities. Flying ability might lower exposure of some pollinators to pollution as a result of avoidance of contaminated sites (Phillips et al. 2021). Sivakoff and Gardiner (2017) observed shorter foraging episodes of bees on sunflowers growing on lead contaminated soil. There are no similar studies of butterflies, but such mechanisms are most likely possible.

The above mentioned examples of detailed pollution reactions of butterflies are rather exceptional. For example, majority of studies of highly toxic PCBs were focused on vertebrates, while invertebrates are still understudied. Hierlmeier et al. (2022) showed that insects were included in just 0,46 % of over 250 thousand papers on PCBs. Filling the gap will greately contribute to answer some of urban ecology questions while traffic is one of the leading sources of this kind of pollution (Phillips et al. 2019). Nevertheless, our current knowledge about influence of urban pollution on development and fitness of particular butterfly species is scarce, highly fragmentary, uncertain, and does not allow for any generalisations

Butterflies vs temperature

Temperature plays a huge role in insect development and activity what makes it one of the main abiotic factors shaping urban butterfly communities. Thermal conditions along with humidity and photoperiod are influencing butterfly phenology, grow rate, and voultinism (Kingsolver 1985, Kingsolver and Huey 1998, Esperk et al. 2012, Enjin 2017, Davies 2019). Moreover, host plant life cycles are also temperature dependent and temporal synchronisation between plants and insects is essential for getting right resources at the right time (Schenk et al. 2016). Accelerating climate change is already causing changes in thermal conditions throughout the season with observed range shifts of some thermophilus butterfly species and decline of cold adapted taxa (Feehan et al. 2009, Zografou 2021). Due to urban heat island effect cities might be treated as laboratories for studies of butterfly ecology in the times of global warming. The effect itself manifests with higher air temperature inside highly urbanised and impervious areas, especially in the city centers, but also in urbanised regions in general (Santamouris 2007).

Differences in temperature between heat island and surrounding areas vary strongly depending on a location. The difference can reach around 4°C as was observed in Barcelona during the day, or even 9-11°C as observed in the Amsterdam during the night (Van Der Hoeven and Wandl 2015, Salvati et al. 2017). Time of the butterfly activity living in such conditions may change, resulting in different scenarios associated with season and ecology of particular species. Warmer seasons create wider window of favourable abiotic conditions, allowing for example to develop additional brood. At the same time elevated temperature can alter synchronisation with necessary resources and may disturb aestivation of early spring flying species like large nymphalids or *Gonepteryx rhamni* (Baldon et al. 2019). At the end of the season there is a possible problem with food shortage and gathering resources needed for wintering time, especially for species that are overwintering in the adult stage (Pullin 1987).

On the other hand higher temperature may have positive effects on butterflies living in highly fragmented landscape that requires good mobility during moving between habitat patchess, searching for partner and food resources. Flying is a highly energy-demanding activity and muscles need to be well warmed before take off (Berwaerts and Van Dyck 2004, Mattila 2015). On the other hand overheating might also cause serious problems for butterflies which can use two strategies allowing them to cope with this problem, microhabitat choice and behavioural excessive heat removal (Bladon et al. 2019). At the same time there are no phenological studies of butterfly communities in European cities. We also do not know much about temperature differences between urban habitats that are used by butterflies and temperature preferences of particular taxa.

Aims of the study

1. Assessment of diversity and distribution patterns of butterfly communities associated with isolated urban wastelands.

2. Description of phenological changes of urban butterfly communities in the city.

3. Assessment of butterfly functional diversity on background of plant communities in the urban wastelands.

4. Assessment of flower preferences of butterflies associated with urban habitats based on qualitative and quantitative methods

Homogenous small scale hot spots: Diversity and phenological dynamics of urban butterfly communities associated with fragmented wastelands in the large post-industrial Central European city

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Abstract

Urban wastelands are amongst the most neglected urban habitats. Our study demonstrated that those fragmented patches of vegetation are important refuge for various species of butterflies. They may have important role in maintaining biodiversity in the city and even on larger regional scale. We have assessed diversity, distribution patterns and phenology of butterfly communities based on two year quantitative studies at 5 urban wastelands located in large postindustrial city in the Central Poland. Altogether 214 Pollard walks were conducted between April and September of 2019 and 2020. Forty six species of butterflies were recorded in the city. We have noticed homogeneity of fauna, although all investigated sites were characterized by high diversity and co-occurrence of species associated with different habitats (e.g. grasslands, woodlands). All sites were strongly affected by regional species pool and single habitat patches strongly reflected species composition of areas surrounding the city. Most of the species were common in the Central Poland, although we have also recorded presence of more specialized butterflies, like *Lycaena dispar*, which is associated with wetlands and *Polyommatus coridon*, associated with calcareous grassland. Similarity analysis based on Bray-Curtis formula reflected mostly seasonal changes in species composition. Phenological changes were very similar at all investigated sites and during both seasons pointing at relative stability. Only occurrence of *A. cardamines* in the city started two weeks earlier than typically for Central Europe, probably as a result of the heat island effect. Urban wastelands are small scale biodiversity host spots for butterfly fauna, that stand out from species poor butterfly communities associated with agricultural landscape typical for areas surrounding the city. This pattern results from high diversity of microhabitats and co-occurrence of various plant species at single sites, which is very important for plant dependent organisms like butterflies.

Key words: Lepidopera, ruderal vegetation, urbanization, habitat fragmentation, diversity

Introduction

Butterflies are often mentioned as perfect indicators of urban disturbance (Blair 1999, Dennis et al. 2017, Tzortzakaki et al. 2019) they are functionally diverse, easy to identify, many species are sensitive to changes, disturbance processes or pollution events (Blair 1999, Meléndez-Jaramillo et al. 2021, Kozlov et al. 2022). They are even treated sometimes as good surrogates for general urban biodiversity assessment (Dollar et al. 2014). Nevertheless, when we look into details, the number of studies dedicated to urban butterfly communities is relatively scarce, even in densely populated areas of Europe (Ramirez-Restrepo and MacGregor-Fors 2017). Moreover, large number of studies was focused on simple urbanization gradients, demonstrating relatively obvious pattern of declining diversity towards the city center (e.g. Blair and Launer 1997, Blair 1999, Matsumoto 2015, Sobczyk et al. 2017, Tzortzakaki et al. 2019), or contained only the species lists (Ramirez-Restrepo and MacGregor-Fors 2017). We especially lack studies of resources based approach, including host-plant interactions, floral resources availability, diversity-microhabitat relations (Dennis et al. 2006), and temporal trends based on quantitative data (Ramirez-Restrepo and MacGregor-Fors 2017). There are also large spatial gaps in urban butterfly studies, especially in tropical areas, but also in the Central and Eastern Europe (Ramirez-Restrepo and MacGregor-Fors 2017), an area that is facing increasing level of urbanisation (Restrepo Cadavid et al. 2017) and numerous threats associated with climate change (Engelhardt et al. 2022) an aspect of great importance for urban areas (McCarthy and Sanderson 2011).

Those facts are surprising, especially when we realize that Europe is facing a substantial decline in insect abundance, the most comprehensively documented for protected areas (Hallmann et al. 2017), but certainly visible in even more disturbed and modified urban or agricultural habitats (Moller 2020). Moreover, recent studies have demonstrated decline of European butterfly abundance and diversity, with numerous local extinction events (Warren et al. 2021) and it is becoming evident that butterflies are declining faster in the urban areas (Dennis et al. 2017). Urbanization is listed amongst the most important causes of insects decline on a global scale (Fenoglio et al. 2021). At the same time there are almost no ecological analysis of urban butterflies communities in the Central Europe. The only studies from Poland contain raw species lists (Machnikowski 1999, Winiarska 2003, Palik et al. 2005, Senn 2015, Sielezniew and Dziekańska 2019) or are focused on urbanization gradient (Senn 2015, Sobczyk et al. 2017). There are also a few studies from Czech Republic but all were dedicated to Prague and analysed nature reserves and large parks (Kadlec et al. 2008, Jaroski et al. 2011, Konvicka and Kadlec 2011).

Cities are complicated systems characterized by unique functioning mechanisms, and exceptional evolutionary pathways (Diamond and Martin 2021). The dynamic character, unstable conditions and variety of disturbance agents, makes them a great natural laboratories which may allow to answer more general and very interesting questions associated with ecology and evolution, particularly those related to habitat loss, connectivity, disturbance, recovery processes or resilience to changes (Parris 2018, Diamond and Martin 2021). It is especially evident in the context of growing number of threats associated with climate warming, which are resulting in horizontal and vertical range extensions (Konvicka et al. 2003, Chen et al. 2011), changes in phenology and development time (MacLean et al. 2016), or modifications of the life histories (Magura et al. 2021). Urban heat islands might be an interesting small scale model sites for such studies, allowing for analysis of ecosystem resilience or thermal regimes of particular species facing temperature changes like it was already demonstrated for ants (Angilletta et al. 2007).

Half of the global human population currently lives in urban areas, therefore cities became closest ecosystems we interact with (Ritchie and Roser 2018). Growing attention to biodiversity resulted in increasing interest for studies of urban ecosystems (Pimm and Raven 2000, Sánchez-Bayo and Wyckhuys 2019). Cities are unique fragmented areas consisting of various habitat patches of different quality (Alberti 2005). Our common notion of urban habitat is usually an urban green space, mainly intentionally designed, like parks and lawns or some relicts of natural or semi-natural vegetation, like urban forests, that are often protected as nature reserves (Konvicka and Kadlec 2011, Nielsen et al. 2014, Fontaine et al. 2016, Han et al. 2022. Plociennik et al. 2023). The importance of above mentioned habitats is undoubtedly relevant but there are other urban habitats that are still neglected in modern studies. A good example of such areas are patches of ruderal vegetation and various wastelands that may act as ecological corridors (Oki et al. 2021, Zellmer and Goto 2022) and host a variety of living space and resources for butterflies and other insects associated with open habitats (Karlsson and Wiklund 2004, Twerd and Banaszak-Cibicka 2019). Wastelands are defined as areas where spontaneous vegetation takes over and is mainly or completely left without implementing maintaining practices, therefore becomes a small scale hot spot of resources for local wildlife (Qviström 2008, Bonthoux et al. 2014, Sanches and Pellegrino 2016).

Such green spaces are one of the key elements to understand diversity patterns and ecological processes in the cities and as such should be among main interests for ecologists but also authorities, especially taking into account the fact that those fragmented areas are vulnerable to intensive management practices (Aguilera 2019). It has been proven that urban green spaces increase well-being of citizens, what is highly needed nowadays (Sanches and Pellegrino 2016, Ma et al. 2019, Huma et al. 2021, Reyes-Riveros et al. 2021). Moreover, biodiversity itself have a great value for city citizens (Taylor and Hochuli 2014), not only because of educational reasons, but also as an element of ecosystem services, quality of life and even because of the economic value (Cosquer et al. 2012, Hanley and Perrings 2019). Alongside with city green spaces butterflies are consistently getting more attention as important pollinators but also attractive objects for observations among a growing community of nature enthusiasts willing to participate in data collecting to support citizen science projects and conservation efforts (Baldock et al. 2015, Pendl et al. 2021). Securing existing wilderness and preserving high quality habitats from maintenance practice seems to be the only feasible way to enhance or at least preserve overall biodiversity within urban areas (Aznarez et al. 2022). Nevertheless, sustainable management strategies require a comprehensive baseline knowledge. There are no reference point datasets for the Central European urban butterfly communities that could serve as base for further temporal studies in the times of global change. Therefore our study aims to analyse seasonal changes in butterfly diversity associated with fragmented ruderal sites located in the large city (Lodz, Central Poland) in relation to habitat characteristics, based on two year quantitative approach.

Material and methods

Study area

Łódź is a fourth largest city in Poland, both in terms of surface area and number of citizens. It is located on a upland in the central part of the country. Current area of the city reaches nearly 300 km^2. Lodz is inhabited by about 660 thousand citizens (GUS 2023). It is spatially connected with smaller urbanised areas, namely towns like: Zgierz, Ksawerow, Pabianice, Aleksandrow Lodzki and Konstantynow Lodzki which are together extending the urbanised surface area by about 40%.

The large agglomeration developed rapidly as results of textitle manufacture development in a few decades, starting from the beginning of the XIX century. Two hundred years ago Lodz was a small town barely exceeding one thousand inhabitants. Vast forests of various kind and marshlands initially covered the area of mostly flat relief crossed by net of small rivers and streams (Tranda et al. 1983, Markowski et al. 1998, Witosławski 2006). Industrial development was strategically planned to access water of accurate flow and was associated with elevated and hilly topography of the south-west part of today's urban area, where streams originated (Witosławski 2006). As city grown most of the rivers crossing the area were hidden underground and were eventually transformed into sewage canals. Unlike some older cities often organized along large river banks, Łódź is more uniformly and densely build-up and is not fragmented by riverbed, that might bring opportunity for some species spreading.

Three urbanization zones (Fig.1) were distinguished in Lodz: inner city, peri-urban area and outskirts (Witosławski 2006, Janiszewski et al. 2009). Inner city (zone I) is characterized by the highest impermeable ground coverage and tightly arranged buildings, with green spaces mostly restricted to lawns, parks and cemeteries (usually on the border within inner and peri-urban area). Residential estates, small houses and some industrial facilities dominate in the peri-urban area (zone II). There are more green spaces like parks, gardens and wastelands than in strict city center. Outskirts (zone III) have loose building arrangement, there are some agricultural lands, wastelands, meadows and semi-natural and ruderal habitats. This zone is also characterized by presence of the large forest complex (Łagiewniki Forest - 1200ha) located in the north-east part of the city (Witosławski 2006).

Field studies

Five research sites were distinguished. (Fig 1),They represented wasteland habitats located in the peri-urban area (zone II) and outskirts (zone III), while there are no similar habitats in the most densely urbanized zone I. Butterfly counts followed widely-used monitoring scheme proposed by Pollard (1977) modified from an originally introduced 1100 m distance to match the small size of the urban research sites which is common practice in similar studies (Mattoni et al. 2001, Clark et a; 2007, Aguirre-Gutiérrez et al. 2017, Tzortzakaki et al. 2019). Individuals were counted in 5 m cube boxes as counting person was moving forward through established transect line. All transects were visited weekly for 26 weeks from April to September of 2019 and 2020 unless rain or temperatures below 13°C occured (only a few such exceptions occured in April of both years). Forms for transect description included information about environmental factors: temperature, humidity, wind conditions, cloud cover, start and ending time of each survey. Weather related factors were obtained right before starting transect walk with actual weather information provided through service https://weather.com/ or assessed by observation (for cloud cover). Each transect was divided into 100 m sections for counting purpose. Individuals that were difficult to identify from a distance were collected using an entomological net for detailed examination and released afterward. Identification was based on e guides for Polish and European fauna (Buszko and Masłowski 2008, Sielezniew and Dziekańska 2010, Tolman 1997). Altogether 214 Pollard walks (single walk was treated as quantitative sample) were conducted including 109 in 2019 and 105 in 2020. The number of Pollar walks one each sited equalled 22 in 2019 and 21 in 2020 at Brukowa Site, 24 in 2019 and 21 in 2020 at Maratońska site, 22 in 2019 and 20 in 2020 at Rogi Site, 22 in 2019 and 21 in 2020, 19 in 2019 and 22 in 2020 at Traktorowa Site.

Data about the species composition of flowering plants were also collected for each site, regularly along the whole sampling season. Identification was based on keys and fieldguides along with distribution atlas dedicated to flora of Lodz (Rutkowski 1998, Witosławski 2006, Sudnik-Wójcikowska 2011). This dataset was used for description of sampling sites and the list of species is included in the Appendix 1.

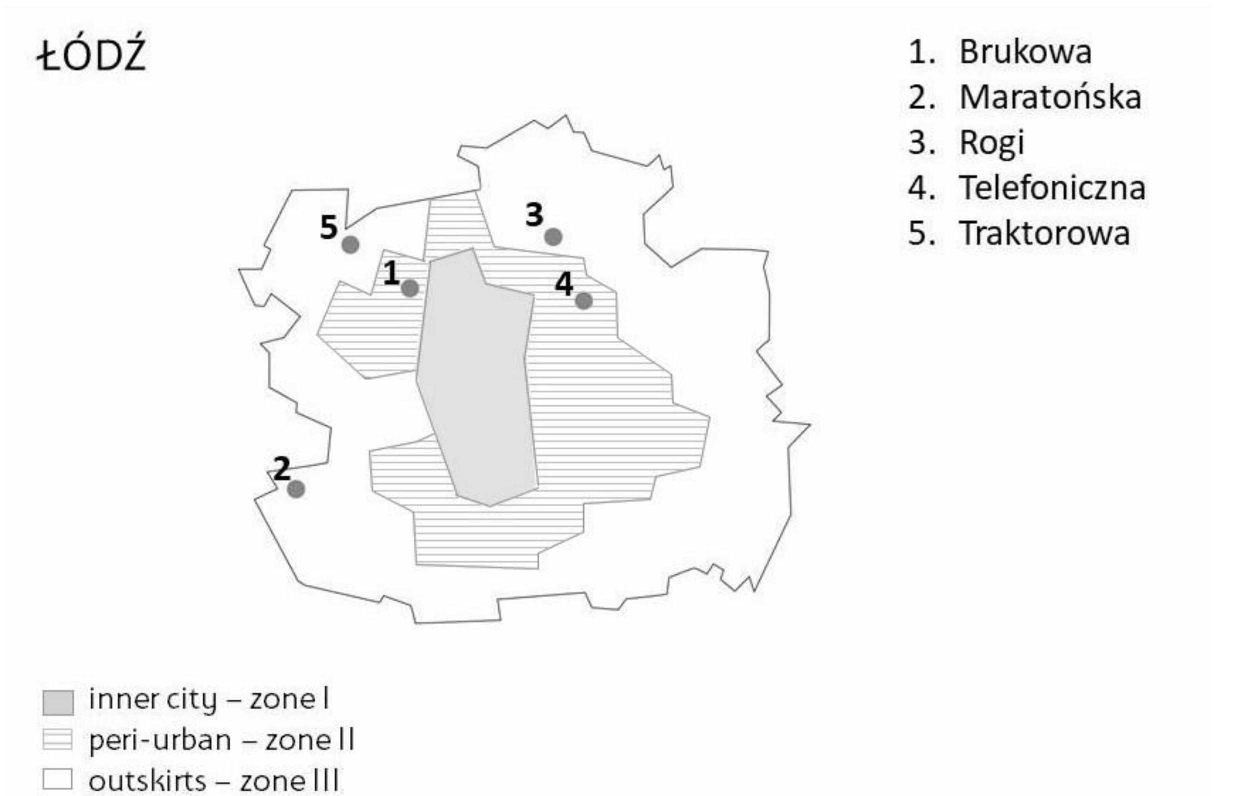

Fig 1 Distribution of sampling sites in the city.

Brukowa Site (B)

Site on Brukowa (about 2ha) was located in predominantly industrial district, in a close vicinity to train station Żabieniec (peri-urban zone of Łódź). It is adjacent to working field of company involved in recycling, including metals, electronical scrap, industrial and constructional wastes. Transect was 700 m long and followed through ruderal shrubs and side of railroad tracks that are leading to the northern borders of the city. (Fig 1). Vegetation included shrubs, small woodland, meadow and railroad-associated flora. Distinction between part following path from Brukowa street to railroad and part along the railroad was clearly visible. Except from early spring part of the site that is not attached to railroad was mostly covered from direct sunlight by leaves of trees and shrubs, thus larger spots of more exposed vegetation can be treated as separate microhabitat. Flora along this path was composed mostly of various grassess mixed with shrubs of *Robinia pseudoacatia*, *Prunus* sp and *Rubus* sp.. Flowering herbaceous plants were i.e. *Berteroa incana, Cirsium* sp., *Erigeron* sp, *Knautia arvensis, Lotus corniculatus, Melilotus albus, Tanacetum vulgare, Trifolium* sp.. In the summer this part was dominated by *Solidago* sp.

Part along the railway was initialy (spring time) covered with *Cardaminopsis arenosa, Viola* sp and *Geranium* sp., later species like *Berteroa incana, Erigeron* sp, *Oenothera* sp, *Origanium vulgare, Echium vulgare, Hypericum* sp, *Reseda lutea, Medicago* sp., *Linaria vulgaris* dominated. *Solidago* sp. was also present here, but not as densely like in the other part of the site.

Maratońska Site (M)

It was situated in a close proximity to the western city border, near the sewage treatment facility in the outskirts zone (Fig 1). Transect was 600 m long and its route led between forest edge and linear mound running along the road (Sanitariuszek Street) then curved following forest edge, through open space between the forest and Maratońska Street. Comprehensively it can be described as a mix of dry meadow with a shrub patches restricted by roads. The size of the site was about 2ha. Vegetation included dry meadow and ecotone zone between meadow and coniferous forest. Shrubs (*Rubus*, *Robinia pseudacacia*, and *Syringa vulgaris*) were intersecting meadow into smaller compartments, creating heterogenous mosaic of habitats, that included patchess of lower and higher grasses or exposed sandy ground. Flora of the site was dominated by Poaceae e.g. *Corynephorus canescens.* Flowering plants include: *Berteroa incana, Centaurea stoebe*, *Erigeron* sp., *Prunus* sp., *Hieracium pilosella, Jasione montana, Viola* sp, *Echium vulgare, Knautia arvensis, Securigera varia, Anchusa officinalis,* and *Solidago* sp.,

Rogi Site (R)

It was situated on the border between peri-urban area and outskirt zone with Łagiewniki forest nearby (Fig. 1). It is about 3ha. Transect led next to residential area, neighbouring to elemental school facility and ongoing construction of new block of flats. There was also a hill of anthropogenic origin on this site. The hill was covered with mixed patches of forest, meadow, shrubs and orchard. Transect was 700 m long and followed a path through slope, hilltop and open habitats of meadowy character below the hill. Vegetation included meadows characterized by different level of moisture and ecotone zone between them and deciduous forest. Microhabitats include sand pits. The site use to be mowed untill 2019. This change resulted in development of higher vegetation especially in more humid part of the site. Flora consists of grasses of different moisture preference, shrubs (*Sambucus nigra*, low *Malus* sp and young *Robinia pseudoacatia*). Flowering herbaceous plants include: *Cirsium* sp, *Pastinaca sativa, Daucus carota, Trifolium* sp., *Vicia* sp, *Lotus corniculatus, Hieracium* sp., *Potentilla* sp., *Jasione montana, Knautia arvensis* and some plants associated with neighbouring estate gardens like *Rudbeckia hirta* and *Lathyrus latifolius*.

Telefoniczna Site (TL)

The site was situated in the peri-urban zone (Fig. 1). The area (about 3ha) was neighbouring with residential area, tramway depot, magazines and workshop. Transect was 700 m long and led through hilly fragmentary humid unused area covered with a mix of ruderal vegetation, grassland, shrubs and forest. Woodland patches can be described as mixed forest although deciduous trees (e.g. birch) dominate. Grassland is partially enclosed by trees and shrubs. In the 2019 vegetation clearance was done under powerlines that are crossing the site resulting in increased connectivity between microhabitat patches. The most charismatic flowering herbaceous plants here are i.e: *Berteroa incana*, *Erigeron* sp., *Melilotus albus, Melilotus officinalis, Lupinus polyphyllus, Convolvulus arvensis, Hieracium pilosella, Knautia arvensis*, *Stellaria* sp., *Lotus corniculatus*, *Vicia* sp, *Trifolium arvense* andvarious Apiaceae i.e. *Daucus carota*. During flowering period *Solidago* sp. largely dominated most of this site.

Traktorowa Site (TR)

Outskirt site situated in Sokołówka river valley, between riverbed and residential area (Fig 1). Transect was 500 m long and followed through patches of humid meadow, ruderal meadow, forest clearing and 100 m part that have forestry character. Final section was located next to horse stables area and crop field. The size of the site was about 2ha. More humid part of the meadow, located closer to the river was covered by *Cardaminopsis arenosa* and *Veronica chamaedrys* at the beginning of the season. Later it was dominated by various flowering plants i.e. *Ranunculaceae*, *Berteroa incana*, *Achillea vulgaris, Silene flos-cuculi, Cirsium* sp.*, Potentilla* sp., *Linaria vulgaris* and *Tanacetum vulgare*. Three patches of dryer meadow differ in flowering plant composition. First patch was adjacent to the humid area and flora include: *Helichrysum arenarium, Jasione montana, Vicia* sp., *Hieracium pilosella*, *Achillea vulgaris, Berteroa incana, Knautia arvensis, Senecio* sp., *Centaurea stoebe, Potentilla* sp., *Tanacetum vulgare* and *Solidago gigantea*. Grasses, were not the main part of vegetation here. Second patch was dominated by grasses and flowering plants like: *Hieracium* sp., *Vicia* sp., *Knautia arvensis, Jasione montana, Senecio* sp. Third patch was adjacent to forest. Flowering plants include *Rubus* sp., *Jasione montana*, *Knautia arvensis* and *Hieracium* sp. Later during the season *Solidago virgaurea* and *Solidago gigantea* covered this part of the site. There are also some Apiaceae, *Urtica* sp., *Lamium* sp. and dense coverage of *Impatiens glandulifera* along the edge of the forest.

Data analysis

Sample was defined as one transect count providing data about number of species and individuals. Since transects had different length in order to cover the whole spectrum of vegetation types at each site and depending on specific character of sites the number of individuals was calculated for the 500 m length (the size of the shortest transect) in order to analyse fully comparable samples.

Diversity analysis was performer in the Primer 5.0 package (Clark and Warwick 2001). Three indices of species richness and diversity were calculated for each sample, including Margalef Index, Shannon Index (log e) and Simpson Index. Pielou evennes was also calculated (Magurran 2004). Taxonomic diversity Delta (Δ) and taxonomic distinctness Delta$*$ ($\Delta*$) were also calculated to provide a view of the phylogenetic diversity at each site based on Linnean ranks, namely: species, genus, tribe, subfamily, family and superfamily.

Analysis was performer in Primer 5.0 package (Clark and Warwick 2001) and based on formulas proposed by Warwick and Clarke (1995) as well as Clarke and Warwick (1998).

Mean values of total butterfly abundance and all above mentioned indices with standard deviation (SD) were calculated for each site, and for each group derived form results of the cluster analysis. Statistical significance of differences between studied sites and dendrogram groups was analysed using appropriate statistical tests in the Statistica 6 pacakge. Normal distribution was checked using Shapiro-Wilk's test, homogeneity of variance was assessed using Levene's test. As a result a non-parametric Kruskall-Wallis test was used. Post hoc testing was done using Dunn's test. Differences between the seasons at each site were assessed using T-test and Man-Whitney U test.

In order to analyse distribution patterns and similarity between analysed samples hierarchical agglomerative clustering based on Bray-Curtis formula was performed using a group–average method. Data were square root transformed in order to minimise the influence of dominant species on the results of analysis (Clark and Warwick 2001). Samples were codded with combination of information about the year, observation week, site abbreviation and sample number (i.e.: 2019_02_B_01 – first sample derived from Brukowa site during second week of the season 2019). SIMPROF test with 5% significance level was performed to check the multivariate structure within groups and SIMPER analysis which allowed to select the species most important for dendrogram division (Clarke and Gorley, 2015). This part of the analysis was performer using a Primer 7 package.

Additionally, frequency of occurrence [%] defined as the percentage of samples where a given species was found in the total number of samples at particular site or particular cluster was calculated. Maximum and mean abundance with standard deviation was calculated for each species in each cluster of samples and for each site. For every species the association index DAI (the percentage of individuals of a given species recorded in a given cluster group/site, within the total number of individuals of that species in the study area) was used. The DAS association index (the percentage of samples containing individuals of a given species in a given cluster group/site within the total number of samples containing that species in the study area) was also calculated (Salzwedel et al. 1985, Sicinski 2004).

Data on total butterfly abundance, species richness and species composition were also visualised on a background of temperature, humidity and other weather conditions data along the whole season, separately for 2019 and 2020 demonstrating phenological dynamics of butterfly communities at each site.

Results

Species composition of fauna

Altogether 46 species (7880 individuals) were recorded at 5 investigated sites during both seasons. Species represented all five butterfly families. The most speciose were Nymphalidae (20 species) followed by Lycaenidae (12 species), Pieridae (8 species), Hesperiidae (5 species) and Papilionidae (1 species). The species with the highest frequency of occurrence in all samples were: *Coenonympha pamphilus* (F=67%), *Pieris rapae* (F=65%) and *Pieris napi* (F=57%) (Table 1)

The species composition was similar for all investigated sites demonstrating homogenous character of fauna. Twenty five species occured at all five sites, 6 species were found at four sites, 5 species at 3 sites (Table 1). Nevertheless, particular sites differed in frequency of occurrence and/or abundance of particular species and values of DAI and DAS association indices demonstrated differences between investigated sites. Therefore the core of fauna differed strongly. For example, *Maniola jurtina*, one of the most common and abundant species had similar values of DAS index (15-23%) for all the sites but DAI values showed that Traktorowa hosted the highest number of individuals (DAI=49%), followed by Rogi site (DAI=35%) (Table).

Only a small group of species had restricted distribution and all of them can be described as rare in the city, although some of them were abundant but only at one particular site showing high affinity to a given location. Those species include *Coenonympha glycerion* that was found only at two sites and four species recorded exclusively on just one site: *Polyommatus coridon* and *Melitaea cinxia* recorded only on Maratońska, *Brenthis ino* recorded only on Traktorowa, *Satyrium pruni* present only on Telefoniczna and *Satyrium w-album* found only on Rogi (Table 1).

Brukowa Site

Altogether 36 species were recorded on Brukowa site, but only 3 with frequency of occurrence higher than 40%: *Coenonympha pamphilus* (F=62,2% 1,6 ± 2,6 ind./500m), *Pieris napi* (F=62,2% 2 ± 2,6 ind./500m) and *Pieris rapae* (F=62,2% 3,6±3,9 ind./500m). The highest DAI and DAS were obtained for *Lasiomata megera* (DAI=32,6%, DAS= 50%), *Colias hyale* (DAI=31,3%, DAS=37,5%) and *Nymphalis antiopa* (DAI=40,5%, DAS=33,3%),

Maratońska Site

Altogether 41 species were recorded here and all 5 families were represented. It was the site with the highest number of species. Eleven species had frequency of occurrence higher than 40% on this site. Most of them were also very abundant. Those species were: *Coenonympha pamphilus* (F=88,2% 10,8±10,9 ind./500m), *Pieris rapae* (F=71,1% 3,4±3,6 ind./500m), *Lycaena phleas* (F=62,2% 1,6±2 ind./500m), *Lycaena tityrus* (F=62,2% 2,6±3,4 ind./500m), *Aricia agestis* (F=53,3% 1,5±1,9 ind./500m), *Issoria lathonia* (F=53,3% 1,3±1,7 ind./500m), *Polyommatus icarus* (F=53,3% 1,5±2 ind./500m), *Maniola jurtina* (F=48,9% 1,8±3 ind./500m), *Polyommatus coridon* (F=46,7% 9,2±15,1 ind./500m), *Pontia edusa* (F=46,7% 1±1,6 ind./500m) and *Pieris napi* (F=42,2% 1,3±2,1 ind./500m). The highest DAI and DAS were recorded for *Polyommatus coridon* (DAI=100%, DAS=100%), *Melitaea cinxia* (DAI=100%, DAS=100%), *Pontia edusa* (DAI=89,1%, DAS=80,8%), *Issoria lathonia* (DAI=73,2%, DAS=50%), *Boloria dia* (DAI=55,3%, DAS=50%), *Coenonympha glycerion* (DAI=54,5%, DAS=50%) and *Lycaena alciphron* (DAI=54,1%, DAS=50%).

Rogi Site

Altogether 36 species were found on Rogi Site, including 6 species with frequency of occurrence higher than 40%: *Pieris napi* (F=64,2% 2,5±3,1 ind./500m), *Coenonympha pamphilus* (F=59,5% 3,2±3,9 ind./500m), *Polyommatus icarus* (F=52,4% 1,9±2,7 ind./500m), *Pieris rapae* (F=52,4% 1,2±1,5 ind./500m), *Maniola jurtina* (F=47,6% 10,1±16,5 ind./500m) and *Cupido argiades* (F=40,5% 0,5±0,8 ind./500m). The highest DAI and DAS were recorded for *Satyrium w-album* (DAI=100%, DAS=100%), *Argynnis paphia* (DAI=90,7%, DAS=76,9%), *Papilio machaon* (DAI=80,2%, DAS=70%), *Apatura ilia* (DAI=60%, DAS=50%) and *Coenonympha glycerion* (DAI=45,5%, DAS=50%).

Telefoniczna Site

Altogether 36 species were recorded here but only 4 had frequency higher than 40%: *Coenonympha pamphilus* (F=72,1% 3,6±4,1 ind./500m), *Pieris rapae* (F=76,7% 2,7±3,7 ind./500m), *Pieris napi* (F=53,5% 1,1±1,6 ind./500m) and *Polyommatus icarus* (F=48,8% 1,1±1,8 ind./500m). The highest DAI and DAS were obtained for *Satyrium pruni*

(DAI=100%, DAS=100%), *Thecla betulae* (DAI=28%, DAS=46,2%), *Polygonia c-album* (DAI=36,7%, DAS=40,5%), and *Lycaena dispar* (DAI=41,7%, DAS=36,8%).

Traktorowa Site

With 34 species recorded it was the least speciose site and the only one lacking *Papilio machaon*, and therefore family Papilionidae. Seven species had frequency higher than 40%: *Coenonympha pamphilus* (F=70,7% 4,3±5,6 ind./500m), *Pieris napi* (F=63,4% 3,4±3,6 ind./500m), *Lycaena phleas* (F=63,4% 1,2±1,2 ind./500m), *Araschnia levana* (F=58,5% 1,3±1,8 ind./500m), *Maniola jurtina* (F=53,7% 14,6±23,8 ind./500m), *Lycaena tityrus* (F=53,7% 1,8±2,4 ind./500m) and *Pieris rapae* (F=51,2% 1,2±1,4 ind./500m). The highest DAI and DAS were obtained for *Brenthis ino* (DAI=100%, DAS=100%), *Carcharodus alceae* (DAI=100%, DAS=100%), *Araschnia levana* (DAI=77%, DAS=60%), *Thymelicus sylvestris* (DAI=59%, DAS=35,7%), *Aphantopus hyperantus* (DAI=53,2%, DAS=27,5%) and *Thecla betulae* (DAI=53,3%, DAS=23,1%).

Table 1 Species composition, frequency of occurrence (F), abundance (M – mean, SD – standard deviation, MAX – maximum value per single transect) and values of association indices (DAI and DAS) at each site, frequency at all sites and total number of indivuduals.

	Brukowa						**Maratońska**						**Rogi**						**Telefoniczna**						**Traktorowa**						**Total**	
species	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	Ind
Carcharodus alceae	0,0%	-	-	-	0,0%	0,0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,4%	0,02	0,16	1,00	100,0%	100,0%	0,5%	1
Erynnis tages	11,6%	0,08	0,23	0,71	20,8%	10,0%	17,8%	0,38	1,25	7,71	33,3%	48,0%	21,4%	0,32	0,71	2,86	37,5%	38,0%	4,7%	0,03	0,15	0,71	8,3%	4,0%	-	-	-	-	-	-	11,2%	46
Ochlodes sylvanus	14,0%	0,28	0,86	4,29	16,7%	12,6%	8,9%	0,21	0,82	4,29	11,1%	9,8%	19,0%	0,58	1,66	7,14	22,2%	25,1%	25,6%	0,71	1,72	7,14	30,6%	31,8%	17,1%	0,49	1,47	7,00	19,4%	20,7%	16,8%	125
Thymelicus lineola	7,0%	0,07	0,26	1,43	8,3%	3,8%	28,9%	0,90	2,29	12,00	36,1%	52,9%	7,1%	0,07	0,26	1,43	8,3%	3,8%	23,3%	0,28	0,59	2,14	27,8%	15,9%	17,1%	0,44	1,12	5,00	19,4%	23,6%	16,8%	90
Thymelicus sylvestris	11,6%	0,10	0,29	1,43	17,9%	8,2%	8,9%	0,11	0,39	1,71	14,3%	9,8%	11,9%	0,17	0,52	2,14	17,9%	13,6%	9,3%	0,12	0,41	2,14	14,3%	9,5%	24,4%	0,76	1,71	8,00	35,7%	59,0%	13,1%	60
Aricia agestis	23,2%	0,32	0,65	2,14	15,6%	10,4%	53,3%	1,52	1,98	7,71	37,5%	52,6%	19,0%	0,15	0,34	1,43	12,5%	4,9%	16,3%	0,13	0,32	1,43	10,9%	4,4%	36,6%	0,88	1,95	11,00	23,4%	27,6%	29,9%	152
Celastrina argiolus	7,0%	0,07	0,26	1,43	23,1%	20,0%	11,1%	0,15	0,49	2,57	38,5%	48,0%	4,8%	0,03	0,15	0,71	15,4%	10,0%	4,7%	0,05	0,24	1,43	15,4%	15,0%	2,4%	0,02	0,16	1,00	7,7%	7,0%	6,1%	18
Cupido argiades	27,9%	0,50	1,14	5,71	28,6%	34,6%	6,7%	0,06	0,22	0,86	7,1%	4,2%	40,5%	0,54	0,80	2,86	40,5%	37,0%	23,3%	0,35	0,79	3,57	23,8%	24,2%	-	-	-	-	-	-	19,6%	86
Lycaena alciphron	7,0%	0,08	0,36	2,14	21,4%	22,5%	15,6%	0,19	0,51	2,57	50,0%	54,1%	-	-	-	-	-	-	2,3%	0,02	0,11	0,71	7,1%	4,5%	7,3%	0,07	0,26	1,00	21,4%	18,9%	6,5%	19
Lycaena dispar	11,6%	0,10	0,29	1,43	26,3%	25,0%	2,2%	0,02	0,13	0,86	5,3%	5,0%	9,5%	0,07	0,21	0,71	21,1%	16,7%	16,3%	0,17	0,49	2,86	36,8%	41,7%	4,9%	0,05	0,22	1,00	10,5%	11,7%	8,9%	23
Lycaena phlaeas	30,2%	0,27	0,44	1,43	15,1%	7,5%	62,2%	1,66	2,00	8,57	32,6%	48,9%	14,3%	0,12	0,31	1,43	7,0%	3,3%	30,2%	0,27	0,47	2,14	15,1%	7,5%	63,4%	1,22	1,26	5,00	30,2%	32,8%	40,2%	176
Lycaena tityrus	18,6%	0,20	0,45	1,43	11,1%	4,0%	62,2%	2,65	3,41	12,86	38,9%	55,3%	9,5%	0,10	0,34	1,43	5,6%	2,0%	23,3%	0,27	0,58	2,86	13,9%	5,3%	53,7%	1,76	2,37	10,00	30,6%	33,4%	33,6%	245
Polyommatus coridon	0,0%	-	-	-	0,0%	0,0%	46,7%	9,24	15,17	55,71	100,0%	100,0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,8%	485
Polyommatus icarus	39,5%	0,95	1,91	7,14	17,0%	15,6%	53,3%	1,49	2,01	7,71	24,0%	25,5%	52,4%	1,89	2,71	10,00	22,0%	30,3%	48,8%	1,11	1,75	8,57	21,0%	18,3%	39,0%	0,66	1,04	4,00	16,0%	10,3%	46,7%	340
Satyrium pruni	0,0%	-	-	-	0,0%	0,0%	-	-	-	-	-	-	-	-	-	-	-	-	2,3%	0,02	0,11	0,71	100,0%	100,0%	-	-	-	-	-	-	0,5%	1
Satyrium w-album	0,0%	-	-	-	0,0%	0,0%	-	-	-	-	-	-	2,4%	0,02	0,11	0,71	100,0%	100,0%	-	-	-	-	-	-	-	-	-	-	-	-	0,5%	1
Thecla betulae	0,0%	-	-	-	0,0%	0,0%	2,2%	0,02	0,13	0,86	7,7%	5,6%	7,1%	0,05	0,19	0,71	23,1%	14,0%	14,0%	0,10	0,25	0,71	46,2%	28,0%	7,3%	0,20	0,95	6,00	23,1%	52,3%	6,1%	18
Aglais io	30,2%	0,47	0,92	4,29	22,4%	18,6%	24,4%	0,67	1,81	9,43	19,0%	27,9%	16,7%	0,19	0,47	2,14	12,1%	7,3%	32,6%	0,55	1,23	5,71	24,1%	21,9%	31,7%	0,63	1,41	8,00	22,4%	24,2%	27,1%	133
Aglais urticae	0,0%	-	-	-	0,0%	0,0%	2,2%	0,02	0,13	0,86	33,3%	33,3%	-	-	-	-	-	-	2,3%	0,02	0,11	0,71	33,3%	27,8%	2,4%	0,02	0,16	1,00	33,3%	38,9%	1,4%	3
Apatura ilia	2,3%	0,02	0,11	0,71	12,5%	10,0%	-	-	-	-	-	-	9,5%	0,10	0,37	2,14	50,0%	60,0%	7,0%	0,05	0,18	0,71	37,5%	30,0%	-	-	-	-	-	-	3,7%	10
Aphantopus hyperantus	23,3%	0,96	2,37	10,71	19,6%	10,4%	17,8%	0,69	1,82	8,57	15,7%	7,8%	26,2%	1,99	4,51	17,86	21,6%	21,1%	18,6%	0,70	1,95	10,00	15,7%	7,6%	34,1%	5,15	10,11	39,00	27,5%	53,2%	23,8%	464
Araschnia levana	4,7%	0,03	0,15	0,71	5,0%	2,0%	6,7%	0,06	0,22	0,86	7,5%	3,7%	16,7%	0,19	0,47	2,14	17,5%	11,2%	9,3%	0,10	0,37	2,14	10,0%	6,1%	58,5%	1,32	1,78	8,00	60,0%	77,0%	18,7%	76
Argynnis paphia	0,0%	-	-	-	0,0%	0,0%	2,2%	0,02	0,13	0,86	7,7%	2,8%	23,8%	0,66	2,03	12,14	76,9%	90,7%	-	-	-	-	-	-	4,9%	0,05	0,22	1,00	15,4%	6,5%	6,1%	42
Boloria dia	9,3%	0,20	0,99	6,43	25,0%	26,3%	17,8%	0,40	1,03	4,29	50,0%	55,3%	-	-	-	-	-	-	-	-	-	-	-	-	9,8%	0,15	0,48	2,00	25,0%	18,4%	7,5%	39
Brenthis ino	0,0%	-	-	-	0,0%	0,0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,9%	0,05	0,22	1,00	100,0%	100,0%	0,9%	2
Coenonympha glycerion	0,0%	-	-	-	0,0%	0,0%	2,2%	0,02	0,13	0,86	50,0%	54,5%	2,4%	0,02	0,11	0,71	50,0%	45,5%	-	-	-	-	-	-	-	-	-	-	-	-	0,9%	2
Coenonympha pamphilus	51,2%	1,63	2,63	9,29	15,3%	6,8%	82,2%	10,84	10,92	46,29	25,7%	47,7%	59,5%	3,18	3,92	12,86	17,4%	13,1%	72,1%	3,62	4,14	14,29	21,5%	15,2%	70,7%	4,27	5,57	25,00	20,1%	17,1%	67,3%	1247
Issoria lathonia	14,0%	0,13	0,39	2,14	12,5%	6,7%	53,3%	1,39	1,70	5,14	50,0%	73,2%	16,7%	0,17	0,44	2,14	14,6%	8,4%	14,0%	0,12	0,31	1,43	12,5%	5,9%	12,2%	0,12	0,33	1,00	10,4%	5,9%	22,4%	103
Lasiommata megera	6,9%	0,05	0,18	0,71	50,0%	32,6%	4,4%	0,08	0,40	2,57	33,3%	52,2%	-	-	-	-	-	-	-	-	-	-	-	-	2,4%	0,02	0,16	1,00	16,7%	15,2%	2,8%	8
Maniola jurtina	32,6%	0,96	1,73	5,71	14,7%	3,4%	48,9%	1,89	3,04	11,14	23,2%	6,9%	47,6%	10,12	16,54	60,71	21,1%	34,7%	39,5%	1,74	3,14	11,43	17,9%	6,1%	53,7%	14,59	23,80	86,00	23,2%	48,8%	44,4%	1455
Melanargia galathea	25,6%	0,63	1,57	8,57	17,5%	7,6%	33,3%	2,57	5,45	24,86	23,8%	32,4%	33,3%	2,57	6,03	27,14	22,2%	30,2%	27,9%	0,93	2,01	7,86	19,0%	11,2%	26,8%	1,61	3,44	15,00	17,5%	18,5%	29,4%	446
Melitaea cinxia	0,0%	-	-	-	0,0%	0,0%	4,4%	0,08	0,36	1,71	100,0%	100,0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,9%	4
Nymphalis antiopa	4,7%	0,05	0,24	1,43	33,3%	40,5%	4,4%	0,04	0,18	0,86	33,3%	32,4%	2,4%	0,02	0,11	0,71	16,7%	13,5%	2,3%	0,02	0,11	0,71	16,7%	13,5%	-	-	-	-	-	-	2,8%	7
Pararge aegeria	9,3%	0,07	0,21	0,71	8,5%	5,1%	2,2%	0,02	0,13	0,86	2,1%	1,5%	33,3%	0,37	0,62	2,14	29,8%	28,2%	27,9%	0,22	0,37	1,43	25,5%	16,7%	39,0%	0,66	1,06	5,00	34,0%	48,5%	22,0%	67
Polygonia c-album	7,0%	0,07	0,26	1,43	8,1%	8,2%	2,2%	0,02	0,13	0,86	2,7%	2,4%	16,7%	0,15	0,37	1,43	18,9%	18,4%	34,9%	0,30	0,47	2,14	40,5%	36,7%	26,8%	0,29	0,51	2,00	29,7%	34,3%	17,3%	44
Vanessa atalanta	11,6%	0,08	0,23	0,71	14,3%	9,2%	8,9%	0,08	0,25	0,86	11,4%	8,8%	19,0%	0,19	0,42	1,43	22,9%	20,1%	23,3%	0,28	0,66	2,86	28,6%	31,1%	19,5%	0,29	0,64	2,00	22,9%	30,8%	16,4%	49
Vanessa cardui	37,2%	1,61	4,08	22,14	24,2%	26,2%	28,9%	1,31	3,17	12,00	19,7%	22,3%	38,1%	1,07	1,98	7,14	24,2%	17,0%	25,6%	0,56	1,18	5,00	16,7%	9,2%	24,4%	1,63	7,05	45,00	15,2%	25,3%	30,8%	330
Papilio machaon	2,3%	0,02	0,11	0,71	10,0%	6,2%	2,2%	0,02	0,13	0,86	10,0%	7,4%	16,7%	0,22	0,60	2,86	70,0%	80,2%	2,3%	0,02	0,11	0,71	10,0%	6,2%	-	-	-	-	-	-	4,7%	16
Anthocharis cardamines	9,3%	0,28	1,00	4,29	18,2%	24,7%	8,9%	0,25	0,85	4,29	18,2%	22,7%	4,8%	0,03	0,15	0,71	9,1%	2,9%	9,3%	0,15	0,51	2,14	18,2%	13,1%	19,5%	0,44	1,05	5,00	36,4%	36,6%	10,3%	59
Colias hyale	7,0%	0,05	0,18	0,71	37,5%	31,3%	6,7%	0,06	0,22	0,86	37,5%	37,5%	4,8%	0,05	0,24	1,43	25,0%	31,3%	-	-	-	-	-	-	-	-	-	-	-	-	3,7%	9

	Brukowa						Maratońska						Rogi						Telefoniczna						Traktorowa						Total	
species	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	Ind
Gonepteryx rhamni	37,2%	0,71	1,63	8,57	22,2%	21,5%	35,6%	0,67	1,38	6,86	22,2%	21,0%	31,0%	0,88	2,15	9,29	18,1%	26,0%	25,6%	0,30	0,59	2,14	15,3%	9,0%	39,0%	0,78	1,33	6,00	22,2%	22,4%	33,6%	180
Leptidea juvernica	2,3%	0,02	0,11	0,71	11,1%	9,4%	6,7%	0,06	0,22	0,86	33,3%	34,0%	9,5%	0,09	0,28	1,43	44,4%	47,2%	2,3%	0,02	0,11	0,71	11,1%	9,4%	-	-	-	-	-	-	4,2%	10
Pieris brassicae	11,6%	0,10	0,29	1,43	23,8%	17,6%	17,8%	0,23	0,62	3,43	38,1%	42,4%	7,1%	0,07	0,26	1,43	14,3%	11,8%	7,0%	0,07	0,26	1,43	14,3%	11,8%	4,9%	0,10	0,49	3,00	9,5%	16,5%	9,8%	30
Pieris napi	62,8%	2,03	2,58	10,71	22,1%	20,1%	42,2%	1,31	2,15	7,71	15,6%	13,6%	64,3%	2,50	3,10	13,57	22,1%	24,2%	53,5%	1,05	1,58	7,14	18,9%	10,4%	63,4%	3,37	3,58	13,00	21,3%	31,8%	57,0%	539
Pieris rapae	72,1%	3,62	3,93	15,71	22,3%	29,8%	71,1%	3,41	3,61	14,57	23,0%	29,4%	52,4%	1,17	1,48	5,00	15,8%	9,4%	76,7%	2,71	3,68	20,00	23,7%	22,3%	51,2%	1,15	1,35	5,00	15,1%	9,0%	65,0%	676
Pontia edusa	4,65%	0,05	0,24	1,43	7,7%	3,9%	46,7%	1,09	1,64	6,00	80,8%	89,1%	-	-	-	-	-	-	4,7%	0,07	0,34	2,14	7,7%	5,2%	2,4%	0,02	0,16	1,00	3,8%	1,8%	12,1%	65

Diversity and abundance at investigated sites

The highest mean abundance of butterflies was noted on Maratońska (46 ± 35 ind./500m) and Traktorowa (43 ± 39 ind./500m). The lowest abundance was recorded on Brukowa (17 ± 14 ind./500m). Statistically significant results were recorded between Brukowa vs Maratońska, Traktorowa vs Maratońska, Rogi vs Telefoniczna and Telefoniczna vs Traktorowa (Kruskal-Wallis test, Dunn test $p<0.05$). Mean species richness per sample was similar on all the sites. The highest value was recorded on Maratońska (10 ± 4), and the lowest on Brukowa (7 ± 4). Statistically significant results were recorded only between Maratońska and Brukowa (Kruskal-Wallis test, Dunn test $p<0.05$). The highest mean value of Margalef index was recorded on Telefoniczna (2,4±1) and the lowest on Rogi (2,2±1). There were no statistically significant results for differences (Kruskal-Wallis test $p<0.05$).

Values of diversity indices and evennes were overall similar on all the sites and there were no statistically significant differences (Kruskal-Wallis test $p<0.05$). Mean value of Shannon index was the highest on Maratońska (1,7 ± 0,5) and the lowest on Brukowa (1,4±0,6). Simpson index was the highest on Traktorowa (0,8 ± 0,1) and the lowest on Brukowa (0,7 ± 0,2). Eveness was the highest on Brukowa (0,9±0,1) and the lowest on Maratońska (0,8±0,1) The taxonomic distinctness Delta was the highest on Brukowa (62,8±32,8) and the lowest on Rogi (53,1±17,4) although there were no statistically significant differences (Kruskal-Wallis test $p<0.05$). Taxonomic distinctness Delta* was the highest on Maratońska (74,9±7,3) and the lowest on Rogi (68,1±18,5). Statistically significant differences were found only between Maratońska and Traktorowa (Kruskal-Wallis test, Dunn test $p<0.05$).

Statistically significant seasonal (2019 vs 2020) differences in abundance (Mann-Whitney U-test, $p<0.05$), species richness (T-test, $p<0.05$), evennes (T-test, $p<0.05$), and diversity (Shannon index) (Mann-Whitney U-test, $p<0.05$) were recorded on Brukowa. Lower values of diversity and abundance and higher evenness was found in 2020 (Fig.). Significantly lower values of Delta* were recorded on Telefoniczna in 2020 (Mann-Whitney U-test, $p<0.05$).

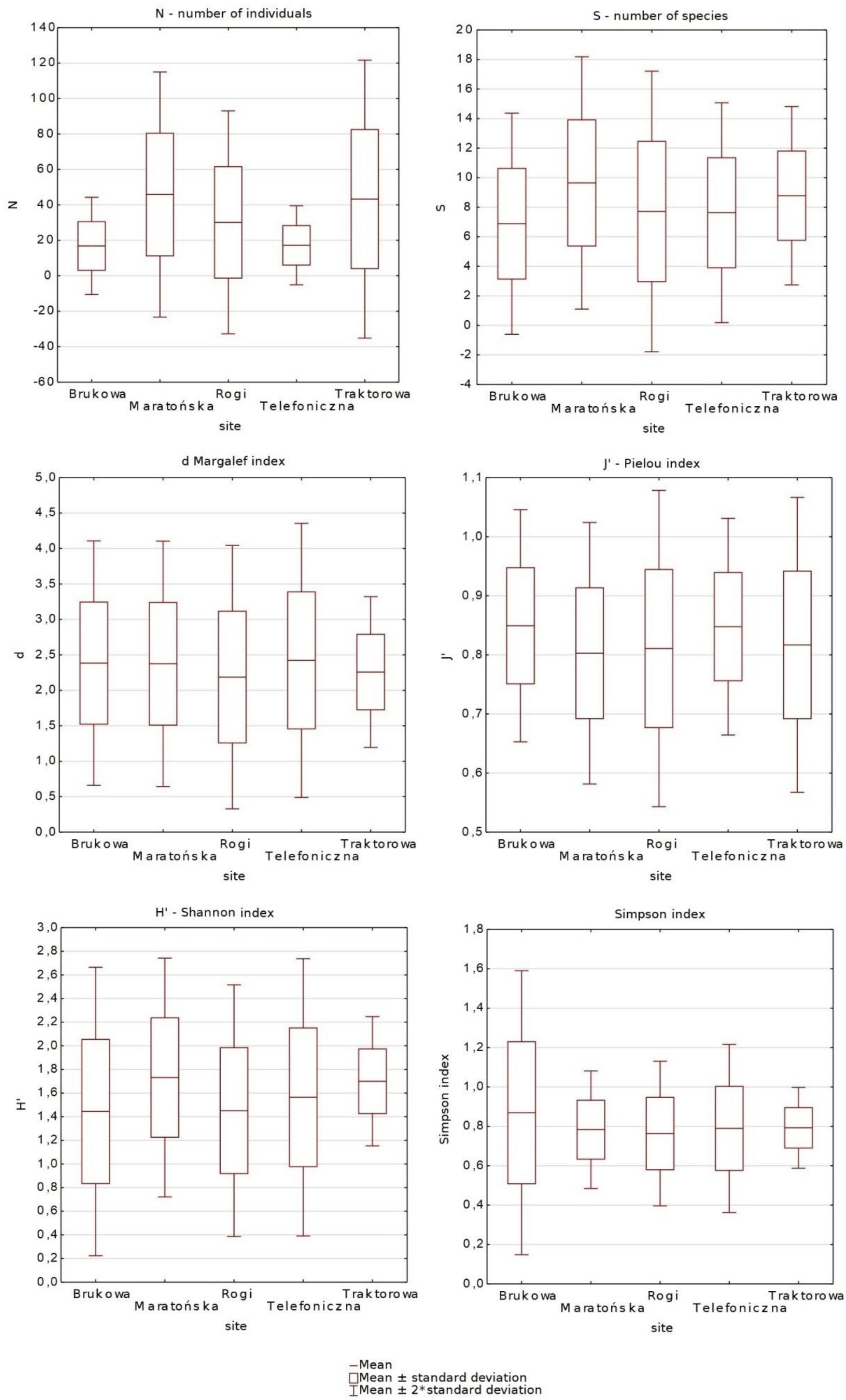

Fig 2 Mean values of abundance, evennes and diversity on sites

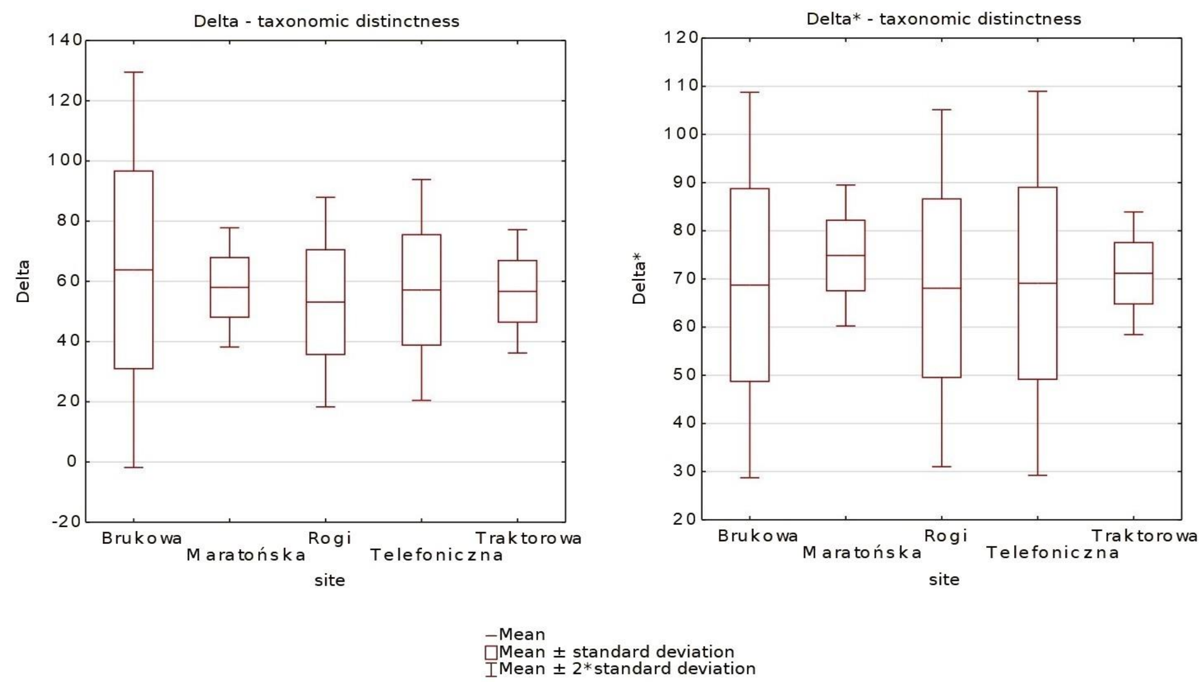

Fig 3 Mean values of taxonomic distinctness on sites

Similarity analysis

Similarity analysis allowed to describe seasonal and spatial patterns in species distribution, although seasonal differences were more pronounced with differences between species poor early spring and end of summer and most speciose summer months. Maratońska and Traktorowa were most clearly separated from other sites. Dendrogram based on Bray-Curtis's similarity index showed eight clusters mostly on 40-50% similarity level. SIMPROOF differentiated eighteen smaller groups but we have decided to follow more general pattern, because faunistic composition of subclusters was very similar (Fig.4) .

Cluster 1 grouped 8 samples from turn of May and June of 2020 (weeks 8 – 13). Altogether 4 species were recorded in this group of samples (Table 2). Samples were colected on Brukowa, Telefoniczna and Rogi. *Coenonympha pamphilus* (F=100%) had the highest frequency but none of the species had high values of association indices. The highest values were recorded for *C. pamphilus* (DAS=5,6% DAI=3,2%).

Cluster 2 grouped 12 samples from May and September (4-6 week and 21-26 week) from both seasons. Altogether 14 species were recorded in this group of samples (Table 2). Samples were colected on sites: Brukowa, Telefoniczna and Rogi. The highest frequency of occurrence was recorded for *Coenonympha pamphilus* (F=100%), *Pieris napi* (F=75%) and *Pararge aegeria* (F=50%) but values of association indices were very low e.g. the highest DAS=12.8% (*P. aegeria*) and highest DAI=14.7% (*Vanessa atalanta*).

Cluster 3 grouped 41 samples from June and July of both seasons (weeks 12-19) and from all five sites. Altogether 40 species were recorded in this group of samples (Table 2). The most frequent species were *Maniola jurtina* (F=98%), *Melanargia galathea* (F=95%), *Aphantopus hyperantus* (F=83%), Pieris rapae (F=78%), Pieris napi (F=78%), and *Thymelicus sylvestris* (F=54%). Large group of species had high values of both association indices including *Satyrium w-album* (DAS=100,0% DAI=100,0%), *Thymelicus_sylvestris* (DAS=78,6% DAI=87,8%), *Apatura ilia* (DAS=75,0% DAI=80,0%), *Lycaena alciphron* (DAS=71,4% DAI=70,3%), *Aphantopus hyperantus* (DAS=66,7% DAI=85,6%), *Melanargia galathea* (DAS=61,9% DAI=69,2%), *Maniola jurtina* (DAS=42,1% DAI=76,0%) and *Argynnis paphia* (DAS=46,2% DAI=64,7%)

Cluster 4 grouped 22 samples from July and August (weeks 16-22) of both seasons and from all five sites, although the highest number of samples was from Maratońska and Traktorowa. Altogether 33 species were recorded in this group of samples (Table 2). The most frequent species were *Pieris rapae* (F=95%), *Coenonympha pamphilus* (F=95%), *Aricia agestis* (F=91%), *Maniola jurtina* (F=86%), *Lycaena tityrus* (F=86%), *Lycaena phlaeas* (F=82%), *Polyommatus icarus* (F=77%), *Pontia edusa* (F=77%), *Polyommatus coridon* (F=77%), *Melanargia galathea* (F=68%), *Pieris napi* (F=59%) and *Vanessa cardui* (F=55%). The highest values of association indices was recorded for *Polyommatus coridon* (DAS=81% DAI=95,5%) and *Pontia edusa* (DAS= 65,4% DAI=79,2%).

Cluster 5 grouped 43 samples from July and August (weeks 17-26) of both seasons and there was temporal overlap between this group and previous cluster. Samples also represented all sites but in contrast to cluster 4 Maratońska and Traktorowa were represented by small number of samples. Altogether 34 species were recorded in this group of samples (Table 3). The most frequent species were *Coenonympha pamphilus* (F=96%), *Pieris rapae* (F=90%), *Polyommatus icarus* (F=88%), *Lycaena tityrus* (F=55%), *Lycaena phlaeas* (F=55%) and *Maniola jurtina* (F=55%). Three species had relatively high values of association indices, including *Thecla betulae* (DAS=76,9%, DAI=51,4%), *Polyommatus icarus* (DAS=45% DAI=55,8) and *Lycaena dispar* (DAS=42,1% DAI=47,5%).

Cluster 6 grouped 33 samples collected in May and June (weeks 7-13) on all sites and from both seasons. There are two main subgroups in this cluster that are divided spatially, mainly between Brukowa and Rogi. Altogether 31 species were recorded in this group of samples (Table 3). Highest frequency was recorded for *Coenonympha pamphilus* (F=100%). Lower values were found for *Polyommatus icarus* (F=61%), *Lycaena tityrus* (F=61%), *Vanessa cardui* (F=55%) and *Ochlodes sylvanus* (F=52%). The highest association indices were recorded for *Melitaea cinxia* (DAS=100% DAI=100%), *Satyrium pruni* (DAS=100% DAI=100%), *Coenonympha glycerion* (DAS=50% DAI=45,5%), *Brenthis ino* (DAS=50% DAI=50%) and *Ochlodes sylvanus* (DAS=47,2% DAI=64,2%).

Cluster 7 grouped 40 samples from early spring and end of summer (April-May and September, weeks 1-7 and 24-26) from both seasons and all sites. Altogether 30 species were recorded in this group of samples (Table 3). The most frequent species were *Aglais io* (F=78%), *Pieris napi* (F=68%), *Gonepteryx rhamni* (F=55%) and *Pieris rapae* (F=50%). The highest values of association indices were recorded for *Carcharodus alceae* (DAS=100% DAI=100%), *Anthocharis cardamines* (DAS=81,8% DAI=85,5%), *Aglais io* (DAS=53,4% DAI=68%) and *Papilio machaon* (DAS=50% DAI=67,9%).

Cluster 8 grouped only 7 samples from April and September (weeks 2 and 24-26) of both seasons and all sites. Altogether 8 species were recorded in this group of samples (Table 3). The most frequent species were *Gonepteryx rhamni* (F=57%) and *Polygonia c-album* (F=43%). Other species included *Aglais io* (F=29%), *Vanessa cardui* (F=29%), *Aglais urticae* (F=29%), *Issoria lathonia* (F=14%), *Vanessa atalanta* (F=14%) and *Nymphalis antiopa* (F=14%). *Aglais urticae* (DAS=66,7%, DAI=72,2%) had the highest values of association indices.

SIMPER analysis pointed at *Coenonympha pamphilus*, *Pieris rapae*, *Pieris napi*, *Maniola jurtina*, *Meleanargia galathea* and *Aphantopus hypernatus* as species with the highest contributions for similarity within clusters as well as dissimilarities with other clusters i.e. *Coenonympha pamphilus* contributed above 25 % to similarity in cluster 5, above 50% in cluster 6 and was the only contributing species to tie group 1. Except for *Polyommatus coridon* less numberous species like *Aglais io*, *Gonepteryx rhamni*, *Polyommatus icarus* and *Lycaena tityrus* also contributed to the grouping results e.g.. *A .io* was associated with cluster 7 (similarity contribution 26,9%) and *P.coridon* with cluster 4 (similarity contribution 13,9%). Details of SIMPER results were provided in Appendix 2.

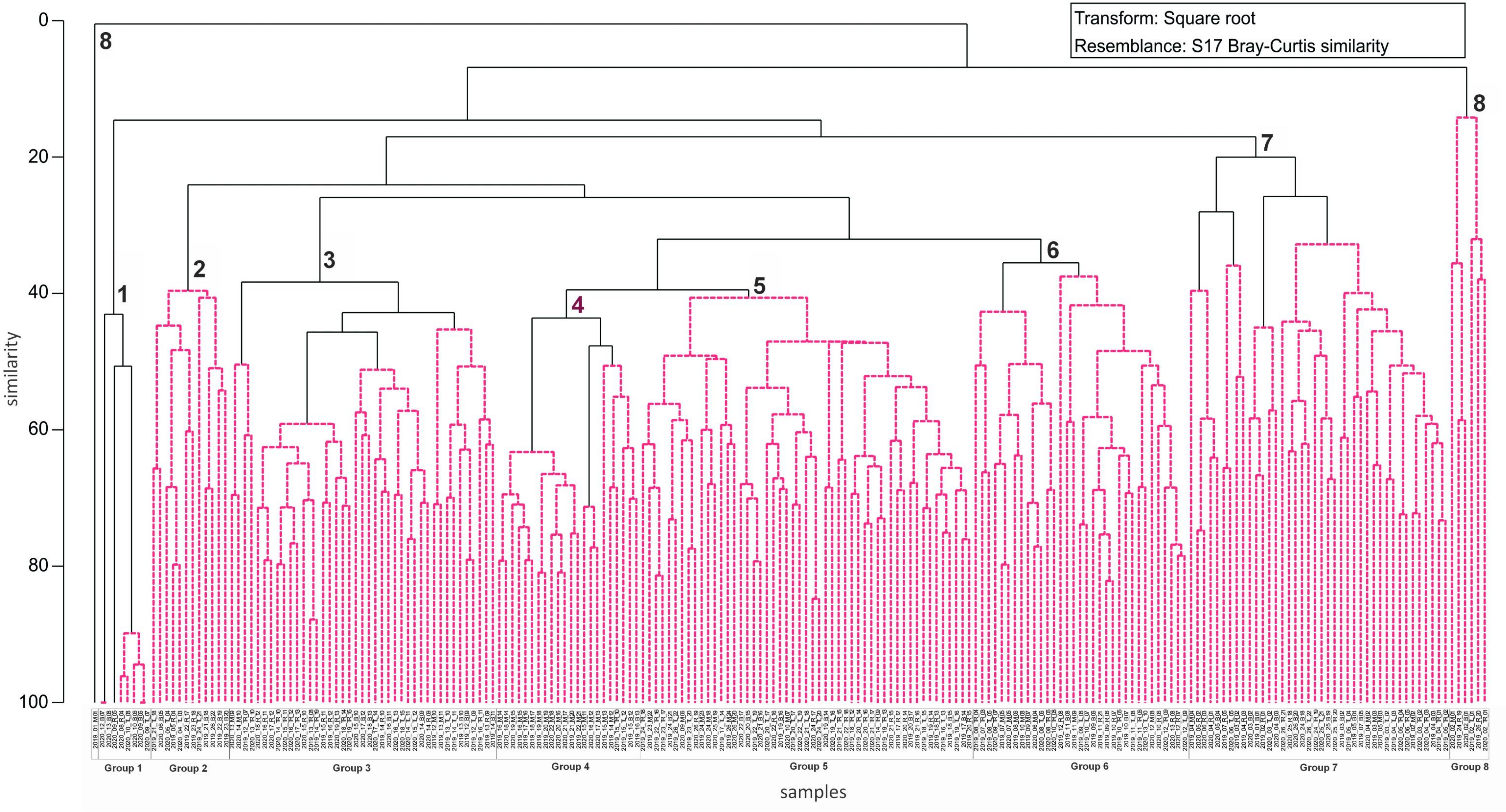

Fig 4 Dendrogram of samples based in Bray-Curtis similarity, square root transformed data and group average method.

Table 2 (cluster 1- cluster 4) Species composition, frequency of occurrence (F), abundance (M – mean, SD – standard deviation, MAX – maximum value per single transect) and values of association indices (DAI and DAS) for each cluster (cluster 1- cluster 4).

	Cluster 1						Cluster 2						Cluster 3						Cluster 4					
	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI
Erynnis tages	13%	0,18	0,51	1,43	4,2%	4,0%	-	-	-	-	-	-	7%	0,09	0,36	2,14	12,5%	10,0%	23%	0,62	1,72	7,71	20,8%	38,4%
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	-	-	-	-	39%	0,57	0,98	5,00	44,4%	30,6%	50%	1,80	3,06	12,00	30,6%	52,0%
Ochlodes sylvanus	25%	0,18	0,33	0,71	5,6%	1,5%	-	-	-	-	-	-	41%	0,81	1,47	7,00	47,2%	34,3%	-	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	-	-	-	-	54%	1,13	1,68	8,00	78,6%	87,8%	14%	0,15	0,42	1,71	10,7%	6,3%
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	2%	0,02	0,11	0,71	7,7%	4,7%	-	-	-	-	-	-
Lycaena phlaeas	-	-	-	-	-	-	25%	0,30	0,64	2,14	3,5%	2,3%	41%	0,68	1,12	5,00	19,8%	18,3%	82%	2,34	2,34	8,57	20,9%	33,7%
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	-	-	15%	0,13	0,33	1,43	46,2%	37,0%	9%	0,10	0,35	1,43	15,4%	16,0%
Polyommatus icarus	-	-	-	-	-	-	17%	0,42	0,98	2,86	2,0%	1,9%	24%	0,49	1,23	6,43	10,0%	7,6%	77%	2,34	2,26	7,14	17,0%	19,7%
Cupido argiades	-	-	-	-	-	-	33%	0,48	0,77	2,14	9,5%	9,2%	34%	0,64	1,26	5,71	33,3%	42,7%	18%	0,14	0,31	0,86	9,5%	5,1%
Lycaena dispar	-	-	-	-	-	-	-	-	-	-	-	-	5%	0,03	0,16	0,71	10,5%	8,3%	5%	0,04	0,18	0,86	5,3%	5,0%
Aricia agestis	-	-	-	-	-	-	25%	0,24	0,47	1,43	4,7%	2,2%	22%	0,50	1,78	11,00	14,1%	15,8%	91%	2,82	2,03	7,71	31,3%	47,6%
Lycaena alciphron	-	-	-	-	-	-	-	-	-	-	-	-	24%	0,27	0,56	2,57	71,4%	70,3%	5%	0,04	0,18	0,86	7,1%	5,4%
Lycaena tityrus	-	-	-	-	-	-	-	-	-	-	-	-	12%	0,30	1,04	6,00	6,9%	5,8%	86%	3,54	3,54	12,86	26,4%	36,1%
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77%	18,04	17,82	55,71	81,0%	95,5%
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	2%	0,02	0,11	0,71	100,0%	100,0%	-	-	-	-	-	-
Aglais io	-	-	-	-	-	-	-	-	-	-	-	-	17%	0,20	0,49	2,14	12,1%	7,6%	23%	0,37	0,84	3,43	8,6%	7,6%
Boloria dia	-	-	-	-	-	-	-	-	-	-	-	-	17%	0,33	0,86	3,43	43,8%	41,7%	18%	0,43	1,08	4,29	25,0%	28,9%
Araschnia levana	13%	0,09	0,25	0,71	2,5%	1,0%	-	-	-	-	-	-	44%	0,94	1,60	8,00	45,0%	55,0%	14%	0,12	0,30	1,00	7,5%	3,7%
Issoria lathonia	-	-	-	-	-	-	17%	0,18	0,44	1,43	4,2%	2,5%	7%	0,10	0,39	2,14	6,3%	4,7%	45%	1,28	1,81	5,14	20,8%	32,9%
Pararge aegeria	-	-	-	-	-	-	50%	0,36	0,37	0,71	12,8%	7,7%	32%	0,52	1,01	5,00	27,7%	38,5%	-	-	-	-	-	-
Coenonympha pamphilus	100%	4,11	3,85	12,86	5,6%	3,2%	42%	0,71	1,29	4,29	3,5%	0,8%	46%	1,28	2,49	12,86	13,2%	5,1%	95%	13,65	12,90	46,29	14,6%	29,4%
Polygonia c-album	-	-	-	-	-	-	-	-	-	-	-	-	34%	0,29	0,42	1,43	37,8%	33,9%	-	-	-	-	-	-
Vanessa atalanta	-	-	-	-	-	-	33%	0,48	0,88	2,86	11,4%	14,7%	27%	0,29	0,54	2,00	31,4%	30,0%	9%	0,08	0,25	0,86	5,7%	4,4%
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	2%	0,02	0,11	0,71	16,7%	13,5%	5%	0,03	0,15	0,71	16,7%	13,5%
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	5%	0,04	0,19	1,00	33,3%	26,1%	5%	0,12	0,55	2,57	16,7%	39,1%
Vanessa cardui	-	-	-	-	-	-	25%	0,30	0,64	2,14	4,5%	1,3%	37%	1,04	3,50	22,14	22,7%	16,1%	55%	2,31	3,51	12,00	18,2%	19,2%
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	15%	0,14	0,40	2,14	75,0%	80,0%	-	-	-	-	-	-
Aphantopus hyperantus	-	-	-	-	-	-	-	-	-	-	-	-	83%	8,29	9,47	39,00	66,7%	85,6%	45%	1,97	3,61	15,00	19,6%	10,9%
Argynnis paphia	-	-	-	-	-	-	8%	0,06	0,21	0,71	7,7%	2,3%	15%	0,48	1,97	12,14	46,2%	64,7%	5%	0,04	0,18	0,86	7,7%	2,8%
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	2%	0,02	0,16	1,00	50,0%	50,0%	-	-	-	-	-	-
Coenonympha glycerion	-	-	-	-	-	-	-	-	-	-	-	-	2%	0,02	0,13	0,86	50,0%	54,5%	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	-	-	-	-	-	98%	22,69	24,36	86,00	42,1%	76,0%	86%	3,99	3,88	11,14	20,0%	7,2%
Melanargia galathea	-	-	-	-	-	-	-	-	-	-	-	-	95%	6,02	5,84	27,14	61,9%	69,2%	68%	4,53	6,78	24,86	23,8%	27,9%
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	7%	0,05	0,19	0,71	30,0%	18,5%	5%	0,04	0,18	0,86	10,0%	7,4%
Pieris napi	-	-	-	-	-	-	75%	1,61	1,73	5,71	7,4%	4,4%	78%	3,64	3,01	10,00	26,2%	34,4%	59%	1,86	2,57	7,71	10,7%	9,4%
Anthocharis cardamines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris rapae	-	-	-	-	-	-	100%	3,39	2,44	9,29	8,6%	7,8%	78%	2,18	1,93	6,43	23,0%	17,1%	95%	6,70	4,50	15,71	15,1%	28,3%
Gonepteryx rhamni	-	-	-	-	-	-	8%	0,06	0,21	0,71	1,4%	0,5%	49%	1,58	2,59	9,29	27,8%	45,4%	36%	0,86	1,71	6,86	11,1%	13,2%
Pieris brassicae	-	-	-	-	-	-	-	-	-	-	-	-	17%	0,17	0,41	1,71	33,3%	28,2%	18%	0,16	0,34	0,86	19,0%	14,1%

	Cluster 1						Cluster 2						Cluster 3						Cluster 4					
	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI
Leptidea juvernica	-	-	-	-	-	-	-	-	-	-	-	-	2%	0,02	0,11	0,71	11,1%	9,4%	9%	0,08	0,25	0,86	22,2%	22,6%
Colias hyale	-	-	-	-	-	-	8%	0,06	0,21	0,71	12,5%	10,4%	2%	0,03	0,22	1,43	12,5%	20,8%	5%	0,04	0,18	0,86	12,5%	12,5%
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	2%	0,02	0,13	0,86	3,8%	1,6%	77%	1,97	1,90	6,00	65,4%	79,2%

Table 3 Species composition, frequency of occurrence (F), abundance (M – mean, SD – standard deviation, MAX – maximum value per single transect) and values of association indices (DAI and DAS) for each cluster(clusters 5-8)

	Cluster 5						Cluster 6						Cluster 7						Cluster 8					
	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI
Erynnis tages	8%	0,08	0,34	2,14	16,7%	12,0%	-	-	-	-	-	-	28%	0,32	0,62	2,86	45,8%	35,6%	-	-	-	-	-	-
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	3%	0,03	0,16	1,00	100,0%	100,0%	-	-	-	-	-	-
Thymelicus lineola	16%	0,25	0,70	4,00	22,2%	16,5%	-	-	-	-	-	-	3%	0,02	0,11	0,71	2,8%	0,9%	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	-	52%	1,88	2,53	7,14	47,2%	64,2%	-	-	-	-	-	-	-	-	-	-	-	-
Thymelicus sylvestris	2%	0,01	0,10	0,71	3,6%	1,4%	6%	0,07	0,30	1,43	7,1%	4,6%	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	20%	0,15	0,32	1,00	76,9%	51,4%	-	-	-	-	-	-	5%	0,17	0,95	6,00	15,4%	43,9%	-	-	-	-	-	-
Lycaena phlaeas	55%	0,90	1,14	4,29	32,6%	30,2%	15%	0,12	0,29	1,00	5,8%	2,6%	38%	0,49	0,75	3,00	17,4%	12,8%	-	-	-	-	-	-
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	-	-	13%	0,17	0,52	2,57	38,5%	47,0%	-	-	-	-	-	-
Polyommatus icarus	88%	2,87	2,67	10,00	45,0%	55,8%	61%	0,96	1,04	3,57	20,0%	12,1%	15%	0,19	0,51	2,14	6,0%	2,8%	-	-	-	-	-	-
Cupido argiades	24%	0,35	0,72	2,86	28,6%	28,9%	3%	0,09	0,50	2,86	2,4%	4,6%	18%	0,15	0,34	1,43	16,7%	9,5%	-	-	-	-	-	-
Lycaena dispar	16%	0,16	0,47	2,86	42,1%	47,5%	21%	0,18	0,38	1,43	36,8%	35,0%	3%	0,02	0,11	0,71	5,3%	4,2%	-	-	-	-	-	-
Aricia agestis	49%	0,71	1,00	5,00	39,1%	28,0%	21%	0,26	0,62	3,00	10,9%	6,5%	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena alciphron	-	-	-	-	-	-	9%	0,12	0,42	2,14	21,4%	24,3%	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena tityrus	55%	1,16	1,68	7,00	38,9%	27,5%	61%	2,00	2,98	12,86	27,8%	30,6%	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus coridon	8%	0,37	1,61	10,29	19,0%	4,5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium pruni	-	-	-	-	-	-	3%	0,02	0,12	0,71	100,0%	100,0%	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aglais io	12%	0,15	0,49	2,57	10,3%	7,3%	21%	0,26	0,62	3,00	12,1%	8,0%	78%	1,83	2,26	9,43	53,4%	68,0%	29%	0,24	0,43	1,00	3,4%	1,6%
Boloria dia	-	-	-	-	-	-	3%	0,03	0,15	0,86	6,3%	2,6%	10%	0,22	1,03	6,43	25,0%	26,8%	-	-	-	-	-	-
Araschnia levana	8%	0,09	0,35	2,00	10,0%	6,7%	18%	0,21	0,48	2,00	15,0%	10,0%	20%	0,41	1,17	6,00	20,0%	23,6%	-	-	-	-	-	-
Issoria lathonia	33%	0,51	1,03	4,29	35,4%	30,4%	9%	0,10	0,35	1,71	6,3%	3,8%	30%	0,50	1,04	4,29	25,0%	23,6%	14%	0,24	0,65	1,71	2,1%	2,0%
Pararge aegeria	25%	0,25	0,49	2,14	27,7%	23,3%	9%	0,09	0,30	1,43	6,4%	5,1%	30%	0,35	0,66	3,00	25,5%	25,4%	-	-	-	-	-	-
Coenonympha pamphilus	96%	6,80	5,61	25,00	34,0%	33,9%	100%	8,08	5,54	24,00	22,9%	26,1%	23%	0,36	0,75	2,57	6,3%	1,4%	-	-	-	-	-	-
Polygonia c-album	18%	0,16	0,37	1,43	24,3%	23,3%	6%	0,04	0,17	0,71	5,4%	4,1%	23%	0,25	0,51	2,14	24,3%	29,0%	43%	0,49	0,75	2,00	8,1%	9,8%
Vanessa atalanta	25%	0,28	0,58	2,86	37,1%	36,6%	-	-	-	-	-	-	10%	0,10	0,36	2,00	11,4%	10,6%	14%	0,20	0,54	1,43	2,9%	3,7%
Nymphalis antiopa	2%	0,01	0,10	0,71	16,7%	13,5%	-	-	-	-	-	-	5%	0,06	0,26	1,43	33,3%	43,2%	14%	0,12	0,32	0,86	16,7%	16,2%
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	3%	0,02	0,11	0,71	33,3%	27,8%	29%	0,27	0,45	1,00	66,7%	72,2%
Lasiommata megera	4%	0,03	0,15	0,86	33,3%	23,9%	-	-	-	-	-	-	3%	0,02	0,11	0,71	16,7%	10,9%	-	-	-	-	-	-
Vanessa cardui	29%	0,69	1,47	6,43	22,7%	13,3%	55%	3,91	8,20	45,00	27,3%	48,7%	3%	0,02	0,11	0,71	1,5%	0,3%	29%	0,41	0,70	1,43	3,0%	1,1%
Apatura ilia	4%	0,03	0,14	0,71	25,0%	20,0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphantopus hyperantus	14%	0,27	0,78	3,00	13,7%	3,5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Argynnis paphia	10%	0,18	0,67	3,57	38,5%	30,2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	3%	0,03	0,17	1,00	50,0%	50,0%	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha glycerion	-	-	-	-	-	-	3%	0,02	0,12	0,71	50,0%	45,5%	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	55%	3,51	6,10	27,86	29,5%	14,6%	24%	0,82	2,17	11,43	8,4%	2,2%	-	-	-	-	-	-	-	-	-	-	-	-
Melanargia galathea	16%	0,19	0,52	2,86	12,7%	2,7%	3%	0,02	0,12	0,71	1,6%	0,2%	-	-	-	-	-	-	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	6%	0,10	0,42	1,71	100,0%	100,0%	-	-	-	-	-	-	-	-	-	-	-	-
Papilio machaon	2%	0,01	0,10	0,71	10,0%	6,2%	-	-	-	-	-	-	13%	0,20	0,60	2,86	50,0%	67,9%	-	-	-	-	-	-

	Cluster 5						Cluster 6						Cluster 7						Cluster 8					
	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI	F	M	SD	MAX	DAS	DAI
Pieris napi	67%	2,58	3,23	13,57	27,9%	30,3%	21%	0,39	0,94	4,00	5,7%	3,0%	68%	2,01	2,69	11,00	22,1%	18,5%	-	-	-	-	-	-
Anthocharis cardamines	-	-	-	-	-	-	12%	0,22	0,61	2,14	18,2%	14,5%	45%	1,05	1,49	5,00	81,8%	85,5%	-	-	-	-	-	-
Pieris rapae	90%	3,92	3,52	20,00	33,1%	38,3%	24%	0,20	0,37	1,00	5,8%	1,3%	50%	0,95	1,26	5,00	14,4%	7,3%	-	-	-	-	-	-
Gonepteryx rhamni	20%	0,17	0,35	1,43	13,9%	5,9%	21%	0,22	0,45	1,71	9,7%	5,0%	55%	0,88	1,18	4,29	30,6%	24,5%	57%	1,10	1,58	4,29	5,6%	5,4%
Pieris brassicae	4%	0,03	0,15	0,86	9,5%	6,5%	6%	0,13	0,61	3,43	9,5%	17,1%	15%	0,21	0,59	3,00	28,6%	34,1%	-	-	-	-	-	-
Leptidea juvernica	2%	0,01	0,10	0,71	11,1%	9,4%	3%	0,04	0,25	1,43	11,1%	18,9%	10%	0,08	0,23	0,86	44,4%	39,6%	-	-	-	-	-	-
Colias hyale	4%	0,03	0,15	0,86	25,0%	22,9%	6%	0,05	0,19	0,86	25,0%	22,9%	3%	0,02	0,11	0,71	12,5%	10,4%	-	-	-	-	-	-
Pontia edusa	10%	0,14	0,50	2,57	19,2%	13,3%	6%	0,08	0,33	1,71	7,7%	4,7%	3%	0,02	0,11	0,71	3,8%	1,3%	-	-	-	-	-	-

Diversity and abundance of groups derived from similarity analysis

Generally the highest mean abundance of butterflies was recorded in clusters that grouped samples from the summer (from June to August), like cluster 4 (abundance - 72,6±31,3 ind./500m; species richness - 13,1±3,6) and cluster 3 (abundance 56,1±39,8 ind./500m, species richenss 11,4±3) (Fig. 5). The lowest values were recorded for clusters that grouped samples collected at the end of summer, and beginning of autumn, like cluster 8 (abundance - 3,08±2,33 ind.500m, species richness 2,29±1,25) (Fig. 5). Similar pattern was found for diversity indices with the lowest values at the end and beginning of the season e.g. cluster 8 (Margalef index is 1,5±0,6; Shannon-Wiener index is 0,7±0,5; Simpson index is 0,4±0,0,3) and the highest during the summer e.g. cluster 3 (Margalef index is 2,75±0,67, Shannon-Wiener index is 1,8±0,3; Simpson index is 0,8±0,1) and cluster 4 (Margalef is 2,9±0,9, Shannon-Wiener index is 2±0,3; Simpson 0,8±0,1) (Fig. 5). Taxonomic distincteness partiallly followed this pattern although high values of both indices were recorded in almost all groups except of cluster 1 (Delta=37,4±63,1 and Delta*=30,5±42,2) and cluster 8 (Delta=33±21,6 and Delta*=41,6±35,7) (Fig. 6). Evenness values were the lowest in the early spring and at the end of summer: cluster 7 (Pielou eveness is 0,9±0,1) and cluster 8 (Pielou eveness is 0,9±0,05) (Fig. 5).

Statistically significant differences were found for various combinations of cluster and for different indices (Kruskall-Wallis test, Dunn test ($p<0,05$)). Generally differences between the clusters were statistically significant, especially for abundance, species richness and Shannon index (Table 4).

Table 4 Statistically significant differences in abundance, species richness and diversity between clusters marked with grey cell (S – species richness, N – number of individuals, d – Margalef index, H – Shannon index, J – Pielou index, Simp – Simpson index, Delta and Delta* - taxonomical distinctness indices).

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8
Cluster 1			S, N, d, H, Simp	S, N, d, H, Simp	S, N, d, H, Simp	N	H, Delta	
Cluster 2			S, N, d, H	S, N, d, H, Simp	S, N, H, Simp		Delta	
Cluster 3	S, N, d, H, Simp	S, N, d, H		Delta*	Delta*	S, N, d, H, Delta*, Simp	S, N, J, Delta, Delta*	S, N, d, J, H, Simp
Cluster 4	S, N, d, H, Simp	S, N, d, H, Simp	Delta*		N	S, N, d, H, Simp	S, N, J, H	S, N, d, H, Delta, Simp
Cluster 5	S, N, d, H, Simp	S, N, H, Simp	Delta*	S, N		S, d, H,Simp	S, N, J	S, N, H, Simp
Cluster 6	N		S, N, d, H, Delta*, Simp	S, N, d, H, Simp	S, d, H, Simp		d, J, Delta	N, J
Cluster 7	H, Delta, Simp	Delta	S, N, J, Delta, Delta*	S, N, J, H	S, N, J	d, J, Delta		Delta, Simp
Cluster 8			S, N, d, J, H, Simp	S, N, H, Delta, Simp	S, N, H, Simp	N, J	Delta, Simp	

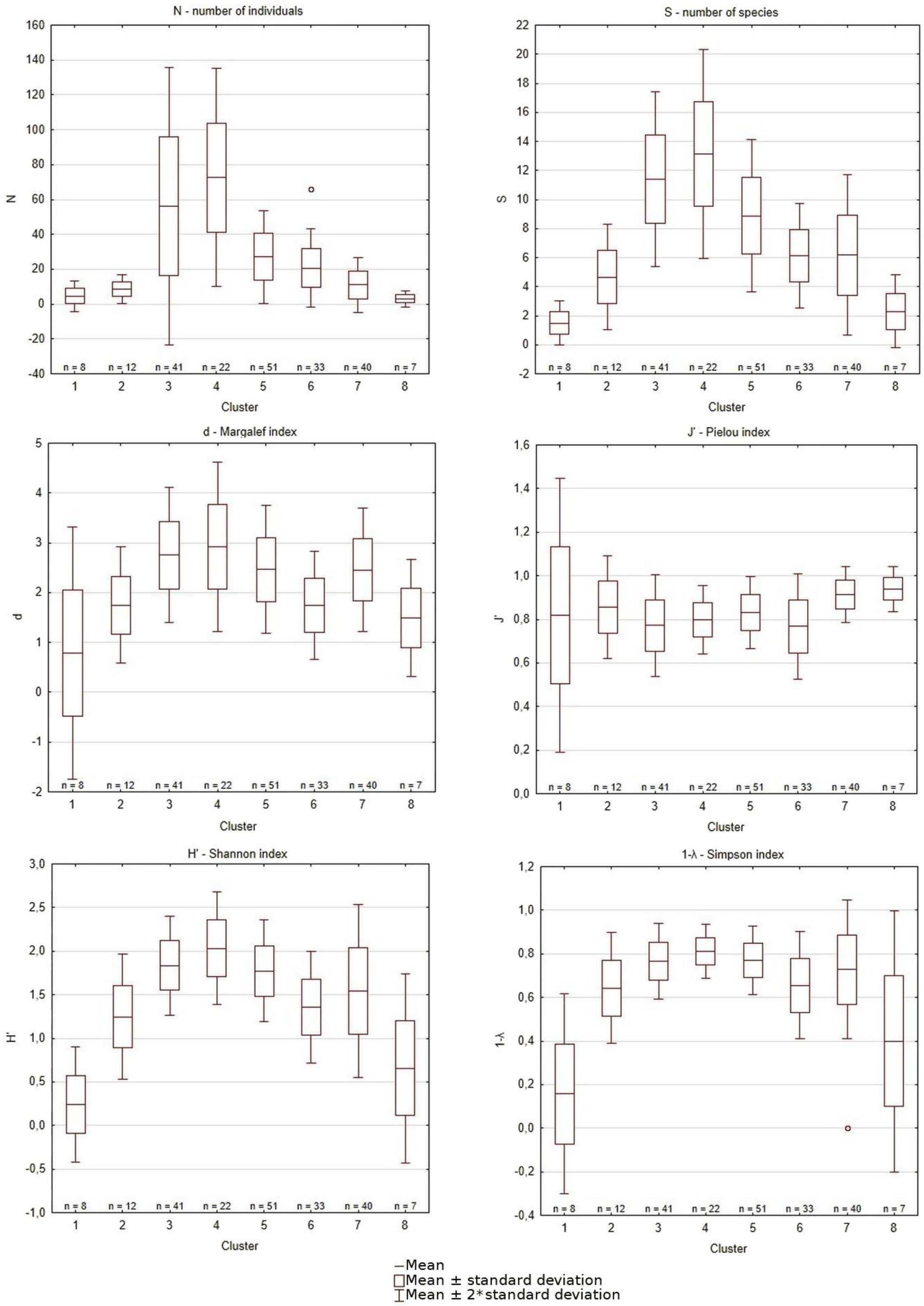

Fig 5 Mean values of abundance, evennes and diversity for clusters.

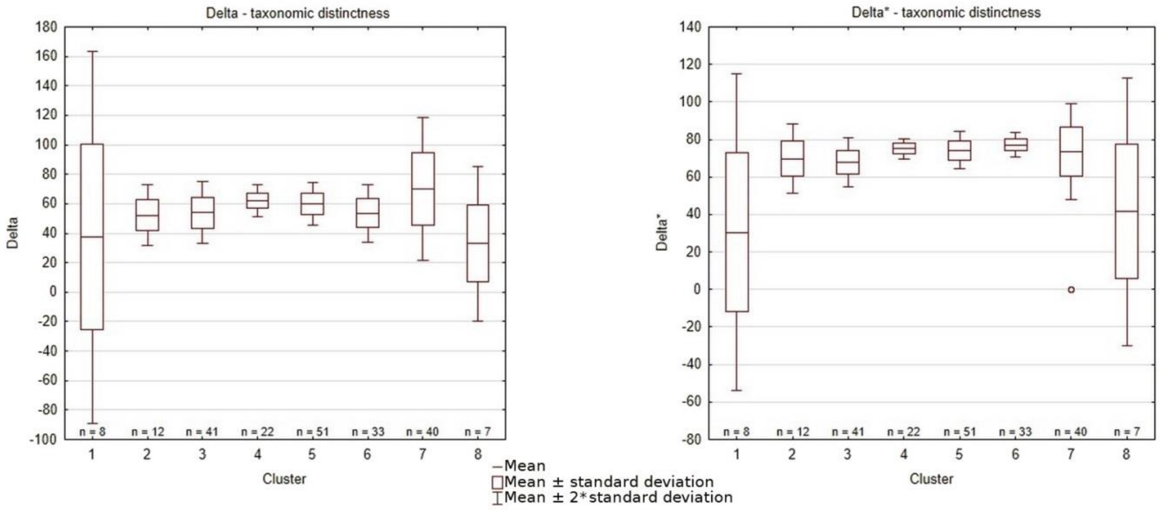

Fig 6 Mean values of taxonomic distinctness for clusters

Phenological changes along the whole season

Most of the species recorded in Łódź were bivoltine but it was not always clearly visible due to temporal overlap of generations. For most of the sites the abundance peak was recorded in July (15-17 week) except of Maratońska where peak was visibe closer to 20 week and was associated with increased abundance of *P.coridon* and second generation of *C. pamphilus* (Fig). In general peaks of abundance were recorded when the highest number of species co-occur and during seasonal maximum of main dominants. For example, on Traktorowa in 2020, peak of species number was recorded in 14 week, while peak of abundance a week later as a result of higher abundance of *Aphantopus hyperantus*.

Seasonal changes of species composition resulted in division into three main periods: (1) start of the season/early spring, (2) middle season/late spring and summer, (3) end of the season/late summer, early autumn. Beginning of the season shows presence of species overwintering as adult forms, mainly *Aglais io*, *Polygonia c-album* or *Gonepteryx rhamni* accompanied with eaarly spring species like *Anthocharis cardamines*, *Pieris napi* and *Pieris rapae*. Middle season starts at the turn of May and June, with apperance of *Ochlodes sylvanus* and *Coenonympha pamphilus.* This latter species is active for most part of the season, together with *Pieris rapae* and *Pieris napi*. Middle season is characterized by the highest number of co-occuring species. *Maniola jurtina* and *Melanarghia galanthea* contribute to highest total abundance of butterflies on sites where they dominate, like Traktorowa and Rogi. End of season is marked by general decline of abundance of individuals representing first or second generation (e.g. *Melanarghia galanthea*, *Maniola jurtina*) and emergence of the third generation of species like *Pieris napi*, *Pieris rapae*, *Polyommaus icarus*, *Lycaena phlaeas*, and *Lycaena tityrus*. In general 2019 was more humid and warmer than season 2020. It is especially visible in colder early spring of 2020. However, abundance was higher in 2020 with an exception on Brukowa site that suffered some additional disturbances disscused later in the paper. Increasing temperatures correspond with beginning of activity of some species like *A. hyperantus* on all sites, *T.lineola* on Maratońska and Telefoniczna, *T. silvestris* on Traktorowa and *M. jurtina* on Traktorowa.

BRUKOWA — weeks of season 20019

Species	1	3	4	5	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26
	april			may			june				july				august					september		
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	-	0,71	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	-	2,86	2,14	4,29	-	-	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	0,71	0,71	-	-	-	-	-	-	-	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	0,71	0,71	1,43	-	0,71	-	-	-	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	0,71	1,43	-	-	-	-	1,43	2,14	-	2,14	2,14	0,71	0,71	1,43	-	-	0,71
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cupido argiades	-	-	0,71	-	-	-	-	-	-	5,71	3,57	0,71	0,71	0,71	1,43	0,71	2,86	-	2,14	-	-	-
Lycaena alciphron	-	-	-	-	-	-	-	2,14	0,71	0,71	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	1,43	0,71	0,71	-	-	0,71	-	-	-	-	0,71	-	-	-	-	-	-
Lycaena phlaeas	-	-	0,71	-	-	-	0,71	-	-	-	-	0,71	0,71	-	-	-	1,43	0,71	-	-	0,71	0,71
Lycaena tityrus	-	-	-	-	-	0,71	1,43	1,43	-	-	-	-	0,71	0,71	1,43	-	-	-	-	-	-	-
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	-	0,71	0,71	-	0,71	-	0,71	2,86	7,14	7,14	5,71	5,71	0,71	2,86	-	-	1,43	-
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aglais io	0,71	2,14	1,43	0,71	0,71	-	-	-	-	-	-	-	1,43	-	-	-	-	-	-	-	0,71	-
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphantopus hyperantus	-	-	-	-	-	-	-	-	-	-	10,71	8,57	3,57	-	0,71	-	-	-	-	-	-	-
Araschnia levana	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boloria dia	-	-	0,71	6,43	0,71	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha glycerion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha pamphilus	-	-	-	-	0,71	5,71	8,57	0,71	1,43	-	-	0,71	1,43	6,43	6,43	9,29	8,57	0,71	0,71	-	-	-
Issoria lathonia	-	-	0,71	2,14	-	-	-	-	-	-	-	-	0,71	-	-	0,71	-	-	-	0,71	-	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	-	5,71	5,00	4,29	3,57	5,71	1,43	3,57	-	0,71	-	-	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	0,71	1,43	8,57	2,14	1,43	1,43	-	-	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	1,43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonia c-album	-	-	-	-	-	-	-	-	0,71	0,71	-	-	-	-	-	-	-	-	-	-	-	-
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	0,71
Vanessa cardui	-	-	-	-	0,71	7,14	2,14	12,14	0,71	1,43	22,14	8,57	2,86	0,71	5,00	-	1,43	2,14	-	0,71	0,71	0,71
Papilio machaon	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthocharis cardamines	-	2,86	4,29	0,71	4,29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	0,71	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71
Gonepteryx rhamni	0,71	-	0,71	-	0,71	-	-	-	0,71	3,57	4,29	-	2,14	0,71	-	0,71	-	-	-	-	-	-
Leptidea juvernica	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	0,71	-	-	-	0,71	-	0,71	0,71	-	-	-	-	-	-	-	-	-	-	-
Pieris napi	-	0,71	2,86	8,57	5,71	0,71	-	-	1,43	-	2,86	-	2,14	3,57	2,86	1,43	10,71	5,71	0,71	0,71	-	1,43
Pieris rapae	-	0,71	-	1,43	2,86	-	-	-	2,14	6,43	4,29	14,29	15,71	7,86	5,00	2,86	1,43	2,86	9,29	6,43	6,43	5,00
Pontia edusa	-	0,71	-	-	-	-	-	-	-	-	-	1,43	-	-	-	-	-	-	-	-	-	-
cloudiness	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	26-60%	26-60%

weeks of season 2020

Species	2	3	4	5	6	9	10	12	13	14	15	16	17	18	19	20	21	22	24	25	26
	april				may		june				july				august				september		
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	0,71	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-
Ochlodes sylvanus	-	-	-	-	-	-	-	0,71	0,71	1,43	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,43	-	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	-	0,71	1,43	0,71	-	-	-	-	-	-	-
Cupido argiades	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	1,43	-	-
Lycaena alciphron	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena phlaeas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	1,43	1,43	0,71	0,71
Lycaena tityrus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,43	0,71	-	-	-	-	-
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	1,43	0,71	0,71	-	0,71
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aglais io	-	0,71	0,71	-	-	-	-	-	-	-	-	1,43	-	-	-	-	-	-	2,14	4,29	2,86
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-
Aphantopus hyperantus	-	-	-	-	-	-	-	-	-	5,00	2,86	2,86	5,71	0,71	0,71	-	-	-	-	-	-
Araschnia levana	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boloria dia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha glycerion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha pamphilus	-	-	-	-	0,71	2,86	3,57	0,71	0,71	-	-	-	-	-	2,14	2,14	2,14	3,57	-	-	-
Issoria lathonia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	0,71	-	-	0,71	-	-
Maniola jurtina	-	-	-	-	-	-	-	-	-	1,43	-	2,86	3,57	2,14	0,71	-	-	0,71	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	-	1,43	1,43	2,14	5,00	1,43	-	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-
Pararge aegeria	-	-	-	-	0,71	-	-	-	-	-	0,71	0,71	-	-	-	-	-	-	-	-	-
Polygonia c-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,43	-
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	0,71	-	0,71
Vanessa cardui	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthocharis cardamines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gonepteryx rhamni	0,71	-	0,71	-	-	-	-	-	-	0,71	-	8,57	-	-	0,71	-	-	-	-	4,29	0,71
Leptidea juvernica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,43	-
Pieris napi	-	0,71	-	0,71	-	-	-	-	-	4,29	2,14	4,29	-	1,43	5,71	7,14	2,86	3,57	2,14	-	-
Pieris rapae	-	-	0,71	-	2,86	-	-	-	-	2,86	4,29	5,71	5,71	2,86	2,14	4,29	7,14	12,86	3,57	5,00	0,71
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cloudiness	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	11-25%	11-25%	11-25%	11-25%	11-25%

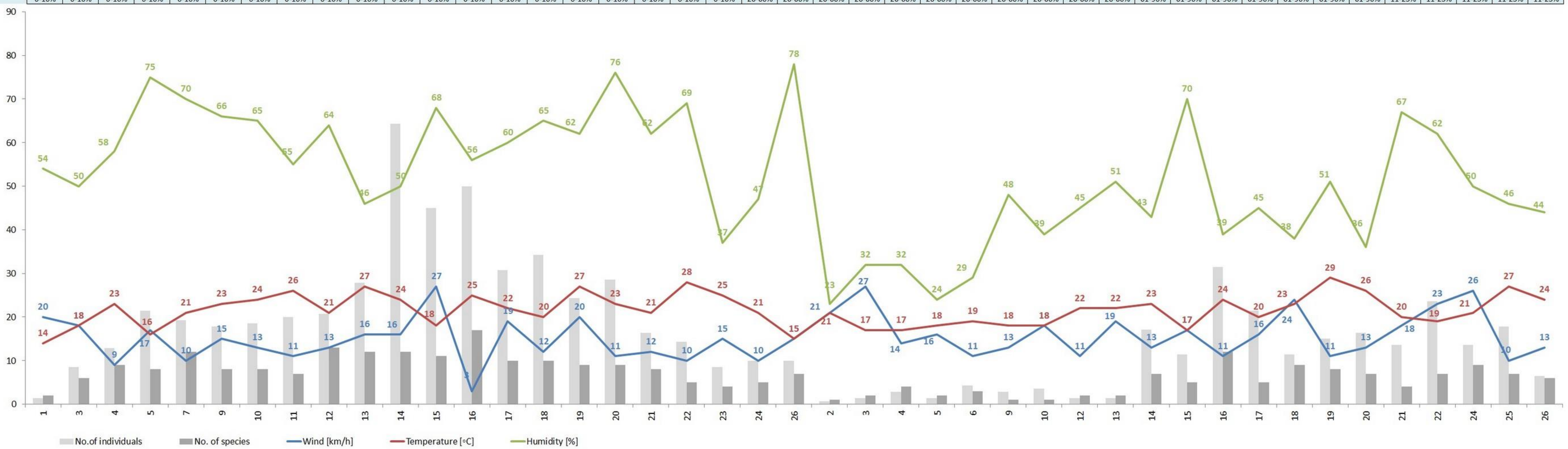

Fig 7 Phenological changes of butterfly communities on a background of weather conditions (Brukowa site).

MARATOŃSKA — weeks of season 2019

MARATOŃSKA	1	2	3	4	7	8	9	10	11	12	13	14	15	16	16	17	18	19	20	21	22	23	24	26
	april				may			june				july					august					september		
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	0,86	1,71	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	-	-	-	3,43	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	-	0,86	0,86	1,71	0,86	1,71	1,71	-	-	-	-	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	-	1,71	0,86	-	-	-	1,71	-	-	0,86	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	-	-	0,86	-	-	-	2,57	-	4,29	1,71	1,71	3,43	3,43	3,43	1,71	1,71	1,71	2,57	0,86
Celastrina argiolus	-	-	2,57	1,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cupido argiades	-	-	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-
Lycaena alciphron	-	-	-	-	-	-	-	0,86	0,86	0,86	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena phlaeas	-	-	0,86	1,71	-	-	-	-	-	2,57	2,57	6,86	-	-	0,86	-	-	2,57	4,29	2,57	0,86	1,71	1,71	-
Lycaena tityrus	-	-	-	-	12,86	3,43	2,57	6,00	-	-	-	0,86	1,71	2,57	6,86	8,57	5,14	0,86	0,86	-	1,71	0,86	2,57	6,00
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	0,86	6,00	13,71	20,57	50,57	42,86	38,57	36,00	20,57	12,00	4,29	10,29	-
Polyommatus icarus	-	-	-	-	-	-	-	0,86	-	-	-	-	-	4,29	0,86	6,86	0,86	5,14	4,29	0,86	0,86	2,57	7,71	1,71
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aglais io	-	9,43	6,86	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aglais urticae	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphantopus	-	-	-	-	-	-	-	-	-	8,57	6,86	4,29	-	2,57	-	-	-	-	-	-	-	-	-	-
Araschnia levana	-	-	0,86	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-	-	-
Boloria dia	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	24,00	23,14	10,29	17,14	7,71	3,43	-	0,86	0,86	12,86	14,57	22,29	24,86	29,14	46,29	22,29	14,57	5,14	0,86	1,71
Issoria lathonia	-	0,86	3,43	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	1,71	3,43
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	-	3,43	2,57	0,86	0,86	2,57	2,57	1,71	2,57	4,29	0,86	-	-	1,71	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	-	5,14	7,71	12,00	4,29	7,71	1,71	2,57	0,86	-	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	1,71	-	1,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	0,86	-	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonia c-album	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	0,86	-	-
Vanessa cardui	-	-	-	-	-	9,43	0,86	0,86	12,00	-	-	4,29	8,57	0,86	0,86	0,86	12,00	6,86	0,86	-	-	0,86	-	-
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-
Anthocharis	-	2,57	1,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-
Gonepteryx rhamni	-	1,71	2,57	0,86	0,86	1,71	-	-	-	-	0,86	-	-	-	-	0,86	-	-	-	-	-	-	-	-
Leptidea juvernica	-	-	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	-	-	-	-	-	3,43	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris napi	-	5,14	4,29	1,71	-	-	-	-	0,86	-	-	0,86	-	-	0,86	-	-	-	-	0,86	4,29	-	-	-
Pieris rapae	-	-	-	-	0,86	0,86	-	-	-	0,86	-	1,71	2,57	4,29	6,86	13,71	6,00	2,57	4,29	6,00	-	3,43	6,86	2,57
Pontia edusa	-	-	-	-	-	-	-	-	0,86	-	-	0,86	-	0,86	0,86	0,86	-	1,71	6,00	4,29	4,29	-	2,57	-
cloudiness	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	91-100%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%

weeks of season 2020

MARATOŃSKA	2	4	5	6	7	9	10	12	13	14	15	16	17	18	19	20	21	22	24	25	26
	april			may			june				july				august				september		
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	0,86	-	-	-	-	-	-	-	7,71	1,71	2,57	0,86	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	-	-	-	4,29	0,86	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	0,86	-	6,00	6,86	12,00	5,14	0,86	-	-	-	-	-	0,86
Thymelicus sylvestris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	-	0,86	-	-	-	-	1,71	4,29	7,71	6,86	3,43	6,00	1,71	2,57	2,57	0,86
Celastrina argiolus	-	0,86	0,86	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-
Cupido argiades	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-
Lycaena alciphron	-	-	-	-	-	-	-	-	1,71	2,57	-	0,86	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-
Lycaena phlaeas	-	-	1,71	0,86	-	4,29	0,86	-	0,86	-	4,29	4,29	3,43	0,86	0,86	1,71	8,57	4,29	4,29	1,71	2,57
Lycaena tityrus	-	-	-	4,29	2,57	-	1,71	0,86	-	-	-	6,00	1,71	5,14	8,57	12,86	7,71	2,57	-	-	1,71
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	3,43	12,86	23,14	55,71	36,00	16,29	7,71	3,43	-	0,86
Polyommatus icarus	-	-	-	-	-	1,71	3,43	1,71	-	-	-	0,86	-	3,43	5,14	1,71	1,71	2,57	3,43	3,43	0,86
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-
Aglais io	-	0,86	0,86	-	0,86	-	-	-	-	-	-	1,71	3,43	-	-	-	0,86	-	1,71	2,57	-
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphantopus	-	-	-	-	-	-	-	-	-	-	3,43	0,86	2,57	1,71	-	-	-	-	-	-	-
Araschnia levana	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boloria dia	-	0,86	-	-	-	-	-	-	3,43	3,43	-	0,86	-	-	-	4,29	2,57	1,71	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	2,57	7,71	13,71	13,71	21,43	13,71	12,86	8,57	4,29	1,71	2,57	12,86	20,57	30,86	27,43	8,57	1,71	0,86	-
Issoria lathonia	1,71	4,29	3,43	-	0,86	-	0,86	1,71	-	0,86	4,29	1,71	5,14	3,43	3,43	1,71	5,14	1,71	4,29	2,57	4,29
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,57	-	-	-	-	0,86	-
Maniola jurtina	-	-	-	-	-	-	-	0,86	3,43	6,00	11,14	11,14	10,29	3,43	8,57	3,43	0,86	-	1,71	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	0,86	11,14	15,43	24,86	17,14	3,43	0,86	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	-	0,86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonia c-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-	0,86
Vanessa cardui	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthocharis	-	4,29	2,57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	0,86	-	-	-	-	-	-	-	-
Gonepteryx rhamni	4,29	0,86	0,86	-	0,86	-	-	-	-	-	6,86	0,86	4,29	0,86	0,86	-	-	-	-	-	-
Leptidea juvernica	-	-	-	-	-	-	-	-	-	-	-	0,86	0,86	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	-	-	-	-	-	1,71	-	0,86	-	-	0,86	0,86	-	0,86	-	0,86	-	-
Pieris napi	-	-	-	-	-	-	1,71	-	1,71	3,43	2,57	0,86	1,71	-	3,43	6,86	7,71	7,71	2,57	-	-
Pieris rapae	-	3,43	-	-	0,86	2,57	2,57	-	2,57	4,29	7,71	7,71	5,14	4,29	6,86	6,86	14,57	10,29	5,14	3,43	1,71
Pontia edusa	-	-	-	-	-	-	0,86	1,71	0,86	-	1,71	1,71	1,71	1,71	6,00	4,29	3,43	1,71	-	-	-
cloudiness	26-60%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%

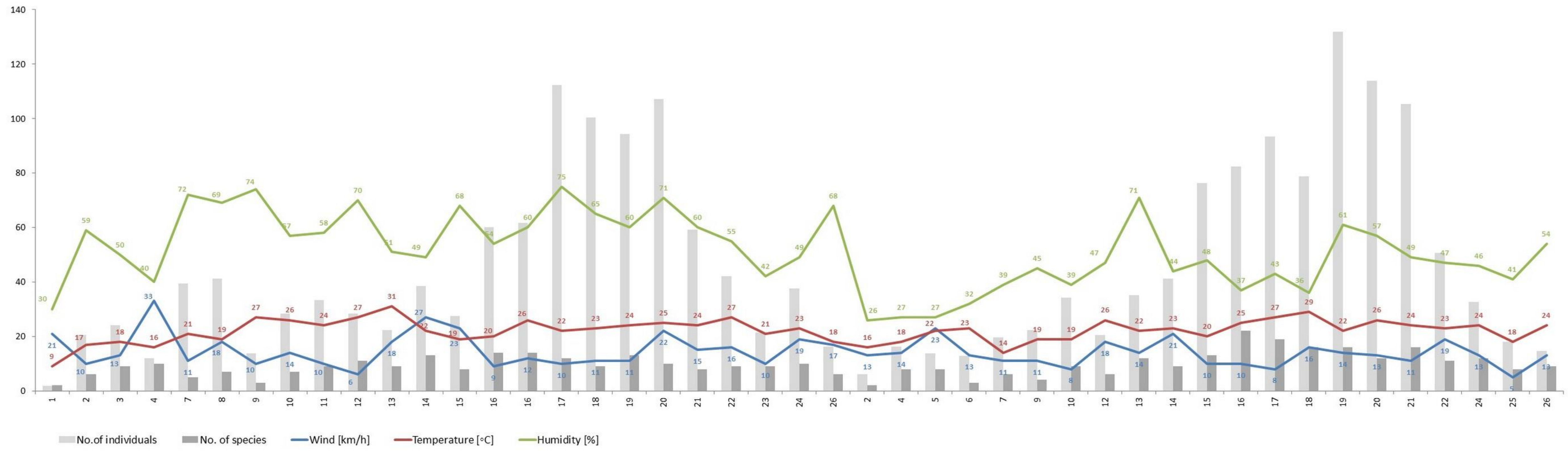

Fig 8 Phenological changes of butterfly communities on a background of weather conditions. (Maratońska site).

ROGI – weeks of season 2019

	2	3	4	5	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26
	april			may			june				july				august					september		
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	-	-	-	-	-	-	-	-	-	2,14	-	2,14	0,71	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	-	1,43	0,71	7,14	-	-	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	-	2,14	1,43	-	0,71	-	-	-	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	0,71	0,71	-	-	-	-	0,71	0,71	-	1,43	-	-	-	-	-	-	-
Celastrina argiolus	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cupido argiades	-	-	-	-	-	-	-	-	2,86	2,14	1,43	-	0,71	-	0,71	-	1,43	1,43	1,43	1,43	-	-
Lycaena alciphron	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	0,71	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena phlaeas	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-
Lycaena tityrus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,43	0,71	-	-	-	-	-	-
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	-	1,43	2,86	2,14	0,71	-	-	2,86	6,43	10,00	6,43	7,86	9,29	2,86	-	-	-	-
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aglais io	0,71	-	-	-	-	-	-	-	-	-	-	0,71	-	-	0,71	-	-	-	-	-	-	0,71
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	2,14	0,71	-	0,71	-	-	-	-	-	-	-	-
Aphantopus hyperantus	-	-	-	-	-	-	-	-	-	8,57	2,86	9,29	2,86	1,43	-	-	-	-	-	-	-	-
Araschnia levana	-	-	-	-	-	-	-	-	-	-	1,43	2,14	0,71	-	-	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	1,43	1,43	3,57	-	-	-	0,71	-	-	-
Boloria dia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	0,71	6,43	7,86	5,00	0,71	2,14	-	0,71	0,71	5,71	9,29	10,00	10,00	8,57	2,14	-	-	-
Issoria lathonia	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	1,43	-	-	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	-	11,43	9,29	13,57	24,29	32,14	27,86	5,71	6,43	5,71	0,71	-	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	-	2,14	2,14	7,14	5,71	2,86	1,43	-	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	-	-	-	0,71	-	-	-	1,43	0,71	-	-	-	-	0,71	0,71	1,43	1,43	0,71	0,71	-	-	-
Polygonia c-album	-	-	-	-	-	-	-	-	-	1,43	-	-	-	0,71	-	-	-	-	-	-	-	0,71
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	0,71	-	-	-	1,43	-	1,43
Vanessa cardui	-	-	-	-	-	5,71	5,00	7,14	0,71	0,71	0,71	1,43	3,57	3,57	6,43	5,00	0,71	-	-	-	1,43	1,43
Papilio machaon	-	2,14	2,86	-	1,43	-	-	-	-	-	-	-	0,71	-	0,71	-	-	-	-	-	-	-
Anthocharis	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	1,43	-	-	-	-	-	-	-	-	-
Gonepteryx rhamni	-	0,71	-	-	-	-	-	-	0,71	5,00	9,29	0,71	0,71	-	-	-	0,71	-	-	-	0,71	-
Leptidea juvernica	-	-	0,71	-	-	-	-	-	-	0,71	-	-	-	0,71	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	0,71	-	-	-	-	-	-	-	-	1,43	-	-	-	-	-	-	-	-	-	-
Pieris napi	-	0,71	2,14	1,43	0,71	-	-	-	-	-	10,00	5,71	8,57	2,86	1,43	1,43	4,29	5,00	3,57	2,86	-	-
Pieris rapae	-	-	-	1,43	-	-	-	-	-	1,43	0,71	3,57	4,29	2,14	0,71	-	1,43	-	2,14	2,14	-	-
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cloudiness	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	91-100%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%

weeks of season 2020

	4	5	6	8	9	10	12	13	14	15	16	17	18	19	20	21	22	24	25	26
	april		may			june				july				august				september		
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	1,43	2,86	1,43	-	1,43	-	-	-	-	-	0,71	-	0,71	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	1,43	7,14	4,29	1,43	0,71	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	-	-	0,71	1,43	-	-	-	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	-	-	2,14	-	-	-	-	-	0,71	-	-	-
Aricia agestis	-	-	-	-	-	-	-	-	0,71	-	-	-	-	0,71	-	-	-	-	-	0,71
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-
Cupido argiades	-	0,71	0,71	-	-	-	-	-	-	1,43	0,71	1,43	0,71	-	-	-	2,86	-	0,71	-
Lycaena alciphron	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	0,71	-	-	-
Lycaena phlaeas	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	0,71	0,71	0,71	1,43
Lycaena tityrus	-	-	-	-	-	-	-	-	-	-	-	-	-	1,43	-	-	0,71	-	-	-
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	-	0,71	3,57	2,14	-	-	-	0,71	-	2,86	5,71	3,57	3,57	1,43	0,71	1,43
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	0,71	0,71
Aglais io	-	-	-	-	-	-	-	-	-	-	-	-	2,14	-	-	-	-	-	1,43	1,43
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-
Aphantopus hyperantus	-	-	-	-	-	-	-	-	4,29	17,86	15,71	14,29	5,71	0,71	-	-	-	-	-	-
Araschnia levana	-	-	-	-	0,71	-	-	-	-	0,71	0,71	-	1,43	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	0,71	-	12,14	3,57	2,86	0,71	0,71	-	-	-
Boloria dia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	4,29	12,86	11,43	7,86	7,14	-	-	-	-	-	2,86	2,14	4,29	7,86	1,43	-	1,43
Issoria lathonia	-	-	-	-	-	-	-	-	-	-	-	-	-	2,14	0,71	-	0,71	0,71	0,71	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	2,86	21,43	40,00	51,43	60,71	47,86	40,71	15,00	6,43	1,43	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	0,71	12,14	27,14	22,86	13,57	8,57	0,71	0,71	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-
Pararge aegeria	-	-	-	-	-	-	-	-	-	-	1,43	-	0,71	2,14	2,14	-	-	-	0,71	-
Polygonia c-album	-	-	-	-	-	-	-	0,71	-	-	0,71	-	0,71	-	-	-	-	1,43	-	-
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	0,71	0,71	0,71	-	-	-	-	1,43	-	-
Vanessa cardui	-	-	-	-	-	-	-	-	-	-	-	0,71	0,71	-	-	-	-	-	-	-
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	0,71	0,71	-	-	-	-	-	-
Anthocharis	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-
Gonepteryx rhamni	-	0,71	-	-	-	-	-	-	-	-	5,71	7,86	3,57	-	-	-	-	-	0,71	-
Leptidea juvernica	-	-	-	-	-	1,43	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-
Pieris napi	1,43	1,43	1,43	-	-	-	-	-	3,57	2,14	7,14	6,43	5,71	3,57	2,86	13,57	2,14	2,86	-	-
Pieris rapae	1,43	-	-	-	-	-	-	-	0,71	0,71	4,29	2,86	0,71	-	2,86	2,14	5,00	4,29	2,14	2,14
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cloudiness	26-60%	26-60%	26-60%	26-60%	26-60%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%

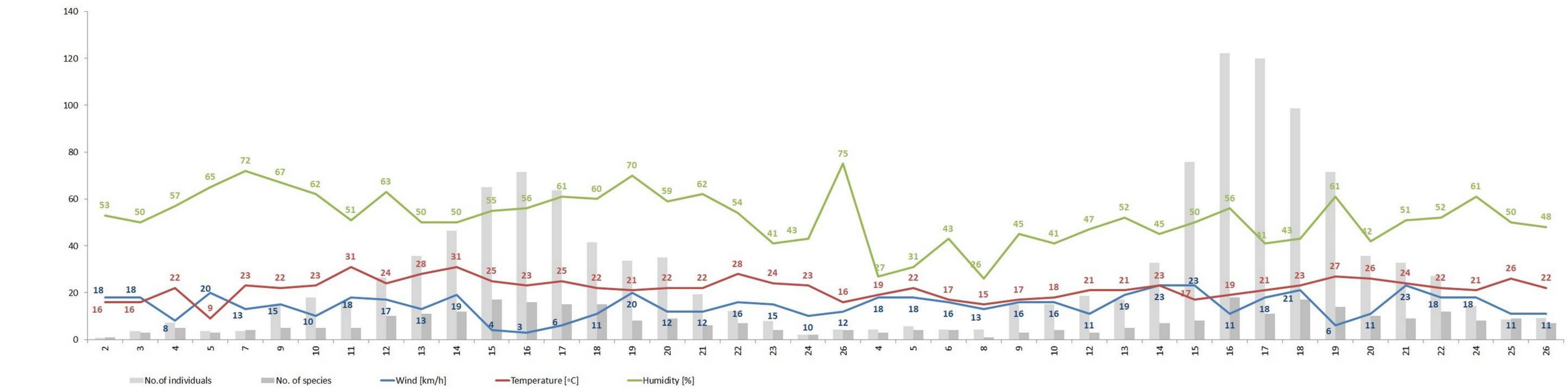

Fig 9 Phenological changes of butterfly communities on a background of weather conditions (Rogi site)

TELEFONICZNA

weeks of season 2019

	2	3	4	5	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26
	april			may			june				july				august					september		
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	-	-	-	-	-	-	-	-	-	-	0,71	0,71	-	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	0,71	5,71	7,14	2,14	2,86	0,71	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	0,71	-	1,43	0,71	-	0,71	-	-	-	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	0,71	2,14	0,71	-	-	-	-	-	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	-	-	-	-	-	-	0,71	1,43	0,71	-	-	-	-	-	0,71	-	-
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	0,71	1,43	-	-	-	-	-	-	-	-	-	-
Cupido argiades	-	-	-	-	-	-	-	-	0,71	3,57	2,86	-	1,43	-	-	1,43	1,43	0,71	-	-	-	-
Lycaena alciphron	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-
Lycaena phlaeas	-	-	-	-	-	0,71	-	-	-	-	-	0,71	0,71	-	-	0,71	-	-	-	1,43	-	0,71
Lycaena tityrus	-	-	-	-	1,43	-	-	0,71	-	-	-	1,43	2,86	1,43	-	-	0,71	-	-	-	-	0,71
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	-	-	0,71	0,71	-	-	-	2,14	8,57	2,14	4,29	5,71	3,57	2,14	0,71	1,43	-	1,43
Satyrium pruni	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	0,71	0,71	-	-	-	-	-
Aglais io	-	5,71	5,00	2,86	1,43	0,71	0,71	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	0,71
Aglais urticae	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphantopus hyperantus	-	-	-	-	-	-	-	-	-	2,14	0,71	0,71	-	-	-	-	-	-	-	-	-	-
Araschnia levana	-	0,71	2,14	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boloria dia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha glycerion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha pamphilus	-	-	-	-	3,57	4,29	5,00	5,00	2,14	-	-	0,71	6,43	7,14	6,43	12,86	11,43	4,29	2,14	0,71	-	1,43
Issoria lathonia	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	-	5,00	4,29	1,43	1,43	3,57	-	1,43	1,43	-	-	-	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	0,71	5,00	2,86	2,14	0,71	-	-	-	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	-	0,71	1,43	-	-	-	-	0,71	-	-	-	-	-	-	0,71	0,71	-	0,71	-	-	-	-
Polygonia c-album	0,71	-	-	-	-	-	-	0,71	0,71	-	-	-	0,71	-	-	0,71	0,71	-	-	-	-	-
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	0,71	-	-	-	2,86	-
Vanessa cardui	-	-	-	-	0,71	3,57	5,00	3,57	1,43	1,43	0,71	2,14	1,43	-	2,86	1,43	-	-	-	-	-	-
Papilio machaon	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthocharis cardamines	-	-	2,14	1,43	2,14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gonepteryx rhamni	-	-	-	-	-	-	-	-	0,71	1,43	1,43	2,14	-	-	-	0,71	-	-	-	-	-	-
Leptidea juvernica	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-
Pieris napi	-	2,86	2,86	0,71	2,14	0,71	-	-	-	1,43	2,14	-	-	-	0,71	-	-	-	1,43	0,71	-	-
Pieris rapae	-	-	1,43	-	-	0,71	0,71	-	0,71	-	0,71	5,00	10,00	0,71	0,71	4,29	8,57	2,86	4,29	2,14	3,57	5,71
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,14	-	-	0,71
cloudiness	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	91-100%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%

weekks of season 2020

	3	4	5	6	8	9	10	12	13	14	15	16	17	18	19	20	21	22	24	25	26
	april			may			june				july			august				september			
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	-	-	6,43	1,43	0,71	2,14	0,71	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	-	2,14	-	-	-	2,14	1,43	1,43	-	0,71	-	0,71	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	1,43	-	-	-	-	-	-	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	0,71	0,71	-	-	-	-	-
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cupido argiades	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	1,43	-	-	0,71
Lycaena alciphron	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	0,71	0,71	2,86	-	-	0,71	-
Lycaena phlaeas	-	-	2,14	-	0,71	-	-	-	-	-	-	0,71	-	0,71	-	0,71	-	0,71	0,71	-	-
Lycaena tityrus	-	-	-	-	0,71	-	-	-	-	-	-	-	-	-	0,71	-	0,71	-	-	-	-
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	-	-	-	2,14	1,43	-	-	-	0,71	-	-	1,43	2,14	0,71	1,43	2,14	2,14
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	0,71	-	-	0,71	-	-
Aglais io	0,71	-	-	-	-	-	-	-	-	-	-	1,43	0,71	0,71	-	-	-	-	-	0,71	1,43
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	0,71	0,71	-	0,71	-	-	-	-	-
Aphantopus hyperantus	-	-	-	-	-	-	-	-	-	6,43	10,00	3,57	3,57	2,86	-	-	-	-	-	-	-
Araschnia levana	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boloria dia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha glycerion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha pamphilus	-	-	-	2,14	8,57	2,86	5,00	5,71	3,57	1,43	1,43	-	0,71	2,14	3,57	14,29	13,57	12,86	2,86	1,43	-
Issoria lathonia	-	-	-	-	-	-	-	0,71	-	-	-	-	-	-	0,71	1,43	0,71	-	0,71	-	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	0,71	2,86	7,86	5,71	10,71	11,43	10,71	3,57	2,14	-	0,71	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	0,71	3,57	7,86	5,71	7,14	2,86	0,71	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	0,71	0,71	0,71	-	-	-	-	-	-	-	-	-	0,71	-	-	-	0,71	-	0,71	-	-
Polygonia c-album	-	-	-	-	-	-	-	-	-	0,71	0,71	0,71	-	0,71	-	-	0,71	0,71	1,43	2,14	0,71
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	0,71	-	1,43	-	-	0,71	0,71	0,71	2,86	0,71	-
Vanessa cardui	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthocharis cardamines	-	-	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gonepteryx rhamni	-	0,71	-	-	-	-	-	-	-	-	0,71	-	-	-	0,71	0,71	1,43	-	-	2,14	-
Leptidea juvernica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,71	-	-	-	1,43	-
Pieris napi	-	2,14	0,71	0,71	1,43	-	-	-	-	6,43	2,86	-	2,14	-	1,43	0,71	7,14	1,43	1,43	-	0,71
Pieris rapae	0,71	0,71	1,43	0,71	-	-	-	0,71	-	2,86	6,43	1,43	1,43	3,57	2,14	5,00	6,43	20,00	5,71	2,14	2,86
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cloudiness	26-60%	26-60%	26-60%	26-60%	26-60%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%

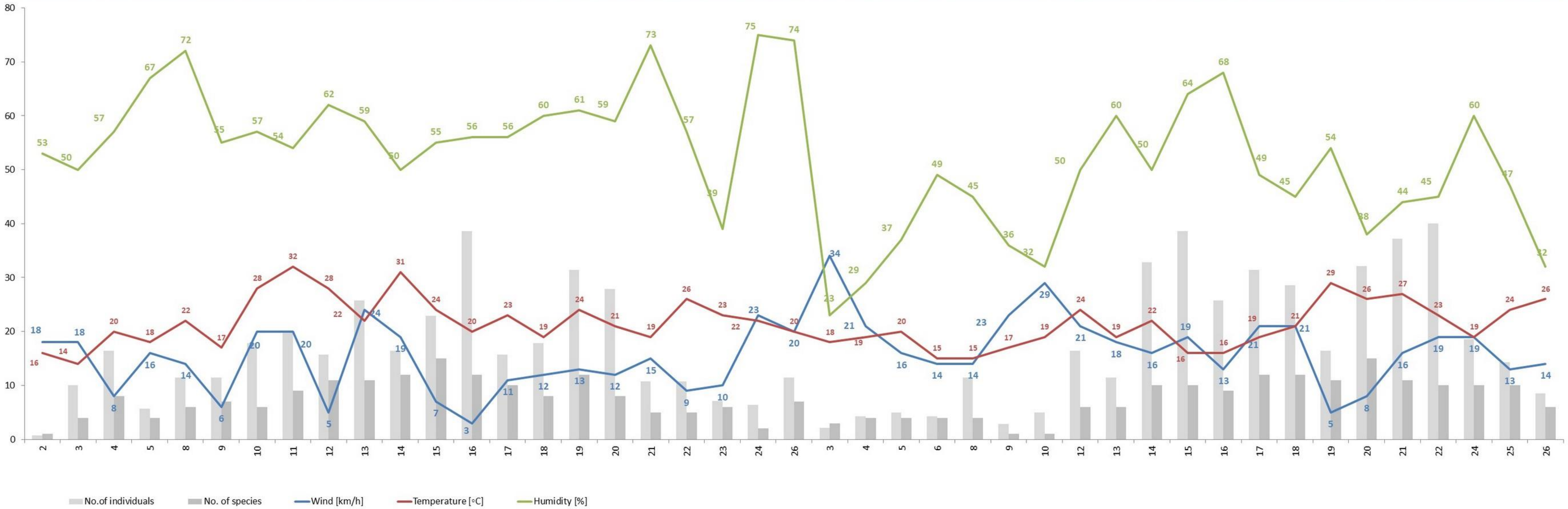

Fig 10 Phenological changes of butterfly communities on a background of weather conditions (Telefoniczna site)

TRAKTOROWA – weeks of season 2019

	4	5	7	8	10	11	12	13	14	14	15	16	18	19	20	21	22	23	24
	april	may			june				july				august					september	
Carcharodus alceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	2,00	2,00	1,00	-	-	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	2,00	-	-	-	2,00	-	-	-	-	-	2,00	-	-
Thymelicus sylvestris	-	-	-	-	-	1,00	8,00	2,00	-	2,00	-	2,00	-	-	-	-	-	-	-
Aricia agestis	-	-	-	3,00	-	1,00	-	-	5,00	2,00	2,00	11,00	1,00	2,00	1,00	-	1,00	1,00	-
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cupido argiades	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena alciphron	-	-	-	-	-	-	1,00	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	-	-	-	-
Lycaena phlaeas	1,00	1,00	-	-	-	-	1,00	3,00	-	1,00	3,00	-	-	-	-	3,00	3,00	3,00	1,00
Lycaena tityrus	-	-	3,00	3,00	2,00	-	-	-	7,00	-	2,00	1,00	3,00	5,00	3,00	-	1,00	2,00	1,00
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	1,00	-	-	-	4,00	-	-	1,00	1,00	-	1,00	-	1,00	1,00	-
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-
Aglais io	8,00	2,00	3,00	1,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aglais urticae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphantopus	-	-	-	-	-	-	-	18,00	3,00	16,00	15,00	16,00	2,00	3,00	-	-	-	-	-
Araschnia levana	6,00	4,00	1,00	1,00	2,00	-	1,00	2,00	1,00	2,00	1,00	2,00	-	-	-	1,00	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boloria dia	-	-	-	-	-	-	2,00	-	-	-	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	1,00	9,00	14,00	4,00	1,00	-	9,00	-	-	2,00	16,00	25,00	17,00	10,00	5,00	2,00	3,00
Issoria lathonia	1,00	-	-	-	-	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	3,00	16,00	30,00	17,00	25,00	11,00	9,00	8,00	18,00	6,00	4,00	-	-	-
Melanargia galathea	-	-	-	-	-	-	6,00	10,00	1,00	10,00	3,00	-	-	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	3,00	1,00	-	-	-	-	-	2,00	-	2,00	-	-	-	-	1,00	-	1,00	1,00	-
Polygonia c-album	-	1,00	-	-	-	-	1,00	-	-	-	-	-	-	-	-	-	-	-	-
Vanessa atalanta	-	-	-	-	-	-	1,00	-	-	-	-	2,00	-	-	-	-	-	2,00	-
Vanessa cardui	-	-	-	45,00	5,00	3,00	-	1,00	-	4,00	2,00	2,00	1,00	3,00	-	-	-	-	1,00
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthocharis	3,00	5,00	2,00	-	1,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gonepteryx rhamni	1,00	2,00	1,00	1,00	-	-	-	-	-	-	-	6,00	1,00	-	-	-	-	-	-
Leptidea juvernica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	1,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris napi	11,00	8,00	4,00	3,00	-	-	3,00	3,00	2,00	6,00	1,00	3,00	-	7,00	4,00	3,00	-	-	-
Pieris rapae	-	1,00	1,00	-	-	-	-	-	-	-	1,00	2,00	3,00	-	2,00	-	3,00	3,00	3,00
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cloudiness	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%

TRAKTOROWA – weeks of season 2020

	2	3	4	5	6	8	9	10	12	13	14	15	16	17	18	19	20	21	22	24	25	26
	april				may			june				july				august				september		
Carcharodus alceae	-	-	-	1,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erynnis tages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ochlodes sylvanus	-	-	-	-	-	-	-	-	6,00	7,00	1,00	1,00	-	-	-	-	-	-	-	-	-	-
Thymelicus lineola	-	-	-	-	-	-	-	-	-	-	1,00	-	-	5,00	-	2,00	4,00	-	-	-	-	-
Thymelicus sylvestris	-	-	-	-	-	-	-	-	-	2,00	4,00	6,00	2,00	2,00	-	-	-	-	-	-	-	-
Aricia agestis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	3,00	1,00	1,00	-	-	-	-
Celastrina argiolus	-	-	-	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-	-	-	-	-	-
Cupido argiades	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena alciphron	-	-	-	-	-	-	-	-	-	-	1,00	-	1,00	-	-	-	-	-	-	-	-	-
Lycaena dispar	-	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycaena phlaeas	-	-	-	2,00	1,00	-	-	1,00	-	1,00	5,00	3,00	1,00	1,00	2,00	1,00	2,00	2,00	2,00	3,00	1,00	2,00
Lycaena tityrus	-	-	-	-	-	1,00	6,00	10,00	2,00	-	-	-	-	2,00	6,00	2,00	4,00	5,00	1,00	-	-	-
Polyommatus coridon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyommatus icarus	-	-	-	-	-	2,00	2,00	1,00	3,00	-	-	-	-	-	3,00	1,00	3,00	1,00	-	-	-	1,00
Satyrium pruni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satyrium w-album	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thecla betulae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	6,00	-	-
Aglais io	1,00	1,00	2,00	1,00	1,00	-	-	-	-	-	-	-	-	-	-	1,00	-	-	-	2,00	2,00	1,00
Aglais urticae	1,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apatura ilia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphantopus	-	-	-	-	-	-	-	-	-	-	6,00	28,00	38,00	39,00	14,00	10,00	3,00	-	-	-	-	-
Araschnia levana	-	-	-	1,00	1,00	1,00	-	1,00	1,00	-	4,00	4,00	3,00	8,00	3,00	1,00	-	-	2,00	-	-	-
Argynnis paphia	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	1,00	-	-	-	-	-	-	-
Boloria dia	-	-	-	-	-	-	-	-	-	1,00	2,00	-	1,00	-	-	-	-	-	-	-	-	-
Brenthis ino	-	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenonympha	-	-	-	-	2,00	3,00	7,00	6,00	8,00	5,00	1,00	1,00	-	-	-	2,00	6,00	5,00	6,00	1,00	2,00	2,00
Issoria lathonia	-	-	1,00	-	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-	-	-	-	1,00
Lasiommata megera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	-	-	-	-	-	-	-
Maniola jurtina	-	-	-	-	-	-	-	-	2,00	17,00	86,00	83,00	69,00	62,00	59,00	38,00	20,00	12,00	3,00	-	-	-
Melanargia galathea	-	-	-	-	-	-	-	-	-	-	5,00	15,00	7,00	3,00	5,00	1,00	-	-	-	-	-	-
Melitaea cinxia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nymphalis antiopa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pararge aegeria	-	-	2,00	1,00	1,00	-	-	-	-	-	1,00	5,00	-	2,00	1,00	2,00	-	-	-	1,00	-	-
Polygonia c-album	2,00	1,00	-	-	-	-	-	-	-	1,00	1,00	1,00	-	-	-	-	-	-	1,00	1,00	1,00	1,00
Vanessa atalanta	-	-	-	-	-	-	-	-	-	-	-	-	1,00	2,00	-	-	1,00	-	1,00	2,00	-	-
Vanessa cardui	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Papilio machaon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthocharis	-	2,00	-	2,00	1,00	-	2,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colias hyale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gonepteryx rhamni	2,00	1,00	4,00	4,00	2,00	-	1,00	-	-	-	-	1,00	2,00	-	-	-	1,00	-	-	-	2,00	-
Leptidea juvernica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pieris brassicae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,00	-	-
Pieris napi	-	2,00	7,00	2,00	-	-	-	-	-	-	6,00	8,00	7,00	10,00	5,00	9,00	4,00	13,00	5,00	2,00	-	-
Pieris rapae	-	-	-	2,00	1,00	-	1,00	-	-	-	3,00	2,00	2,00	-	-	2,00	2,00	5,00	4,00	2,00	2,00	-
Pontia edusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	-	-	-
cloudiness	26-60%	26-60%	26-60%	26-60%	26-60%	26-60%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	61-90%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%	11-25%

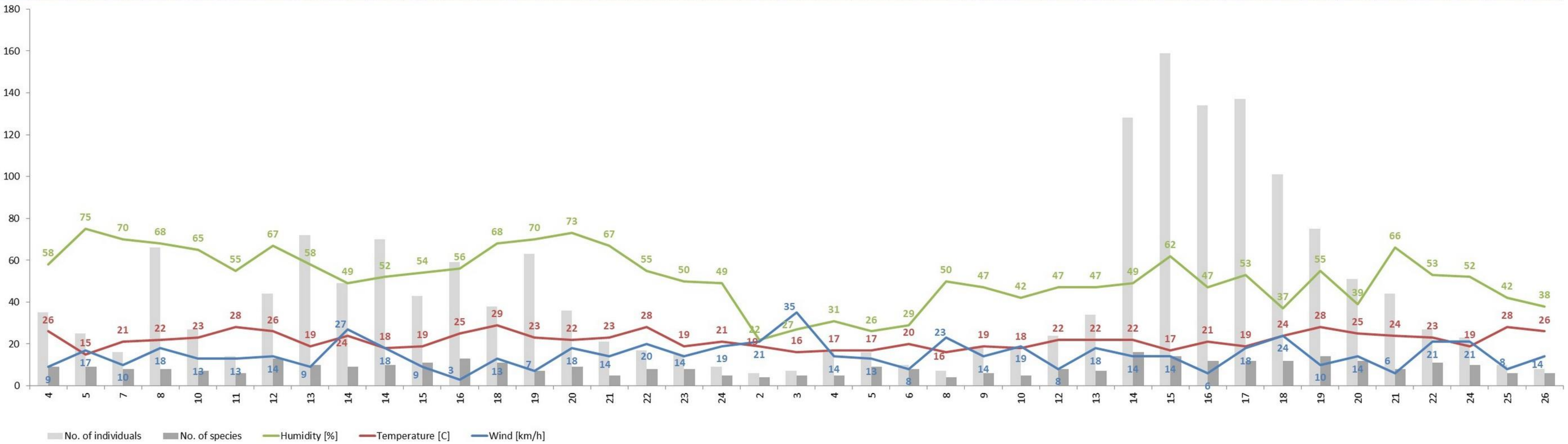

Fig 11 Phenological changes of butterfly communities on a background of weather conditions (Traktorowa site)

Discussion

Local-regional species pools: urban fauna vs seminatural and agricultural areas of Central Poland

In general, 46 out of 60 butterflies currently recorded in Łódź (Sobczyk et al. 2017, 2018) were found at 5 investigated sites. Those numbers include two species that were previously not reported in the city, namely *Satyrium w-album* and *Melitaea cinxia*, that was noticed only in 2019. Łódź does not stand out from other cities in this part of Europe which are inhabited by 50-80 species of butterflies (Machnikowski 1999 – Bydgoszcz, Höttinger – Wienna 2000, Winiarska 2003 – Warsaw, Konvicka and Kadlec 2011 – Prague, Gelbrecht et al. 2016 – Berlin, , Palik et al. 2005 – Kraków, Senn 2015 – Gdynia, Poznań – Dylewski et al. 2019, Sielezniew and Dziekańska 2019 – Białystok), although it worth mentioning that direct comparisons are difficult or impossible due to differences in size and character of each city, including distribution and size of green spaces, geographic position but also time, intensity of studies, dynamic changes in urban communities and composition of regional species pools. In general ecological interactions and distribution patterns of urban organisms are strongly site specific and contex dependant (McKinney 2008, Rega-Brodsky et al. 2022).

Number of butterfly species recorded in Poland equals 160, therefore fauna of Łódź represents around 40% of Polish fauna (Buszko and Masłowski 2015). Nevertheless, more interesting questions occur when we look at our results from a perspective of smaller spatial scale, and try to analyse relations between local (urban habitat island) and regional species pools (the whole Łódź and the whole Central Poland). Only 72 out of 160 Polish butterfly species were recorded recently in the Central Poland as a result of large, long term citizen science project (Buszko and Masłowski 2015, Buszko and Nowacki 2017) and only a few species known from the region were not found in Lodz. Those species include mostly highly specialized species like *P. nausithous, P. teleius, P. alcon* or *P. optilete* recorded only in a very restricted habitat islands and associated with specific or rare host plants (Stankiewicz and Sielezniew 2002, Nowicki et al. 2005, Buszko and Nowacki 2017, Dziekańska et al. 2020) or the most quickly declining central European butterflies like xerothermophilous forest dwelling *Hipparchia semele* (Tropek et al. 2017). In general Central Poland is largely covered by agricultural habitats, planted pine forest or cultivated meadows and lacks natural habitats which are very restricted, isolated, most often forestry type (Link 2008, Kurowski 2013) and not suitable for majority of common European butterflies (Karlsson and Wiklund 2004, Szabo et al. 2022), although it is worth mentioning that historic data collected mostly in the 1945-80

(Śliwiński 2002) showed much higher diversity in the vicinity of Łódź and at least 13 species disappeared from the Central Poland already in the 80's of the XX century (Śliwiński 2002, Buszko and Nowacki 2017). The fauna of Lodz certainly have lost some species like *Limenitis camilla* that was still present in one of the parks in the 90's of the XX century (Pabis 2010) but available data do not allow for analysis of detail changes of fauna recorded within the city borders.

Most of the species currently occurring in the Central Poland are relatively common in the whole country and do not have narrow habitat preferences (Bartonova et al. 2014, Buszko and Masłowski 2015). Therefore, urban butterfly fauna of Lodz is no more homogenous than the typical fauna observed in the whole region and local species pools of particular urban habitat patches strongly reflect regional species pool. On the other hand there are some species recorded in Łódź which are not present anywhere near the city, like for example *Boloria laodice* (Sobczyk et al. 2017, Buszko and Nowacki 2017) but it is just an exception from a rule. The most interesting but also a bit surprising questions occur when we analyse differences in species number between the urban sites within the city and when we look at the relatively common species that can be found in a close proximity to Łódź. It remains diffcult to intepret why species like *Pyrgus malvae, Hyponephele lycaon Callophrys rubi, Boloria selene* or *Melitaea athalia* do not penetrate urban habitats despite the fact that their host plants are common in Łódź (Witosławski 2006) and their nearest populations are found in Łagiewniki Forest, which is located within the borders of the city and well connected with the urbanised areas (including sites like Brukowa and Rogi) by a net of ecological corridors which included large parks and/or railway tracks (Sobczyk et al. 2017, 2018). Similar observation were recently presented for Gdynia for the same group of species (Senn 2015). It is even more interesting when we realize that species like *B. dia* and *B. selene* share the same host plants (*Viola* spp.) although those species differ in habitat preferences, first is associated with dry meadows, latter with moisture habitats. On the other hand *H. comma* and *P. malvae* are generally associated with dry meadows or ruderal sites, and their absence in the large westlands in Łódź is very surprising, pointing at necessity of more detail studies of their biology and search for factors that could restrict their distribution in Łódź. Those factors may be important for potential changes in range and abundance of those species on the larger spatial scale, because urbanization and habitat fragmentation is progressing in the Central Europe (Restrepo Cadavid et al. 2017). *H. comma* is very common in the open habitats at the outskirts of the southern part of the city (Sobczyk et al. 2017), but do not penetrate the typical urban habitats, even those located closely to the nearest inhabited sites, like Maratońska, a site with large grassy areas and suitable host plants. It is a relatively good disperser that may move between habitat patchess as a result of stepping stone colonization (Davies et al. 2005). It was also surprising that highly mobile, migrating species like *Colias crocea* occur regularly in the botanical garden in Łódź (Sobczyk et al. 2018), but was recorded not even once during two year study at the Maratońska Site, which is located in a very close proximity. We might speculate that this species chooses larger green spaces as resting sites and avoids smaller fragmented westalnds within the urbanized areas. Anyway, occurence of migrating mobile taxa is generally occasional. Those butterflies may sometimes invade small habitat patches on a short temporal scale, like it was notice in Łódź for *V. cardui* in 2019 when large number of individuals were recorded on Brukowa and Traktorowa. Favourable conditions in sub-Saharan Africa where migrants starts their journey resulted in large numbers of this butterfly all over Europe (Dobronosov 2019, Czechowski and Dubicka 2021, Hu et al. 2021). Interesting results concern *A. iris* and *A. ilia*, as first of this species was not recorded on any investigated sites and it is generally rare in the city (Sobczyk et al. 2017), despite the presence of *Salix*, and despite excellent dispersal abilities. This fact is surprising while at the same time *A. ilia* penetrates even the strict center of the city in areas with only single poplars, while in natural habitats both species often co-occur (Buszko and Masłowski 2015).

Above mentioned questions may concern also some species that are relatively common in the Central Poland but were never recorded in the city, or even at the outskirts. Those species include for example *Boloria euphrosyne*, although this species is associated with moist meadows, and habitat requirements are most probably the main limiting factors for its distribution in urban areas. *Cupido minimus* is associated with dry calcareous grassland but it was previously reported from urban sites in Gdynia, especially along railroad tracks (Senn 2015). It is however absent in Łódź and sites located near the city, despite the presence of its host plant (Witosławski 2006). On the other hand, species like *Cupido argiades* and *Lycaena dispar* are currently very common in Łódź. Their success in the city is associated probably with high environmental plasticity, at least for some specific factors. At the end of XX century *C. argiades* was quite rare in central Poland, and it was listed among species with declining populations on the scale of the whole country (Buszko and Masłowski 2015). It also disappeared from Prague at the beginnig of the XXI century (Kadlec et al. 2008). His expansion in Poland stared at the beginning of the XXI century, when it started to colonise new areas in the central and even northern part of the country. In Łódź it was already recorded in 2008 (Pabis 2010) and it was abundant even on small cultivated lawns located along one of the largest roads of the city. At the moment it is common and abundant in the city, but it is absent from seminatural or agricultural sites in the Central Poland even those located close to Łódź (personal observations) pointing at its particular affinity for urban habitats. Although it is difficult to define the factors hidden behind its success. It was recently recorded in the urbanized areas of Podgorica (Pietrzak 2021) and Zageb (Koren et al. 2013), although it is generally much more common on Balkans than in central Poland (Tolman 1997). It was also common in some urban park in the large agglomeration of Beijing city, including areas close to the city center (Sing et al. 2019). This thermophilous species is associated with dry habitats and common host plants like: *Trifolium, Lotus* and *Medicago* (Silezniew and Dziekańska 2010, Buszko and Masłowski 2015). It has two generations per year, high fertility, high mobility and good dispersal abilities (Bartonova et al. 2014). Its expansion in Poland and high abundance in Łódź might be associated with climate warming as it was already demonstrated in other parts of Europe (Warren et al. 2021) and presence of the heat island effect typical for urbanised areas (Santamouris 2007, McCarthy and Sanderson 2011).

Lycaena dispar is included in the EU Habitats Directive and it was recently included in the landscape-scale restoration actions in some European countries (Warren et al. 2021). Although, the species is currently labeled as least concern it has become rare or even extinct in some parts of Western Europe (Pullin et al. 1998, Strausz et al. 2012, van Strien et al. 2019), thus its presence in urban area should be included in planning of conservation strategies. *L. dispar* was initially recognized as species associated with wetlands, but it shows important changes in habitat requirements probably resulting from pressure associated with climate warming (Sielezniew and Dziekańska 2010, Lindman et al. 2015) but also changes in host plant preferences, like more xerophilous species of *Rumex* (e.g. *R. crispus, R. obtusifolius*) which are also occuring in urban habitats, including Łódź (Martin and Pullin 2004, Witosławski 2006, Buszko and Masłowski 2015). Although those plants accumulate toxic metals like Cu and Pb (Cakaj et al. 2023), which might influence development of butterflies (Philips et al. 2017), especially in urban populations or along the roads (Phillips et al. 2021). It is also worth mentioning that *L. dispar* was observed in Łódź on dry cultivate lawns, flying between block of flats, and at the same time is absent from many theoretically more suitable locations outside the city (personal observations), which makes its urban population very interesting model for more comprehensive studies of development and/or evolutionary differences that may includ not only changes in host plant utilization but also thermal preferences or susceptibility to parasitoids between urban and non-urban populations (Angilletta et al. 2007, Diamond and Martin 2021, Theodorou 2022). We can even speculate that urban areas might constitute a refuge from a typical agriculture landscape, areas which are disturbed, highly modified and influenced by various chemicals, including insecticides and pesticides. Nevertheless, recent data suggest that occurrence of *L. dispar* is not an exceptional phenomenon in the cities, and therefore, monitoring guidelines for this species already encompass urban habitats (Senn 2015, Dylewski et al. 2019, EUNIS). *L. dispar* seems to be mobile enough to cope with mosaic landscape (Strausz et al. 2012, Van der Sluis et al. 2018), although its presence at all investigated sites in Łódź shows its high environmental plasticity but still is a bit surprising. It was already demonstrated that thermal flexibility and generalist life history may promote urban affinity in butterflies (Callaghan et al. 2021). *L. dispar* can not be unequivocaly categorised as generalist (Pullin et al. 1998, Martin and Pullin 2004), which shows how important are tolerance limits to a particular environmental factors (Dennis et al. 2011), although we lack any studies of *L. dispar* development in different types of environmental conditions.

Homogenous diversity hot spots - Insight into details of community composition

Urban wastelands of Łódź are characterized by an interesting and complex blend of various butterfly species co-occurring at small, isolated and very restricted sites. There are no quantitative data of butterfly communities from agriculture habitats in the Central Poland, but particular habitat patches (e.g. meadows, areas around crop fields or pine forest edges) have much lower species richness (personal observations) than urban habitat patches recorded in Łódź where each small isolated site hosted from 34 to even 41 species of butterflies. Even some relict or natural habitats host lower diversity, although with higher number of rare or specialised taxa, for example clearings isolated by large forests and covered by molinia meadows located in the Bolimowski Landscape Park, about 60km from Łódź. We can find there species like *P. nausithous, P. teius* and *P. alcon* but not *P. aegeria, L. aliciphron, L. coridon, T. betulae* or *L. megera* (Kurowski 2013, personal observations). Moreover, even the Łagiewniki Forest, a 1200ha deciduous forest complex and its surrounding open habitats hosts currently only 48 species of butterflies (Marciniak et al. 2010, Sobczyk et al. 2017) and they does not co-occur on single small site. Studies from swedish grasslands showed that number of species per site most often varied between 5 and 20, moreover investigated sites were not so homogenous and differed in species composition (Bergman et al. 2018). Similar values were also recorded for particular sites sampled in Northern Italy (Guariento et al. 2023).

Butterfly communities associated with wastelands in Łódź include common species characteristic for agricultural areas like pierids, grassland species like satyrines and hesperids, forest dwelling taxa like *P. aegeria* and *Apatura ilia*, species associated with shrubs like hairstreaks, large nymphalids associated with *Urtica dioica*, thermophilous *P. machaon* which is typical for open spaces, but also some more specialized species, like *L. dispar* (Bartonova et al. 2014, Buszko and Masłowski 2015). This kind of unexpected community composition was already observed on urban habitat patches (Angold et al. 2006). Butterflies like *M. cinxia* or *L. camilla* probably occasionally migrate into the city and such visits might result in establishment of the small isolated populations, temporary or more stable, depending on a species. Both of those species were not recorded in the areas surrounding the city, even in historic times (Buszko 1997, Śliwiński 2002). This might be also the case of *L. coridon* at Maratońska, as this species is absent from areas outside the city, including large areas located south to the city, between Łódź and smaller towns like Bełchatów and Pabianice (Buszko 1997, Buszko and Masłowski 2015, personal observations) despite the availability of suitable habitats. It was already mentioned that urban habitats might became an important refuge for some species of pollinators, although not always for Lepidoptera (Ockinger et al. 2009, Hall et al. 2017, Twerd and Banaszak-Cibicka 2019, Dylewski et al. 2019, Theodorou et al. 2020) and urbanisation most often decreased diversity or altered the flower visitations (Aguilera et al. 2019, Theodorou et al. 2020b, Herrmann et al. 2023) but we lack data about butterfly communities from urban wastelands, which are generally neglected in ecological studies and in management or conservation strategies. At the same time, many studies are focused on the role of urban parks in maintaing urban diversity (e.g. Konvicka and Kadlec 2011, Sing et al. 2016, Han et al. 2022, Jasmani et al. 2022). Earlier results from Łódź demonstrated that even the largest parks host only a dozen or so butterfly species (Sobczyk et al. 2017, 2018). Even the largest green space in Łódź (67ha), the Botanical Garden, an area characterized by mix of various habitats including typical flower gardens but also planted reconstructions of natural habitats, including grasslands and forests host 37 species of butterflies, less than 2 ha wasteland on Maratońska. Similar differences between parks and ruderal sites were observed in Malmo (Ockinger et al. 2009), including lower species loss over time (Aguilera et al. 2019) and in Poznań (Dylewski et al. 2019).

Nevertheless, the common notion about the homogeneity and low diversity of urban fauna (McKinney 2008) does not have to be always true. When we look at typical landscape of the central Poland the urban wasteland habitats unexpectedly stand out as small scale biodiversity hot spots, especially for mobile, well flying and strongly plant dependant insects like butterflies. Our conclusions are confirmed by similar values of Margalef Index and Shannon index as well as by values of taxonomic distinctness - indices that showed relatively high phylogenetic diversity. At the same time evenness values and detail analysis of the dominance structure (Table 1) points at lack of communities highly dominated by one or two the most eurytopic or resistant species, like in case of rural butterfly communities highly numerically dominated by *P. napis* and *P. rapae* (Feber et al. 1997, Snoo et al. 1998, Sikkink et al. 2017) as a result of strong dominance of their host plants and monoculture character of plant communities (Outhwaite et al. 2022, Tan et al. 2022). This pattern might be explained by high small scale plant diversity which is not typical for species poor and highly disturbed agricultural landscape surrounding the city, which is characterized by lower phylogenetic and functional diversity on a small scale (Jaskulski and Jaskulska 2012, Ma and Herzon 2014, Guerra et al. 2022). Chemisation and cultivation practice leading to simplification of plant communities around agricultural areas surrounding Łódź is probably pushing butterflies into urban refuges, which are also disturbed and unstable, however provide some exceptional habitat properties. Accidental and random transport of various plant species into the city, disturbance at initial stages of succession, and highly mosaic character of different microhabitats and soil types created by various human activities leads to blend of plant species characterized by different ecological requirements at one site (Maurer et al. 2000, Czortek and Pielech 2020, Czortek et al. 2020, Czortek 2023), which was also observed in Łódź (Witosławski 2006). Such communities include relatively rare native species, typical ruderal plants, various trees and shrubs, species associated with nitrogen and/or phosphorus reach soils, calcareophilous grasses, alien taxa, cultivated flowering plants and even vegetables typical for gardens (Lososova et al. 2011, Czortek and Pielech 2020, Jogan et al. 2022). This creates a mix of various resources and factors crucial for butterfly distribution, including host plants for caterpillars, availability of various nectar plants for adults, but also relatively large open spaces, characterized by elevated temperatures, which are benefitial for many butterflies (Wallis de Vries and van Swaay 2009, Cormont et al. 2011, Gordon and Kerr 2022). For example, dry open, warmer habitats select for increased fecundity and even longevity of species like *C. pamphilus, P. aegeria*, and *A. hyperantus* (Karlsson and Wiklund 2004) that are common in Łódź. Also development of large nettle feeding nymphalids might be affected by elevated temperatures, although it is worth mentioning that when caterpillars develop too fast it might results in smaller size of adults and probably their decreased survival abilities during the winter (Bryant et al. 2000). Thermophilous *L. megera* might even increase the size of adults and larval survival in the cities (Kaiser et al. 2016), while higher temperatures increase dispersal abilities of species like *M. jurtina* and *C, pamphilus* enabling them to cope with fragmented landscape (Cormont et al. 2011). Moreover, grassland species dominated in Łódź and recent studies demonstrated that surrounding forest is beneficial for many grassland butterflies (Bergman et al. 2018) therefore trees and shrubs occurring at paricular sites might be benefitial not only for forest species like *A. ilia* but also for other butterflies. Our results can also be viewed in the light of the intermediate disturbance hypothesis (Parris 2018, Moi et al. 2020), although composition of butterfly communities is rarely shaped by interspecific competition (Kunte 2008, Prieto and Dahners 2009, Theodorou 2022). Nevertheless, this mechanism may function as a result of higher resources availability in the intermediately disturbed urban areas.

The local ecological factors are very important and allow for co-occurence of large number of species characterized by various ecological requirements. At the same time all sites were strongly affected by regional species pool. As a result single habitat patches strongly reflected species composition of the surrounding region, which confirms earlier observations that landscape-level drivers of species diversity are important for butterflies (Viljur et al. 2020). It is even more pronounced when we look at urbanization zones of Łódź. Brukowa and Telefoniczna – relatively small sites located in the second urbanization zone of Łódź host 36 species out of 38 species recorded generally in this zone (Sobczyk et al. 2017). The differences between particular sites and the whole zone are more pronounced in the outskirts. For example 41 species were recorded on Maratońska while 50 species were found in the whole third zone (Sobczyk et al. 2017). Theoretically, over a large timescale, almost all species from a regional pool would reach almost every community (Hillebrand and Blenckner 2002) but not necessarily will stay there for longer time. Moreover, typically, the influence of regionals species pool on local faunas is strongest when local communities are less structured by species interactions (mostly competition) and when many species are rare (Cornell and Harrison 2014). In case of Łódź the urban habitats were invaded by almost all available taxa from regional species pool which constituted mostly from small number of common taxa. Despite the strong disturbance and fragmentation of urban habitats there seems to be no environmental filtering in case of butterfly fauna of wastelands in Łódź (Kraft et al. 2015). The city is surrounded by agricultural areas, where probably many species are already resistant to various toxic substances, including heavy metals (Philips et al. 2017, Sikkink et al.

2017, Shephard et al. 2021), while rare or specialised taxa already disappeared from typical Central European landscape (Buszko and Masłowski 2015, Buszko and Nowacki 2017).

Isolated urban habitat islands are becoming a true microcosmos, although unstable and prone to a dynamic changes. The urban green space that was diversity hot spot in one season, may change into deserted over the course of a year or less. Changes might be permanent (e.g. creation of a new buildings or parkings) or temporary and less pronounced (e.g. management practice, creation of a new park or square or changes along some important ecological corridor leading to a given site) but also changes in vegetation succession stages in each year (Strauss and Biedermann 2006, Aguilera et al. 2019, Habel et al. 2019). It is visible in shifts that occured on Brukowa Site in 2020 when species like B. *dia*, *L. alciphron*, *L. dispar* and *A. cardamines* disappeared as a results of renovations along the railroad tracks. Similar modifications might also happen on Telefoniczna Site where municipal authorities are planning a new park. In this case theoretically pro-environmental management may lead to lowering of pollinator diversity. Railway-associated habitats like Brukowa Site, are pointed out as potentially favorable for butterflies (Kalarus and Bąkowski 2015), especially in the cities like Łódź - densely urbanised and not crossed by any large river. Additionally, railways may serve as ecological corridors (Moroń et al. 2014, Moroń et al. 2017), therefore we might expect relatively fast recovery of the communities. Inspections in following years (2021 and 2022) revealed that plant cover at Brukowa Site is recovering, however it has not reach its former abundance so far.

Interesting questions and conclusions occur when we compare all 5 investigated sites. At first glance all of them are similar and represent typical urban wastelands inhabited by the same group of about 25 butterflies and are characterized by similar values of diversity indices. Even Maratońska site, the area located in the highest distance from the city center and well connected with seminatural and natural habitats outside the city does not stand out much from other locations, even those more isolated and localized in a much more urbanized areas like Brukowa, Traktorowa and Telefoniczna. Therefore migration distance within the city seem to be less important for butterfly distribution, as it was already observed in Malmo (Ockinger et al. 2009). On the other hand sites located in the most urbanized part of the city (Brukowa and Telefoniczna) had the lowest abundance and species number of butterflies which is probably related to the highest rate of disturbance (Blair and Launer 1997, Blair 1999, Matsumoto 2015) and lower diversity of plant communities (Han et al. 2022). Despite general similarities, butterfly communities of particular sites differ in abundance and frequency of occurrence of particular species. Even thoretically the most common and resistant species like *I. lathonia, T. lineola, P. aegeria, A. hyperantus* or *A. io* are not a stable and abundant element of communities at all sites. While some other, like one of the most common European butterflies *A. urticae* was not frequent and abundant at all. It occurred only in early spring which might suggest that this species is using buildings as overwintering sites (Dvořák et al. 2009), but does not prefer urban habitats during the vegetation season. Those differences might result also from details of habitat characteristics but they might be also driven by accidental extinctions and/or migrations between habitat islands as explained by MacArthur and Wilson island biogeography theory (Laurance 2008, Medeiros-Sousa et al. 2017, Dunn et al. 2022) and migration–immigration dynamics in general (Hamback and Englund 2005). Those processes may be also responsible for differences in frequency of occurrence and/or abundance of particular species between 2019 and 2020, like in case of *L. pheleas, T. betulae* or *M. galathea* on Brukowa. The influence of overwintering survival might also differ at particular sites, resulting in dynamic changes in abundance of different species e.g. univoltaine vs bivoltaine or overwintering in different stages of development (Diamond et al. 2011, Dennis et al. 2017), like for *A. agestis* on Traktorowa site (frequent in 2019, almost absent in 2020). This species is overwintering as young caterpillar (Buszko and Masłowski 2015) and may face a food shortage as a results of differences in spring temperatures.

Analysis of phenological dynamics along both seasons do not demonstrated any major differences between the investigated sites and between the seasons, pointing a stable phenological pattern. We did not detect differences between sites located in the second and third urbanization zone of Łódź, which might be related to generally large size of all studied wastelands. The spring species *A. cardamines* occured earlier on Telefoniczna in 2019, although it is difficult to interpret this difference. Nevertheless, the occurrence of *A. cardamines* in the city starts even two weeks earlier than typically for this species in Poland (Sielezniew and Dziekańska 2010, Buszko and Masłowski 2015), probably as a result of the heat island effect (Kaiser et al. 2016). Its presence in the first week of April is comparable to phenology of this species in the Southern Europe, for example the Sicily (Fileccia et al. 2015), but earlier studies suggest that it should not affect its host plant utilization strategy (Navarro-Cano et al. 2015). Extended flight phenology was already observed in the cities and urban population might even develop genetic shift toward a lower daylength treshold (Dennis et al. 2017, Merckx et al. 2021). Heat island effect seems to be visible in Łódź only in early spring, and even *P. napi* and *P. rapae* occured in typical time for Poland (Buszko and Masłowski

2015). None of the species developed additional generations when compared to typical phenology in Poland, although *I. lathonia* generally develops three generations in Łódź. It is not typical for all parts of Poland, but does not stand out from phenology in the central part of the country (Sielezniew and Dziekańska 2010, Buszko and Masłowski 2015). Similar observation concern *L. dispar* which is bivoltine in Łódź, but not always in natural habitats (Buszko and Masłowski 2015). Our results do not allowed for final conclusions although, they may suggest some changes in species temporal overlap and therefore alternation of the community composition along the season which might be caused by increased temperatures (Gezon et al. 2018). This indicate possible changes in competition for resources (Gezon et al. 2019) and may also lead to dys-synchronisation with host plants' development (Donoso et al. 2016, Schenk et al. 2016), although those aspects need further, more comprehensive studies. We have to acknowledge that community composition of urban wastelands in Łódź is already altered when compared to areas surrounding the city, and competition for resources is probably not an important factor influencing butterfly communities in Łódź. The occurrence of large nymphalids and *G. rhamni* from the very beginning of the season showed that those species are overwintering in the city, which is not surprising as many of those species use buildings as overwintering sites (Dvořák et al. 2009).

Conclusions

All above mentioned factors and processes create a complicated web of mutual interactions that are difficult to interpret in community ecology studies and need further research focused on details of biology and ecology of urban population of particular species. Our study pointed at interesting research questions that should be address in the near future to enhance our understanding of urban butterfly community dynamics in the Central Europe. There is a great need for mark-release-recapture studies and studies of genetic diversity and connectivity of local urban populations including migration within the city and from surrounding areas (Takami et al. 2004). There is undoubtedly a group of species that can be considered as best suited for the city life, including: *C. pamphilus, M. jurtina, P. napi, P. rapae* and *P. icarus.* They constitute a very narrow group of species abundant and frequent on all investigated sites. There are no quantitave data from any other Central European city. although those species were often recorded in the urban habitats (Machnikowski 1999, Höttinger 2000, Winiarska 2003, Ockinger et al. 2009, Konvicka and Kadlec 2011, Gelbrecht et al. 2016, Palik et al. 2005, Senn 2015, Dennis et al. 2017, Dylewski et al. 2019, Sielezniew and Dziekańska 2019), and it is worth to develop more comprehensive studies of their ecology in the cities. At the same time more specialized taxa, like *L. dispar* urgently need studies in the urban areas, because such results may facilitate their protection in Europe, by helping to understand their reactions to elevated temperatures, host plant switch or fragmented landscape.

Our results demonstrated a great role of urban wastelands in maintaning biodiversity in the city, which might be important not only from perspective of wellbeing and education of citizens (Taylor and Hochuli 2015), but also for providing the protection of butterflies in the Central Europe, where urban wastelands appear to be a small scale biodiversity hot spots of importantce higher than a local scale within city borders. Since European butterfly populations are declining (Warren et al. 2021) urban habitats can constitute refuge for some species, especially grassland butterflies. Nevertheless, role of wastelands will be diminished if the green spaces will be destroyed as a results of urban management. Therefore, it is crucial to link the results of the ecological studies with appropriate urban planning that is suited for a particular area (Niemela 1999). Our results could constitute a valuable tool for the city management and are a base and reference point for further research, including citizen science projects. Earlier studies already allowed to create publicly available field guide to the butterflies of Łódź (Sobczyk et al. 2018) and it can be used for further monitoring of wastelands and other habitats within the city, with participation of nature enthusiasts. It is also worth to think if the new park on Telefoniczna Site will be more important for citizens, than an educational nature trail prepared for this westland. . This concept suits general opinion of mutual interactions between biodiversity, education and wellbeing of the urban residents (Taylor and Hochuli 2015). Participatory approach to the management of ecosystems services in urban areas is generally desirable and probably the most effective (Dennis and James 2016).

Our studies showed also importance of reference point data, especially quantitative or long-term results which are lacking from a large part of the Central Europe. Regular monitoring of urban biodiversity might help to answer more detailed questions associated with local dynamics of butterfly population or long term phenological changes, and we hope that insect monitoring programs of large cities will become more frequent in this part of the continent.

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Appendix 1List of plant species with their presence on sites. (Site marked as: M – Maratońska site, B – Brukowa site, R – Rogi site, TL- Telefoniczna site, TR – Traktorowa site)

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Sambucus nigra ssp. nigra	Adoxaceae	*Sambucus*				X	
Allium vineale	Amaryllidaceae	*Allium*	X	X	X		
Aegopodium podagraria	Apiaceae	*Aegopodium*					X
Anthriscus sylvestris	Apiaceae	*Anthriscus*			X		
Chaerophyllum temulum	Apiaceae	*Chaerophyll um*			X		
Daucus carota ssp. carota	Apiaceae	*Daucus*	X	X	X	X	X
Heracleum sphondylium ssp. glabrum	Apiaceae	*Heracleum*					X
Heracleum sphondylium ssp. sphondylium/glabrum	Apiaceae	*Heracleum*		X			
Pastinaca sativa	Apiaceae	*Pastinaca*		X	X		
Peucedanum oreoselinum	Apiaceae	*Peucedanu m*		X		X	
Pimpinella saxifraga ssp. saxifraga	Apiaceae	*Pimpinella*		X	X		
Pimpinella sp.	Apiaceae	*Pimpinella*			X		
Torilis japonica	Apiaceae	*Torilis*		X	X	X	X
Achillea millefolium	Asteraceae	*Achillea*		X	X		X
Achillea vulgaris	Asteraceae	*Achillea*				X	
Alchemilla millefolium	Asteraceae	*Alchemilla*				X	
Anchusa officinalis	Asteraceae	*Anchusa*	X				
Aquilegia ×hybrida/vulgaris	Asteraceae	*Aquilegia*			X		
Arctium tomentosum	Asteraceae	*Arctium*					
Artemisia absinthium	Asteraceae	*Artemisia*	X				
Artemisia camperstris ssp. campestris	Asteraceae	*Artemisia*	X	X	X	X	X
Artemisia vulgaris	Asteraceae	*Artemisia*	X	X	X	X	
Cantaurea stoebe	Asteraceae	*Cantaurea*	X	X	X	X	X
Carduus acanthoides	Asteraceae	*Carduus*		X	X		
Centaurea jacea	Asteraceae	*Centaurea*			X		
Cerastium sp.	Asteraceae	*Cerastium*			X		X
Chamomilla suaveolens	Asteraceae	*Chamomilla*				X	
Cichorium intybus ssp. intybus	Asteraceae	*Cichorium*		X	X	X	X
Cirsium arvense	Asteraceae	*Cirsium*		X	X	X	X
Cirsium vulgare	Asteraceae	*Cirsium*		X	X	X	X
Conyza canadensis	Asteraceae	*Conyza*	X	X		X	X
Coreopsis lanceolata	Asteraceae	*Coreopsis*					X
Echium vulgare	Asteraceae	*Echium*	X	X	X		

Name of the species	Family	Genus	Presence on sites				
			M	B	R	TL	TR
Erigeron acris	Asteraceae	*Erigeron*			X		
Erigeron annuus ssp. annuus	Asteraceae	*Erigeron*		X	X	X	X
Erigeron annuus ssp. septentrionalis	Asteraceae	*Erigeron*	X	X	X		
Galinsoga parviflora	Asteraceae	*Galinsoga*		X			
Helianthus sp.	Asteraceae	*Helianthus*		X		X	
Helichrysum arenarium	Asteraceae	*Helichrysum*	X		X		X
Heliopsis scabra	Asteraceae	*Heliopsis*					X
Hieracium pilosella	Asteraceae	*Hieracium*		X	X	X	X
Hieracium sabaudum	Asteraceae	*Hieracium*		X			X
Hieracium umbellatum var. umbellatum	Asteraceae	*Hieracium*			X	X	X
Hypericum perforatum	Asteraceae	*Hypericum*	X	X	X	X	X
Hypochoeris radicata	Asteraceae	*Hypochoeris*	X	X	X	X	X
Jasione montana	Asteraceae	*Jasione*	X	X	X		X
Knautia arvensis	Asteraceae	*Knautia*		X		X	
Lactuca serriola	Asteraceae	*Lactuca*		X			X
Lapsana communis	Asteraceae	*Lapsana*		X	X		
Leontodon autumnalis ssp. autumnalis	Asteraceae	*Leontodon*	X	X		X	X
Matricaria perforata	Asteraceae	*Matricaria*				X	
Rudbeckia hirta	Asteraceae	*Rudbeckia*			X		X
Rudbeckia hirta var. hirta	Asteraceae	*Rudbeckia*					
Senecio jacobaea	Asteraceae	*Senecio*	X	X			X
Senecio vulgaris	Asteraceae	*Senecio*		X			
Solidago ×niederederi	Asteraceae	*Solidago*					X
Solidago canadensis	Asteraceae	*Solidago*		X	X	X	X
Solidago gigantea	Asteraceae	*Solidago*		X		X	
Solidago virgaurea	Asteraceae	*Solidago*		X	X	X	X
Sonchus asper	Asteraceae	*Sonchus*		X			
Tanacetum vulgare	Asteraceae	*Tanacetum*		X	X	X	X
Taraxacum officinale coll.	Asteraceae	*Taraxacum*			X	X	
Tragopogon dubius	Asteraceae	*Tragopogon*	X	X			
Tragopogon sp.	Asteraceae	*Tragopogon*		X	X		
Impatiens glandulifera	Balsaminaceae	*Impatiens*					X
Myosotis arvensis	Boraginaceae	*Myosotis*		X			
Alliaria petiolata	Brassicaceae	*Alliaria*			X		
Arabidopsis thaliana	Brassicaceae	*Arabidopsis*		X			

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Barbarea vulgaris	Brassicaceae	*Barbarea*		X			
Berteroa incana	Brassicaceae	*Berteroa*	X	X	X	X	X
Cardaminopsis arenosa ssp. arenosa	Brassicaceae	*Cardaminopsis*					
Descurainia sophia	Brassicaceae	*Descurainia*				X	
Lepidium campestre	Brassicaceae	*Lepidium*		X			
Lunaria annua	Brassicaceae	*Lunaria*		X			
Raphanus raphanistrum	Brassicaceae	*Raphanus*		X			
Rorippa sp.	Brassicaceae	*Rorippa*		X			
Sisymbrium loeselii	Brassicaceae	*Sisymbrium*		X	X	X	X
Campanula rapunculoides	Campanulaceae	*Campanula*			X	X	
Dianthus deltoides	Caryophyllacaeae	*Dianthus*				X	
Melandrium album	Caryophyllacaeae	*Melandrium*	X	X	X	X	X
Saponaria officinalis	Caryophyllacaeae	*Saponaria*	X	X	X		
Saponaria officinalis f. plena	Caryophyllacaeae	*Saponaria*			X		
Silene vulgaris	Caryophyllacaeae	*Silene*		X	X		
Stellaria graminea	Caryophyllacaeae	*Stellaria*		X		X	
Convolvulus arvensis	Convolvulaceae	*Convolvulus*	X	X	X	X	X
Sedum maximum	Crassulaceae	*Sedum*			X	X	
Echinocystsis lobata	Cucurbitaceae	*Echinocystsis*					X
Euphorbia esula	Euphorbiaceae	*Euphorbia*		X	X	X	
Euphorbia helioscopia	Euphorbiaceae	*Euphorbia*		X			
Caragana arborescens	Fabaceae	*Caragana*					
Coronilla varia	Fabaceae	*Coronilla*	X	X	X		
Cytisus scoparius	Fabaceae	*Cytisus*			X		
Lathyrus latifolius	Fabaceae	*Lathyrus*			X		X
Lathyrus tuberosus	Fabaceae	*Lathyrus*			X		
Lotus corniculatus	Fabaceae	*Lotus*		X	X	X	
Lupinus polyphyllus	Fabaceae	*Lupinus*				X	
Medicago ×varia	Fabaceae	*Medicago*		X	X		
Medicago falcata	Fabaceae	*Medicago*		X			
Medicago lupulina	Fabaceae	*Medicago*			X		
Medicago sativa	Fabaceae	*Medicago*				X	

Name of the species	Family	Genus	Presence on sites				
			M	B	R	TL	TR
Melilotus alba	Fabaceae	*Melilotus*		X		X	
Melilotus officinalis	Fabaceae	*Melilotus*		X	X	X	
Robinia pseudoacacia	Fabaceae	*Robinia*	X	X	X	X	
Trifolium arvense	Fabaceae	*Trifolium*	X	X	X	X	X
Trifolium campestre	Fabaceae	*Trifolium*			X		
Trifolium medium	Fabaceae	*Trifolium*		X	X	X	
Trifolium pratense ssp. pratense	Fabaceae	*Trifolium*			X	X	
Trifolium pratense ssp. sativum	Fabaceae	*Trifolium*		X			
Trifolium repens ssp. repens	Fabaceae	*Trifolium*			X	X	
Vicia cracca	Fabaceae	*Vicia*		X	X	X	
Vicia villosa	Fabaceae	*Vicia*		X			X
Geranium molle	Geraniaceae	*Geranium molle*					X
Geranium robertianum	Geraniaceae	*Geranium*		X			
Ballota nigra ssp. nigra	Lamiaceae	*Ballota*			X	X	
Betonica officinalis	Lamiaceae	*Betonica*				X	
Lamium purpureum	Lamiaceae	*Lamium*		X			
Leonurus cardiaca	Lamiaceae	*Leonurus*			X		
Mentha ×villosa	Lamiaceae	*Mentha*			X		
Origanum vulgare	Lamiaceae	*Origanum*		X			X
Lythrum saliciaria	Lythraceae	*Lythrum*					X
Malus sp.	Malvaceae	*Malus*			X	X	
Lavatera thuringiaca	Malvaceae	*Lavatera*			X		
Ligustrum vulgare	Oleaceae	*Ligustrum*				X	
Epilobium hirsutum	Onagraceae	*Epilobium*					X
Epilobium lamyi	Onagraceae	*Epilobium*		X			
Epilobium montanum	Onagraceae	*Epilobium*		X			
Oenothera sp./spp.	Onagraceae	*Oenothera*	X	X	X	X	X
Chelidonium majus	Papaveraceae	*Chelidonium*		X	X		X
Papaver dubium	Papaveraceae	*Papaver*		X		X	
Papaver rhoeas	Papaveraceae	*Papaver*			X		
Linaria vulgaris	Plantaginaceae	*Linaria*		X			X
Plantago lanceolata	Plantaginaceae	*Plantago*			X	X	X
Reynoutria japonica	Polygonaceae	*Reynoutria*					
Polygonum rurivagum	Polygonaceae	*Polygonum*		X			
Reseda lutea	Resedaceae	*Reseda*		X			

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Crataegus sp.	Rosaceae	*Crataegus*			X	X	
Filipendula ulmaria	Rosaceae	*Filipendula*					X
Geum urbanum	Rosaceae	*Geum*		X	X	X	
Padus serotina	Rosaceae	*Padus*		X	X	X	X
Potentilla anserina	Rosaceae	*Potentilla*					X
Potentilla argentea	Rosaceae	*Potentilla*		X	X		X
Potentilla dissecta/impolita	Rosaceae	*Potentilla*		X			X
Potentilla intermedia	Rosaceae	*Potentilla*			X		X
Potentilla repens	Rosaceae	*Potentilla*			X	X	X
Potentilla tenuiloba	Rosaceae	*Potentilla*			X	X	
Prunus cerasifera	Rosaceae	*Prunus*		X	X		
Prunus sp.	Rosaceae	*Prunus*				X	
Rosa sp.	Rosaceae	*Rosa*	X	X	X	X	
Rubus caesius	Rosaceae	*Rubus*	X	X		X	
Rubus idaeus	Rosaceae	*Rubus*				X	
Rubus sp.	Rosaceae	*Rubus*					X
Sanguisorba minor	Rosaceae	*Sanguisorba*		X			
Sorbus aucuparia	Rosaceae	*Sorbus*				X	
Galium album	Rubiaceae	*Galium*		X			
Galium verum	Rubiaceae	*Galium*				X	
Acer campestris	Sapindaceae	*Acer*			X		
Acer platanoides	Sapindaceae	*Acer*			X		
Verbascum densiflorum	Scrophulariaceae	*Verbascum*	X	X		X	
Verbascum nigrum	Scrophulariaceae	*Verbascum*	X				
Verbascum phlomoides	Scrophulariaceae	*Verbascum*			X		
Verbascum sp.	Scrophulariaceae	*Verbascum*					
Solanum dulcamara	Solanaceae	*Solanum*		X			
Veronica chamaedrys	Veronicaceae	*Veronica*			X		X
Viola arvensis	Violaceae	*Viola*		X			
Viola tricolor	Violaceae	*Viola*		X			

Appendix 2 SIMPER raport

SIMPER
Similarity Percentages - species contributions

Sample selection: All
Variable selection: All

Parameters

Standardise data: No
Transform: Square root
Cut off for low contributions: 95,00%
Factor name: grupy większe

Factor groups
7
8
2
6
3
4
5
1

Group 7

Average similarity: 30,79

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Aglais_io	1,82	8,27	0,96	26,85	26,85
Pieris_napi	2,01	7,03	0,81	22,82	49,68
Gonepteryx_rhamni	0,87	3,39	0,59	11,00	60,68
Pieris_rapae	0,95	3,13	0,54	10,18	70,86
Anthocharis_cardamines	1,05	2,55	0,47	8,29	79,15
Lycaena_phlaeas	0,49	1,25	0,38	4,06	83,21
Erynnis_tages	0,32	0,96	0,24	3,12	86,33
Pararge_aegeria	0,35	0,81	0,29	2,61	88,95
Issoria_lathonia	0,50	0,79	0,29	2,55	91,50
Coenonympha_pamphilus	0,36	0,61	0,20	1,97	93,47
Polygonia_c-album	0,25	0,47	0,22	1,53	94,99
Araschnia_levana	0,41	0,32	0,19	1,03	96,02

Group 8

Average similarity: 18,45

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Gonepteryx_rhamni	1,10	10,41	0,58	56,43	56,43
Polygonia_c-album	0,49	3,96	0,39	21,44	77,87
Vanessa_cardui	0,41	1,86	0,22	10,08	87,95
Aglais_urticae	0,27	1,32	0,22	7,15	95,10

Group 2

Average similarity: 44,78

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Pieris_rapae	3,39	24,77	3,21	55,32	55,32
Pieris_napi	1,61	9,57	0,99	21,38	76,71
Pararge_aegeria	0,36	4,00	0,52	8,93	85,64

Coenonympha_pamphilus	0,71	1,91	0,40	4,27	89,92
Cupido_argiades	0,48	1,30	0,31	2,90	92,82
Vanessa_atalanta	0,48	1,30	0,29	2,90	95,72

Group 6

Average similarity: 43,11

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Coenonympha_pamphilus	8,08	22,96	2,60	53,25	53,25
Lycaena_tityrus	2,00	4,54	0,68	10,54	63,79
Vanessa_cardui	3,91	4,38	0,57	10,16	73,95
Polyommatus_icarus	0,96	3,97	0,69	9,21	83,16
Ochlodes_sylvanus	1,88	3,64	0,55	8,44	91,61
Maniola_jurtina	0,82	0,64	0,23	1,48	93,08
Pieris_rapae	0,20	0,46	0,24	1,07	94,15
Pieris_napi	0,39	0,39	0,19	0,89	95,04

Group 3

Average similarity: 46,84

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Maniola_jurtina	22,69	12,47	2,07	26,62	26,62
Melanargia_galathea	6,02	7,64	1,93	16,31	42,94
Aphantopus_hyperantus	8,29	6,89	1,22	14,71	57,64
Pieris_napi	3,64	4,87	1,15	10,40	68,05
Pieris_rapae	2,18	4,15	1,01	8,85	76,90
Thymelicus_sylvestris	1,13	1,48	0,60	3,15	80,05
Gonepteryx_rhamni	1,58	1,29	0,50	2,75	82,80
Coenonympha_pamphilus	1,28	1,20	0,46	2,57	85,37
Ochlodes_sylvanus	0,81	1,00	0,41	2,15	87,52
Araschnia_levana	0,94	0,77	0,46	1,64	89,16
Lycaena_phlaeas	0,68	0,74	0,42	1,58	90,74
Thymelicus_lineola	0,57	0,69	0,40	1,48	92,21
Vanessa_cardui	1,04	0,60	0,37	1,28	93,49
Cupido_argiades	0,64	0,58	0,33	1,25	94,74
Polygonia_c-album	0,29	0,49	0,34	1,04	95,78

Group 4

Average similarity: 52,91

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Coenonympha_pamphilus	13,65	7,57	1,33	14,31	14,31
Polyommatus_coridon	18,04	7,33	0,99	13,86	28,17
Pieris_rapae	6,70	7,10	2,24	13,43	41,60
Aricia_agestis	2,82	4,38	1,96	8,28	49,87
Maniola_jurtina	3,99	4,18	1,38	7,91	57,78
Lycaena_tityrus	3,54	3,82	1,41	7,22	65,00
Lycaena_phlaeas	2,34	3,02	1,17	5,70	70,70
Polyommatus_icarus	2,34	2,86	1,06	5,41	76,12
Melanargia_galathea	4,53	2,73	0,79	5,16	81,28
Pontia_edusa	1,97	2,63	1,07	4,97	86,25
Vanessa_cardui	2,31	1,72	0,54	3,25	89,49
Pieris_napi	1,86	1,52	0,65	2,87	92,36
Thymelicus_lineola	1,80	1,10	0,53	2,08	94,44
Aphantopus_hyperantus	1,97	1,06	0,44	2,01	96,45

Group 5

Average similarity: 46,91

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Coenonympha_pamphilus	6,80	12,55	2,10	26,77	26,77
Pieris_rapae	3,92	9,99	1,55	21,29	48,06
Polyommatus_icarus	2,87	7,30	1,56	15,57	63,62
Pieris_napi	2,58	4,42	0,80	9,42	73,05
Maniola_jurtina	3,51	2,71	0,58	5,78	78,82
Lycaena_phlaeas	0,90	2,45	0,60	5,21	84,04
Lycaena_tityrus	1,16	2,18	0,61	4,66	88,69
Aricia_agestis	0,71	1,58	0,54	3,37	92,06
Issoria_lathonia	0,51	0,68	0,33	1,45	93,51
Vanessa_cardui	0,69	0,59	0,29	1,26	94,77
Vanessa_atalanta	0,28	0,39	0,25	0,83	95,60

Group 1

Average similarity: 64,07

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Coenonympha_pamphilus	4,11	62,29	2,59	97,21	97,21

Groups 7 & 8

Average dissimilarity = 88,05

Species	Group 7 Av.Abund	Group 8 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pieris_napi	2,01	0,00	10,63	1,22	12,07	12,07
Aglais_io	1,82	0,24	10,24	1,10	11,62	23,69
Gonepteryx_rhamni	0,87	1,10	8,75	0,96	9,94	33,63
Pieris_rapae	0,95	0,00	6,27	0,89	7,12	40,74
Anthocharis_cardamines	1,05	0,00	5,81	0,83	6,60	47,35
Polygonia_c-album	0,25	0,49	5,55	0,77	6,30	53,65
Issoria_lathonia	0,50	0,24	4,17	0,67	4,73	58,38
Vanessa_cardui	0,02	0,41	3,91	0,55	4,44	62,82
Erynnis_tages	0,32	0,00	3,57	0,50	4,05	66,87
Lycaena_phlaeas	0,49	0,00	3,32	0,72	3,77	70,64
Aglais_urticae	0,02	0,27	3,11	0,55	3,53	74,17
Coenonympha_pamphilus	0,36	0,00	2,81	0,48	3,19	77,36
Pararge_aegeria	0,35	0,00	2,74	0,59	3,11	80,47
Vanessa_atalanta	0,10	0,20	2,26	0,48	2,56	83,03
Nymphalis_antiopa	0,06	0,12	2,12	0,40	2,41	85,44
Papilio_machaon	0,20	0,00	2,00	0,32	2,28	87,71

Araschnia_levana 89,86	0,41	0,00	1,89	0,47	2,15
Cupido_argiades 91,73	0,15	0,00	1,64	0,44	1,86
Polyommatus_icarus 93,48	0,19	0,00	1,54	0,40	1,75
Pieris_brassicae 94,90	0,21	0,00	1,25	0,40	1,42
Celastrina_argiolus 96,18	0,17	0,00	1,12	0,37	1,27

Groups 7 & 2

Average dissimilarity = 76,10

Species Cum.%	Group 7 Av.Abund	Group 2 Av.Abund	Av.Diss	Diss/SD	Contrib%
Pieris_rapae 13,82	0,95	3,39	10,51	1,22	13,82
Aglais_io 24,38	1,82	0,00	8,04	1,35	10,56
Pieris_napi 33,98	2,01	1,61	7,31	1,27	9,61
Gonepteryx_rhamni 40,13	0,87	0,06	4,68	0,98	6,15
Coenonympha_pamphilus 46,14	0,36	0,71	4,57	0,82	6,00
Anthocharis_cardamines 51,97	1,05	0,00	4,44	0,84	5,83
Pararge_aegeria 57,36	0,35	0,36	4,10	0,92	5,39
Lycaena_phlaeas 62,17	0,49	0,30	3,66	0,78	4,81
Vanessa_atalanta 66,69	0,10	0,48	3,44	0,59	4,52
Cupido_argiades 71,13	0,15	0,48	3,38	0,76	4,44
Issoria_lathonia 75,06	0,50	0,18	2,99	0,73	3,93
Polyommatus_icarus 78,44	0,19	0,42	2,57	0,58	3,38
Erynnis_tages 81,66	0,32	0,00	2,45	0,53	3,22
Vanessa_cardui 84,12	0,02	0,30	1,87	0,56	2,46
Aricia_agestis 86,24	0,00	0,24	1,61	0,53	2,12
Polygonia_c-album 88,32	0,25	0,00	1,58	0,52	2,08
Araschnia_levana 90,32	0,41	0,00	1,53	0,47	2,01
Papilio_machaon 92,13	0,20	0,00	1,37	0,33	1,80
Pieris_brassicae 93,45	0,21	0,00	1,00	0,40	1,32
Celastrina_argiolus 94,61	0,17	0,00	0,89	0,37	1,16
Boloria_dia 95,61	0,22	0,00	0,76	0,28	1,00

Groups 8 & 2

Average dissimilarity = 96,01

Species	Group 8 Av.Abund	Group 2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pieris_rapae	0,00	3,39	22,29	2,49	23,22	23,22
Pieris_napi	0,00	1,61	12,25	1,39	12,76	35,98
Gonepteryx_rhamni	1,10	0,06	8,88	1,00	9,25	45,23
Pararge_aegeria	0,00	0,36	6,14	0,90	6,39	51,62
Vanessa_atalanta	0,20	0,48	5,77	0,64	6,01	57,63
Coenonympha_pamphilus	0,00	0,71	5,47	0,72	5,70	63,33
Vanessa_cardui	0,41	0,30	5,43	0,79	5,65	68,98
Polygonia_c-album	0,49	0,00	5,24	0,79	5,46	74,45
Cupido_argiades	0,00	0,48	4,17	0,67	4,34	78,79
Issoria_lathonia	0,24	0,18	3,51	0,58	3,66	82,44
Aglais_urticae	0,27	0,00	3,25	0,59	3,38	85,82
Lycaena_phlaeas	0,00	0,30	3,09	0,47	3,22	89,04
Aglais_io	0,24	0,00	2,66	0,61	2,78	91,82
Polyommatus_icarus	0,00	0,42	2,40	0,44	2,50	94,32
Aricia_agestis	0,00	0,24	2,27	0,54	2,36	96,68

Groups 7 & 6

Average dissimilarity = 87,59

Species	Group 7 Av.Abund	Group 6 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,36	8,08	15,14	1,87	17,29	17,29
Vanessa_cardui	0,02	3,91	7,03	0,88	8,03	25,31
Lycaena_tityrus	0,00	2,00	6,11	0,94	6,98	32,29
Pieris_napi	2,01	0,39	5,78	1,25	6,60	38,89
Aglais_io	1,82	0,26	5,72	1,30	6,53	45,42
Ochlodes_sylvanus	0,00	1,88	5,54	0,87	6,32	51,74
Polyommatus_icarus	0,19	0,96	4,57	1,02	5,22	56,96
Anthocharis_cardamines	1,05	0,22	3,78	0,90	4,31	61,27

Pieris_rapae	0,95	0,20	3,77	1,02	4,30	65,58
Gonepteryx_rhamni	0,87	0,22	3,68	1,03	4,20	69,78
Lycaena_phlaeas	0,49	0,12	2,51	0,81	2,86	72,64
Maniola_jurtina	0,00	0,82	2,32	0,51	2,65	75,29
Issoria_lathonia	0,50	0,10	2,16	0,67	2,46	77,75
Araschnia_levana	0,41	0,21	2,05	0,64	2,34	80,09
Pararge_aegeria	0,35	0,09	1,91	0,68	2,18	82,27
Erynnis_tages	0,32	0,00	1,81	0,54	2,06	84,33
Polygonia_c-album	0,25	0,04	1,44	0,58	1,64	85,97
Aricia_agestis	0,00	0,26	1,25	0,50	1,43	87,40
Lycaena_dispar	0,02	0,18	1,16	0,51	1,32	88,73
Pieris_brassicae	0,21	0,13	1,14	0,47	1,30	90,03
Cupido_argiades	0,15	0,09	1,14	0,48	1,30	91,33
Papilio_machaon	0,20	0,00	1,00	0,34	1,15	92,47
Leptidea_juvernica	0,07	0,04	0,74	0,35	0,84	93,32
Boloria_dia	0,22	0,03	0,72	0,32	0,83	94,15
Celastrina_argiolus	0,17	0,00	0,71	0,37	0,81	94,96
Lycaena_alciphron	0,00	0,12	0,54	0,29	0,62	95,57

Groups 8 & 6

Average dissimilarity = 94,54

Species	Group 8 Av.Abund	Group 6 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,00	8,08	23,06	2,51	24,39	24,39
Vanessa_cardui	0,41	3,91	9,57	1,04	10,13	34,52
Lycaena_tityrus	0,00	2,00	8,42	0,97	8,90	43,42
Ochlodes_sylvanus	0,00	1,88	7,53	0,90	7,97	51,39
Polyommatus_icarus	0,00	0,96	6,48	1,04	6,85	58,24
Gonepteryx_rhamni	1,10	0,22	6,04	1,02	6,39	64,63
Polygonia_c-album	0,49	0,04	3,64	0,83	3,85	68,48
Maniola_jurtina	0,00	0,82	3,12	0,52	3,30	71,77
Aglais_io	0,24	0,26	2,99	0,75	3,16	

						74,93
Aglais_urticae	0,27	0,00	2,22	0,61	2,35	77,28
Pieris_napi	0,00	0,39	2,18	0,47	2,31	79,59
Issoria_lathonia	0,24	0,10	2,08	0,50	2,20	81,80
Pieris_rapae	0,00	0,20	1,78	0,56	1,88	83,68
Aricia_agestis	0,00	0,26	1,68	0,51	1,78	85,46
Araschnia_levana	0,00	0,21	1,55	0,44	1,64	87,10
Lycaena_dispar	0,00	0,18	1,47	0,50	1,55	88,65
Lycaena_phlaeas	0,00	0,12	1,37	0,41	1,45	90,10
Anthocharis_cardamines	0,00	0,22	1,30	0,36	1,38	91,48
Vanessa_atalanta	0,20	0,00	1,28	0,40	1,36	92,84
Nymphalis_antiopa	0,12	0,00	1,21	0,39	1,28	94,11
Lycaena_alciphron	0,00	0,12	0,71	0,29	0,75	94,86
Pararge_aegeria	0,00	0,09	0,67	0,29	0,71	95,58

Groups 2 & 6

Average dissimilarity = 84,34

	Group 2	Group 6				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,71	8,08	15,04	1,83	17,83	17,83
Pieris_rapae	3,39	0,20	10,18	2,00	12,07	29,90
Vanessa_cardui	0,30	3,91	7,55	0,98	8,96	38,85
Lycaena_tityrus	0,00	2,00	6,57	0,97	7,79	46,65
Pieris_napi	1,61	0,39	6,18	1,38	7,33	53,97
Ochlodes_sylvanus	0,00	1,88	5,95	0,90	7,05	61,03
Polyommatus_icarus	0,42	0,96	5,13	1,09	6,09	67,11
Pararge_aegeria	0,36	0,09	3,05	0,96	3,62	70,73
Vanessa_atalanta	0,48	0,00	2,54	0,60	3,01	73,75
Cupido_argiades	0,48	0,09	2,53	0,70	3,00	76,75
Maniola_jurtina	0,00	0,82	2,49	0,52	2,95	79,70
Lycaena_phlaeas	0,30	0,12	2,25	0,64	2,67	82,37
Aricia_agestis	0,24	0,26	2,21	0,74	2,62	84,99

Gonepteryx_rhamni	0,06	0,22	1,55	0,58	1,83	86,82
Issoria_lathonia	0,18	0,10	1,50	0,53	1,77	88,60
Aglais_io	0,00	0,26	1,43	0,49	1,70	90,29
Araschnia_levana	0,00	0,21	1,22	0,45	1,44	91,74
Lycaena_dispar	0,00	0,18	1,18	0,50	1,40	93,13
Anthocharis_cardamines	0,00	0,22	1,03	0,36	1,22	94,36
Colias_hyale	0,06	0,05	0,67	0,39	0,80	95,16

Groups 7 & 3

Average dissimilarity = 83,92

Species	Group 7 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Maniola_jurtina	0,00	22,69	13,88	2,16	16,54	16,54
Aphantopus_hyperantus	0,00	8,29	8,40	1,59	10,02	26,56
Melanargia_galathea	0,00	6,02	7,96	2,11	9,49	36,05
Pieris_napi	2,01	3,64	4,54	1,41	5,41	41,46
Pieris_rapae	0,95	2,18	4,02	1,10	4,79	46,25
Aglais_io	1,82	0,20	3,76	1,23	4,48	50,73
Gonepteryx_rhamni	0,87	1,58	3,30	1,09	3,93	54,66
Coenonympha_pamphilus	0,36	1,28	2,91	0,81	3,47	58,12
Thymelicus_sylvestris	0,00	1,13	2,60	0,95	3,10	61,22
Ochlodes_sylvanus	0,00	0,81	2,33	0,69	2,78	64,01
Anthocharis_cardamines	1,05	0,00	2,33	0,81	2,77	66,78
Lycaena_phlaeas	0,49	0,68	2,22	0,95	2,65	69,43
Araschnia_levana	0,41	0,94	2,15	0,92	2,57	72,00
Cupido_argiades	0,15	0,64	1,94	0,71	2,31	74,30
Vanessa_cardui	0,02	1,04	1,81	0,61	2,16	76,47
Pararge_aegeria	0,35	0,52	1,79	0,86	2,14	78,60
Thymelicus_lineola	0,02	0,57	1,67	0,74	1,99	80,59
Polygonia_c-album	0,25	0,29	1,55	0,81	1,85	82,44
Issoria_lathonia	0,50	0,10	1,39	0,64	1,65	84,10
Polyommatus_icarus	0,19	0,49	1,39	0,65	1,65	

						85,75
Erynnis_tages	0,32	0,09	1,25	0,59	1,48	87,23
Boloria_dia	0,22	0,33	1,16	0,50	1,38	88,62
Vanessa_atalanta	0,10	0,29	1,07	0,65	1,28	89,89
Pieris_brassicae	0,21	0,17	1,03	0,58	1,23	91,12
Lycaena_alciphron	0,00	0,27	0,98	0,53	1,17	92,28
Celastrina_argiolus	0,17	0,13	0,95	0,51	1,14	93,42
Aricia_agestis	0,00	0,50	0,94	0,45	1,12	94,54
Papilio_machaon	0,20	0,05	0,76	0,40	0,90	95,44

Groups 8 & 3

Average dissimilarity = 94,54

Species	Group 8 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Maniola_jurtina	0,00	22,69	16,74	2,35	17,71	17,71
Aphantopus_hyperantus	0,00	8,29	10,25	1,64	10,85	28,55
Melanargia_galathea	0,00	6,02	9,75	2,20	10,32	38,87
Pieris_napi	0,00	3,64	6,95	1,57	7,36	46,22
Pieris_rapae	0,00	2,18	6,27	1,21	6,63	52,85
Gonepteryx_rhamni	1,10	1,58	4,31	1,10	4,56	57,41
Coenonympha_pamphilus	0,00	1,28	3,30	0,73	3,49	60,89
Thymelicus_sylvestris	0,00	1,13	3,17	0,96	3,35	64,24
Ochlodes_sylvanus	0,00	0,81	2,94	0,70	3,10	67,35
Vanessa_cardui	0,41	1,04	2,85	0,78	3,01	70,36
Polygonia_c-album	0,49	0,29	2,38	0,92	2,52	72,88
Cupido_argiades	0,00	0,64	2,14	0,62	2,27	75,15
Lycaena_phlaeas	0,00	0,68	2,10	0,74	2,22	77,36
Araschnia_levana	0,00	0,94	2,09	0,83	2,21	79,57
Thymelicus_lineola	0,00	0,57	2,02	0,73	2,14	81,71
Aglais_io	0,24	0,20	1,61	0,71	1,71	83,41
Vanessa_atalanta	0,20	0,29	1,54	0,67	1,63	85,04
Pararge_aegeria	0,00	0,52	1,48	0,63	1,57	86,61

Aglais_urticae	0,27	0,00	1,29	0,59	1,37	87,97
Lycaena_alciphron	0,00	0,27	1,20	0,54	1,27	89,25
Polyommatus_icarus	0,00	0,49	1,18	0,53	1,25	90,49
Aricia_agestis	0,00	0,50	1,12	0,45	1,18	91,67
Issoria_lathonia	0,24	0,10	1,10	0,46	1,16	92,84
Boloria_dia	0,00	0,33	1,02	0,42	1,08	93,92
Celastrina_argiolus	0,00	0,13	0,76	0,36	0,80	94,72
Pieris_brassicae	0,00	0,17	0,75	0,43	0,79	95,51

Groups 2 & 3

Average dissimilarity = 79,18

Species	Group 2 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Maniola_jurtina	0,00	22,69	14,62	2,27	18,46	18,46
Aphantopus_hyperantus	0,00	8,29	8,87	1,64	11,20	29,66
Melanargia_galathea	0,00	6,02	8,41	2,21	10,62	40,28
Pieris_napi	1,61	3,64	4,47	1,43	5,64	45,93
Pieris_rapae	3,39	2,18	3,63	1,23	4,58	50,51
Coenonympha_pamphilus	0,71	1,28	3,33	0,92	4,20	54,71
Gonepteryx_rhamni	0,06	1,58	3,01	0,85	3,80	58,51
Thymelicus_sylvestris	0,00	1,13	2,75	0,97	3,47	61,98
Ochlodes_sylvanus	0,00	0,81	2,48	0,70	3,13	65,11
Cupido_argiades	0,48	0,64	2,46	0,85	3,11	68,22
Vanessa_cardui	0,30	1,04	2,28	0,74	2,87	71,10
Lycaena_phlaeas	0,30	0,68	2,20	0,86	2,78	73,88
Pararge_aegeria	0,36	0,52	2,15	1,06	2,72	76,59
Vanessa_atalanta	0,48	0,29	1,95	0,75	2,47	79,06
Araschnia_levana	0,00	0,94	1,87	0,82	2,36	81,42
Thymelicus_lineola	0,00	0,57	1,75	0,74	2,21	83,63
Polyommatus_icarus	0,42	0,49	1,73	0,67	2,18	85,81
Aricia_agestis	0,24	0,50	1,57	0,67	1,98	87,79
Polygonia_c-album	0,00	0,29	1,26	0,68	1,59	

						89,38
Lycaena_alciphron	0,00	0,27	1,04	0,54	1,31	90,69
Boloria_dia	0,00	0,33	0,89	0,42	1,12	91,81
Issoria_lathonia	0,18	0,10	0,87	0,50	1,09	92,90
Argynnis_paphia	0,06	0,48	0,86	0,44	1,09	93,99
Aglais_io	0,00	0,20	0,70	0,43	0,88	94,87
Pieris_brassicae	0,00	0,17	0,65	0,43	0,82	95,69

Groups 6 & 3

Average dissimilarity = 82,77

Species	Group 6 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Maniola_jurtina	0,82	22,69	11,68	1,89	14,11	14,11
Aphantopus_hyperantus	0,00	8,29	7,68	1,64	9,27	23,38
Coenonympha_pamphilus	8,08	1,28	7,46	1,61	9,01	32,40
Melanargia_galathea	0,02	6,02	7,17	2,18	8,66	41,06
Pieris_napi	0,39	3,64	4,83	1,57	5,84	46,90
Vanessa_cardui	3,91	1,04	4,39	0,97	5,30	52,20
Pieris_rapae	0,20	2,18	4,07	1,26	4,92	57,12
Lycaena_tityrus	2,00	0,30	3,53	0,97	4,26	61,38
Ochlodes_sylvanus	1,88	0,81	3,45	1,07	4,16	65,54
Polyommatus_icarus	0,96	0,49	2,69	1,08	3,25	68,79
Gonepteryx_rhamni	0,22	1,58	2,67	0,90	3,23	72,02
Thymelicus_sylvestris	0,07	1,13	2,39	0,99	2,89	74,91
Araschnia_levana	0,21	0,94	1,89	0,92	2,28	77,19
Lycaena_phlaeas	0,12	0,68	1,73	0,84	2,09	79,28
Cupido_argiades	0,09	0,64	1,65	0,65	2,00	81,28
Thymelicus_lineola	0,00	0,57	1,51	0,74	1,82	83,10
Aricia_agestis	0,26	0,50	1,36	0,65	1,65	84,75
Pararge_aegeria	0,09	0,52	1,28	0,71	1,55	86,30
Aglais_io	0,26	0,20	1,17	0,64	1,41	87,70
Polygonia_c-album	0,04	0,29	1,14	0,72	1,38	89,08

Lycaena_alciphron	0,12	0,27	1,09	0,61	1,31	90,40
Boloria_dia	0,03	0,33	0,82	0,45	1,00	91,39
Vanessa_atalanta	0,00	0,29	0,81	0,58	0,98	92,37
Pieris_brassicae	0,13	0,17	0,76	0,49	0,91	93,28
Lycaena_dispar	0,18	0,03	0,74	0,54	0,89	94,18
Argynnis_paphia	0,00	0,48	0,59	0,35	0,72	94,89
Anthocharis_cardamines	0,22	0,00	0,56	0,35	0,68	95,57

Groups 7 & 4

Average dissimilarity = 85,81

Species	Group 7 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polyommatus_coridon	0,00	18,04	10,14	1,42	11,82	11,82
Coenonympha_pamphilus	0,36	13,65	8,78	1,50	10,23	22,05
Pieris_rapae	0,95	6,70	5,68	1,62	6,62	28,67
Maniola_jurtina	0,00	3,99	5,11	1,65	5,96	34,63
Lycaena_tityrus	0,00	3,54	4,69	1,77	5,47	40,09
Melanargia_galathea	0,00	4,53	4,64	1,10	5,40	45,50
Aricia_agestis	0,00	2,82	4,55	2,49	5,30	50,79
Polyommatus_icarus	0,19	2,34	3,59	1,40	4,18	54,98
Vanessa_cardui	0,02	2,31	3,55	0,83	4,14	59,12
Pontia_edusa	0,02	1,97	3,43	1,36	4,00	63,11
Lycaena_phlaeas	0,49	2,34	3,32	1,29	3,87	66,98
Pieris_napi	2,01	1,86	3,22	1,25	3,75	70,74
Aglais_io	1,82	0,37	3,02	1,26	3,52	74,25
Aphantopus_hyperantus	0,00	1,97	2,79	0,69	3,25	77,50
Thymelicus_lineola	0,02	1,80	2,47	0,91	2,87	80,37
Gonepteryx_rhamni	0,87	0,86	2,28	1,06	2,65	83,03
Issoria_lathonia	0,50	1,28	2,17	1,01	2,53	85,56
Anthocharis_cardamines	1,05	0,00	1,90	0,82	2,22	87,78
Erynnis_tages	0,32	0,62	1,47	0,72	1,71	89,49
Boloria_dia	0,22	0,43	0,97	0,53	1,14	

90,62

Araschnia_levana	0,41	0,12	0,97	0,59	1,13	91,75
Pararge_aegeria	0,35	0,00	0,90	0,62	1,05	92,81
Cupido_argiades	0,15	0,14	0,81	0,63	0,94	93,75
Pieris_brassicae	0,21	0,16	0,77	0,60	0,90	94,64
Polygonia_c-album	0,25	0,00	0,69	0,52	0,80	95,44

Groups 8 & 4

Average dissimilarity = 96,30

Species	Group 8 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polyommatus_coridon	0,00	18,04	11,86	1,44	12,32	12,32
Coenonympha_pamphilus	0,00	13,65	11,01	1,63	11,43	23,75
Pieris_rapae	0,00	6,70	8,58	2,34	8,91	32,65
Maniola_jurtina	0,00	3,99	6,01	1,66	6,24	38,89
Lycaena_tityrus	0,00	3,54	5,49	1,83	5,70	44,59
Melanargia_galathea	0,00	4,53	5,46	1,11	5,67	50,26
Aricia_agestis	0,00	2,82	5,32	2,61	5,52	55,79
Lycaena_phlaeas	0,00	2,34	4,55	1,48	4,73	60,51
Polyommatus_icarus	0,00	2,34	4,44	1,47	4,61	65,13
Vanessa_cardui	0,41	2,31	4,14	0,89	4,30	69,42
Pontia_edusa	0,00	1,97	4,05	1,35	4,21	73,63
Pieris_napi	0,00	1,86	3,34	0,97	3,47	77,10
Aphantopus_hyperantus	0,00	1,97	3,31	0,69	3,43	80,53
Gonepteryx_rhamni	1,10	0,86	2,96	1,06	3,07	83,60
Thymelicus_lineola	0,00	1,80	2,88	0,92	2,99	86,60
Issoria_lathonia	0,24	1,28	2,33	0,93	2,42	89,01
Polygonia_c-album	0,49	0,00	1,59	0,79	1,65	90,67
Aglais_io	0,24	0,37	1,41	0,80	1,47	92,13
Erynnis_tages	0,00	0,62	0,99	0,47	1,03	93,17
Aglais_urticae	0,27	0,00	0,99	0,60	1,03	94,20
Boloria_dia	0,00	0,43	0,81	0,44	0,84	95,04

Groups 2 & 4

Average dissimilarity = 78,83

Species	Group 2 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polyommatus_coridon	0,00	18,04	10,61	1,44	13,46	13,46
Coenonympha_pamphilus	0,71	13,65	8,70	1,45	11,03	24,50
Maniola_jurtina	0,00	3,99	5,36	1,68	6,79	31,29
Lycaena_tityrus	0,00	3,54	4,91	1,81	6,23	37,52
Melanargia_galathea	0,00	4,53	4,86	1,11	6,16	43,69
Aricia_agestis	0,24	2,82	4,20	1,99	5,32	49,01
Polyommatus_icarus	0,42	2,34	3,76	1,40	4,76	53,77
Lycaena_phlaeas	0,30	2,34	3,66	1,37	4,65	58,42
Vanessa_cardui	0,30	2,31	3,65	0,88	4,63	63,05
Pontia_edusa	0,00	1,97	3,62	1,38	4,59	67,65
Pieris_rapae	3,39	6,70	3,50	1,34	4,44	72,09
Pieris_napi	1,61	1,86	3,17	1,30	4,02	76,10
Aphantopus_hyperantus	0,00	1,97	2,93	0,70	3,71	79,82
Thymelicus_lineola	0,00	1,80	2,58	0,92	3,27	83,09
Issoria_lathonia	0,18	1,28	2,07	0,96	2,63	85,71
Gonepteryx_rhamni	0,06	0,86	1,57	0,71	1,99	87,71
Pararge_aegeria	0,36	0,00	1,43	0,94	1,82	89,52
Cupido_argiades	0,48	0,14	1,42	0,79	1,80	91,32
Vanessa_atalanta	0,48	0,08	1,33	0,66	1,69	93,01
Erynnis_tages	0,00	0,62	0,91	0,47	1,15	94,16
Aglais_io	0,00	0,37	0,77	0,53	0,98	95,14

Groups 6 & 4

Average dissimilarity = 72,62

Species	Group 6 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polyommatus_coridon	0,00	18,04	9,46	1,44	13,02	13,02
Pieris_rapae	0,20	6,70	6,23	2,14	8,58	

21,60

Coenonympha_pamphilus	8,08	13,65	5,42	1,57	7,47	29,07
Maniola_jurtina	0,82	3,99	4,30	1,52	5,92	34,99
Melanargia_galathea	0,02	4,53	4,28	1,11	5,90	40,89
Vanessa_cardui	3,91	2,31	4,04	1,10	5,56	46,45
Aricia_agestis	0,26	2,82	3,79	2,07	5,22	51,67
Lycaena_tityrus	2,00	3,54	3,44	1,41	4,73	56,40
Lycaena_phlaeas	0,12	2,34	3,36	1,44	4,63	61,03
Pontia_edusa	0,08	1,97	3,15	1,37	4,34	65,37
Polyommatus_icarus	0,96	2,34	2,75	1,34	3,78	69,15
Pieris_napi	0,39	1,86	2,67	1,04	3,68	72,83
Ochlodes_sylvanus	1,88	0,00	2,65	0,89	3,65	76,48
Aphantopus_hyperantus	0,00	1,97	2,58	0,70	3,55	80,03
Thymelicus_lineola	0,00	1,80	2,30	0,91	3,17	83,19
Issoria_lathonia	0,10	1,28	1,82	0,91	2,50	85,70
Gonepteryx_rhamni	0,22	0,86	1,54	0,79	2,12	87,82
Aglais_io	0,26	0,37	1,10	0,71	1,52	89,34
Erynnis_tages	0,00	0,62	0,82	0,47	1,13	90,48
Araschnia_levana	0,21	0,12	0,78	0,59	1,07	91,55
Boloria_dia	0,03	0,43	0,71	0,48	0,98	92,53
Lycaena_dispar	0,18	0,04	0,60	0,54	0,83	93,36
Pieris_brassicae	0,13	0,16	0,56	0,50	0,77	94,13
Cupido_argiades	0,09	0,14	0,56	0,48	0,77	94,89
Thymelicus_sylvestris	0,07	0,15	0,55	0,46	0,76	95,65

Groups 3 & 4

Average dissimilarity = 67,73

Species	Group 3 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polyommatus_coridon	0,00	18,04	7,44	1,39	10,99	10,99
Coenonympha_pamphilus	1,28	13,65	5,87	1,41	8,66	19,65
Maniola_jurtina	22,69	3,99	5,69	1,33	8,40	28,06

Aphantopus_hyperantus	8,29	1,97	4,26	1,40	6,29	34,35
Melanargia_galathea	6,02	4,53	3,46	1,51	5,10	39,45
Lycaena_tityrus	0,30	3,54	3,28	1,60	4,85	44,30
Pieris_rapae	2,18	6,70	3,10	1,39	4,58	48,88
Aricia_agestis	0,50	2,82	3,04	1,96	4,49	53,36
Pieris_napi	3,64	1,86	2,78	1,41	4,11	57,47
Polyommatus_icarus	0,49	2,34	2,58	1,35	3,81	61,28
Vanessa_cardui	1,04	2,31	2,56	0,94	3,78	65,06
Pontia_edusa	0,02	1,97	2,51	1,38	3,70	68,76
Lycaena_phlaeas	0,68	2,34	2,38	1,29	3,51	72,27
Gonepteryx_rhamni	1,58	0,86	1,96	0,98	2,90	75,17
Thymelicus_lineola	0,57	1,80	1,91	1,07	2,82	77,99
Thymelicus_sylvestris	1,13	0,15	1,56	0,99	2,31	80,30
Issoria_lathonia	0,10	1,28	1,45	0,88	2,14	82,44
Ochlodes_sylvanus	0,81	0,00	1,30	0,71	1,92	84,36
Araschnia_levana	0,94	0,12	1,23	0,88	1,81	86,17
Cupido_argiades	0,64	0,14	1,12	0,73	1,65	87,81
Boloria_dia	0,33	0,43	0,90	0,61	1,32	89,14
Aglais_io	0,20	0,37	0,80	0,68	1,18	90,32
Pararge_aegeria	0,52	0,00	0,77	0,64	1,13	91,45
Erynnis_tages	0,09	0,62	0,75	0,53	1,11	92,56
Polygonia_c-album	0,29	0,00	0,70	0,69	1,03	93,59
Vanessa_atalanta	0,29	0,08	0,63	0,65	0,94	94,53
Lycaena_alciphron	0,27	0,04	0,61	0,57	0,90	95,43

Groups 7 & 5

Average dissimilarity = 79,61

Species	Group 7 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,36	6,80	10,30	1,74	12,94	12,94
Pieris_rapae	0,95	3,92	6,91	1,22	8,68	21,62
Polyommatus_icarus	0,19	2,87	6,59	1,65	8,28	

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
						29,90
Pieris_napi	2,01	2,58	5,52	1,24	6,93	36,83
Maniola_jurtina	0,00	3,51	5,05	0,89	6,34	43,18
Aglais_io	1,82	0,15	4,88	1,31	6,13	49,31
Lycaena_phlaeas	0,49	0,90	3,56	0,98	4,48	53,79
Lycaena_tityrus	0,00	1,16	3,49	0,92	4,38	58,17
Gonepteryx_rhamni	0,87	0,17	3,02	1,00	3,79	61,96
Anthocharis_cardamines	1,05	0,00	2,93	0,83	3,68	65,65
Aricia_agestis	0,00	0,71	2,64	0,89	3,32	68,97
Issoria_lathonia	0,50	0,51	2,62	0,80	3,29	72,26
Pararge_aegeria	0,35	0,25	1,98	0,80	2,49	74,75
Vanessa_cardui	0,02	0,69	1,91	0,60	2,40	77,15
Cupido_argiades	0,15	0,35	1,72	0,67	2,16	79,31
Erynnis_tages	0,32	0,08	1,63	0,59	2,04	81,35
Polygonia_c-album	0,25	0,16	1,52	0,66	1,91	83,26
Vanessa_atalanta	0,10	0,28	1,50	0,61	1,88	85,14
Araschnia_levana	0,41	0,09	1,35	0,54	1,70	86,84
Thecla_betulae	0,17	0,15	1,07	0,50	1,35	88,19
Thymelicus_lineola	0,02	0,25	0,96	0,43	1,21	89,40
Papilio_machaon	0,20	0,01	0,86	0,35	1,08	90,48
Pieris_brassicae	0,21	0,03	0,79	0,44	1,00	91,48
Lycaena_dispar	0,02	0,16	0,73	0,44	0,92	92,39
Aphantopus_hyperantus	0,00	0,27	0,72	0,38	0,91	93,30
Pontia_edusa	0,02	0,14	0,70	0,33	0,89	94,19
Polyommatus_coridon	0,00	0,37	0,70	0,27	0,87	95,06

Groups 8 & 5

Average dissimilarity = 95,78

Species	Group 8 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,00	6,80	14,76	2,22	15,41	15,41
Pieris_rapae	0,00	3,92	11,99	1,67	12,51	27,92

Polyommatus_icarus	0,00	2,87	9,17	1,96	9,57	37,50
Pieris_napi	0,00	2,58	7,55	1,11	7,88	45,38
Maniola_jurtina	0,00	3,51	6,28	0,92	6,56	51,94
Lycaena_phlaeas	0,00	0,90	4,76	0,92	4,96	56,90
Gonepteryx_rhamni	1,10	0,17	4,69	0,97	4,90	61,80
Lycaena_tityrus	0,00	1,16	4,48	0,93	4,68	66,48
Vanessa_cardui	0,41	0,69	3,56	0,83	3,72	70,20
Aricia_agestis	0,00	0,71	3,39	0,90	3,54	73,73
Polygonia_c-album	0,49	0,16	3,04	0,85	3,17	76,91
Issoria_lathonia	0,24	0,51	2,99	0,70	3,12	80,03
Vanessa_atalanta	0,20	0,28	2,26	0,66	2,36	82,39
Aglais_io	0,24	0,15	2,14	0,65	2,24	84,63
Aglais_urticae	0,27	0,00	1,75	0,60	1,83	86,45
Cupido_argiades	0,00	0,35	1,60	0,52	1,67	88,12
Pararge_aegeria	0,00	0,25	1,48	0,56	1,55	89,66
Thymelicus_lineola	0,00	0,25	1,17	0,41	1,22	90,88
Thecla_betulae	0,00	0,15	1,05	0,48	1,10	91,98
Nymphalis_antiopa	0,12	0,01	1,02	0,41	1,06	93,04
Aphantopus_hyperantus	0,00	0,27	0,89	0,39	0,93	93,97
Polyommatus_coridon	0,00	0,37	0,87	0,28	0,91	94,88
Lycaena_dispar	0,00	0,16	0,84	0,41	0,88	95,75

Groups 2 & 5

Average dissimilarity = 66,61

Species	Group 2 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,71	6,80	10,18	1,68	15,29	15,29
Polyommatus_icarus	0,42	2,87	7,00	1,71	10,50	25,79
Pieris_napi	1,61	2,58	5,53	1,26	8,31	34,10
Maniola_jurtina	0,00	3,51	5,35	0,91	8,04	42,13
Pieris_rapae	3,39	3,92	4,43	1,18	6,65	48,79
Lycaena_phlaeas	0,30	0,90	3,82	0,99	5,73	

54,52

Lycaena_tityrus	0,00	1,16	3,72	0,94	5,58	60,10
Aricia_agestis	0,24	0,71	2,97	0,99	4,46	64,56
Vanessa_atalanta	0,48	0,28	2,64	0,76	3,96	68,53
Vanessa_cardui	0,30	0,69	2,63	0,79	3,95	72,47
Cupido_argiades	0,48	0,35	2,58	0,82	3,87	76,34
Pararge_aegeria	0,36	0,25	2,55	0,98	3,82	80,16
Issoria_lathonia	0,18	0,51	2,34	0,72	3,51	83,67
Gonepteryx_rhamni	0,06	0,17	1,12	0,55	1,68	85,35
Thymelicus_lineola	0,00	0,25	0,97	0,41	1,45	86,80
Thecla_betulae	0,00	0,15	0,87	0,48	1,31	88,11
Polygonia_c-album	0,00	0,16	0,80	0,43	1,20	89,31
Argynnis_paphia	0,06	0,18	0,78	0,43	1,18	90,49
Aglais_io	0,00	0,15	0,78	0,34	1,17	91,66
Aphantopus_hyperantus	0,00	0,27	0,76	0,38	1,15	92,81
Polyommatus_coridon	0,00	0,37	0,74	0,27	1,11	93,92
Lycaena_dispar	0,00	0,16	0,71	0,41	1,07	94,99
Melanargia_galathea	0,00	0,19	0,69	0,42	1,03	96,02

Groups 6 & 5

Average dissimilarity = 65,94

Species	Group 6 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pieris_rapae	0,20	3,92	7,20	1,63	10,91	10,91
Coenonympha_pamphilus	8,08	6,80	5,41	1,23	8,20	19,12
Vanessa_cardui	3,91	0,69	5,31	0,98	8,06	27,18
Pieris_napi	0,39	2,58	4,98	1,15	7,56	34,73
Maniola_jurtina	0,82	3,51	4,93	1,01	7,47	42,21
Lycaena_tityrus	2,00	1,16	4,37	1,11	6,62	48,83
Polyommatus_icarus	0,96	2,87	4,36	1,40	6,61	55,44
Ochlodes_sylvanus	1,88	0,00	4,04	0,89	6,12	61,56
Lycaena_phlaeas	0,12	0,90	3,04	1,00	4,62	66,18

Aricia_agestis	0,26	0,71	2,50	1,00	3,80	69,97
Issoria_lathonia	0,10	0,51	1,82	0,67	2,76	72,74
Aglais_io	0,26	0,15	1,39	0,59	2,10	74,84
Gonepteryx_rhamni	0,22	0,17	1,29	0,69	1,96	76,79
Cupido_argiades	0,09	0,35	1,27	0,55	1,92	78,71
Pararge_aegeria	0,09	0,25	1,25	0,63	1,89	80,61
Lycaena_dispar	0,18	0,16	1,20	0,64	1,82	82,43
Vanessa_atalanta	0,00	0,28	1,12	0,54	1,71	84,14
Araschnia_levana	0,21	0,09	1,07	0,53	1,62	85,76
Polygonia_c-album	0,04	0,16	0,82	0,50	1,25	87,01
Thymelicus_lineola	0,00	0,25	0,80	0,42	1,22	88,23
Pontia_edusa	0,08	0,14	0,76	0,39	1,16	89,38
Thecla_betulae	0,00	0,15	0,73	0,48	1,11	90,49
Anthocharis_cardamines	0,22	0,00	0,70	0,36	1,06	91,55
Melanargia_galathea	0,02	0,19	0,69	0,46	1,04	92,59
Aphantopus_hyperantus	0,00	0,27	0,66	0,38	1,00	93,59
Polyommatus_coridon	0,00	0,37	0,63	0,27	0,95	94,54
Argynnis_paphia	0,00	0,18	0,44	0,31	0,67	95,21

Groups 3 & 5

Average dissimilarity = 71,15

Species	Group 3 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Maniola_jurtina	22,69	3,51	9,26	1,55	13,01	13,01
Aphantopus_hyperantus	8,29	0,27	6,55	1,54	9,21	22,22
Melanargia_galathea	6,02	0,19	6,07	1,91	8,53	30,75
Coenonympha_pamphilus	1,28	6,80	5,67	1,49	7,97	38,72
Polyommatus_icarus	0,49	2,87	4,03	1,53	5,67	44,39
Pieris_napi	3,64	2,58	3,73	1,29	5,24	49,63
Pieris_rapae	2,18	3,92	3,19	1,20	4,48	54,11
Gonepteryx_rhamni	1,58	0,17	2,35	0,88	3,30	57,41
Lycaena_tityrus	0,30	1,16	2,30	0,97	3,24	

60,65

Species	Group Av.Abund	Group Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Lycaena_phlaeas	0,68	0,90	2,26	1,06	3,17	63,82
Thymelicus_sylvestris	1,13	0,01	2,12	0,96	2,97	66,79
Vanessa_cardui	1,04	0,69	2,05	0,80	2,89	69,68
Aricia_agestis	0,50	0,71	1,92	0,94	2,70	72,37
Ochlodes_sylvanus	0,81	0,00	1,84	0,70	2,58	74,95
Cupido_argiades	0,64	0,35	1,73	0,78	2,43	77,38
Araschnia_levana	0,94	0,09	1,59	0,86	2,24	79,62
Thymelicus_lineola	0,57	0,25	1,55	0,83	2,18	81,80
Pararge_aegeria	0,52	0,25	1,38	0,83	1,94	83,74
Issoria_lathonia	0,10	0,51	1,26	0,65	1,78	85,51
Vanessa_atalanta	0,29	0,28	1,20	0,75	1,69	87,20
Polygonia_c-album	0,29	0,16	1,15	0,78	1,61	88,82
Aglais_io	0,20	0,15	0,85	0,54	1,19	90,01
Argynnis_paphia	0,48	0,18	0,81	0,46	1,14	91,15
Lycaena_alciphron	0,27	0,00	0,79	0,54	1,11	92,26
Boloria_dia	0,33	0,00	0,68	0,42	0,96	93,22
Thecla_betulae	0,02	0,15	0,56	0,50	0,79	94,01
Pieris_brassicae	0,17	0,03	0,56	0,47	0,79	94,80
Lycaena_dispar	0,03	0,16	0,53	0,46	0,74	95,54

Groups 4 & 5

Average dissimilarity = 60,53

Species	Group 4 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polyommatus_coridon	18,04	0,37	8,41	1,41	13,89	13,89
Coenonympha_pamphilus	13,65	6,80	5,11	1,41	8,45	22,34
Maniola_jurtina	3,99	3,51	3,83	1,42	6,32	28,66
Melanargia_galathea	4,53	0,19	3,77	1,10	6,23	34,89
Lycaena_tityrus	3,54	1,16	3,08	1,42	5,08	39,98
Pieris_rapae	6,70	3,92	3,00	1,26	4,95	44,93
Pieris_napi	1,86	2,58	2,97	1,22	4,91	49,83

Vanessa_cardui	2,31	0,69	2,93	0,94	4,84	54,67
Aricia_agestis	2,82	0,71	2,85	1,59	4,70	59,37
Pontia_edusa	1,97	0,14	2,81	1,37	4,65	64,02
Polyommatus_icarus	2,34	2,87	2,55	1,32	4,21	68,23
Lycaena_phlaeas	2,34	0,90	2,53	1,32	4,18	72,41
Aphantopus_hyperantus	1,97	0,27	2,40	0,75	3,96	76,37
Thymelicus_lineola	1,80	0,25	2,14	0,97	3,53	79,90
Issoria_lathonia	1,28	0,51	1,89	1,02	3,12	83,02
Gonepteryx_rhamni	0,86	0,17	1,37	0,77	2,26	85,28
Cupido_argiades	0,14	0,35	0,92	0,69	1,52	86,80
Erynnis_tages	0,62	0,08	0,87	0,54	1,43	88,23
Aglais_io	0,37	0,15	0,86	0,63	1,42	89,66
Vanessa_atalanta	0,08	0,28	0,77	0,61	1,27	90,92
Pararge_aegeria	0,00	0,25	0,63	0,56	1,04	91,96
Boloria_dia	0,43	0,00	0,61	0,45	1,01	92,96
Araschnia_levana	0,12	0,09	0,49	0,47	0,81	93,77
Thecla_betulae	0,00	0,15	0,44	0,48	0,73	94,50
Lycaena_dispar	0,04	0,16	0,44	0,46	0,72	95,22

Groups 7 & 1

Average dissimilarity = 93,97

Species	Group 7 Av.Abund	Group 1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,36	4,11	19,87	1,37	21,14	21,14
Aglais_io	1,82	0,00	11,30	1,29	12,03	33,17
Pieris_napi	2,01	0,00	10,76	1,26	11,45	44,62
Pieris_rapae	0,95	0,00	6,35	0,90	6,76	51,38
Gonepteryx_rhamni	0,87	0,00	6,33	0,95	6,73	58,11
Anthocharis_cardamines	1,05	0,00	5,90	0,84	6,27	64,38
Erynnis_tages	0,32	0,18	4,29	0,59	4,56	68,95
Lycaena_phlaeas	0,49	0,00	3,37	0,72	3,58	72,53
Issoria_lathonia	0,50	0,00	2,88	0,60	3,07	

						75,60
Ochlodes_sylvanus	0,00	0,18	2,88	0,48	3,06	78,66
Pararge_aegeria	0,35	0,00	2,77	0,59	2,95	81,61
Araschnia_levana	0,41	0,09	2,54	0,59	2,70	84,31
Polygonia_c-album	0,25	0,00	2,07	0,52	2,20	86,51
Papilio_machaon	0,20	0,00	2,03	0,32	2,16	88,68
Cupido_argiades	0,15	0,00	1,67	0,44	1,77	90,45
Polyommatus_icarus	0,19	0,00	1,57	0,40	1,67	92,12
Pieris_brassicae	0,21	0,00	1,27	0,40	1,35	93,46
Celastrina_argiolus	0,17	0,00	1,14	0,37	1,21	94,68
Boloria_dia	0,22	0,00	0,95	0,29	1,01	95,68

Groups 8 & 1

Average dissimilarity = 100,00

Species	Group 8 Av.Abund	Group 1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coenonympha_pamphilus	0,00	4,11	41,06	2,37	41,06	41,06
Gonepteryx_rhamni	1,10	0,00	15,35	1,03	15,35	56,41
Polygonia_c-album	0,49	0,00	9,00	0,77	9,00	65,42
Vanessa_cardui	0,41	0,00	6,87	0,60	6,87	72,29
Ochlodes_sylvanus	0,00	0,18	5,62	0,53	5,62	77,91
Aglais_urticae	0,27	0,00	5,40	0,59	5,40	83,31
Aglais_io	0,24	0,00	3,98	0,62	3,98	87,29
Issoria_lathonia	0,24	0,00	3,39	0,40	3,39	90,69
Nymphalis_antiopa	0,12	0,00	3,36	0,40	3,36	94,04
Vanessa_atalanta	0,20	0,00	2,74	0,40	2,74	96,78

Groups 2 & 1

Average dissimilarity = 89,96

Species	Group 2 Av.Abund	Group 1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pieris_rapae	3,39	0,00	22,63	2,71	25,15	25,15
Coenonympha_pamphilus	0,71	4,11	19,19	1,59	21,33	46,49

Pieris_napi	1,61	0,00	12,44	1,43	13,83
60,31					
Pararge_aegeria	0,36	0,00	6,23	0,92	6,92
67,24					
Vanessa_atalanta	0,48	0,00	5,02	0,56	5,58
72,82					
Cupido_argiades	0,48	0,00	4,23	0,67	4,71
77,52					
Lycaena_phlaeas	0,30	0,00	3,14	0,48	3,49
81,01					
Ochlodes_sylvanus	0,00	0,18	3,04	0,55	3,38
84,39					
Vanessa_cardui	0,30	0,00	2,64	0,56	2,93
87,32					
Polyommatus_icarus	0,42	0,00	2,44	0,44	2,71
90,03					
Aricia_agestis	0,24	0,00	2,30	0,55	2,56
92,59					
Issoria_lathonia	0,18	0,00	1,87	0,44	2,08
94,67					
Erynnis_tages	0,00	0,18	1,35	0,37	1,50
96,17					

Groups 6 & 1

Average dissimilarity = 69,03

Species	Group 6 Av.Abund	Group 1 Av.Abund	Av.Diss	Diss/SD	Contrib%
Cum.%					
Coenonympha_pamphilus	8,08	4,11	10,39	1,38	15,04
15,04					
Vanessa_cardui	3,91	0,00	9,55	0,93	13,83
28,88					
Lycaena_tityrus	2,00	0,00	8,54	0,97	12,37
41,24					
Ochlodes_sylvanus	1,88	0,18	7,67	1,02	11,11
52,35					
Polyommatus_icarus	0,96	0,00	6,57	1,05	9,52
61,87					
Maniola_jurtina	0,82	0,00	3,16	0,52	4,57
66,45					
Pieris_napi	0,39	0,00	2,22	0,47	3,21
69,65					
Araschnia_levana	0,21	0,09	2,04	0,56	2,96
72,61					
Aglais_io	0,26	0,00	1,83	0,49	2,65
75,26					
Pieris_rapae	0,20	0,00	1,81	0,56	2,62
77,88					
Aricia_agestis	0,26	0,00	1,70	0,51	2,46
80,34					
Gonepteryx_rhamni	0,22	0,00	1,49	0,51	2,16
82,50					
Lycaena_dispar	0,18	0,00	1,49	0,50	2,15
84,66					
Lycaena_phlaeas	0,12	0,00	1,39	0,41	2,02
86,67					
Anthocharis_cardamines	0,22	0,00	1,32	0,36	1,92
88,59					
Erynnis_tages	0,00	0,18	1,00	0,37	1,45

					90,04
Issoria_lathonia	0,10	0,00	0,82	0,31	1,19
					91,23
Lycaena_alciphron	0,12	0,00	0,72	0,29	1,04
					92,27
Pararge_aegeria	0,09	0,00	0,68	0,29	0,99
					93,26
Thymelicus_sylvestris	0,07	0,00	0,63	0,25	0,91
					94,17
Melitaea_cinxia	0,10	0,00	0,53	0,25	0,77
					94,94
Pieris_brassicae	0,13	0,00	0,52	0,25	0,76
					95,70

Groups 3 & 1

Average dissimilarity = 93,28

Species	Group 3 Av.Abund	Group 1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Maniola_jurtina	22,69	0,00	16,89	2,37	18,11	18,11
Aphantopus_hyperantus	8,29	0,00	10,35	1,64	11,10	29,21
Melanargia_galathea	6,02	0,00	9,85	2,21	10,56	39,76
Pieris_napi	3,64	0,00	7,02	1,58	7,53	47,29
Coenonympha_pamphilus	1,28	4,11	6,95	1,34	7,45	54,73
Pieris_rapae	2,18	0,00	6,33	1,21	6,79	61,52
Gonepteryx_rhamni	1,58	0,00	3,46	0,82	3,71	65,23
Thymelicus_sylvestris	1,13	0,00	3,20	0,96	3,43	68,66
Ochlodes_sylvanus	0,81	0,18	3,07	0,79	3,29	71,95
Araschnia_levana	0,94	0,09	2,24	0,90	2,40	74,36
Vanessa_cardui	1,04	0,00	2,18	0,61	2,34	76,70
Cupido_argiades	0,64	0,00	2,16	0,62	2,32	79,02
Lycaena_phlaeas	0,68	0,00	2,12	0,74	2,27	81,28
Thymelicus_lineola	0,57	0,00	2,04	0,74	2,19	83,47
Pararge_aegeria	0,52	0,00	1,49	0,63	1,60	85,07
Polygonia_c-album	0,29	0,00	1,48	0,67	1,59	86,66
Lycaena_alciphron	0,27	0,00	1,21	0,54	1,30	87,96
Polyommatus_icarus	0,49	0,00	1,19	0,53	1,27	89,23
Aricia_agestis	0,50	0,00	1,13	0,45	1,21	90,44
Vanessa_atalanta	0,29	0,00	1,04	0,57	1,12	91,56

Boloria_dia	0,33	0,00	1,03	0,42	1,10	92,67
Erynnis_tages	0,09	0,18	0,81	0,44	0,87	93,54
Aglais_io	0,20	0,00	0,81	0,43	0,87	94,41
Celastrina_argiolus	0,13	0,00	0,77	0,37	0,82	95,23

Groups 4 & 1

Average dissimilarity = 89,11

Species	Group 4 Av.Abund	Group 1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polyommatus_coridon	18,04	0,00	11,95	1,44	13,41	13,41
Pieris_rapae	6,70	0,00	8,64	2,35	9,70	23,11
Coenonympha_pamphilus	13,65	4,11	7,31	1,45	8,20	31,31
Maniola_jurtina	3,99	0,00	6,05	1,66	6,80	38,11
Lycaena_tityrus	3,54	0,00	5,53	1,83	6,21	44,32
Melanargia_galathea	4,53	0,00	5,50	1,11	6,18	50,49
Aricia_agestis	2,82	0,00	5,36	2,62	6,01	56,51
Lycaena_phlaeas	2,34	0,00	4,59	1,48	5,15	61,66
Polyommatus_icarus	2,34	0,00	4,48	1,47	5,03	66,68
Vanessa_cardui	2,31	0,00	4,32	0,83	4,85	71,53
Pontia_edusa	1,97	0,00	4,08	1,35	4,58	76,11
Pieris_napi	1,86	0,00	3,37	0,97	3,78	79,89
Aphantopus_hyperantus	1,97	0,00	3,33	0,69	3,74	83,63
Thymelicus_lineola	1,80	0,00	2,91	0,92	3,26	86,89
Issoria_lathonia	1,28	0,00	2,13	0,86	2,39	89,28
Gonepteryx_rhamni	0,86	0,00	1,65	0,65	1,85	91,13
Erynnis_tages	0,62	0,18	1,33	0,59	1,50	92,63
Aglais_io	0,37	0,00	0,86	0,53	0,97	93,59
Boloria_dia	0,43	0,00	0,82	0,45	0,92	94,51
Ochlodes_sylvanus	0,00	0,18	0,81	0,55	0,91	95,42

Groups 5 & 1

Average dissimilarity = 80,28

Species	Group 5 Av.Abund	Group 1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pieris_rapae	3,92	0,00	12,14	1,69	15,12	15,12
Polyommatus_icarus	2,87	0,00	9,28	1,98	11,56	26,68
Coenonympha_pamphilus	6,80	4,11	7,71	1,35	9,60	36,28
Pieris_napi	2,58	0,00	7,64	1,12	9,51	45,79
Maniola_jurtina	3,51	0,00	6,35	0,92	7,91	53,70
Lycaena_phlaeas	0,90	0,00	4,82	0,93	6,00	59,70
Lycaena_tityrus	1,16	0,00	4,54	0,94	5,65	65,36
Aricia_agestis	0,71	0,00	3,43	0,91	4,27	69,63
Vanessa_cardui	0,69	0,00	2,43	0,59	3,02	72,65
Issoria_lathonia	0,51	0,00	2,39	0,59	2,97	75,62
Vanessa_atalanta	0,28	0,00	1,65	0,53	2,06	77,68
Cupido_argiades	0,35	0,00	1,61	0,52	2,01	79,69
Ochlodes_sylvanus	0,00	0,18	1,50	0,54	1,87	81,56
Pararge_aegeria	0,25	0,00	1,50	0,56	1,87	83,43
Thymelicus_lineola	0,25	0,00	1,18	0,41	1,47	84,90
Erynnis_tages	0,08	0,18	1,11	0,46	1,39	86,29
Thecla_betulae	0,15	0,00	1,06	0,48	1,32	87,61
Araschnia_levana	0,09	0,09	1,02	0,45	1,27	88,88
Aglais_io	0,15	0,00	1,00	0,34	1,25	90,13
Gonepteryx_rhamni	0,17	0,00	1,00	0,48	1,24	91,37
Polygonia_c-album	0,16	0,00	0,96	0,43	1,20	92,57
Aphantopus_hyperantus	0,27	0,00	0,90	0,39	1,12	93,69
Polyommatus_coridon	0,37	0,00	0,88	0,28	1,10	94,79
Lycaena_dispar	0,16	0,00	0,85	0,42	1,06	95,85

Manuscript 1: Homogenous small scale hot spots: Diversity and phenological dynamics of urban butterfly communities associated with fragmented wastelands in the large post-industrial Central European city

AUTHORSHIP CONTRIBUTION AND ORDER OF AUTHORS

Sylwia Pietrzak (70%) concept of the paper (main contribution), taxonomic analysis, field studies, methodology planning, methodology testing in the field, main part of literature research, preparation of dataset for analysis, performing of data analysis, interpretation of the results, preparation of figures, tables and graphics, writing of the manuscript (main draft), manuscript editing, coresponding author

Krzysztof Pabis (30%) supervision of the research, concept of the paper, planning of the field methodology and data analysis, literature research, involvement in manuscript writing and interpretation of the results, manuscript editing

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Funtional diversity of the Central European butterfly communities associated with urban wastelands: a specialist-generalist point of view on a background of plant diversity

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Abstract

Analysis of butterfly functional traits allows for more comprehensive insight into ecological interactions structuring butterfly communities, although it is still rarely performed in the urban ecosystems. Our study analyzed functional traits of butterfly fauna associated with urban wastelands of the large postindustrial city in the Central Europe. Analysis was based on quantitative samples (214 Pollard walks) collected between April and September of 2019 and 2020. Butterfly communities were functionally diverse, although dominated by species with wide ecological requirements. Thirty eight, out of 45 recorded species were associated with common herbaceous plants, and about half of the species can be described as polyphagous. They are mostly good dispersers, overwintering as caterpillars or adults. About half of the species is univoltine, while the other half displays 2 or 3 generations per year. Investigated sites were functionally similar although sites located at the outskirts of the city were characterized by significantly higher species richness of small winged species with polyphagous caterpillars probably reflecting higher connectivity with areas surrounding the city. Richness of flowering plants positively influenced the richness of univoltine butterflies and those that lie eggs on short and tall herbs and grasses and those utilizing only tall herbs. In general high abundance was recorded for moderately good dispersers with small wings like *C. pamphilus* and *P. icarus*, a species characterized by high fertility, cryptic solitary caterpillars that display nocturnal activity and are often hidden close to the ground. More specialized species like facultative myrmecophile *Polyommatus coridon* were also abundant although only on one site located in the outskirts.

Key words: functional traits, Lepidoptera, distribution patterns, fragmentation

Introduction

Lepidoptera are the largest group of foliovores. With about 170 000 described species they exceed the number of chrysomelids and other plant feeding beetles (Kristensen et al. 2007, Mitter et al. 2017). The long term co-evolution with angiosperms allowed for development of complex ecological relationships, including diversity of caterpillar host plants strategies and flower preferences of the adults (Powell et al. 1998, Tiple et al. 2009, Kawahara et al. 2019). Butterflies comprise about 12% of known lepidopteran species. They are mostly external foliovores in the larval stage, although there are some florivore and carnivorous taxa know, especially amongst Lycaenidae, some lichen feeding species and a small group feeding on detritus (Powell et al. 1998, Pierce et al. 2002). Recent phylogenetic studies demonstrated that diversification of butterflies lagged far behind the origin of angiosperms, and those lepidopterans are associated with plants representing 300 families (Kawahara et al. 2023) including trees, shrubs and various herbaceous plants (Tiple et al. 2011). About 70% of butterflies feeds only on one plant family and the most plant-specific taxa are found in butterflies associated with Poaceae and Fabaceae. Another 30% displays generalist mode of life, although in most cases they feed on very closely related plant families and generally closely related butterflies are associated with closely related plants (Kawahara et al. 2023). At first glance butterflies are relatively uniform clade, although they represent high diversity of feeding strategies, dispersal abilities, defence mechanisms and ecological preferences, which makes them functionally diversified group of insects (Settele et al. 2009). They are also involved in various interactions with other animals. Their larvae constitute a food for birds and other vertebrates (Singer et al. 2014),are hosts of various parasites and parasitoids (Audusseau et al. 2021) and even vectors for phoretic behaviour (Fatouros and Huigens 2012). On the other hand large group of species is involved in mutual interactions with ants making them a highly specialised group of insects (Pierce et al. 2002), while ants may even influence host plant selection (Pierce and Elgar 1985).

Strong evolutionary association with angiosperms resulted in ability for sequestration of plant secondary compounds (Nishida 2002) and complex plant-butterfly arm race (Braga et al. 2021). Predator avoidance strategies include i.e.: cryptic coloration, aposematism, mimicry, solitary foraging and gregarious feeding (Lichter-Marck et al. 2015, Campbell and Stastny 2015, Deshmukh et al. 2017). Caterpillars may display exposed foraging or are hidden in rolled leafs (Bryant et al. 2000). Floral preferences of the adults may match the preferences of the caterpillars or differ, resulting in various degree of specialization (Altermatt and Pearse 2011). Moreover, diet specialization might be associated with reduced susceptibility to predation (Singer et al. 2014), making the complexity of interactions even grater. Butterflies are also characterized by diversity of size, wing shape and flying performance which include fast flyers, migratory species and poor dispersers as well as variety of intermediate forms (Sekar 2012). Also the diversity of occupied habitats varies from deserts, grasslands and forests, through oceanic islands, or mountains and ending with cities, crop fields and various disturbed areas (Despland 2014, Minter et al. 2020, Attiwilli et al. 2022, Han et al. 2022, Szabo et al. 2022). Life cycle may differ in number of produce offspring, pupation site, overwintering stage, and number of generations throughout the year, resulting in very diverse responses to ecosystem changes (Bartonova et al. 2014, Slancarova et al. 2016).

Functional diversity of butterflies is inseparably linked with the resource based approach to butterfly ecology which is gaining more attention in the recent years (Dennis et al. 2011), resulting in studies analysing species traits (e.g. Borchig et al. 2013, Pavoine et al. 2014, Correra-Carmona et al. 2021, Korosi et al. 2022, Pla-Narbona et al. 2022, Szabo et al. 2022), or various plant-lepidoptera community relations (e.g.Menken et al. 2009, Aguirre-Gutiérrez et al. 2016, Braga and Diniz 2021, Płociennik et al. 2023), although such analysis are still scarce in the urban ecosystems (e.g. Clark et al. 2007, Tiple et al. 2011, Calaghan et al. 2021, Pla-Narbona et al. 2022). Functional approach allows for analysis that is independant from traditional assessment of taxonomic diversity, and more focused on ecological affinities. Therefore, it is recently often used is various studies of terrestrial and aquatic organisms. including plant communities (Czortek et al. 2020), lichens (Łubek et al. 2020) or marine benthic polychates (Sobczyk et al. 2021) and birds (Mariano-Neto and Santos 2023).

Urban ecosystems are disturbed and highly fragmented. They are influenced by pollution, heat island effect and altered water balance (Rega-Brodsky et al. 2022). All those factors have a great influence on functional interactions within the communities, host-plant availability species richness and diversity, (Fenoglio et al. 2021). Recent reviews pointed at substantial lack of butterfly functional analysis of the urban ecosystems, a very important element, especially in so dynamically changing areas (Dennis et al. 2006, Ramirez-Restrepo and MacGregor-Fors 2017). Analysis of species traits may provide important insights into interspecific competition, dispersal abilities, resources use and overall functioning of the urban ecosytem (Calaghan et al. 2021, Pla-Narbona et al. 2022). Urbanization may result in simplification of the functional interactions leading to decline or extinction of specialised taxa (Aguilera et al. 2019, Callaghan et al. 2021). Habitat degradation might also cause community shift into generalist character (Borschig et al. 2013), although it is worth mentioning that definitions of the generalist and specialist (Bartonova et al. 2014) are often blurred and require approach focused on specific types of resources (Dennis et al. 2011). European butterfly fauna is amongst the most comprehensively studied in terms of species ecological traits (Middleton-Welling et al. 2020), and there are also valuable data from specific part of the range, including the Central Europe (Sielezniew and Dziekańska 2010, Warecki 2010, Buszko and Masłowski 2008) which allows for detailed functional characteristic of particular species. Therefore, we have used butterflies (one of the model groups in studies of urban fauna) (Blair 1999, Ramirez-Restrepo and MacGregor-Fors 2017, Tzortzakaki et al. 2019) and westland habitats (potential hot spots for various resources in the cities) (Karlsson and Wiklund 2004, Qviström 2008, Bonthoux et al. 2014, Kalarus et al. 2019, Twerd and Banaszak-Cibicka 2019) to answer questions associated with functional interactions in the fragmented urban landscape of the large postindustrial Central European city, based on two year quantitative approach.

Material and methods

Study area

Łódź is a large Central European postindustrial city and covers the area of about 300 km^2 (GUS 2023). The total area of the urbanized space is larger by about 40% when neighbouring smaller towns are included. Łódź bacame a center of textile manufacture more than 100 years ago. Development of the city started at the beginning of the XIX century when Łódź was still a small town surrounded by forests, marshlands and net of small rivers (Markowski et al. 1998, Witosławski 2006). Currently most of the rivers are hidden underground and transformed into sewage canals, therefore Łódź is not divided by a large river valley that could potentially serve as migration route for fauna. The ecological corridors are mostly associated with parks and railroads.

There are three urbanization zones in Łódź. The city center (zone I) is the most urbanised area where green spaces are restricted to lawns, small parks or cemeteries. The periurban area (zone II) is characterized by larger green areas, including large parks, gardens, and wastelands. The outskirts (zone III) is characterized by loose building arrangement and much larger green spaces that are not so highly fragmented. Habitats include large wastelands, meadows and even agricultural lands. This zone includes also a large (1200ha) deciduous forest complex (Lagiewniki Forest) located within the borders of the city (Witosławski 2006, Janiszewski et al. 2009).

Field studies

Studies were conducted on five large wastelands located in the peri-urban area (zone II) and outskirts (zone III) (Fig. 1). We have used quantitative approach based on Pollard walks, a method often used in monitoring of butterfly communities (Pollard 1977). Transect were shorter than originally proposed 1100 m distance to mach the size of small urban green spaces (Kitahara and Fujii 1994, MacDonald et al. 2017, Tzortzakaki et al. 2019). Butterflies were counted in 5 m squares as counting person was moving forward along the transect. Transects were visited every week between April and September of 2019 and 2020. The only exceptions include weeks with heavy rain and temperatures below 13°C. Weather factors were obtained right before starting transect walk with actual weather information provided through service https://weather.com/ or assessed by observation (for cloud cover). Temperature and humidity were provided for all Pollard walks. Individuals that were difficult to identify from a distance were collected using an entomological net and released afterward. Identification was based on field guides for Polish and European fauna (Buszko and Masłowski 2008, Sielezniew and Dziekańska 2010, Tolman 1997) Altogether 214 Pollard walks (single walk was treated as quantitative samples) were conducted including 109 in 2019 and 105 in 2020. The number of Pollard walks on each sited equalled 22 in 2019 and 21 in 2020 at Brukowa Site, 24 in 2019 and 21 in 2020 at Maratońska site, 22 in 2019 and 20 in 2020 at Rogi Site, 22 in 2019 and 21 in 2020, 19 in 2019 and 22 in 2020 at Traktorowa Site.

Data about the species composition of flowering plants and vegetations characteristics were also gathered at each site, regularly during both seasons. Identification was based on keys and field guides along with distribution atlas dedicated to flora of Łódź (Rutkowski 1998, Witosławski 2006, Sudnik-Wójcikowska 2011). This part of the analysis allowed for description of sampling sites, while the list of collected plant species is given in the Appendix 1.

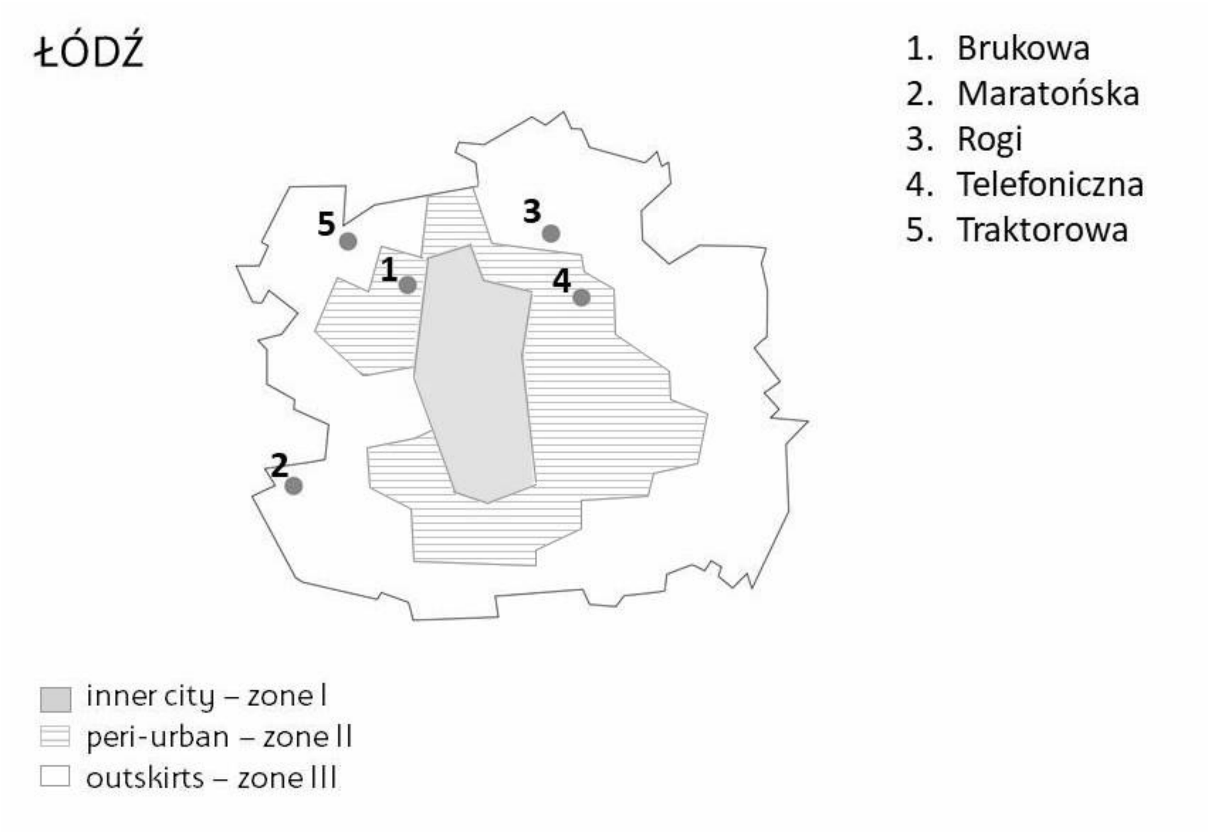

Fig. Distribution of sites in Łódź

Brukowa Site (B) was located in the peri-urban zone of Łódź, a predominantly industrial part of the city. It covers the area of about 2 ha. A 700 m transect followed along railroad tracks that could serve as ecological corridor linking this site with the northern borders of the city (Fig). Vegetation included shrubs (mainly *Robinia pseudoacatia*, *Prunus* sp and *Rubus* sp*)*, small woodland, meadow and railroad-associated flora. Part of the site remains in the shadow of larger trees during most part of the season except of the early spring. Herbaceous plants in the shadowed area include: *Berteroa incana, Cirsium* sp.*, Erigeron* sp*, Knautia arvensis, Lotus corniculatus, Melilotus albus, Tanacetum vulgare*, *Trifolium* sp.. In the summer this part is dominated by *Solidago* sp. Part along the railway is covered with *Cardaminopsis arenosa, Viola* sp and *Geranium* sp. in the spring. Later during the season it is dominated by *Berteroa incana, Erigeron* sp*, Oenothera* sp*, Origanium vulgare, Echium vulgare, Hypericum* sp*, Reseda lutea, Medicago* sp., *Linaria vulgaris* and *Solidago* sp.

Maratońska Site (M) covered the area of about 2 ha and was located in the western part of the city in the III zone. A 600 m long transect followed the route between edge of the forest and linear mound. Vegetation include fragment of dry meadow, ecotone zone between meadow and coniferous forest and shrub patches restricted by roads. Shrubs (*Rubus, Robinia pseudacacia*, and *Syringa vulgaris*) intersected the meadow and created a mosaic of habitats including patches of different species of grasses and even exposed sandy ground. Flowering plants include: *Berteroa incana, Centaurea stoebe*, *Erigeron* sp., *Prunus* sp*., Hieracium pilosella, Jasione montana, Viola* sp*, Echium vulgare, Knautia arvensis, Securigera varia, Anchusa officinalis,* and *Solidago* sp.

Rogi Site (R) covered the area of about 3 ha and was located on the border of the III and II urbanisation zone (Fig 1). This area was neighbouring to Lagiewniki Forest, and it was surrounded by small buildings, including elemental school and construction of new block of flats. The hill of anthropogenic origin was covered with mixed forest, meadow, shrubs and small orchard. The 700 m long transect led along meadow and the path leading to the hilltop. Meadow was characterized by different moisture level and an ecotone zone on a border with deciduous forest. Moving practice was stopped in 2019 resulting in changes of vegetation structure. Higher plants developed especially in more humid part of the site. Flora consists of grasses, shrubs (*Sambucus nigra*, low *Malus* sp. and young *Robinia pseudoacatia*). Flowering herbaceous plants include: *Cirsium* sp., *Pastinaca sativa, Daucus carota, Trifolium* sp.*, Vicia* sp.*, Lotus corniculatus, Hieracium* sp.*, Potentilla* sp.*, Jasione montana, Knautia arvensis* and some typical garden plants like *Rudbeckia hirta* and *Lathyrus latifolius*.

Telefoniczna Site (TL) covered the area of about 2ha and was located in the II zone near the residential area, tramway depot, magazines and workshop. A 700 m long transect led through hilly wasteland covered with a mix of ruderal vegetation, grassland, shrubs and mixed forest dominated be deciduous trees (Fig.). Grassland was enclosed by trees and shrubs from one side. Vegetation clearence conducted in 2019 along the powerlines probably infuenced connectivity between parts of the sites cover by different vegetation. Flowering plants was dominated by *Solidago* but included also many other species including: *Berteroa incana*, *Erigeron* sp., *Melilotus albus, Melilotus officinalis, Lupinus polyphyllus, Convolvulus arvensis, Hieracium pilosella*, *Knautia arvensis*, *Stellaria* sp., *Lotus corniculatus, Vicia* sp, *Trifolium arvense* and various Apiaceae.

Traktorowa Site (TR) covered the area of about 2 ha and was located in the III zone of the city, between the riverbed of Sokołówka and residential area. A 500 m long transect followed through patches of humid meadow, ruderal meadow, forest clearing and 100 m part that have forestry character. Part of the meadow that was located close to the river was covered by *Cardaminopsis arenosa* and *Veronica chamaedrys* in the spring. In the summer time it was covered by *Ranunculaceae*, *Berteroa incana*, *Achillea vulgaris*, *Silene flos-cuculi, Cirsium* sp*., Potentilla* sp*., Linaria vulgaris* and *Tanacetum vulgare*. Three dryer patches of vegetation differd in composition of plant communities. The part neighbouring to humid meadow include: *Helichrysum arenarium, Jasione montana, Vicia* sp*., Hieracium pilosella*, *Achillea vulgaris, Berteroa incana, Knautia arvensis, Senecio* sp., *Centaurea stoebe*, *Potentilla* sp., *Tanacetum vulgare* and *Solidago gigantea*. Second fragment was dominated by grasses and flowering plants like: *Hieracium* sp, *Vicia* sp, *Knautia arvensis*, *Jasione montana, Senecio* sp. Third part of the meadow was neighbouring to the forest. The main flower resources included *Rubus* sp., *Jasione montana*, *Knautia arvensis* and *Hieracium* sp. In the summer *Solidago virgaurea* and *Solidago gigantea* dominate the area. Vegetation along the Edge of the forest was composed of various Apiaceae, *Urtica, Lamium* and *Impatiens glandulifera*.

Data analysis

R Software (R Core Team, 2020) was used to deploy almost all analyses excluding variation analysis which was done using the Statistica 13 software. Butterfly functional traits were extracted from database of European and Maghreb butterflies provided by Middleton-Welling et al. (2020) and supplemented by data regarding Polish fauna (Sielezniew and Dziekańska 2010, Warecki 2010, Buszko and Masłowski 2008), while information about plants were obtained from Sudnik-Wójcikowska (2011) and Flora Polski website (2022). Since transects had different length in order to cover the whole spectrum of vegetation types at each site the number of individuals was calculated for the 500 m length (the size of the shortest transect).

Overall species richness, richness of oligophagous (feeding on 3 or less hostplant species) and polyphagous (feeding on 4 or more hostplant species) butterflies, overwintering stadium (egg, larvae, pupa, adult), voltinism (one generation per year, 2-3 generations per year), egg laying (bare ground, short herbs/grass/turf, tall herbs/grass, shrub, tree trunk, canopy, liana) and hostplant growth form (short herbs/grass, tall herbs/grass, shrub, tree, liana) (Middleton-Welling et al. 2020) were calculated for each sample by using vegan::decostand (Oksanen et al. 2020) function. In addition, butterflies were divided by wing span into three groups: small wings, average wings, large wings. Data were based on database of European and Maghreb butterflies (Middleton-Welling et al. 2020). Only traits represented by more than 4 species were included into further analysis.

The statistical significance of differences in overall species richness of butterflies as well as richness of selected functional traits (Table. 1) between each site were tested using parametric analysis of variance (ANOVA) with post-hoc Tukey test or non-parametric Kruskal-Wallis with post-hoc Dunn test, depending on the results of Levene's test.

To visualize foodweb relationships between butterfly species and their foodplants bipartite::plotweb function (Dormann et al. 2008) was used. Presence of nectariferous plants at studied sites was detected during the field work. Non-flowering plant occurrence was obtained from Distribution atlas of plants in Łódź (Witosławski 2006). Additionally, the bipartite::plotweb function was used to visualize total number of specimens for each butterfly species on investigated sites.

Left side of correlation matrix was created using GGally::ggpairs (Schloerke et al., 2021) to show regression. The right side of corrplot figure was created by using corrplot::corrplot (Wei and Simko, 2017) and allowed to calculate Pearson correlation matrix for the environmental variables. Environmental data were transformed for reducing biases associated with unequal ranges of some factors by using Yeo-Johnson power transformation (caret::preProcess(); Kuhn 2020). Transformed values of environmental factors (richness of flowering plants, temperature, wind speed, humidity and cloudiness) were used in further analysis. Association between environmental factors and butterfly communities was performed using canonical correspondence analysis (CCA) vegan::cca (Oksanen et al. 2020). Function anova.cca from vegan package was used to determine statistical significance of analyzed variables. Additionally, the amount of the multicollinearity between variables was analysed. Next we used anova.cca() function from vegan package (Oksanen et al. 2020) to determine which factors were statistically significant in shaping diversity on each station. By using vif() function from car package (Fox & Weisberg 2019) we have assessed the amount of the multicollinearity between analysed variables.

Based on the corrected Akaike Information Criterion (AICc) the set of best fitted models was choose by conducting MuMIn::dredge function (Bartoń 2018). To calculated estimates of function slopes for sets of the most parsimonious models with ΔAICc < 2 the model averaging model.avg(), confset95p(), avgmod.95p() functions from MuMIn package

(Bartoń 2018) were implemented. Species richness and richness of species representing selected functional traits (Table 1) was analyzed by using generalized linear models (GLM) based on the Poisson distribution. Five available environmental factors (richness of flowering plants, wind speed, cloudiness – fuzzy clustering (Appendix 1), temperature, humidity) were included as fixed effect by using lmer4::glm function (Bates et al. 2020).

The independent contribution of each environmental variable, and its percentage value of independent effect (joint contribution to all other predictors) were assessed by computing a hierarchical partitioning hier.part::hier.part function (Walsh & Mac Nally 2013). Goodness-of-fit measures for all model combinations with all predictors, using Poisson distribution were computed. Randomization test was performed using the hierp.part::rand.hp (Walsh & Mac Nally 2013) function to check statistical significance of the relative contribution of each predictor (p-values and z-scores).

Results

Butterfly communities associated with urban wastelands in Łódź were functionally diversified, although rather dominated by generalist species (Table 1, Table 2). Majority of butterflies (38 species) were associated with herbaceous plants. About a half of species (22 taxa) were polyphagous during the larval stage, although large group was associated with only one plant family. The number of univoltine and polivoltine species was very similar with 22 and 26 species respectively. The largest group of species overwinters as caterpillar (24 taxa) (Table 1). Species with the highest frequency of occurrence at investigated sites and with highest abundance can be described as generalists in regard to at least a few types of resources (Table 2). They generally can be described as good dispersers associated with very common species of plants and/or polyphages (Table 2).

Table 5 Number of species characterized by particular functional traits

Trait	Number of species
Univoltine	20
Univoltine (occasionally bivoltine)	2
Bivoltine/trivoltine	26
Facultative myrmecophiles	8
Obligatory myrmecophiles	0
Monophagous	5
Oligophagous (1 family)	12
Oligophagous	7
Polyphagous	6
Polyphagous (1 family)	16
Host plant herbaceous	38
Host plant trees/shrubs	8
Migratory	2
Overwintering egg	5
Overwintering caterpillar	24
Overwintering pupa	9
Overwintering adult	7

Table 6 Functional characteristics of the most frequent (F%) and abundant (TA – total abundance) species

Species	Total abundance and frequency of occurrence on sites	Life cycle	Host plants relationships	Caterpillars	Adults and their flight performance	Other	References
Overall common and abundant species							
Pieris rapae	Max F%= 77 (Telefoniczna) Min F%= 51 (Traktorowa) TA= 676	Bivoltine/Trivoltine, egg lying on underside of the leafs in samll patches, pupation on host plant or other surfaces, overwintering in pupal stage, poliandrous females	Polyphagous although mostly related to one plan family (wild and cultivated Brassicaceae: Brassica napus, Brassica oleracea, Sinapis arvensis, Raphanus raphanistrum) sometimes Tropaeolum majus, Reseda	Cryptic (green color), no chemical defence, Often infected by parasitoids, braconids Cotesia glomerata, pteromalids e.g. Pteromalus puparum or tachinid flies	Wing span: 42-46 mm, good disperser, occasional migrations, flower preferences generalist, puddling behavior	Pest of brassica, might grow faster in Pb contaminated environment, resistant to pollution	Shaw et al. (2009), Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Philips et al. (2017), Kobiela and Snell-Rood 2018
Pieris napi	Max F%= 63 (Rogi) Min F%= 42 (Maratońska) TA= 539	Bivoltine/trivoltine, egg lying on leafs, pupation on plants and other surfaces,overwintering in pupal stage, poliandrous females	Polyphagous although related to one plan family (wild Brassicaceae: Cardamina pratensis, Ariallia petiolata, Sinapis arvensis, Arabis)	Cryptic (green color), parasitoids include ichneumonids: Apechthis quadridentata, Pimpla rufipes and braconids Cotesia glomerata,	Wing span: 40-45 mm, good disperser, nectar generalist, although prefers flowers of caterpillar host plants, puddling behvior,		Shaw et al. (2009), Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015)
Gonepteryx rhamni	Max F%=39 (Traktorowa) Min F%= 26 (Telefoniczna) TA= 180	Univoltine, single egg lying or small patches, on leafs, puaption on leafs and stems of plants, overwintering as adult	Oligophagous (Frangula alnus, Rhamnus cathartica)	Cryptic (green color), parasitoids include hymenopterans e.g.: Cotesia gonepterygis, Hyposoter rhodocerae	Wing span: 48-55 mm, good disperser,often observed in a distance from caterpillar sites, long lived, nectar generalist, overwinter is the leaflitter		Shaw et al. (2009), Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015)
Polyommatus icarus	Max F%=53 (Maratońska) Min F%= 39	Bivoltine/Trivoltine, single eggs lied on the leafs and flowers,	Polyphagous on various Fabaceae: Lotus, Medicago, Trifolium, Coronilla, foliovorous	Cryptic (green color), nocturnal, parasitoids include	Wing span: 28-32 mm, small wing surface, good	Caterpillar development might be	Goverde et al. (2000), Shaw et al. (2009),

Species	Total abundance and frequency of occurrence on sites	Life cycle	Host plants relationships	Caterpillars	Adults and their flight performance	Other	References
	(Traktorowa) TA= 340	pupation on the ground	and florivorous	Cotesia, Hyposoter notatus, Virgichneumon tergenus	disperser,nectar generalists, prefers Fabaceae including caterpillar host plants, but also Achillea, Thymus, Hieracium, territorial males	affected by presence of soil mycorrhizal fungi, phosphorous concentrations and carbon/nitrogen ratio in leafs, wide habitata preferences, facultative myrmecophile associated with Lasius, Formica and Myrmica	Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Warecki (2010)
Aricia agestis	Max F%= 53 (Maratońska) Min F%= 16 (Telefoniczna) TA= 152	Bivoltine/Trivoltine, single egg lying on leafs, stems or floers, pupation on the ground, overwintering in caterpillar stage on the ground	Oligophagous: Geranium, Erodium cicutarium, Helianthemum nummularium, foliovorous and florivorous	Cryptic (green color), diurnal, parasitoids include Cotesia	Wing span: 24-27 mm, small wing Surface, good disperser, probably nectar generalist: Jasione montana, Veronica spicata, Berteroa incana, Eupatorium cannbinum	Facultative myrmecophile associated with Lasius and Myrmica	Shaw et al. (2009), Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Bury et al. 2016
Vanessa cardui	Max F%= 38 (Rogi) Min F%=24 (Traktorowa) TA= 330	Univoltine, single egg lying on plants, does not overwinter in Poland, pupation on plants	Polyphagous, associated with Cirsium, Carduus, Carlina, Arctium, Artemisia, Urtica, Cynoglossum	Solitary, hidden in the leafs, diurnal, parasitoids include Cotesia, Pteromalus puparum, Thyrateles camelinus	Wing span: 55-60 mm, fast flyer, good disperser, migratory, nectar generalist, Trifolium, Jasione, Centaurea, Eupatorium, Cirsium	oogenesis–flight syndrome (females are able to locate potential breeding areas and host plant sites)	Shaw et al. (2009), Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Stefanescu et al. 2021
Aglais io	Max F%= 33 (Telefoniczna) Min F%= 17	Univoltine/Bivoltine, adult overwintering, often in agggregations at	Monophagous/Oligophagous, (*Urtica dioica, Humulus lupulus*)	Gragarious up to fifth instar, often in the webing,	Wing span: 56-64mm, fast flyer, good disperser, long	caterpillar development might be	Pullin 1986, 1987, Pullin and Bale 1998, Bryant et

Species	Total abundance and frequency of occurrence on sites	Life cycle	Host plants relationships	Caterpillars	Adults and their flight performance	Other	References
	(Rogi) TA= 133	ceilings or in basements, lipid accumulation before wintering, 200-600 eggs attached to leafs, pupae attached to plants, walls and other surfaces		caterpillar for about 4 weeks, exposed on plant leafs, not aposematic, increased temperatures might shorten development and affcet size and survival of the adults, parasitoids like hymenopterans Apechthis compunctor,, Thyrateles haereticus and Phobocampe confusa and tachinid flies e.g. Pelatachina tibialis or Sturmia bella, not parasitetized by braconids	lived, cryptic while resting, startle display and sound defence against rodents during overwintering and againts the birds but not against hornets, winter survival is reduced in higher temperatures, flower preferences generalist although with affinity to violet color	infuenced by changes in nitrogen-phosphorous ratio, higher lipid content and wing loadings outside the urban gardens	al. 2000, Vallin et al. (2005), Wiklund (2005), Shaw et al. 2009, Olofsson et al. (2011, 2012), Nijssen et al. 2017, Schäpers et al. 2015, Audusseau et al. 2015 2021, Buszko and Masłowski 2015, Sielezniew and Dziekanska 2010, 42. Serruys et al. 2014
Coenonympha pamphilus	Max F%=82 (Maratońska) Min F%= 51 (Brukowa) TA= 1247	Bivoltine/trivolitine, single egg lying on host plants, close to the ground, pupation on plants, overwintering in caterpillar stage on the ground	Oligophagous but associated only with grassess: Festuca rubra, Poa pratensis, Nardus stricta	Cryptic (green color), nocturnal, parasitoids include Casinaria petiolaris, Hoplismenus axillatorius,	Wing span: 30-34 mm, smal wing Surface, moderately good disperser, nectar generalist (Medicago, Trifolium, Achillea, Veronica, Jasione, Calluna, Sambucus), teritorial males,	wide habitata preferences	Shaw et al. (2009), Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Warecki 2020
Aphantopus hyperantus	Max F%= 34 (Traktorowa) Min F%=18	Univoltine, egg droped into the ground, pupation on grassess,	Polyphagous but associated only with grassess: Calamagrostis epigejos, Bromus	Solitary, nocturnal, camouflage (brown color), parasitoids:	Wing span: 36-44 mm, moderately good disperser,	Young caterpillars can survive short	Shaw et al. (2009), Sielezniew and

Species	Total abundance and frequency of occurrence on sites	Life cycle	Host plants relationships	Caterpillars	Adults and their flight performance	Other	References
	(Maratońska) TA= 464	close to the ground, overwintering in caterpillar stage	erectus, Festuca rubra, Holcus mollis)	Erigorgus foersteri	large wing surface, nectar generalist with preference to violet and white flower color: Cirsium, Origanum, Eupatorium, Achillea, Heracleum	periods (1-2 days) of starvation, wide habitatat preferences, avoids very hot and dry sites	Dziekańska (2010), Buszko and Masłowski (2015), Warecki 2020
Maniola jurtina	Max F%= 54 (Traktorowa) Min F%=33 (Brukowa) TA= 1455	Univoltine, Temprature infuence on development, geographical variability in phenology, influence of site topograhy of phenology, synchronized flight period, single egg lying on host plants or droped on the ground, close to the ground, pupation on plants close to the ground, overwintering as Caterpillar, protandry	Polyphagous although related to one plan family (Grasses e.g. Festuca rubra, Poa pratensis, Bromus erectus, Lolium perenne)	Solitary, camouflage (green color), nocturnal, hidden in the liter during the day, hod and dry summer may decrease caterpillar survival rate, Parasitoid hymenoptera: e.g. Campoletis annulata, Hyposter	Wing span: 40-52 mm, cryptic coloration, large wing surface, low flight performance, relatively good disperal abilities although along the grassland habitats, Nectar generalist but with clear preferences for selected plants, puddling behavior	Moderately resistant to pollution, broad habitat prferences, moving practice may positively infuence survival	Brakefield 1982, 1987, Merckx and Van Dyck (2002), Shaw et al. 2009, Sielezniew and Dziekańska 2010, Warecki 2010, Kulfan et al. 2012, Lebeau et al. (2015, 2017), Buszko and Masłowski 2015, Villemey et al. 2016, Krajcik et al. 2016, Greenwell et al. 2021.
Melanargia galathea	Max F%= 33 (Rogi) Min F%= 26 (Brukowa) TA= 446	Univoltine, eggs droped on the ground, pupation on the ground, overwinetering in Caterpillar stage	Polyphagous but associated only with grassess: Festuca rubra, Poa pratensis, Agrotis capillaris, Brachypodium pinnatum)	Cryptic, nocturnal, parasitoids Erigorgus melanops	Wing span: 44-50 mm, large wing Surface, good disperser, slow flying, nectar generalist Centaurea, Jasione montana, Cirsium, Knautia arvensis, puddling behavior		Shaw et al. (2009), Habel et al. 2010, Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Warecki 2020
Species frequent and/or abundant on at least one site							
Lycaena phleas	Max F%= 63	Bivoltine/trivoltine,	Oligophagous (Rumex),	Cryptic (green	Wing span: 25-30	Wide habitat	Sielezniew and

Species	Total abundance and frequency of occurrence on sites	Life cycle	Host plants relationships	Caterpillars	Adults and their flight performance	Other	References
	(Maratońska) Min F%=14 (Rogi) TA= 176	overlaping generations, single egg lying on host leafs, pupation on the ground under the leafs of Rumex, overwintering in caterpillar stage		color), diurnal	mm, smal wing Surface, good disperser, atracted to Jasione montana, Achille millefolium, Thymus serpyllum, teritorial males	preferences	Dziekańska (2010), Buszko and Masłowski (2015), Warecki 2020
Lycaena tityrus	Max F%= 62 (Maratońska) Min F%=10 (Rogi) TA= 245	Bivoltine/trivoltine, single egg lying on leafs, pupation on the ground under the leafs, overwintering in caterpillar stage	Oligophagous (Rumex),	Cryptic (green), diurnal, crepuscular, parasitoids Ichneumon sculpturatus	Wing span: 27-30 mm, small wing surface, nectra generalist Thymus serpyllum, Achillea millefolium, Tanacetum vulgare, Solidago virgaurea, Eupatorium cannabium, teritorial males		Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Warecki 2020
Polyommatus coridon	Max F%=47 (Maratońska) Min F%=0 (all other sites) TA= 485	Univoltine, single egg lying on leafs and stems, pupation in chamber build by ants, overwintering in egg stage	Monophagous: Coronilla varia, foliovore and florivore	Cryptic, nocturnal, burried by ants during the day	Wing span: 33-37 mm, small wing Surface, moderately good disperser, visits flowers of Lotus corniculatus, Centaurea, and Origanum vulgare puddling behawior, puddling behavior	Facultative myrmecophile associated with Lasius, Myrmica, Tetramorium, Tapinoma. Relatively narrow habitat preferences, mostly dry meadows	Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Warecki 2020
Cupido argiades	Max F%= 40 (Rogi) Min F%= 0 (Traktorowa) TA= 86	Bivoltine/trivoltaine, overlapping generations, single egg lying on flower buds, pupation on plants, overwintering in Caterpillar stage in the litter	Polyphagous but associated only with Fabaceae: Lotus, Medicago, Trifolium, florivore, feeding also on young fruits	Cryptic, diurnal, crepuscular, parasitoids include Ichneumon exilicornis, Cotesia	Wing span: 20-28 mm, good disperser, feeds on yellow flowers, mostly Fabaceae including caterpillar host plants, teritorial males	Termophilous, facultative myrmecofile associated with Formica and Lasius	Shaw et al. (2009), Sielezniew and Dziekańska (2010), Buszko and Masłowski (2015), Warecki 2020

Altogether 46 species were recorded at all 5 sites. Thirty species were included into oligophagous group. Maximum richness of the group was detected on Maratońska (15 species), Brukowa (12 species) and Rogi (12 species) in July. Species representing this functional trait were absent on the first visit of 2019 in April at Rogi and Telefoniczna. Fifteen polyphagous species were recorded. Again, the highest number of polyphagous species was detected at Maratońska in July (8 species), while absence of the group was observed at 9 visits on April (at Maratońska and Brukowa), May (Rogi, Brukowa, Maratońska), June (Brukowa and Telefoniczna) and August (Traktorowa and Rogi). Thirteen species were recognized as butterflies with small wing span (<33 mm). Seven species of small-winged butterflies were found at Maratońska, Brukowa and Telefoniczna in July. The representatives of this group were absent at all five sites during twenty two visits, mostly in spring. There were 22 species of butterflies with average wing span (between 33 and 52 mm) recorded. The highest number of species from this group was found at Maratońska in July during two visits (12 and 10 species, respectively) as well as at Traktorowa (10 species). Average wing span butterflies were absent during visits in May and June at all investigated

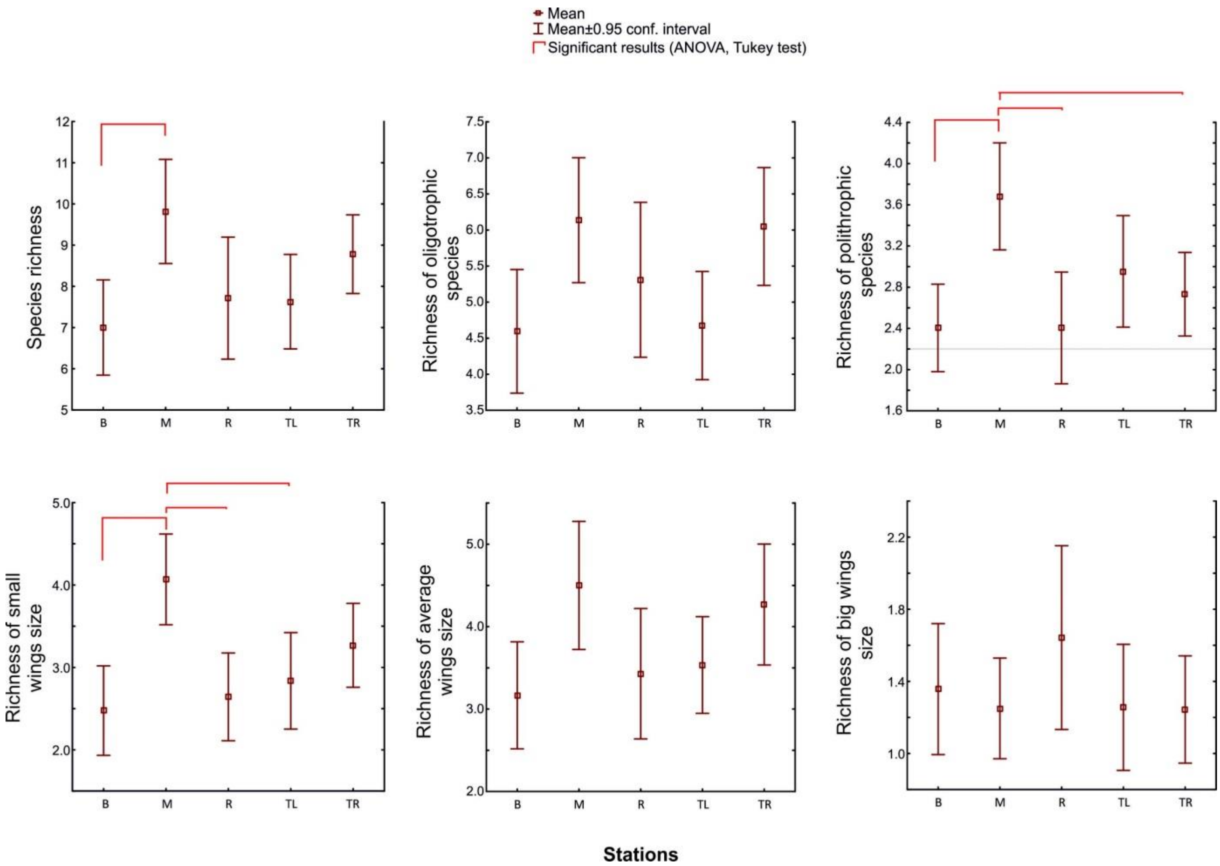

Fig. 1 Species richness of selected functional groups of butterflies (mean with 95% confidence limits), statistically significant differences are marked by strait lines.

sites. Ten species were classified as butterflies with large wing span (>53 mm) and reached the highest richness during three visits at Rogi site in July (5, 5 and 7 species respectively).

Overall species richness significantly differed between Brukowa (mean±SD: 7.0±3.7) and Maratońska (mean±SD: 9.8±4.2). There were no statistically significant differences between richness of oligophagous species. Maratońska (mean±SD: 3.7±1.7) was characterized by significantly higher mean species richness of poliphagous species than Brukowa (mean±SD: 2.4±1.4), Rogi (mean±SD: 2.4±1.7) and Traktorowa (mean±SD: 2.7±1.3). Mean species richness of small winged butterflies at Maratońska (mean±SD: 4.1±1.8) was significantly higher than at Brukowa (mean±SD: 2.5±1.7), Rogi (mean±SD: 2.6±1.7) and Telefoniczna (mean±SD: 2.8±1.9). There were no significant differences between analyzed stations for butterflies with average and large wings span (Fig. 2).

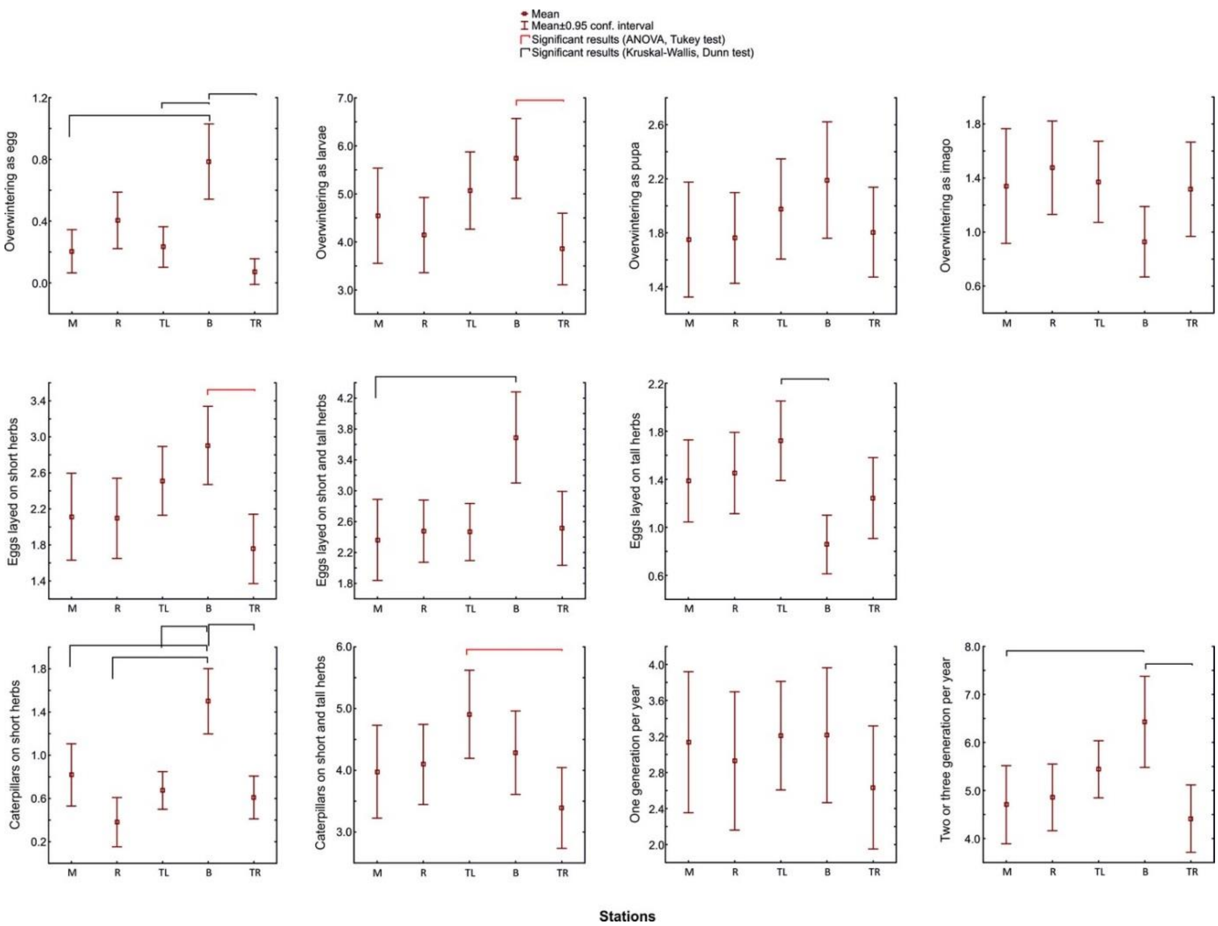

Fig. 2 Species richness of selected functional groups of butterflies (mean with 95% confidence limits), statistically significant differences are marked by strait lines.

We have recorded five species overwintering as eggs and 25 overwintering in the larval stage. Mean species richness of butterflies overwintering as eggs was significantly higher at Brukowa site (0.79±0.79) than at Maratońska (0.20±0.41), Telefoniczna (0.23±0.43) and Traktorowa (0.07±0.26). Richness of species overwintering in the larval stage was significantly higher at Brukowa (5.74±2.67) than at Traktorowa (3.85±2.36). There were no statistically significant results for butterflies overwintering in the pupal and adult stage.

Ten species were characterized by egglaying only on short herbs and grasses, 15 were categorized as lying eggs at short and tall herbs and 8 species were characterized by egglaying only on tall herbs. Mean species richness of butterflies characterized by egglaying only on short herbs and grasses was significantly lower on Traktorowa (1.76±1.22) than on Brukowa (2.90±1.39). Significant differences were also found between Brukowa (3.69±1.89) and Maratońska for mean species richness of species laying eggs at short and tall herbs. Species richness of species laying eggs only on tall herbs was significantly higher at Telefoniczna (1.72±1.08) than at Brukowa (0.86±0.78).

Eight species feeding at short herbs and grasses were recorded in the studied material. Nineteen species of butterflies were feeding on hostplants classified as short herbs and grasses or tall herbs and grasses. Species richness of species feeding at short herbs and grasses was significantly higher at Brukowa (1.50±0.97) than at Maratońska (0.82±0.97), Rogi (0.38±0.73), Traktorowa (0.61±0.63) and Telefoniczna (0.67±0.57). In case of richness of buttefflies feeding at short herbs and grasses or tall herbs and grasses statistically significant differences were found between Telefoniczna (4.91±2.32) and Traktorowa (3.39±2.07).

There were no statistically significant differences between sites in terms of richness of univoltine butteflies. Significant differences were recorded for richness of polivoltine butteflies between Brukowa (6.43±3.05) and Maratońska (4.70±2.67) as well as Traktorowa (4.41±2.22) (Fig. 3).

Results of web visualizations for butterfly abundance at each site and for occurrence of plants demonstrated a complicated web of interactions (Fig. 4, 5).

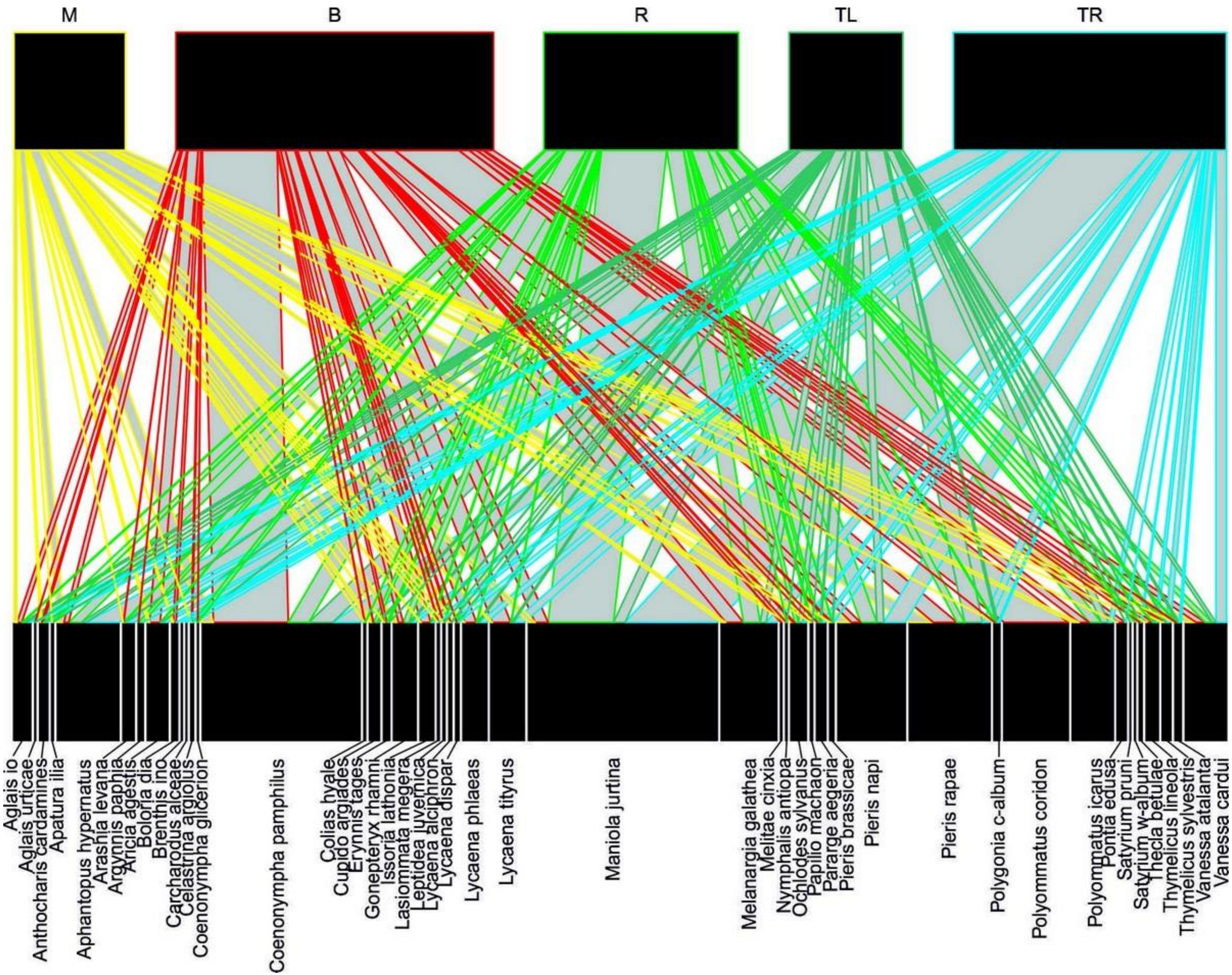

Fig. 3 Bipartite graph showing affinities between butterfly species and investigated sites.

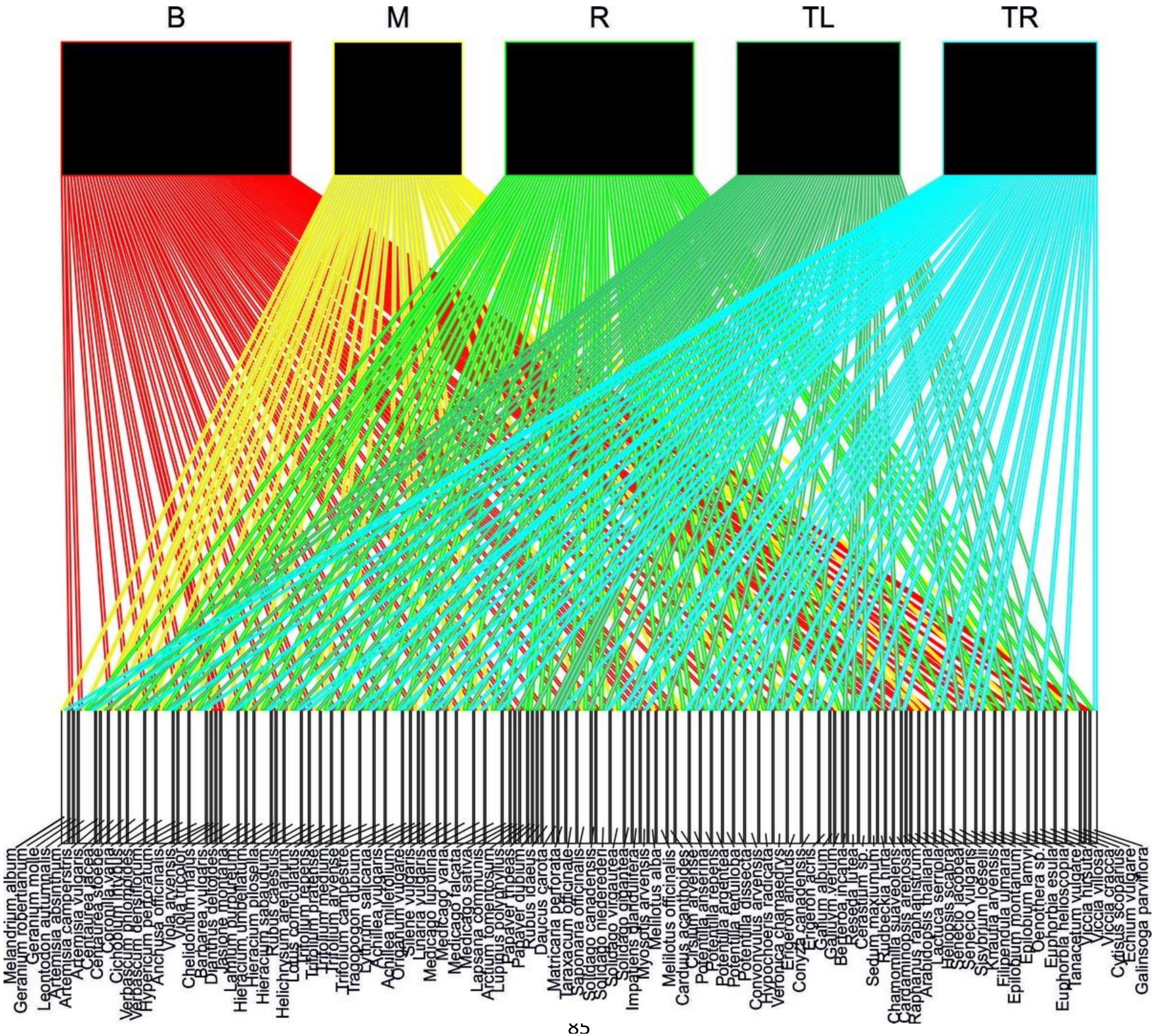

Fig. 4 Bipartite graph showing affinities between plant species and investigated sites

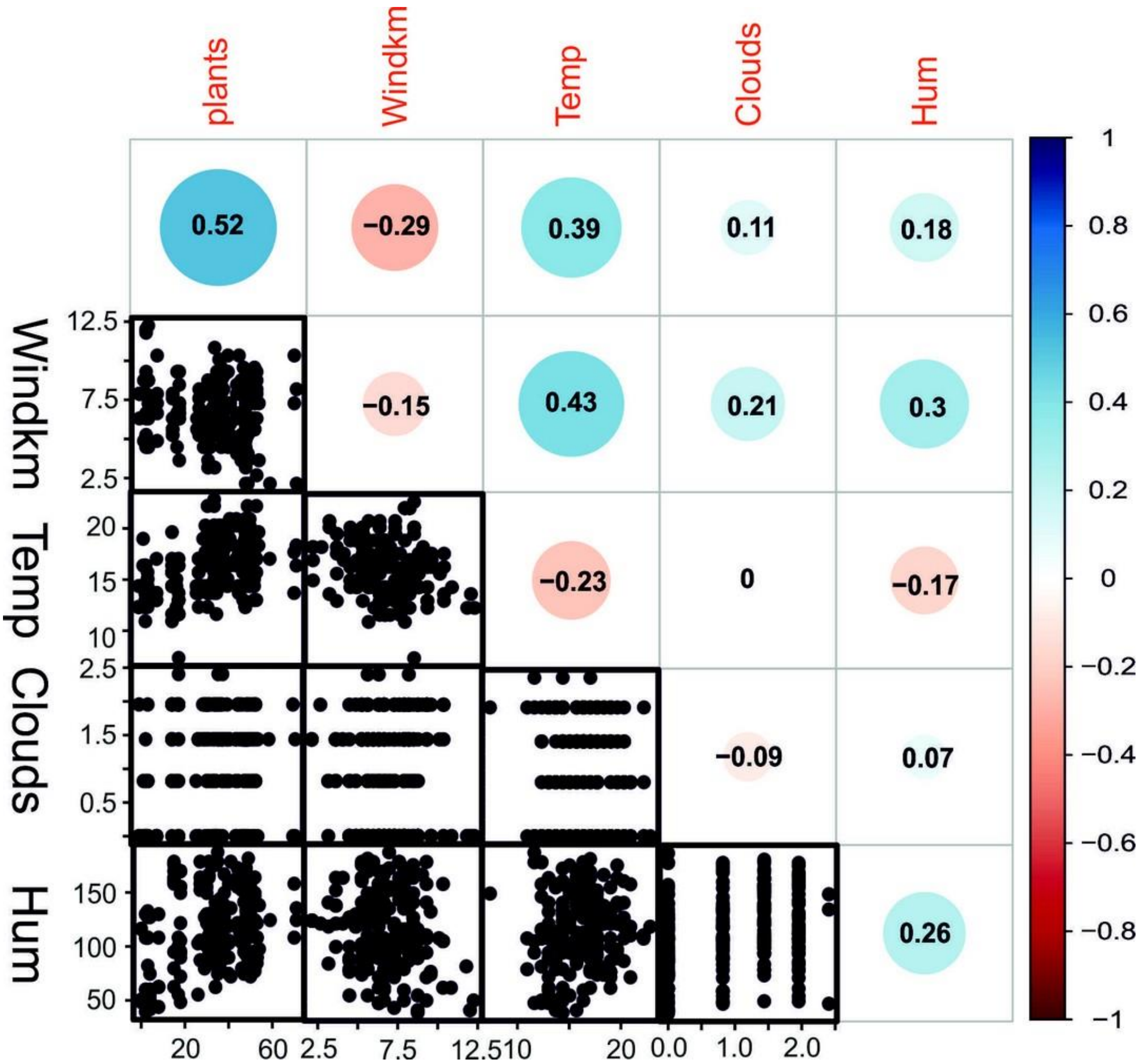

Fig. 5 Pearson correlation matrix of selected variables and indices describing diversity of butterflies and plants on analyzed sites. Distribution of indices was based on observations from visits on all sites. Note that only flowering plant were identified to the species or morphospecies level on each site.

Pearson correlation matrix showed low correlation between analyzed environmental variables (Fig. 6). Results of CCA showed that the highest number of species was detected in samples from July (Fig. 7). Samples were grouped by season rather than sites. Richness of flowering plants had influence on butterfly species richness, however the analysis explained only 9% of variance. Two groups were established along CCA axis 1. The first one (right part of gradient) grouped samples characterized by the highest richness of butterflies and flowering plants (summer time - mostly from July). Second group was characterized by lower richness of butterflies and flowering plants (spring - April and May; early summer – June; late summer – August and September). Three groups were distinguished along CCA axis 2. First one, located in the upper part of gradient contained samples characterized by higher temperatures, humidity and cloudiness, mostly from June and August. The second group contained samples from July and September, while third grouped samples from spring (April and May) which were characterized by lower temperatures, humidity and cloudiness. A set of three most parsimonious models, containing all five variables best explained richness of butterflies (Table 2, 3, Fig. 8). However, due to statistical significance of random intercept, the results were characterized by high uncertainty (Table 2). Hierarchical partitioning indicated that richness of flowering plants (relative contribution: 57.22%) and temperature (relative contribution: 23.34%) had positively significant influence on richness of butterflies, while wind speed (relative contribution: 13.81) had negative contribution (Fig. 8, Fig. 13).

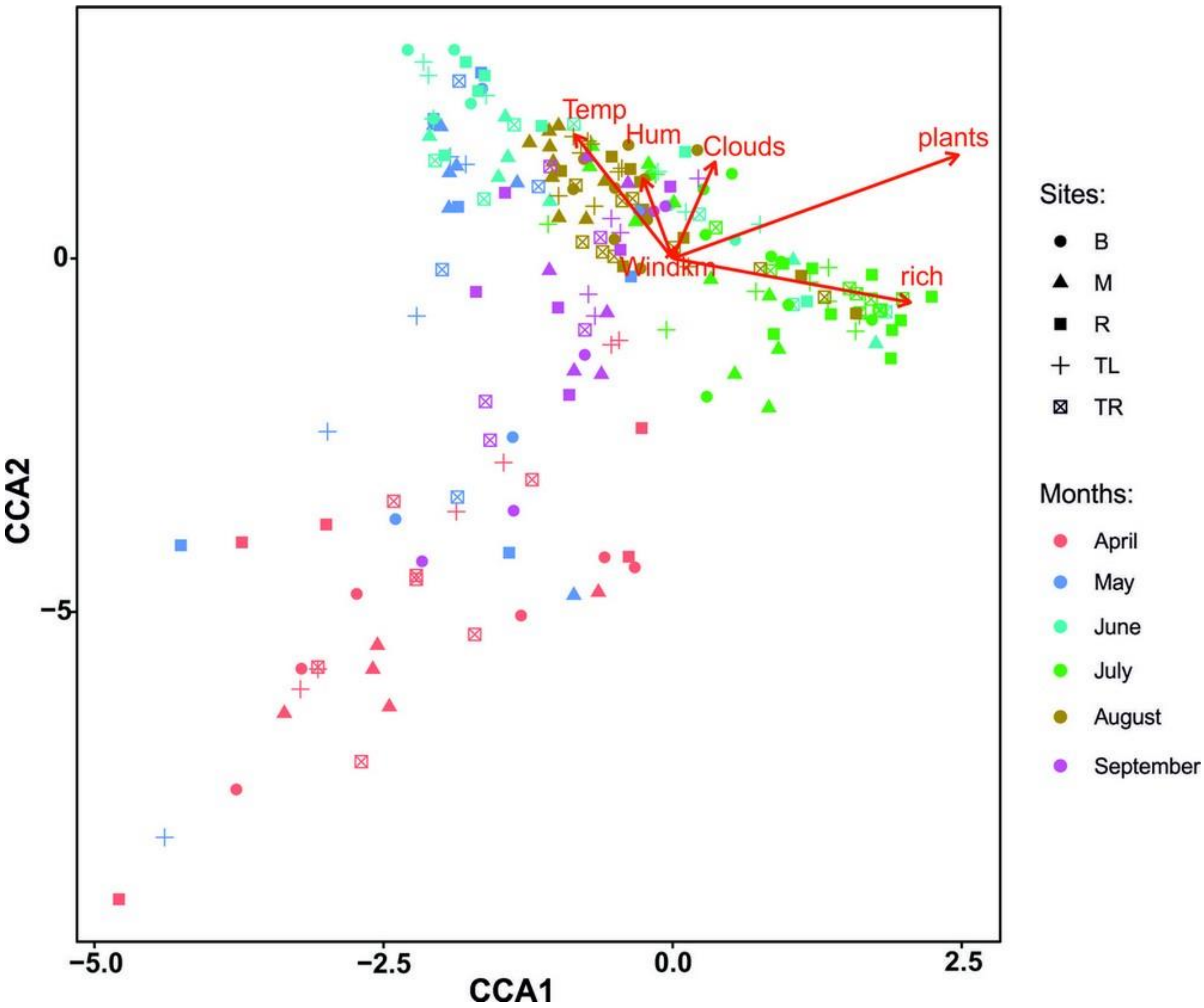

Fig. 6 Canonical correspondence analysis (CCA) with environmental factors as red arrows

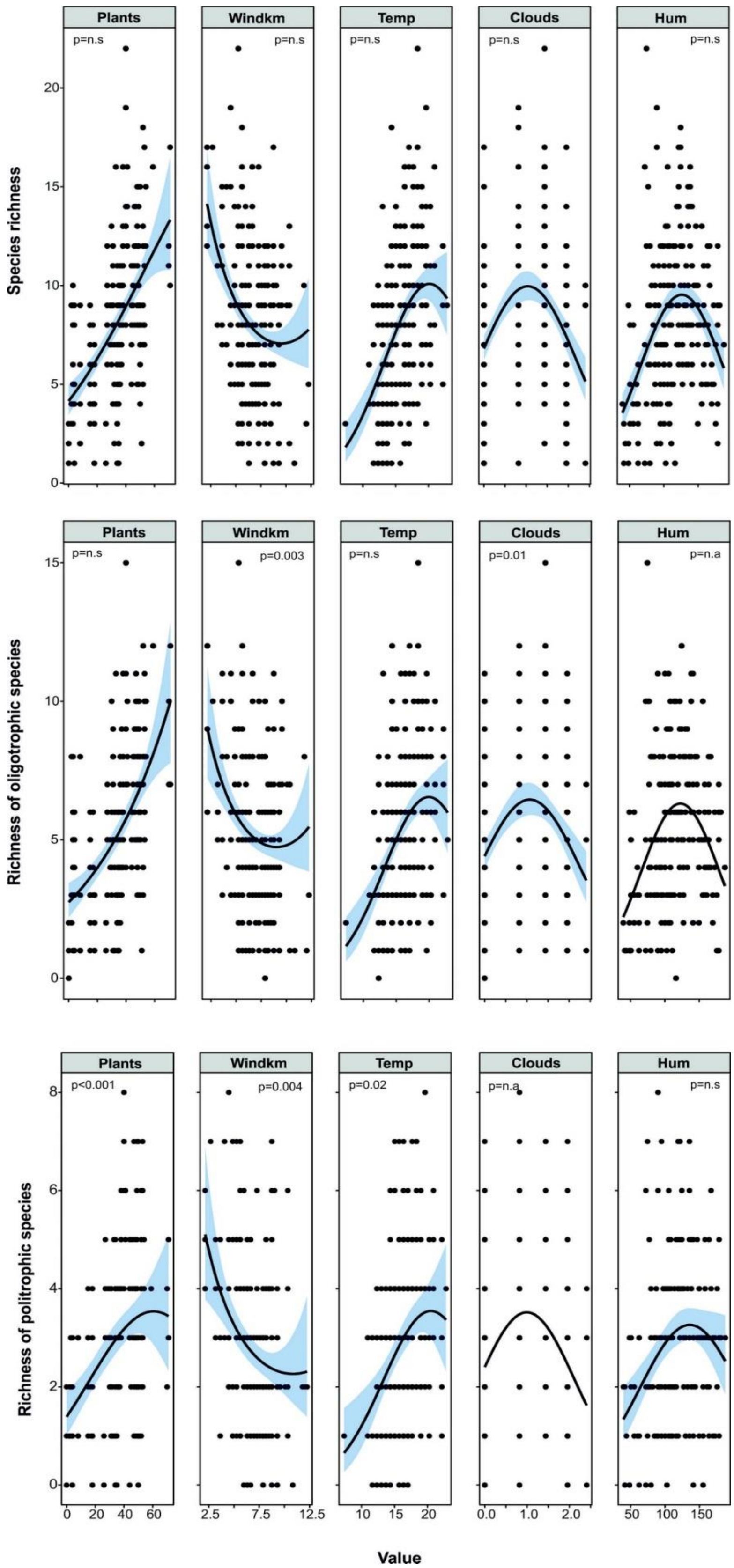

Fig. 7 Visualization of models testing for effects of environmental factors on species richness as well as richness of oligophagous and polyphagous species Code "n.a." indicates that predictor was not included in a set of the most parsimonious models. Code "n.s." indicates that predictor was included in a set of the most parsimonious models, but its explanatory power was not significant. Note that lack of significance of all factors resulted from significant result of random intercept.

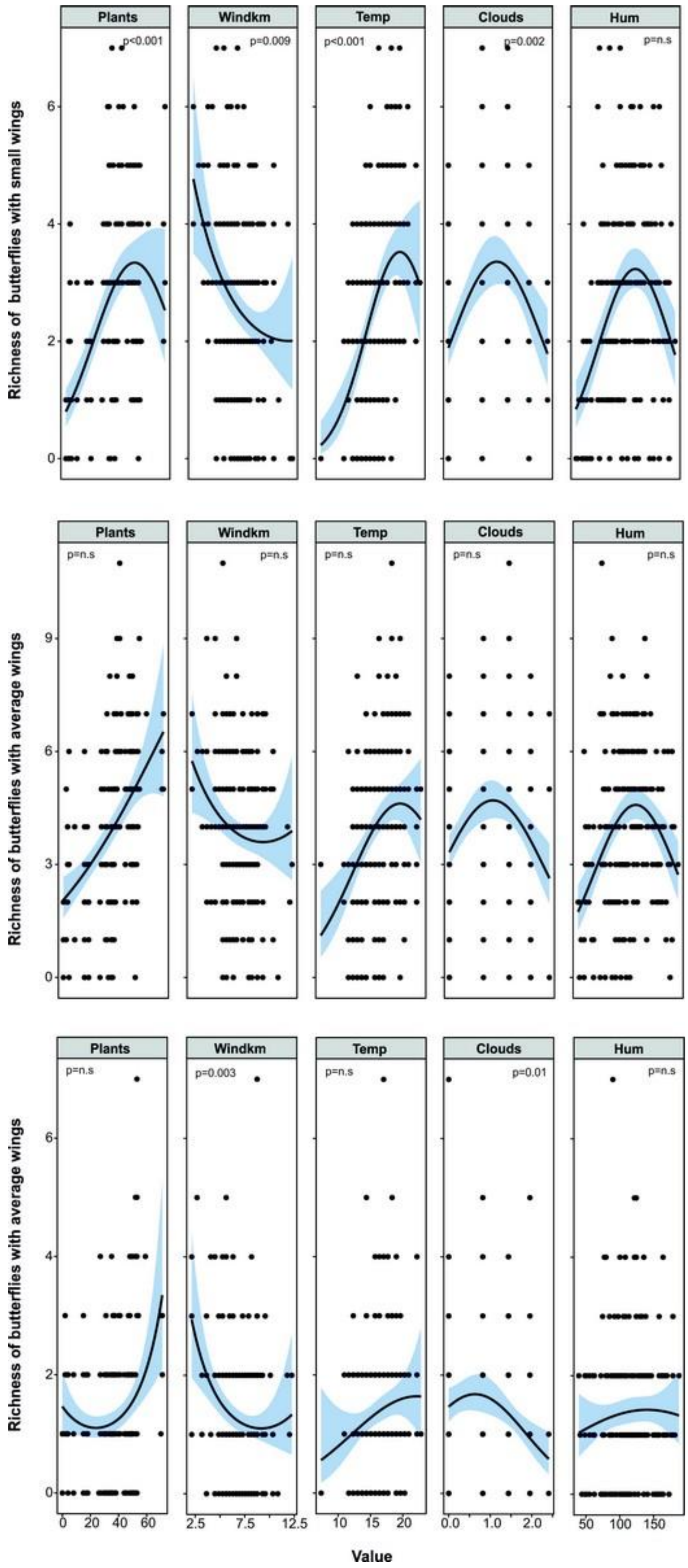

Fig. 8 Visualization of models testing for effects of environmental factors on butterflies divided by average wings lenght: small, average and large wings. Code "n.a." indicates that predictor was not included in a set of the most parsimonious models. Code "n.s." indicates that predictor was included in a set of the most parsimonious models, but its explanatory power was not significant. Note that lack of significance of all factors resulted from significant result of random intercept.

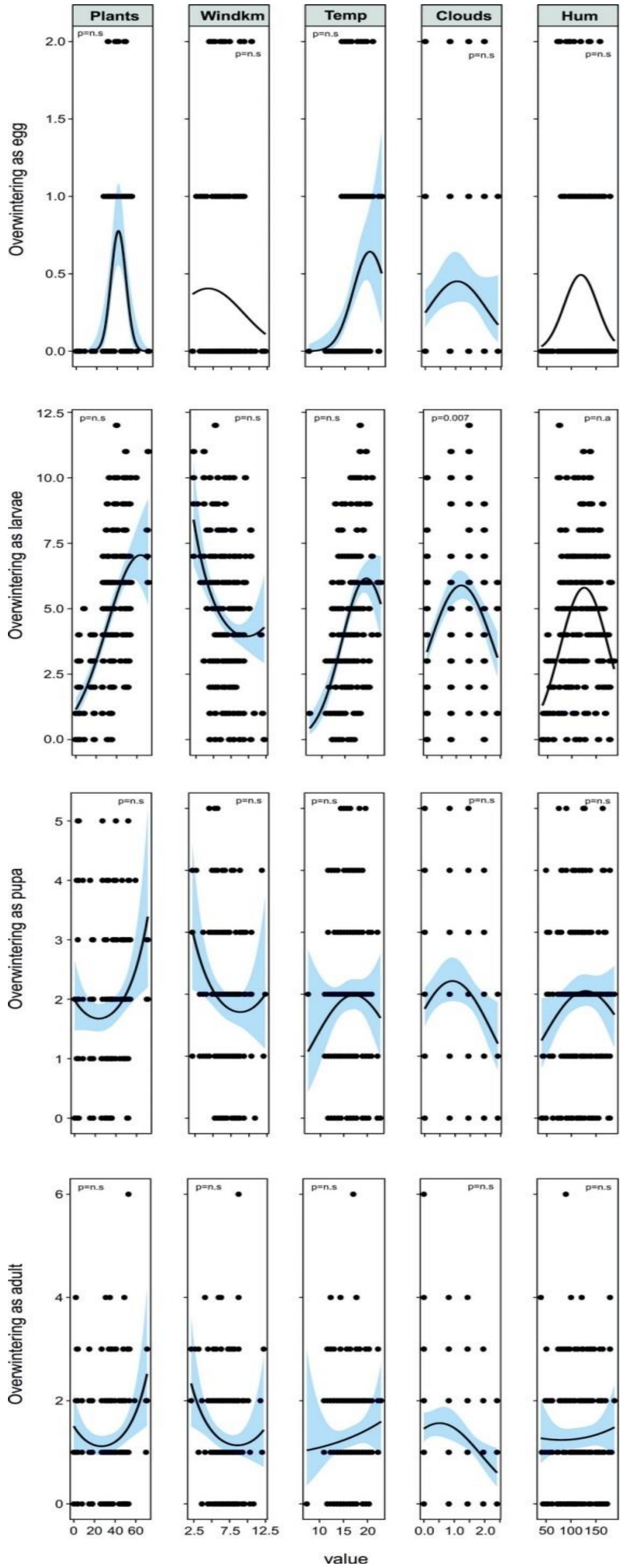

Fig. 9 Visualization of models testing for effects of environmental factors on each wintering stadiums of butterflies. Code “n.a.” indicates that predictor was not included in a set of the most parsimonious models. Code “n.s.” indicates that predictor was included in a set of the most parsimonious models, but its explanatory power was not significant. Note that lack of significance of all factors resulted from significant result of random intercept.

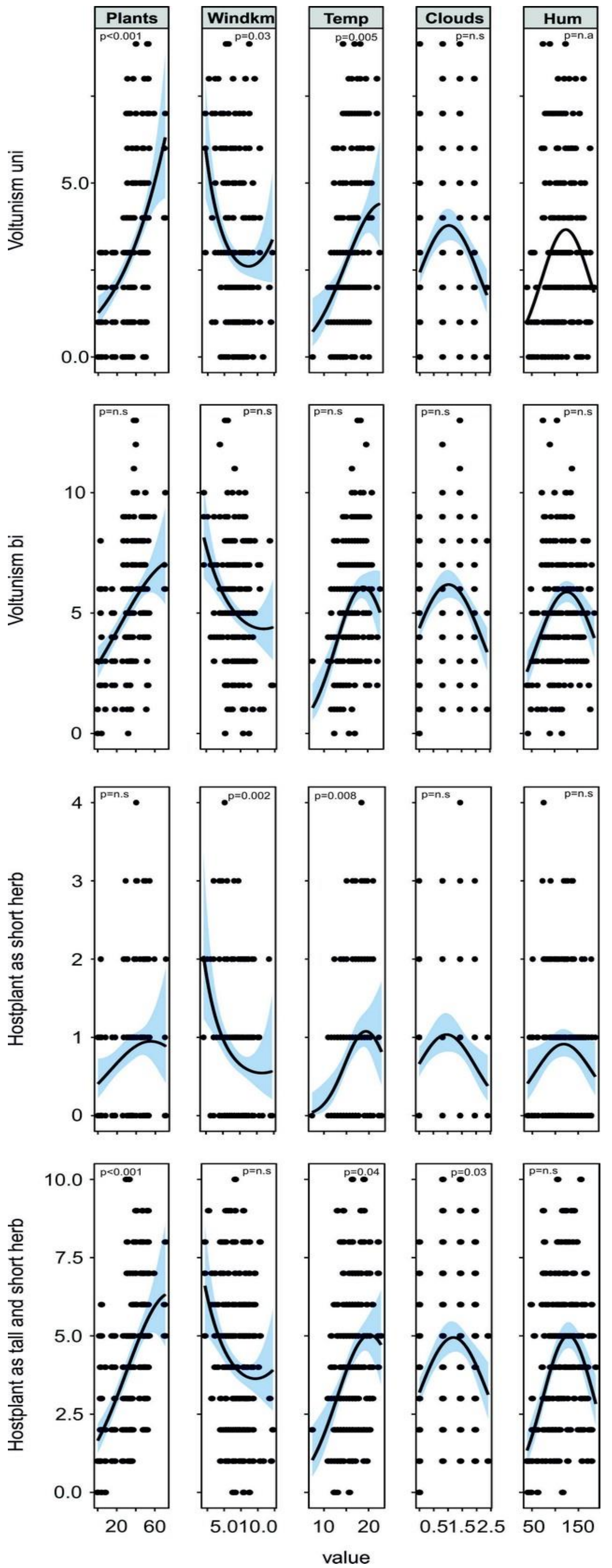

Fig. 10 Visualization of models testing for effects of environmental factors on the most representative (represented by the highest number of species) types of hostplants and number of generations per year. Code "n.a." indicates that predictor was not included in a set of the most parsimonious models. Code "n.s." indicates that predictor was included in a set of the most parsimonious models, but its explanatory power was not significant. Note that lack of significance of all factors resulted from significant result of random intercept.

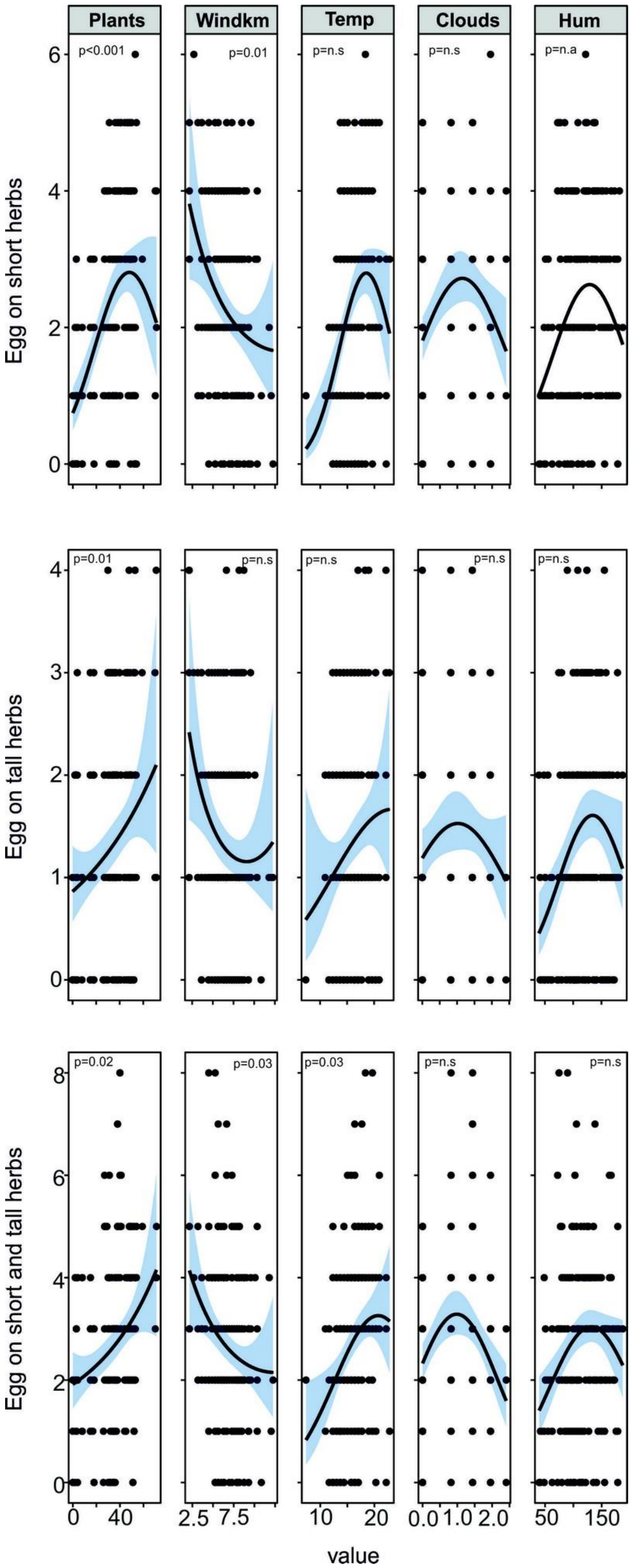

Fig. 11 Visualization of models testing for effects of environmental factors on the most representative (represented by the highest number of species) egg laying types. Code "n.a." indicates that predictor was not included in a set of the most parsimonious models. Code "n.s." indicates that predictor was included in a set of the most parsimonious models, but its explanatory power was not significant. Note that lack of significance of all factors resulted from significant result of random intercept.

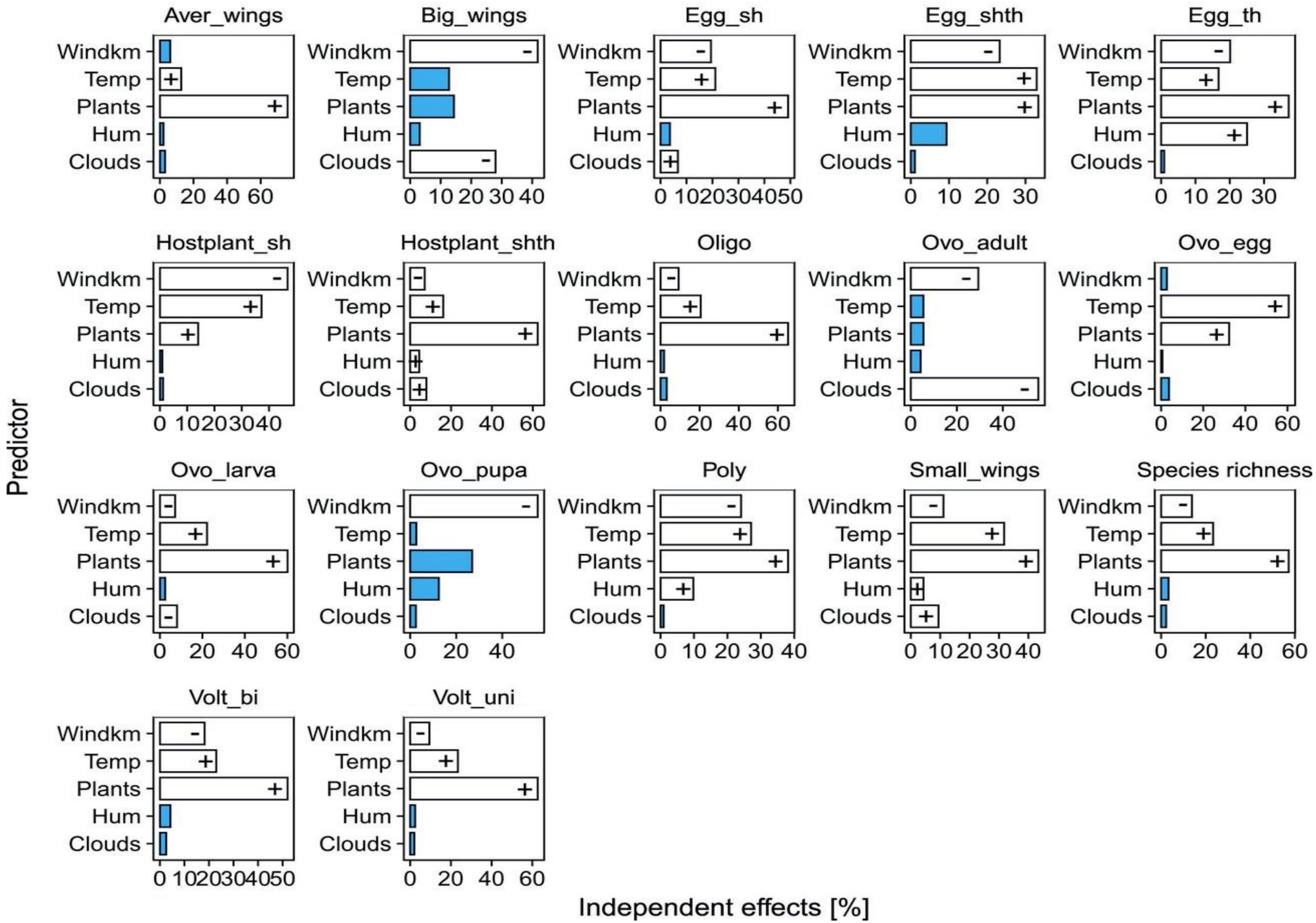

Fig. 12 Relative contribution of each predictor to shared variability of full models testing for effects of environmental factors on species richness, richness of oligophagous and polyphagous species, butterflies divided by average wings length, wintering stadiums of butterflies, egg laying types, types of hostplants and number of generations per year. Plus (+) signs indicate positive impact of predictors on response variables and minus (-) signs indicate negative impacts. For full names of variables see Table 1.

Table 7 Species richness, environmental variables and functional traits used in analysis with mean, standard deviation and maximum values

Variable	Code	Mean±SD	Max
Species richness	rich	8.19±4.00	22
Richness of flowering plants	plants	33.69±16.51	71
Wind speed [km/h]	Windkm	14.86±5.72	35
Temperature [°C]	Temp	21.82±3.95	32
Cloudiness	Clouds	1.40±1.17	4
Humidity [%]	Hum	52.16±12.85	78
Richness of oligophage species	Oligo	5.35±2.88	15
Richness of polyphage species	Poly	2.84±1.64	8
Richness of species with small wings	Small_wings	3.05±1.84	7
Richness of species with average wings	Aver_wings	3.78±2.33	12
Richness of species with big wings	Big_wings	1.35±1.18	7
Richness of species overwintering as adult	Ovo_adult	1.30±1.11	6
Richness of species overwintering as egg	Ovo_egg	0.34±0.58	2
Richness of species overwintering as larvae	Ovo_larva	4.66±2.77	12
Richness of species overwintering as pupa	Ovo_pupa	1.90±1.23	5
Richness of species with one generation per year	Volt_uni	3.03±2.31	9
Richness of species with two generations per year	Volt_bi	5.16±2.53	13
Richness of species feeding at short herbs	Hostplant_sh	0.80±0.86	4
Richness of species feeding at short and tall herbs	Hostplant_shth	4.13±2.26	10
Richness of species laying eggs on short herbs	Egg_sh	2.27±1.43	6
Richness of species laying eggs on short and tall herbs	Egg_shth	2.70±1.61	8
Richness of species laying eggs on tall herbs	Egg_th	1.33±1.06	4

Table 8 Estimates of function slopes of variables present in set of most parsimonious models testing for impacts of environmental variables (fixed effects) on parameters of species richness, oligophagous and polyphagous caterpillars, wings length (small, average and large), overwintering stadium, number of generations per year, hostplant type, egg laying location). For testing impacts of environmental variables generalized mixed effects model with Poisson distribution was employed.

	Fixed effects	**Estimate**	**SE**	**z**	**Pr(>|z|)**
Species richness	(Intercept)	1.32	0.21	6.1	**0.001**
	Plants	0.01	0.002	7.9	**0.001**
	Temp	0.03	0.01	3.3	**0.001**
	Windkm	-0.05	0.01	3.5	**0.001**
	Clouds	0.04	0.03	1.3	0.18
	Hum	0.0001	0.00007	0.70	0.49
Richness of oligophagous species	(Intercept)	0.84	0.33	2.6	**0.01**
	Plants	0.02	0.002	7.1	**0.001**
	Temp	0.03	0.01	2.4	**0.02**
	Windkm	-0.04	0.02	1.2	**0.02**
	Clouds	0.05	0.04	1.2	0.22
	Hum	-0.0004	0.0001	0.4	0.68

	Fixed effects	Estimate	SE	z	Pr(>|z|)
Richness of polyphagous species	(Intercept)	0.41	0.45	0.9	0.36
	Plants	0.01	0.003	3.4	**0.001**
	Temp	0.04	0.02	2.3	**0.02**
	Windkm	-0.07	0.02	2.9	**0.004**
	Clouds	0.02	0.06	0.3	0.74
	Hum	0.002	0.001	1.5	0.14
Butterflies with small wings	(Intercept)	-0.56	0.38	1.5	0.14
	Plants	0.01	0.003	5.0	**0.001**
	Temp	0.08	0.02	4.3	**0.001**
	Windkm	-0.05	0.02	2.4	**0.01**
	Clouds	0.17	0.06	3.0	**0.003**
	Hum	0.0008	0.001	0.6	0.53
Butterflies with average wings	(Intercept)	0.76	0.26	2.7	**0.004**
	Plants	0.02	0.002	6.6	**0.001**
	Temp	0.01	0.02	0.9	0.35
	Windkm	-0.03	0.02	1.5	0.14
	Clouds	44.8	66.7	0.6	0.51
	Hum	-0.0003	0.001	0.3	0.78
Butterflies with large wings	(Intercept)	0.75	0.46	1.6	0.11
	Plants	0.007	0.004	1.8	0.07
	Temp	0.03	0.03	1.0	0.33
	Windkm	-0.1	0.03	3.0	**0.003**
	Clouds	-0.21	0.08	2.5	**0.01**
	Hum	0.001	0.002	0.7	0.46

Overwintering as egg	(Intercept)	-5.10	1.00	5.08	**0.001**
	Plants	0.02	0.01	2.27	**0.02**
	Temp	0.19	0.05	3.68	**0.001**
	Windkm	-0.02	0.06	0.30	0.77
	Clouds	0.21	0.17	1.24	0.21
	Hum	-0.001	0.004	0.20	0.84
Overwintering as larvae	(Intercept)	-0.07	0.31	-0.24	0.81
	Plants	0.02	0.002	8.61	**0.001**
	Temp	0.06	0.01	4.16	**0.001**
	Windkm	-0.04	0.02	-2.46	**0.01**
	Clouds	0.16	0.05	3.39	**0.001**
	Hum	-0.0002	0.001	-0.17	0.87
Overwintering as pupa	(Intercept)	0.80	0.34	2.32	**0.02**
	Plants	0.004	0.003	1.26	0.21
	Temp	-0.002	0.02	0.07	0.94
	Windkm	-0.05	0.03	1.91	0.06
	Clouds	-0.02	0.07	0.28	0.78
	Hum	0.001	0.002	0.81	0.42
Overwintering	(Intercept)	0.58	0.45	1.28	0.20

	Fixed effects	Estimate	SE	z	Pr(>|z|)
as adult	Plants	0.004	0.004	1.07	0.29
	Temp	0.01	0.03	0.48	0.63
	Windkm	-0.07	0.03	1.97	**0.05**
	Clouds	-0.22	0.08	2.61	**0.009**
	Hum	0.002	0.002	0.96	0.34
Voltinism uni	(Intercept)	-0.15	0.41	0.36	0.72
	Plants	0.02	0.003	6.55	**0.001**
	Temp	0.05	0.02	2.72	**0.006**
	Windkm	-0.05	0.02	2.13	**0.03**
	Clouds	0.05	0.06	0.96	0.34
	Hum	0.0003	0.001	0.26	0.79
Voltunism bi	(Intercept)	1.18	0.31	3.74	**0.001**
	Plants	0.01	0.002	4.92	**0.001**
	Temp	0.03	0.01	2.11	**0.03**
	Windkm	-0.05	0.02	2.88	**0.004**
	Clouds	0.04	0.04	0.87	0.39
	Hum	0.0006	0.0001	0.59	0.56
Hostplant sh	(Intercept)	-0.81	0.71	1.14	0.26
	Plants	0.006	0.006	1.03	0.30
	Temp	0.09	0.03	2.67	**0.008**
	Windkm	-0.13	0.04	3.10	**0.002**
	Clouds	0.07	0.11	0.68	0.50
	Hum	-0.001	0.003	0.47	0.64
Hostplant shth	(Intercept)	0.42	0.41	1.02	0.31
	Plants	0.02	0.003	6.53	**0.001**
	Temp	0.03	0.02	2.09	**0.04**
	Windkm	-0.04	0.02	1.93	0.05
	Clouds	0.11	0.05	2.15	**0.03**
	Hum	0.001	0.001	1.09	0.27
Egg sh	(Intercept)	0.30	0.48	0.63	0.53
	Plants	0.01	0.003	4.13	**0.001**
	Temp	0.04	0.02	1.75	0.08
	Windkm	-0.07	0.03	2.59	**0.01**
	Clouds	0.09	0.07	1.40	0.16
	Hum	0.0005	0.002	0.32	0.75
Egg shth	(Intecept)	0.39	0.48	0.81	0.42
	Plants	0.007	0.003	2.39	**0.02**
	Temp	0.04	0.02	2.21	**0.03**
	Windkm	-0.05	0.02	2.19	**0.03**
	Clouds	0.02	0.06	0.41	0.68
	Hum	0.001	0.001	1.20	0.23
Egg th	(Intercept)	-0.29	0.57	0.51	0.61

Fixed effects	Estimate	SE	z	Pr(>|z|)
Plants	0.01	0.004	2.38	**0.02**
Temp	0.03	0.03	1.20	0.23
Windkm	-0.06	0.03	1.72	0.08
Clouds	-0.02	0.08	0.19	0.85
Hum	0.004	0.002	1.82	0.07

Table 9 Most supported (ΔAIC < 2) mixed effect models testing for impacts of environmental variables on parameters of species richness, oligophagous and polyphagous caterpillars, wings length (small, average and large), overwintering stadium, number of generations per year, hostplant type, egg laying location. For testing impacts of environmental variables on parameters of species richness and wings length (small, average and large) the generalized mixed effects models with Poisson distribution was employed. Note that random term was included in all model combinations.

Response variable	Model	df	logLik	AICc	ΔAICc	weight
Species richness	Plants+Temp+Windkm	4	-549.0	1106.3	0.00	0.38
	Clouds+Plants+Temp+Windkm	5	-548.1	1106.6	0.32	0.32
	Hum+Plants+Temp+Windkm	5	-548.8	1107.9	1.61	0.17
Richness of oligophagous species	Plants+Temp+Windkm	4	-478.6	965.3	0.00	0.30
	Clouds+Plants+Temp+Windkm	5	-477.8	965.8	0.51	0.23
Richness of polyphagous species	Hum+Plants+Temp+Windkm	5	-373.3	756.8	0.00	0.31
	Plants+Temp+Windkm	4	-374.4	757.1	0.25	0.27
Richness of butterflies with small wings	Plants+Temp+Windkm	4	-378.5	767.3	0.00	0.60
	Hum+Clouds+Plants+Temp+Windkm	6	-378.3	769.0	1.71	0.25
Richness of butterflies with average wings	Plants+Windkm	3	-452.8	911.8	0.00	0.18
	Plants	2	-454.0	912.0	0.28	0.15
	Plants+Temp	3	-453.4	913.0	1.21	0.10
	Plants+Temp+Windkm	4	-452.5	913.2	1.47	0.09
	Clouds+Plants+Windkm	4	-452.7	913.6	1.80	0.07
	Hum+Plants+Windkm	4	-452.8	913.7	1.95	0.07
Richness of butterflies with large wings	Clouds+Plants+Windkm	4	-304.2	616.6	0.00	0.29
	Clouds+Hum+Plants+Windkm	5	-304.0	618.3	1.70	0.12
	Clouds+Plants+Temp+Windkm	5	-304.0	618.4	1.74	0.12
Overwintering as egg	Plants+Temp	3	-143.9	294.0	0.00	0.26
	Clouds+Plants+Temp	4	-143.2	294.6	0.62	0.19
Overwintering as larvae	Clouds+Plants+Temp+Windkm	5	-442.3	894.9	0.00	0.64
Overwintering as pupa	Windkm	2	-339.3	682.6	0.00	0.14
	Plants+Windkm	3	-338.5	683.1	0.54	0.11
	Hum+Windkm	3	-338.9	683.9	1.34	0.07
	Plants	2	-340.2	684.5	1.94	0.05
Overwintering as adult	Clouds+Windkm	3	-300.6	607.3	0.00	0.19
	Clouds+Plants+Windkm	4	-300.0	608.2	0.83	0.12
	Clouds+Hum+Windkm	4	-300.2	608.5	1.17	0.11
	Clouds+Temp+Windkm	4	-300.5	609.1	1.76	0.08

Response variable	Model	df	logLik	AICc	ΔAICc	weight
Voltinism uni	Plants+Temp+Windkm	4	-432.9	874.0	0.00	0.34
	Clouds+Plants+Temp+Wind km	5	-432.5	875.2	1.16	0.19
Voltinism bi	Plants+Temp+Windkm	4	-464.5	937.2	0.00	0.33
	Clouds+Plants+Temp+Wind km	5	-464.0	938.4	1.13	0.19
	Hum+Plants+Temp+Windk m	5	-464.3	938.9	1.62	0.15
Hostplant sh	Temp+Windkm	3	-235.3	476.7	0.00	0.29
	Plants+Temp+Windkm	4	-234.8	477.8	1.11	0.16
	Clouds+Temp+Windkm	4	-235.1	478.3	1.56	0.13
	Hum+Temp+Windkm	4	-235.3	478.7	1.97	0.11
Hostplant shth	Clouds+Plants+Temp+Wind km	5	-424.4	859.2	0.00	0.27
	Clouds+Hum+Plants+Temp+ Windkm	6	-424.0	860.4	1.22	0.15
	Clouds+Plants+Temp	4	-426.3	860.7	1.53	0.13
Egg sh	Clouds+Plants+Temp+Wind km	5	-348.3	706.9	0.00	0.22
	Plants+Temp+Windkm	4	-349.5	707.3	0.40	0.18
	Plants+Windkm	3	-350.8	707.7	0.82	0.15
	Clouds+Plants+Windkm	4	-350.1	708.4	1.50	0.11
Egg shth	Plants+Temp+Windkm	4	-384.8	777.8	0.00	0.23
	Hum+Plants+Temp+Windk m	5	-384.2	778.6	0.79	0.16
	Clouds+Plants+Temp+Wind km	5	-384.7	779.7	1.84	0.09
Egg th	Hum+Plants+Windkm	4	-294.7	597.7	0.00	0.15
	Plants+Windkm	3	-296.1	598.3	0.66	0.10
	Hum+Plants+Temp+Windk m	5	-294.2	598.7	1.03	0.09
	Hum+Plants	3	-296.3	598.8	1.07	0.09
	Hum+Plants+Temp	4	-295.4	598.9	1.25	0.08
	Clouds+Hum+Plants+Windk m	5	-294.7	599.6	1.95	0.05

Based on the analysis of set of two most parsimonious models describing the richness of oligophagous species (containing richness of flowering plants, wind speed, temperature and cloudiness; (Table 4, 5, Fig. 8), we found out that wind speed and cloudiness were the most important variables (Table 4, Fig. 8). Impact of both factors on richness of this functional group was negative. Considering the results of hierarchical partitioning, the relative explanatory contribution was higher for richness of flowering plants (65.22%) than temperature (20.57%) and wind speed (9.22%) (Fig. 8, Fig. 13).

From two of the best models explaining richness of polyphagous species (containing richness of flowering plants, wind speed, temperature and humidity (Table 4,5) richness of flowering plants, wind speed and temperature were the most important variables. Number of flowering plants and temperature had significantly positive impact on richness of this functional group while wind speed had opposite effect (Table 4, Fig. 8). Hierarchical partitioning indicated that richness of flowering plants (relative contribution: 38.14%), temperature (relative contribution: 27.06%), wind speed (relative contribution: 24.07%) and humidity (relative contribution: 9.80%) had significant influence on richness of polyphagous species (Fig. 8, Fig. 13).

From a set of the three most parsimonious models describing the richness of butterflies with small wing span (containing all predictors; Table 4, 5), we found out that richness of flowering plants, wind speed, temperature and cloudiness were the most important variables (Table 4, Fig. 9). The influence of temperature and richness of flowering plants on small-winged butterflies was positive, while wind speed contributed negatively to this functional group. Relation between cloudiness and richness of butterflies with small wing span was unclear, and its positively correlated with cloudiness (Appendix 1), then decreases with higher intensity of this factor. The results of hierarchical partitioning showed that the relative explanatory contribution was higher for richness of flowering plants (relative contribution: 43.41%) than for temperature (relative contribution: 31.75%), wind speed (relative contribution: 11.08), cloudiness (relative contribution: 9.43) and humidity (relative contribution: 4.31) (Fig. 9, Fig. 13).

A set of six most parsimonious models, including all predictors best explained richness of butterflies with average wing span (Table 4, 5; Fig. 9). However, due to statistical significance of random intercept, the results were characterized by high uncertainty (Table 4). Hierarchical partitioning indicated that richness of flowering plants (relatively contribution: 75.93%), and temperature (relatively contribution: 12.70%) had positive significant influence on richness of average-winged butterflies (Fig. 9, Fig. 13).

From three of the best models explaining richness of butterflies with large wing span (containing all five predictors; Table 4, 5; Fig. 9) wind speed and cloudiness were the most important variables negatively affecting species richness of this functional group. Based on hierarchical partitioning we can conclude that wind speed (relative contribution: 41.81%) and cloudiness (relative contribution: 27.96) significantly influenced richness of large-winged butterflies (Fig. 9, Fig. 13).

Two models, with cloudiness, richness of flowering plants and temperature as independent variables, best explained the richness of butterflies overwintering as eggs (Table 4, 5; Fig 10). However, due to statistical significance of random intercept, the results were characterized by high uncertainty. Considering the results of hierarchical partitioning, the relative explanatory contribution was higher for temperature (relative contribution: 60.57%) than richness of flowering plants (relative contribution: 32.30%) (Fig. 10, Fig. 13).

Only one model, which included richness of flowering plants, wind speed, temperature and cloudiness, best predicted richness of butterflies species overwintering as larvae (Table 4, 5; Fig 10). We found uncertain relation of cloudiness, and it was positively correlated with cloudiness (Appendix 1), then decreased with higher intensity of this factor. Hierarchical partitioning indicated significant effects of richness of flowering plants, temperature, cloudiness and wind speed (relative contribution: 60.05%, 22.16%, 8.09% and 7.19%) (Fig. 10, Fig. 13).

From four models best describing species richness of butterflies overwintering in the pupal stage all predictors were included (Table 4, 5; Fig. 10). However, due to statistical significance of random intercept, the results were characterized by high uncertainty. Hierarchical partitioning showed that the relative contribution of wind speed was 55.43% (Fig. 10, Fig. 13).

Due to statistical significance of random intercept the results from four of the best models explaining richness of butterflies overwintering as adult (including all predictors) were considered as highly uncontained (Table 4,5; Fig.10). Based on hierarchical partitioning we can conclude that cloudiness and wind speed (relatively contribution: 55.47% and 29.34% respectively) significantly influenced richness of butterflies overwintering as adults (Fig. 10).

A set of two parsimonious models, containing four variables (richness of flowering plants, cloudiness, temperature and wind speed) best explained richness of butterflies with one generation per year (Table 4, 5; Fig. 11). Positive effects were indicated for richness of flowering plants and temperature, while negative effects on this functional trait was indicated for wind speed. Results of hierarchical partitioning indicated that richness of flowering plants (relative contribution: 62.67%), temperature (relatively contribution: 23.47%) and wind speed (relatively contribution: 9.44%) (Fig. 11, Fig. 13).

Results from a set of three most parsimonious models describing the richness of butterflies with more than one generation per year (including all predictors) (Table 4,5 ; Fig. 11) showed statistical significance of random intercept. Thus, the results were characterized by high uncertainty. Hierarchical partitioning showed that the relative contribution of flowering plants richness, temperature and wind speed (relative contribution: 51.98%, 23.47% and 9.44% respectively) were statistically significant (Fig. 11, Fig. 13).

From a set of the four most parsimonious models describing the richness of butterflies feeding only on short herbs and grasses (containing all five predictors; Table 4, 5; Fig. 11), we found out that temperature had significantly positively influence, while wind speed negatively influenced butterflies characterized by this trait. Considering the results of hierarchical partitioning, the relative explanatory contribution was statistically significant for wind speed (relative contribution: 46.74%), temperature (relative contribution: 37.25%) and richness of flowering plants (relative contribution: 13.99%) (Fig. 11, Fig. 13).

From three models best describing richness of butterflies feeding on short and tall herbs and grasses (containing all five predictors) the significantly positive influence was found for richness of flowering plants and temperature (Table 4, 5; Fig. 11). Uncertain relation with cloudiness (Appendix 1) which then decreases with higher intensity of this factor. Based on hierarchical partitioning (all predictors) richness of flowering plants, temperature, wind speed, cloudiness and humidity (relative contribution: 62.43%,16.13%, 7.95%, 7.07% and 4.41% respectively) significantly influenced richness of butterflies overwintering as adults (Fig. 11, Fig. 13).

Four models best explaining richness of butterflies laying eggs on short herbs and grasses revealed (including four variables: richness of flowering plants, wind speed, temperature, cloudiness) statistically significant influence of richness of plants and wind speed (Table 4, 5; Fig. 12). Results of hierarchical partitioning indicated that richness of flowering plants, temperature, wind speed and cloudiness (relative contribution: 49.12%, 21.16%, 19.41%, 6.70%, 3.64% respectively) (Fig. 12, Fig. 13).

A set of three parsimonious models, containing all five variables best explained richness of butterflies laying eggs on short or tall herbs and grasses (Table 4, 5; Fig. 12). Only influence of flowering plants was statistically significant and positively influenced richness of this group of butterflies. Considering the results of hierarchical partitioning, the relative explanatory contribution of richness of flowering plants (33.38%), temperature (32.94%) and wind speed (23.23%) were statistically significant (Fig. 12, Fig. 13).

From a set of six parsimonious models (containing all variables) for richness of butterflies laying eggs only on tall herbs only influence of flowering plants, wind speed and temperature was statistically significant (Table 4, 5; Fig. 14). Hierarchical partitioning showed that the relative contribution of richness of flowering plants (relatively contribution: 37.19%), humidity (relative contribution: 25.03%), wind speed (relatively contribution: 20.15%) and temperature (relative contribution: 16.75%) significantly influenced richness of this group of butterflies (Fig. 12, Fig. 13).

Discussion

Many earlier studies showed that urban lepidopteran fauna is dominated by generalists (e.g. Clark et al. 2007, Di Mauro et al. 2007, Dennis et al. 2017, Franzen et al. 2020). Some other demonstrated that wide thermal preferences and generalist life history may even promote urban affinity (Callaghan et al. 2021), although it is often difficult to categorise particular species as unequivocal generalists (Dennis et al. 2011, Bartonova et al. 2014.) and details of the life cycle or preferences to one given factor might limit distribution of potential generalist, like in case of oligophagous *G. rhamni* (Gutiérrez and Thomas 2001) or may change in time, like in case of *L. dispar*, which recently adapted to dry habitats (Martin and Pullin 2004, Buszko and Masłowski 2008), as it was also observed in Łódź. Moreover, cities are often described as areas characterized by species richness impoverishment, lower functional diversity and simplification of functional interactions within communities of plants and animals (Schütz and Schulze 2015, Milanovic et al. 2021, Fenoglio et al. 2021). In contrast to this common notion butterfly communities of wastelands in Łódź were functionally diverse especially when we focus our attention on habitat preferences, overwintering strategies, host-plant growth form and even facultative associations with ants (Table 1, 2). What is more important functional diversity was also high when compared to composition of regional fauna of the Central Poland. As a result typical forest taxa associated with shrubs and trees, territorial forest dwelling *P. aegeria* or nettele feeding nymphalids coexisted with grassland butterflies on very small restricted sites. We have already analysed those problems on a background of regional species pool (Pietrzak and Pabis unpublished manuscript 01). Those species often co-occured in the European cities, although on a scale of the whole agglomeration, but not necessarly on a scale of the small habitat patch (Shereeve et al. 2001, Winiarska 2003, Palik et al. 2005, Konvicka and Kadlec 2011, Sobczyk et al. 2017, Pietrzak 2021), although quantitative data from particular habitats are very limited especially in the Central Europe. Nevertheless, some studies of bird and butterfly communities already demonstrated that even low species richness might not be correlated with low functional diversity (Aguirre-Gutierrez et al. 2016, Lee et al. 2021). On the other hand our results clearly demonstrated that urban fauna lacks the most specialized taxa with narrow habitat preferences or more complex biology, like for example obligatory myrmecophiles or hygrophilous species (Bartonova et al. 2014).

Many studies suggested that specialists tend to be monophagous or oligophagous, sedentary, small-bodied butterflies developing small number of generations (discussed in Bartonova et al. 2014) although such generalisations are far from beeing true. It seem rather that combination of traits is important, especially in corelation with particular characteristics of investigated habitat which allows to utilize those traits in a succesfull way. Even common and not particularly demanding species like *C. pamphilus, G. rhamni, L. megera* or *A. io* are declining in Europe (van Dyck et al. 2009, van Swaay et al. 2013), while they can be very abundant and succesfull in the fragmented, disturbed urban habitats of Łódź. Our study demonstrated that ecological succes might be associated with combination of traits that are suited for city life, although some of those traits probably have higher importance, depending on a particular species. It could results in selection of species that can be called urban exploiters as it was already demonstrated for birds (Kark et al. 2006). Paradoxically future conservation of those species might depend on their affinities to urban habitats, maybe even on larger regional scale, and despite the fact that urbanization is one of the most important causes of insect decline in general (Fenoglio et al. 2021). We might also speculate that despite some general habitat characteristics of urban habitats there are no universal functional characteristic that guarantee the success of a given butterfly in a particular city, because urban ecological patterns are strongly influenced by local conditions and are very context dependant (Ferrari and Polidori 2022, Rega-Brodsky et al. 2022). Therefore, success of particular species in Łódź (or other cities) does not mean that this species will be generally common and abundant in urbanized areas on a regional scale or on a scale of European continent. For example, *A. urticae* was often observed in the cities (Konvicka and Kadlec 2011, Dennis et al. 2017, Kuussaari et al. 2021), and its functional traits might favor his survival in urban areas (Merckx et al. 2015), but it was almost absent in Łódź, despite the fact that it is common in the Central Poland (Buszko and Masłowski 2008). At the same time, species that seem to be functionally and ecologically similar, like *A. io* or *A. levana* were much more frequent and abundant in Łódź (Pietrzak and Pabis unpublished). Similar observations concern *P. brassicae* in contrast to *P. rapae* and *P. napi*.

Dispersal abilities in a fragmented landscape seem to be one of the key functional features of urban butterfly fauna of Łódź, and mobility was often mentioned as a key factor for lepidopteran distribution, although with various combinations with other traits, depending on habitat characteristics (Borschig et al. 2013, Korosi et al. 2022, Pla-Narbona et al. 2022). We did not detect significant differences in diversity and distribution of species with larger and smaller wings between majority of sites, although we have to remember that wingspan itself is not a perfect proxy for dispersal abilities (Sekar 2012). Earlier study from urban gardens of Barcelona showed that distribution of sedentary specialists and medium size mobile species was influenced by connectivity between patches, while highly mobile generalists were affected only by quality of habitat (Pla-Narbona et al. 2022). The fastest flyers like large nymphalids were not a major component of fauna at investigated sites although they are certainly not affected by habitat fragmentation (Cant et al. 2005). *P. napis* and *P. rapae* also have excellent flying abilities (Ryan et al. 2019) and were very common on all sites. On the other hand moderately good dispersers with small wings like *C. pamphilus* and *P. icarus* characterized by high fertility, cryptic solitary caterpillars that display nocturnal activity and are hidden during the day (Sielezniew and Dziekańska 2010, Bartnonova et al. 2014, Buszko and Masłowski 2008, Kurze et al. 2018) were found in very high abundance. Similar pattern was found for other small species like *A. agestis, L. phleas, L. tityrus* or *C. argiades,* which are also characterized by small solitary, caterpillars, although active during the day time (Sielezniew and Dziekańska 2010, Bartnonova et al. 2014, Buszko and Masłowski 2008). Those caterpillars are often living close to the ground, or hidden in dense patchess of grasses (Sielezniew and Dziekańska 2010, Warecki 2010). Some other species like *P. napi* have the ability to lay eggs even on small plants growing on frequently moved urban lawns (Hardy and Dennis 2010). Earlier studies demonstrated that moving might be beneficial for some butterflies if it is not done too often (Smallidge and Leopold 1997, Mazalova et al. 2015). Some wastelands in Łódź fit perfectly in such strategy, although this practice is not intentional. Moreover, functional diversity may even increase shortly after moving, but also on a larger time scale (Mazalova et al. 2015). Moving may change succession patterns of plants, probably also maintain different types of small and large plants characterized be different tempo of development, creating mosaic of microhabitats and allowing to maintain host plants of different butterflies on a small spatial scale. It is also worth mentioning that linear forest edges or patches of trees and shrubs typical for urban wastelands in Łódź might be beneficial for grassland butterflies (Mazalova et al. 2015, Bergman et al. 2018). On the other hand presence of trees and shrubs allows to maintain populations of species associated with those plants, like *N. antiopa, P. c-album* or *A. ilia* (Sielezniew and Dziekańska 2010, Buszko and Masłowski 2008) and increase overall functional diversity at wastelands.

Moving practice are done during the day. Therefore, they may not destroy the larvae or pupae, especially if caterpillars are nocturnal and hidden on the ground or in small clumps of grasses (Sielezniew and Dziekańska 2010, Buszko and Masłowski 2008). Moving combined with particular functional traits of a particular species may be a reason behind the success of some taxa in Łódź, however it may at the same time affect some other species. For example, studies from Sweden demonstrated that moving in urban areas reduced the number of *L. virgaure* individuals almost to zero (Haaland and Den Bosch 2017). This species was not recorded in Łódź but similar problem might concern closely related *L. alciphron* (only several individuals were found). Its low abundance is especially pronounced when compared to abundance of *L. phlaeas* and *L. tityrus,* which at first glance have very similar functional traits and utilize the same host plants. They are generally common in Central Poland, although populations of *L. alciphron* are often small and restricted to smaller areas (Buszko 1997, Sielezniew and Dziekańska 2010, Buszko and Masłowski 2008). Therefore funtional diversity of butteflies might be indirectly shaped by human activities through modification of plant communities and landscape or intensification of management practice.

In case of facultative myrmecophiles representing family Lycaenidae (Table 1, Table 2), the presence of ants might additionally influence survival rate of caterpillars and allows protection from parasitoids (Mizuno et al. 2019, Pierce and Dankowicz 2022). *Myrmica rubra*, *M. ruginodis* representants of genus *Lasius* and *Formica* are common in Łódź, some of them even in the strict center (Pełczyńska A. unpublished results) and some of them are adapted to urban environment (Konorov et al. 2017). The presence of ants might influence high abundance of *L. coridon* at Maratońska, because caterpillars of this species are buried by ants during the day (Sielezniew and Dziekańska 2010). Nevertheless, in favorable conditions this species might have high abundance (Schmitt and Seitz 2002, Schmitt et al. 2006), although it is vulnerable to habitat fragmentation (Krauss et al. 2004) and it is not dispersing in Łódź, despite the fact that *Securigera varia* can be found all over the city (Witosławski 2006). He was often found on calcareous grasslands and some earlier observations suggested its urban affinities (Rosin et al. 2011, Senn 2015) although this species is generally not typical for urban habitats in Europe (Shereeve et al. 2001, Winiarska 2003, Konvicka and Kadlec 2011, Pietrzak 2021) or declines in the cities (Palik et al. 2005). In case of facultative myrmecophiles relatively specialised traits and biological interactions might promote success in fragmented urban landscape, although it is also worth mentioning that a group of myrmecophiles observed in Łódź is not uniform when it comes to other functional traits (Sielezniew and Dziekańska 2010, Warecki 2010, Buszko and Masłowski 2008).

Dry urban habitat patches affected by heat island effect might be also perfect resting sites for migrating species. Latest studies demonstrated that females of *V. cardui* are able to locate potential breeding areas and host plant sites (Stefanescu et al. 2021) Therefore, large groups of migrating *V. cardui* might use urban wastelands as good breeding sites and resting spots rich in flower resources. It might by very important along the migration route in the structurally and ecologically monotonous agricultural landscape of Central Europe. High availability of different types of plants typical for ruderal areas including *Cirsium, Cardus,* and *Urtica*, which were all common in Łodz (Witosławski 2006) and on investigated wastelands, might promote visits of this species in the city. Therefore, important functional trait that have a strong evolutionary base and it is associated with search for breeding sites (Stefanescu et al. 2021) might be advantageous in urban ecosystems, although such mass occurrence has rather random character and is not observed every year (Pietrzak and Pabis unpublished manuscript 01).

The number of utlized host plants (monophagy, oligophagy, polyphagy) was not a key element structuring butterfly communities in Łódź. Truly polyphagous species constituted minority and were not particularly common or abundant (Table 2). Even extremely polyphagous *C. argiolus*, a species associated with almost 50 species of plants (Middleton-Welling et al. 2020) was recorded only occasionally in small numbers, but on all investigated sites. Availability of common plants was more important even if species was monophagous or oligophagous. It is not surprising, especially taking into account the fact that butterflies are generally often related to Fabaceae and Poaceae and have rather narrow host-plant preferences (Kawahara et al. 2023), also in urban communities (Tiple et al. 2011). Mobile, monophagous species that display wide habitat preferences in the adult stage like *A. io* might be observed even far away from host plants, although *Urtica dioica* is common in the whole Łódź (Witosławski et al. 2006) and caterpillars of this species were observed even on small patches of nettles growing in the city (personal observations). Adults must remain on the move to find patchilly distributed clumps of the host plant. On the other hand we have to notice that large Nymphalinae (7 species in Łodz) and species like *P. machaon* and *G. rhamni* are rarely seen in high abundance on small restricted sites. They might be occasionally found in higher density on patches of flowering plants (e.g. *A. io* and *A urticae*), but they rarely occur in large numbers, except of overwintering sites. Wintering in the urban areas might be affected by rodents especially rats, that can be found in Łodz. In this case urban survival might be increased by succesful antipredator strategies which include startle effect and eye spots (Olofsson et al. 2011, 2012). Buszko and Masłowski (2008) suggested also that good dispersal abilities of *G. rhamni* allows to fly far away from breeding sites, and even overwinter in areas where *Rhamnus cantharicus* and *Frangula alnus* are absent. Both of those species can be found in Łódź, however mostly in the outskirts and latter species has much wider distribution in the city (Witosławski 2006). *G. rhamni* was common in Łodz but it was not very abundant (Table 1) (Pietrzak and Pabis unpublished article 1) and it is probable that part of the individuals emigrated and/or immigrated between the city and neighbouring areas. Therefore, low abundance of all above mentioned species on wastelands in Łodz does not proves lower affinity to urban ecosystems, but rather reflect behavioral traits. At the same time species like *C. pamphilus* and *M. jurtina* might have high population densities even on small patches of suitable habitat and they are not searching for host plants which are abundant everywhere. Both species are often quite sedentary and many individuals from local populations do not move further than a few hundred metres during their whole life (Brakefield 1982, Ockinger and Smith 2007). Some specimens may migrate on larger distances and develop new sedentary populations on habitat islands, although dispersal is often facilitated by ecological corridors of appropriate habitats (Ockinger and Smith 2007, Villemey et al. 2016).

Earlier studies demonstrated that temperature combined with life history traits plays a key role in butterfly phenology (Larsen et al. 2022). Nevertheless, we did not recorded any phenological changes associated with heat island effect, with only one exception for *A. cardamines* in the early spring (Pietrzak and Pabis unpublsished) and there were no phenological responses that can be attributed to particular functional group or particular functional trait among butterflies observed in Łódź. Even the phenology of more specialized species that need to synchronize egg hatching and caterpillar development with development of plants like an exclusively florivore *C. argiades* (Sielezniew and Dziekańska 2010, Warecki 2010) were not affected.

Conclusions

All previous studies dedicated to functional diversity of butterfly communities are based on categorization derived from literature data (e.g. Borschig et al. 2013, Callghan et al. 2021, Korosi et al. 2022, Pla-Narbona et al. 2022, Szabo et al. 2022). Such approach is fully justified, especially in community ecology studies, when we can not focus our attention on details of the biology of particular species in particular type of habitat. Moreover, similar analysis became possible with growing data about European butterfly species traits (Middleton-Welling et al. 2020). Nevertheless, functional traits might differ regionally, e.g. voltinism, host-plant preferences, but even life-span or habitat preferences (Nylin 1988, Altermatt 2010, Navarro-Cano et al. 2015, Sielezniew at al. 2019, Middleton-Welling et al. 2020). Such differences could be even more pronounced in the urban environment. The same species of butterfly can display different preferences in different cities or even between the seasons and microhabitats, which is associated with dynamic character and unpredictability of changes typical for urban ecosystem (Rega-Brodsky et al. 2022). Urban factors affecting butterfly communities may vary strongly depending on presence of large rivers, density of roads, number of ecological corridors, number of citizens, size of the city, temperature, industrialization and pollution level. For example, number of road killed butterflies is dependant on the level of traffic on particular streats (Skórka 2016). Even studies performed in the natural ecosystems demonstrated differences in resources use between various habitats (Kalarus and Nowicki 2017) or differences in migration level between generations or between males and females (Plazio and Nowicki 2021).

Similar questions ed when we anlysed data collected in Łódź. For example, we do not know which species of *Rumex* is utilized by *L. dispar* in the city. Is it previously reported *R. crispus* (Buszko and Masłowski 2008) or maybe some other xerpohilous species of *Rumex* (e.g. *R. acetosa, R. acetosella*) which are more abundant in Łodz (Witosławski 2006). Are there differences in host-plant prefrerences for common and abundant grassland butterflies like *C. pamphilus, M. jutrina* or *P. rapae* between particular wastelands in Łodz? Are large good dispersers like *A. io* and *G. rhamni* developing in the city or their presence is maintained by imigration? Are there differences in survival rate between moved and non-moved lawns or wastelands? Our study demonstrated urgent need of more comprehensive butterfly trait analysis based on in situ collected data, like for example mark-release-recapture studies in the city, but also attempts to assess the true longevity of individuals in the urban landscape (Bubova et al. 2016) or truly used host-plants in a particular city. Urban survival (and therefore life span) of particular individuals might be also affected by presence and/or intensity of different factors that are strongly site dependant, even in natural habitats (Sielezniew at al. 2019). It is also important to ask about the time of real life span in the city, influence of protandry or time between occurrence of the adults and moment of egg lying. Combination of actually used species traits with landscape characteristics in the studies of particular species and particular urban populations could bring new important insights into our knowledge about survival rates and adaptations to life in the fragmented urban landscape. Moreover, at least some of those studies e.g. mark-release-recapture might be done within the citizen science based projects which are becoming very succesful in urbal ecology (Wei et al. 20016)

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Appendix 1 Description of code applied for cloudiness with percentage sky cover

Variable	Code	[%]
without clouds	0	0-10%
light cloudiness	1	11-25%
partial cloudiness	2	26-60%
high cloudiness	3	61-90%
clouded	4	90-100%

Appendix 2 Value of variance influence factor and statistically significance of selected variables used in canonical correspondence analysis. For full names of variables see Table 3.

	VIF	Sig
plants	1.06	0.001
Windkm	1.05	0.874
Temp	1.14	0.001
Clouds	1.17	0.001
Hum	1.12	0.001

Appendix 3 Plants recorded on investigated sites

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Sambucus nigra ssp. nigra	Adoxaceae	*Sambucus*				X	
Allium vineale	Amaryllidaceae	*Allium*	X	X	X		
Aegopodium podagraria	Apiaceae	*Aegopodium*					X
Anthriscus sylvestris	Apiaceae	*Anthriscus*			X		
Chaerophyllum temulum	Apiaceae	*Chaerophyll um*			X		
Daucus carota ssp. carota	Apiaceae	*Daucus*	X	X	X	X	X
Heracleum sphondylium ssp. glabrum	Apiaceae	*Heracleum*					X
Heracleum sphondylium ssp. sphondylium/glabrum	Apiaceae	*Heracleum*		X			
Pastinaca sativa	Apiaceae	*Pastinaca*		X	X		
Peucedanum oreoselinum	Apiaceae	*Peucedanu m*		X		X	
Pimpinella saxifraga ssp. saxifraga	Apiaceae	*Pimpinella*		X	X		
Pimpinella sp.	Apiaceae	*Pimpinella*			X		
Torilis japonica	Apiaceae	*Torilis*		X	X	X	X
Achillea millefolium	Asteraceae	*Achillea*		X	X		X
Achillea vulgaris	Asteraceae	*Achillea*				X	
Alchemilla millefolium	Asteraceae	*Alchemilla*				X	
Anchusa officinalis	Asteraceae	*Anchusa*	X				
Aquilegia ×hybrida/vulgaris	Asteraceae	*Aquilegia*			X		
Arctium tomentosum	Asteraceae	*Arctium*					
Artemisia absinthium	Asteraceae	*Artemisia*	X				
Artemisia camperstris ssp. campestris	Asteraceae	*Artemisia*	X	X	X	X	X
Artemisia vulgaris	Asteraceae	*Artemisia*	X	X	X	X	

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Cantaurea stoebe	Asteraceae	*Cantaurea*	X	X	X	X	X
Carduus acanthoides	Asteraceae	*Carduus*		X	X		
Centaurea jacea	Asteraceae	*Centaurea*			X		
Cerastium sp.	Asteraceae	*Cerastium*			X		X
Chamomilla suaveolens	Asteraceae	*Chamomilla*				X	
Cichorium intybus ssp. intybus	Asteraceae	*Cichorium*		X	X	X	X
Cirsium arvense	Asteraceae	*Cirsium*		X	X	X	X
Cirsium vulgare	Asteraceae	*Cirsium*		X	X	X	X
Conyza canadensis	Asteraceae	*Conyza*	X	X		X	X
Coreopsis lanceolata	Asteraceae	*Coreopsis*					X
Echium vulgare	Asteraceae	*Echium*	X	X	X		
Erigeron acris	Asteraceae	*Erigeron*			X		
Erigeron annuus ssp. annuus	Asteraceae	*Erigeron*		X	X	X	X
Erigeron annuus ssp. septentrionalis	Asteraceae	*Erigeron*	X	X	X		
Galinsoga parviflora	Asteraceae	*Galinsoga*		X			
Helianthus sp.	Asteraceae	*Helianthus*		X		X	
Helichrysum arenarium	Asteraceae	*Helichrysum*	X		X		X
Heliopsis scabra	Asteraceae	*Heliopsis*					X
Hieracium pilosella	Asteraceae	*Hieracium*		X	X	X	X
Hieracium sabaudum	Asteraceae	*Hieracium*		X			X
Hieracium umbellatum var. umbellatum	Asteraceae	*Hieracium*			X	X	X
Hypericum perforatum	Asteraceae	*Hypericum*	X	X	X	X	X
Hypochoeris radicata	Asteraceae	*Hypochoeris*	X	X	X	X	X
Jasione montana	Asteraceae	*Jasione*	X	X	X		X
Knautia arvensis	Asteraceae	*Knautia*		X		X	
Lactuca serriola	Asteraceae	*Lactuca*		X			X
Lapsana communis	Asteraceae	*Lapsana*		X	X		
Leontodon autumnalis ssp. autumnalis	Asteraceae	*Leontodon*	X	X		X	X
Matricaria perforata	Asteraceae	*Matricaria*				X	
Rudbeckia hirta	Asteraceae	*Rudbeckia*			X		X
Rudbeckia hirta var. hirta	Asteraceae	*Rudbeckia*					
Senecio jacobaea	Asteraceae	*Senecio*	X	X			X
Senecio vulgaris	Asteraceae	*Senecio*		X			
Solidago ×niederederi	Asteraceae	*Solidago*					X
Solidago canadensis	Asteraceae	*Solidago*		X	X	X	X

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Solidago gigantea	Asteraceae	*Solidago*		X		X	
Solidago virgaurea	Asteraceae	*Solidago*		X	X	X	X
Sonchus asper	Asteraceae	*Sonchus*		X			
Tanacetum vulgare	Asteraceae	*Tanacetum*		X	X	X	X
Taraxacum officinale coll.	Asteraceae	*Taraxacum*			X	X	
Tragopogon dubius	Asteraceae	*Tragopogon*	X	X			
Tragopogon sp.	Asteraceae	*Tragopogon*		X	X		
Impatiens glandulifera	Balsaminaceae	*Impatiens*					X
Myosotis arvensis	Boraginaceae	*Myosotis*		X			
Alliaria petiolata	Brassicaceae	*Alliaria*			X		
Arabidopsis thaliana	Brassicaceae	*Arabidopsis*		X			
Barbarea vulgaris	Brassicaceae	*Barbarea*		X			
Berteroa incana	Brassicaceae	*Berteroa*	X	X	X	X	X
Cardaminopsis arenosa ssp. arenosa	Brassicaceae	*Cardaminopsis*					
Descurainia sophia	Brassicaceae	*Descurainia*				X	
Lepidium campestre	Brassicaceae	*Lepidium*		X			
Lunaria annua	Brassicaceae	*Lunaria*		X			
Raphanus raphanistrum	Brassicaceae	*Raphanus*		X			
Rorippa sp.	Brassicaceae	*Rorippa*		X			
Sisymbrium loeselii	Brassicaceae	*Sisymbrium*		X	X	X	X
Campanula rapunculoides	Campanulaceae	*Campanula*			X	X	
Dianthus deltoides	Caryophyllacaeae	*Dianthus*				X	
Melandrium album	Caryophyllacaeae	*Melandrium*	X	X	X	X	X
Saponaria officinalis	Caryophyllacaeae	*Saponaria*	X	X	X		
Saponaria officinalis f. plena	Caryophyllacaeae	*Saponaria*			X		
Silene vulgaris	Caryophyllacaeae	*Silene*		X	X		
Stellaria graminea	Caryophyllacaeae	*Stellaria*		X		X	
Convolvulus arvensis	Convolvulaceae	*Convolvulus*	X	X	X	X	X
Sedum maximum	Crassulaceae	*Sedum*			X	X	
Echinocystsis lobata	Cucurbitaceae	*Echinocystsis*					X
Euphorbia esula	Euphorbiaceae	*Euphorbia*		X	X	X	
Euphorbia helioscopia	Euphorbiaceae	*Euphorbia*		X			

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Caragana arborescens	Fabaceae	*Caragana*					
Coronilla varia	Fabaceae	*Coronilla*	X	X	X		
Cytisus scoparius	Fabaceae	*Cytisus*			X		
Lathyrus latifolius	Fabaceae	*Lathyrus*			X		X
Lathyrus tuberosus	Fabaceae	*Lathyrus*			X		
Lotus corniculatus	Fabaceae	*Lotus*		X	X	X	
Lupinus polyphyllus	Fabaceae	*Lupinus*				X	
Medicago ×varia	Fabaceae	*Medicago*		X	X		
Medicago falcata	Fabaceae	*Medicago*		X			
Medicago lupulina	Fabaceae	*Medicago*			X		
Medicago sativa	Fabaceae	*Medicago*				X	
Melilotus alba	Fabaceae	*Melilotus*		X		X	
Melilotus officinalis	Fabaceae	*Melilotus*		X	X	X	
Robinia pseudoacacia	Fabaceae	*Robinia*	X	X	X	X	
Trifolium arvense	Fabaceae	*Trifolium*	X	X	X	X	X
Trifolium campestre	Fabaceae	*Trifolium*			X		
Trifolium medium	Fabaceae	*Trifolium*		X	X	X	
Trifolium pratense ssp. pratense	Fabaceae	*Trifolium*			X	X	
Trifolium pratense ssp. sativum	Fabaceae	*Trifolium*		X			
Trifolium repens ssp. repens	Fabaceae	*Trifolium*			X	X	
Vicia cracca	Fabaceae	*Vicia*		X	X	X	
Vicia villosa	Fabaceae	*Vicia*		X			X
Geranium molle	Geraniaceae	*Geranium molle*					X
Geranium robertianum	Geraniaceae	*Geranium*		X			
Ballota nigra ssp. nigra	Lamiaceae	*Ballota*			X	X	
Betonica officinalis	Lamiaceae	*Betonica*				X	
Lamium purpureum	Lamiaceae	*Lamium*		X			
Leonurus cardiaca	Lamiaceae	*Leonurus*			X		
Mentha ×villosa	Lamiaceae	*Mentha*			X		
Origanum vulgare	Lamiaceae	*Origanum*		X			X
Lythrum saliciaria	Lythraceae	*Lythrum*					X
Malus sp.	Malvaceae	*Malus*			X	X	
Lavatera thuringiaca	Malvaceae	*Lavatera*			X		
Ligustrum vulgare	Oleaceae	*Ligustrum*				X	
Epilobium hirsutum	Onagraceae	*Epilobium*					X

Name of the species	Family	Genus	Presence on sites				
			M	B	R	TL	TR
Epilobium lamyi	Onagraceae	*Epilobium*		X			
Epilobium montanum	Onagraceae	*Epilobium*		X			
Oenothera sp./spp.	Onagraceae	*Oenothera*	X	X	X	X	X
Chelidonium majus	Papaveraceae	*Chelidonium*		X	X		X
Papaver dubium	Papaveraceae	*Papaver*		X		X	
Papaver rhoeas	Papaveraceae	*Papaver*			X		
Linaria vulgaris	Plantaginaceae	*Linaria*		X			X
Plantago lanceolata	Plantaginaceae	*Plantago*			X	X	X
Reynoutria japonica	Polygonaceae	*Reynoutria*					
Polygonum rurivagum	Polygonaceae	*Polygonum*		X			
Reseda lutea	Resedaceae	*Reseda*		X			
Crataegus sp.	Rosaceae	*Crataegus*			X	X	
Filipendula ulmaria	Rosaceae	*Filipendula*					X
Geum urbanum	Rosaceae	*Geum*		X	X	X	
Padus serotina	Rosaceae	*Padus*		X	X	X	X
Potentilla anserina	Rosaceae	*Potentilla*					X
Potentilla argentea	Rosaceae	*Potentilla*		X	X		X
Potentilla dissecta/impolita	Rosaceae	*Potentilla*		X			X
Potentilla intermedia	Rosaceae	*Potentilla*			X		X
Potentilla repens	Rosaceae	*Potentilla*			X	X	X
Potentilla tenuiloba	Rosaceae	*Potentilla*			X	X	
Prunus cerasifera	Rosaceae	*Prunus*		X	X		
Prunus sp.	Rosaceae	*Prunus*				X	
Rosa sp.	Rosaceae	*Rosa*	X	X	X	X	
Rubus caesius	Rosaceae	*Rubus*	X	X		X	
Rubus idaeus	Rosaceae	*Rubus*				X	
Rubus sp.	Rosaceae	*Rubus*					X
Sanguisorba minor	Rosaceae	*Sanguisorba*		X			
Sorbus aucuparia	Rosaceae	*Sorbus*				X	
Galium album	Rubiaceae	*Galium*		X			
Galium verum	Rubiaceae	*Galium*				X	
Acer campestris	Sapindaceae	*Acer*			X		
Acer platanoides	Sapindaceae	*Acer*			X		
Verbascum densiflorum	Scrophulariaceae	*Verbascum*	X	X		X	
Verbascum nigrum	Scrophulariaceae	*Verbascum*	X				

			Presence on sites				
Name of the species	**Family**	**Genus**	M	B	R	TL	TR
Verbascum phlomoides	Scrophulariaceae	*Verbascum*			X		
Verbascum sp.	Scrophulariaceae	*Verbascum*					
Solanum dulcamara	Solanaceae	*Solanum*		X			
Veronica chamaedrys	Veronicaceae	*Veronica*			X		X
Viola arvensis	Violaceae	*Viola*		X			
Viola tricolor	Violaceae	*Viola*		X			

Manuscript 2: Funtional diversity of the Central European butterfly communities associated with urban wastelands: a specialist-generalist point of view on a background of plant diversity

AUTHORSHIP CONTRIBUTION AND ORDER OF AUTHORS

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(65%) concept of the paper (main contribution), taxonomic analysis, field studies, methodology planning, methodology testing in the field, main part of literature research, preparation of dataset for analysis, categorization of species into functional categories, performing of data analysis in cooperation with second author , interpretation of the results, preparation of figures, tables and graphics, writing of the manuscript (main draft), manuscript editing, coresponding author

Robert Sobczyk (10%)
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Krzysztof Pabis (25%)
supervision of the research, concept of the paper, planning of the field methodology and data analysis, literature research, involvement in manuscript writing and interpretation of the results, manuscript editing

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Blooming urban table – flower resources and preferences of butterflies on fragmented wastelands of the large European city

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Abstract

There are almost no studies of butterfly flower preferences in the urban habitats and overall knowledge about their floral affinities in Europe is still very scarce. Our study was based on a long term (two seasons from April to September of 2019 and 2020) qualitative observations and quantitative studies of flower visits performed for 18 species of plants in the summer season of 2021 and 2022. During the qualitative observations we have recorded flower visits of 39 butterflies on 81 species of plants, representing 19 families and 16 orders. Species like *Apatura ilia* and *Pararge aegeria* were not observed on flowers. Majority of species recorded in Łódź were flower generalists, associated with many species of plants. Some of them like *Aglais io* were recorded on 35 species of plants, representing 13 families. We also did not record clear preferences for color of flower and depth of flower, although in general butterflies were observed on pink (21 species), yellow (20 species), white (17 species), and violet (13 species) flowers, while they avoided orange, blue and red flowers. The most important flowering plants represented Asteraceae, Fabaceae and Lamiaceae. The highest number of butterflies was recorded on *Jasione montana* (22 species), *Cirsium arvense* (19 species), *Berteroa incana* (22 species), *Trifolium pratense* (22 species), and *Origanum vulgare* (21 species). Quantitative analysis demonstrated that the highest number of individuals was observed on *Centaurea stoebe*, followed by *Senecio jacobaea*, *Cirsium arvense* and *Echium vulgare*.

Key words: Lepidoptera, floral preferences, urbanization, urban vegatation, wastelands

Introduction

Butterflies are one of the most important pollinators, although not so efficient as bees and other hymenopterans (Barrios et al. 2016, Ollerton 2017). The long-term evolutionary relations between lepidopterans and plants resulted in various strategies and adaptations associated with butterfly flower preferences. All butterflies have well developed proboscis and are mainly nectar feeders that reflect full spectrum of flower specialization (Kristensen et al. 2007, Jain et al. 2016). They may favour particular components of nectar (Alm et al. 1990, Erhardt 1991), display flower color preferences (Pohl et al. 2011, Arikawa et al. 2017), and can even learn how to link flower color with nectar reward (Drewniak et al. 2020). Some of them are dependant on single species of plant (Jain et al. 2016), other forage on large number of species (Martinez-Adriano et al. 2018). Their floral affinities may match host-plant preferences of caterpillars, or may be completely different (Menken et al. 2009, Tudor et al. 2004, Altermatt and Pearse 2011). The length of the proboscis may also differ between the species, allowing for penetration of flowers of different shape, depth and size, sometimes without pollination, resulting in so called „nectar robbery" (Bauder et al. 2015). Moreover, differences in length of the proboscis might be found between individuals representing the same species, resulting in different flower preferences (Szigeti et al. 2020). In general pollinator attraction to flowers is mediate by multimodal signals, that are still relatively scarcely studied and poorly understood (Pohl et al. 2011, Erickson et al. 2022a, Erickson et al. 2022b).

Flower visits might be affected by presence of predators (Fukano et al. 2016), weather conditions, habitat type and time of the season (Primack and Inouye 1993, Mertens et al. 2021), urbanization level (Herrmann et al. 2023), but also air pollution, that may distract the insects by altering of floral odors (Ryalls et al. 2022). Natural and anthoropogenic changes in plant communities may also alter flower preferences in particular habitats or even influence distribution of some species (Steffan-Dewenter and Westphal 2008, Thomas et al. 2011, Curtis et al. 2015, Martinez-Adriano et al. 2018). Therefore, flower specialization might be very important for conservation strategies (Tudor et al. 2004). On the other hand we have to remember that some species of butterflies rarely visit flowers (Buszko and Masłowski 2008).

Despite the fact that European butterfly fauna is probably the most comprehensively studied in all possible aspects, our knowledge about the flower preferences of even common butterfly species is still relatively limited. There are many spatial and temporal gaps in studies describing butterfly-flower relationships in various habitats (Jennersten 1984, Tudor et al.

2004, Buszko and Masłowski 2008, Curtis et al. 2015, Shackleton and Ratnieks 2016), and those lacks are even more pronounced in urban areas (e.g. Bergerot et al. 2010, Dylewski et al. 2020, Herrmann et al. 2023). The nourishment in adult stage may extend lifespan, increase overwintering survival of the adults and enhance quality and number of eggs, ultimately leading to more succesful offspring, and it is amongst key elements of butterfly biology (Mevi-Schütz & Erhardt 2005, Geister et al. 2008, Cahenzli & Erhardt 2012). Taking into account the fact that lack of appropriate nectar supply might be an important limiting factor of butterfly distribution and reason of population declines (Curtis et al. 2015) we must pay particular attention to flower resources used by butterfly communities in large agglomerations. Urban environments are known for altered ecological interactions (Theodorou 2022), disturbance (Fenoglio et al. 2021) and development of specific plant communities, that would not developed in other circumstances (Kühn & Klotz 2006, Wittig & Becker 2010, Lososová et al. 2012, Deák et al. 2016). Floras observed in the cities consist of species that cope well with pollution, water shortage and high temperatures (McKinney 2008, Deák et al. 2016, Kalusová et al. 2017), but do not necessarily constitute rich food resources for pollinators (Tew et al. 2021).

Moreover, the main attention of earlier studies was focused on pollinator associations with garden plants (Di Mauro 2007, Garbuzov & Ratnieks 2014, Garbuzov et al. 2015a, Garbuzov et al. 2015b, Shackleton & Ratnieks 2016, Garbuzov et al. 2017, Marquardt et al. 2021). At first glance such approach seems to be fully understandable, because cultivated ornamental plants are recognized as one of the most rich and diverse sources of nectar (Tew et al. 2021, Plummer et al. 2023). In case of quantitative studies it is also methodologically convenient to conduct standardised counts, if we can control number clumps in the garden (Shackleton & Ratnieks 2016). Recent studies demonstrated that other urban habitats, like parks, railways, pathways, larger or smaller wastelands, and various areas covered by spontaneous vegetation may constitute potentially valuable resources for pollinators (Bonthoux et al. 2019, Dylewski et al. 2019, Twerd and Banaszak-Cibicka 2019, Theodorou et al. 2020) Those neglected communities of native and alien weeds might provide a food resource in various types of disturbed and highly modified ecosystems (Ricotta et al. 2012, Rollin et al. 2016). At the same time we know almost nothing about floral preferences of European butterflies in urban areas. Without similar studies it will be impossible to provide succesfull and sustainable management practice (Aguilera et al. 2019), urban grassland restorations (Klaus 2013) or creation of urban flower meadows (Hicks et al. 2016).

Therefore, our study aims to explore flower preferences of butterfly communities associated with wasteland habitats of the large central European city.

Materials and methods

Study area

Łódź is a fourth largest (300 km^2, 660 thousand citizens) city in Poland, and it is located in the Central Europe (GUS 2023). It is a relatively young city that developed in the XIX century as a results of textitle manufacture development (Markowski et al. 1998, Witosławski 2006). It is a uniformly build and not divided by any large river. Three urbanization zones (Fig. 1) were distinguished in Lodz: inner city (zone I), peri-urban area (zone II) and outskirts (zone III) (Witosławski 2006, Janiszewski et al. 2009). Zones II and III are characterized by larger number of green spaces including parks, gardens, wastelands or even agricultural lands.

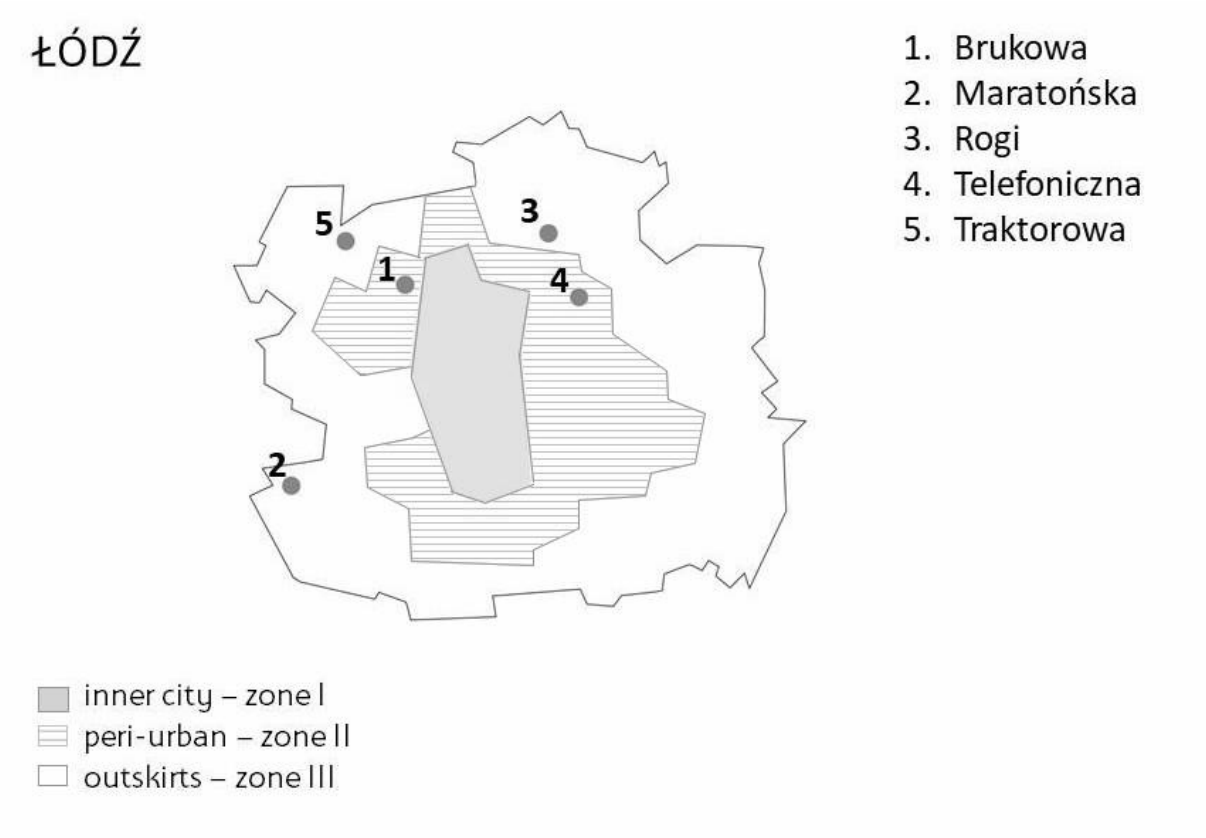

Fig. 13 Urbanization zones in Łódź with localizations of the most frequently visited sites

Field studies and data analysis

Studies were conducted mostly on five large wastelands located in the peri-urban area (zone II) and outskirts (zone III). Observations were conducted during 214 visits, including including 109 in 2019 and 105 in 2020 (every week between April and September of both seasons). Additionally, all other observations of butterfly associations in the city were noted in 2019, 2020, 2021 and 2022. Five major sampling sites had the surface area of about 2-3 ha. All were characterized by a mosaic of microhabitats that included dry and moist meadows, patches of shrubs, trees (Pietrzak and Pabis unpublished manuscript 01). Identification of plants was based on keys and field guides along with distribution atlas dedicated to flora of Lodz (Rutkowski 1998, Witosławski 2006, Sudnik-Wójcikowska 2011). All plants were categorized into groups based on color of flower, plant growth form (herbaceous plant, shrubs, trees) and depth of the flower (shallow, medium, deep). Preferences of each butterfly species and family were analysed in regards to number of used plants and composition of diet. Analysis of similarity between flower preferences of butterflies were based on Bray-Curtis formula using a group–average method (Clark and Warwick 2001). We have used non-transformed counts of plant species representing each family in a diet of each butterfly and presence/absence records of plant species in a diet of each butterfly.

Quantitative analysis of butterfly visits was also done on 25 species of plants, including: *Berteroa incana, Hieracium pilosella, Jasione montana, Echium vulgare, Centaurea jacea, Centaurea stoebe, Anchusa officinalis, Erigeron annuus, Solidago canadensis/gigantea, Cirsium arvense, Trifolium repens, Trifolium pratense, Lotus corniculatus*, *Medicago* x *varia*, *Achillea millefolium, Oenothera* sp., *Cerastium tomentosum, Potentilla* sp., *Helichrysum arenarium*, *Daucus carrota*, *Erigeron strigosus*, *Cerastium tomentosum*, *Securigera* varia, *Potentilla* sp., *Oenothera* sp..

We have followed the method proposed by Shackleton and Ratnieks (2016) for garden plants. Restricted clumps of each plant were selected in the field. Butterflies visiting each clump were counted during 12 visits conducted in regular intervals during 4 hours and such dataset was treated as single observation (sample). Altogether 141 observations/samples were conducted during the period from June to August of 2021 and 2022. Based on this dataset we calculated number of species, number of individuals and Shannon index values for every sample. Mean values (with standard deviation - SD) of those three indices were calculated for each plant species.

Results

We have recorded flower visits of 39 butterflies on 81 species of plants, representing 19 families and 16 orders (Appendix 1, 2). Six species: *Melitaea cinxia, Nymphalis antiopa, Satyrium pruni, Saturium w-album, Apatura ilia* and *Pararge aegeria* were never observed on flowers in Łódź. Butterflies visited mostly herbaceous plants and 5 shrubs and 1 tree. The higher number of plant species represented families Asteraceae (27 species), Fabaceae (13 species) and Lamiaceae (9 species). Representants of 2 major plant clades dominated in diet of butterflies in Łódź, namely: asterids (49 species) and rosids (26 species). We have noted a group of plants that attracted 15 or more species of butterflies. The largest number of species were observed on Asteraceae like: *Centaurea stoebe* (23 species), *Jasione montana* (22 species), *Cirsium arvense* (19 species), *Knautia arvensis* (16 species), *Achillea vulgaris* (12 species), *Tanacetum vulgare* (11 species) and on flowers of 7 species representing other families, including: Brassicaceae (*Berteroa incana* – 22 species), Fabaceae (*Trifolium pratense* 22 – species), Lamiaceae (*Origanum vulgare* - 21 species, *Lavendula officinalis* 14 species), Fabaceae (*Lotus corniculatus* - 11 species, *Medicago sativa/falcata* violet - 12 species, and Boraginaceae (*Echium vulgare* – 9 species). In general those plant species attracted representants of all butterfly families recorded in Łódź, except of *Tanacetum vulgare* that did not attract Pieridae and Hesperidae, *Achillea vulgaris* and *Lavendula officinalis* that did not attract Hesperidae. Plant families that attracted the highest number of butterfly species included Asteraceae (34 species), Fabaceae (33 species), Brassicaceae (25 species), and Lamiaceae (25 species).

In general butterflies were observed on 6 flower colors, including: pink (21 species), yellow (20 species), white (17 species), violet (13 species), white/yellow (2 species), orange (2 species), blue (2 species), grey (1 species), red (1 species). Two genera (Aster and Zinnia) were represented by various color forms and were not classified to none of the previous categories (Table 1, 2). In general species visited shallow (47 species) and medium depth (32 species) flowers. Only two taxa (*Saponaria officinalis* and *Phlox*) represented plants with deep flowers (Table 1, 2).

The number of plants visited by particular butterflies varied strongly and specialist and generalists were found in all families (Table 2). Eighteen species can be considered generalists and were observed on more than 10 species of plants. The highest number of visited plants was recorded for *Aglais io* (35 species, 13 families), *Polyommatus icarus* (25 species, 6 families), *Pieris napi* (26 species, 6 families), *Thymelicus lineola* (21 species, 7 families), *Maniola jurtina* (21 species, 8 families). On the other hand species like: *Lycaena alciphron, Brenthis ino, Lasiommata megera, Anthocharis cardamines, Leptidea juvernica, Celastrina argiolus, Papilio machaon, Colias hyale, Boloria dia,* and *Coenonympha glycerion* were recorded on less than 5 species of plants.

Table 10 Flower preferences of butterfly families recorded in Łódź

Family	No. of plant species	No. of plant families	Major plant families	No. of butterfly species	No. of plant species in dominant color groups	No. of butterfly species on particular flower color	No. of plant species with particular depth of flowers	No. of butterfly species recorded on particular depth of flower
Hesperidae	23	7	Fabaceae (8 species), Asteraceae (6 species)	4 (all 4 recorded on *Centaurea stoebe*, *Jasione montana*, *Echium vulgare*, *Lotus corniculatus*)	Pink (8 species), Violet (6 species), Yellow (3 species), white (3 species)	Violet (4 species), Yellow (4 species), pink (4 species), white (2 species)	Shallow (8 species), medium (14 species),	Shallow (4 species), medium (4 species),
Pieridae	39	9	Asteraceae (11 species), Fabaceae (8 species), Lamiaceae (6 species), Brassicaceae (5 species)	8 (5 species recorded on *Cirsium arvense*, *Trifolium pratense* and *Lavendula officinalis*)	Pink (12 species), Violet (8 species), Yellow (7 species), white (7 species)	Yellow (6 species), white (6 species), pink (6 species), violet (5 species)	medium (19 species), shallow (17 species), deep (2 species)	Shallow (8 species), medium (7 species), deep (2 species)
Papilionidae	3	2	Lamiaceae (2 species), Fabaceae (1 species)	1 (*P. machaon* was recorded only on *Trifolium pratense*, *Lamium purpureum* and *Lavendula officinalis*)	Pink (2 species), violet (1 species)	Pink/violet (1 species)	Medium (3 species)	Medium (1 species)
Lycaenidae	43	11	Asteraceae (15 species), Fabaceae (12 species)	10 (8 species recorded on *Berteroa incana*, 6 species on *Tanacetum vulgare*, 5 species on *Achillea vulgaris*, *Jasione montana, Knautia arvensis, Kolkwitzia amabilis, Origanum vulgare*)	Yellow (11 species), white (9 species), violet (9 species), pink (8 species)	Pink (10 species), white (10 species), yellow (9 species), violet (8 species),	Shallow (22 species), medium (21 species),	Shallow (9 species), medium (9 species),
Nymphalidae	62	17	Asteraceae (26 species) Lamiaceae (7 species), Fabaceae (6 species)	18 (9 species recorded on *Centaurea stoebe, Jasione montana, Berteroa incana, Origanum vulgare*, 8 species found on *Trifolium pratense*, 7 on *Cirsium arvense* and *Lavendula officinalis)*	Pink (17 species), Yellow (15 species), white (11 species), violet (10 species)	Pink (14 species), Violet (14 species), Yellow (11 species), white (11 species),	Shallow (41 species), medium (19 species), deep (2 species)	Shallow (16 species), medium (14 species), deep (2 species)

Table 2 Flower preferences of butterflies species recorded in Łódź

Species	No. of plant species	Plant families	No. of plant families	No. of plant orders	Plant orders	No. of plant colors	Flower color	Flower depth
Erynnis tages	7	Asteraceae (2 species), Boraginaceae (2 species), Fabaceae (2 species), Lamiaceae (1 species)	4	4	Asterales (2 species) Boraginales (2 species) Fabales (1 species) Lamiales (1 species)	4	blue (1 species) pink (2 species) violet (2 species) yellow (2 species)	shallow (3 species) medium (4 species)
Ochlodes sylvanus	13	Asteraceae (3 species), Boraginaceae (1 species), Fabaceae (1 species), Lamiaceae (1 species) Rosaceae (1 species)	5	5	Asterales (3 species) Boraginales (1 species) Fabales (1 species) Lamiales (1 species) Rosales (1 species)	4	pink (5 species) violet (5 species) white (1 species) yellow (2 species)	medium (9 species) shallow (4 species)
Thymelicus lineola	21	Asteraceae (6species) Boraginaceae (2 species) Brassicaceae (1 species) Caryophyllaceae (1 species) Fabaceae (7 species) Lamiaceae (2 species) Plantaginaceae (2 species)	7	6	Asterales (6 species) Boraginales (2 species) Brassicales (1 species) Caryophyllales (1 species) Fabales (7 species) Lamiales (4 species)	5	blue (1 species) pink (7 species) violet (7 species) white (2 species) yellow (4 species)	medium (13 species) shallow (8 species)

Thymelicus sylvestris	9	Asteraceae (4 species) Boraginaceae (1 species) Caryophyllaceae (1 species) Fabaceae (3 species)	4	4	Asterales (4 species) Boraginales (1 species) Caryophyllales (1 species) Fabales (3 species)	3	pink (4 species) violet (4 species) yellow (1 species)	medium (5 species) shallow (4 species)
Papilio machaon	3	Fabaceae (1 species) Lamiaceae (2 species)	2	2	Fabales (1 species) Lamiales (2 species)	2	pink (2 species) violet (1 species)	medium (3 species)
Anthocharis cardamines	2	Brassicaceae (2 species)	1	1	Brassicales (2 species)	1	white (2 species)	shallow (2 species)
Colias hyale	3	Asteraceae (2 species) Fabaceae (1 species)	2	2	Asterales (2 species) Fabales (1 species)	2	pink (1 species) yellow (2 species)	medium (1 species) shallow (2 species)
Gonepteryx rhamni	9	Asteraceae (2 species) Boraginaceae (1 species) Fabaceae (4 species) Lamiaceae (2 species)	4	4	Asterales (2 species) Boraginales (1 species) Fabales (4 species) Lamiales (2 species)	2	pink (3 species) violet (6 species)	medium(7 species) shallow (2 species)

Leptidea juvernica	2	Brassicaceae (1 species) Fabaceae (1 species)	2	2	Brassicales (1 species) Fabales (1 species)	2	white (1 species) yellow (1 species)	medium (1 species) shallow (1 species)
Pieris brassicae	17	Asteraceae (6 species) Brassicaceae (1 species) Boraginaceae (1 species) Fabaceae (3 species) Lamiaceae (4 species) Polemoniaceae (1 species) Scrophulariaceae (1 species)	7	6	Asterales (6 species) Brassicales (1 species) Boraginales (1 species) Fabales (3 species) Lamiales (5 species) Ericales (1 species)	6	blue (1 species) pink (6 species) various (1 species) violet (5 species) white (2 species) yellow (1 species)	Deep (1 species) Medium (9 species) Shallow (5 species)
Pieris napi	21	Asteraceae (7 species) Brassicaceae (2 species) Convolvulaceae (1 species) Fabaceae (4 species) Geraniaceae (2 species) Lamiaceae(5 species)	6	6	Asterales (7 species) Brassicales (2 species) Solanales (1 species) Fabales (4 species) Geraniales (2 species) Lamiales (5 species)	5	orange (1 species) pink (8 species) violet (6 species) white (3 species) yellow (3 species)	medium (11 species) shallow (10 species)
Pieris rapae	16	Asteraceae (6 species) Boraginaceae (1 species)	5	5	Asterales (6 species)	4	pink (4 species) violet (6 species)	medium (7 species)

		Brassicaceae (3 species) Fabaceae (3 species) Lamiaceae (3 species)			Boraginales (1 species) Brassicales (3 species) Fabales (3 species) Lamiales (3 species)		white (1 species) yellow (3 species)	shallow (8 species)
Pontia edusa	10	Asteraceae (5 species) Brassicaceae (2 species) Caryophyllaceae (1 species) Fabaceae (1 species) Lamiaceae (1 species)	5	5	Asterales (5 species) Brassicales (2 species) Caryophyllales (1 species) Fabales (1 species) Lamiales (1 species)	4	pink (2 species) violet (4 species) white (3 species) yellow (1 species)	deep (1 species) medium (2 species) shallow (7 species)
Aricia agestis	9	Asteraceae (6 species) Brassicaceae (1 species) Fabaceae (1 species) Lamiaceae (1 species)	4	4	Asterales (6 species) Brassicales (1 species) Fabales (1 species) Lamiales (1 species)	4	pink (2 species) violet (2 species) white (2 species) yellow (3 species)	medium (2 species) shallow (7 species)
Celestina argiolus	4	Asteraceae (1 species) Fabaceae (2 species) Lamiaceae (1 species)	3	3	Asterales (1 species) Fabales (2 species) Lamiales (1 species)	3	pink (1 species) white (1 species) yellow (2 species)	medium (3 species) shallow (1 species)
Cupido argiades	7	Brassicaceae (1 species) Fabaceae (6 species)	2	2	Brassicales (1 species)	4	pink (2 species) violet (1 species)	medium (6 species)

					Fabales (6 species)		white (2 species) yellow (2 species)	shallow (1 species)
Lycaena alciphron	2	Asteraceae (1 species) Brassicaceae (1 species)	2	2	Asterales (1 species) Brassicales (1 species)	2	pink (1 species) white (1 species)	shallow (2 species)
Lycaena dispar	12	Asteraceae (3 species) Brassicaceae (3 species) Fabaceae (5 species) Rosaceae (1 species)	4	4	Asterales (3 species) Brassicales (3 species) Fabales (5 species) Rosales (1 species)	5	pink (2 species) violet (1 species) white (4 species) white+yellow (1 species) yellow (4 species)	medium (5 species) shallow (7 species)
Lycaena phlaeas	17	Apiaceae (1 species) Asteraceae (11 species) Brassicaceae (2 species) Fabaceae (2 species) Lamiaceae (1 species)	5	5	Apiales (1 species) Asterales (11 species) Brassicales (2 species) Fabales (2 species) Lamiales (1 species)	5	pink (3 species) violet (3 species) white (5 species) white+yellow (1 species) yellow (5 species)	medium (3 species) shallow (14 species)
Lycaena tityrus	11	Asteraceae (6 species) Brassicaceae (1 species) Caryophyllaceae (1 species) Fabaceae (1 species) Lamiaceae (1 species) Rosaceae (1 species)	6	6	Asterales (6 species) Brassicales (1 species) Caryophyllales (1 species) Fabales (1 species)	5	pink (1 species) violet (3 species) white (4 species) white+yellow (1 species) yellow (2 species)	medium (2 species) shallow (9 species)

					Lamiales (1 species) Rosales (1 species)			
Polyommatus coridon	15	Asteraceae (9 species) Boraginaceae (1 species) Brassicaceae (1 species) Fabaceae (2 species) Lamiaceae (1 species) Rosaceae (1 species)	6	6	Asterales (9 species) Boraginales (1 species) Brassicales (1 species) Fabales (2 species) Lamiales (1 species) Rosales (1 species)	6	blue (1 species) pink (5 species) violet (2 species) white (3 species) white+yellow (1 species) yellow (3 species)	medium (4 species) shallow (11 species)
Polyommatus icarus	26	Asteraceae (8 species) Boraginaceae (2 species) Brassicaceae (2 species) Crassulaceae (1 species) Fabaceae (9 species) Lamiaceae (4 species)	6	6	Asterales (8 species) Boraginales (2 species) Brassicales (2 species) Saxifragales (1 species) Fabales (9 species) Lamiales (4 species)	6	grey (1 species) orange (1 species) pink (6 species) violet (9 species) white (5 species) yellow (4 species)	medium (16 species) shallow (10 species)
Thecla betulae	6	Asteraceae (5 species) Fabaceae (1 species)	2	2	Asterales (5 species) Fabales (1 species)	4	pink (1 species) violet (1 species) white+yellow (1 species) yellow (3	medium (1 species) shallow (5 species)

							species)	
Aglais io	35	Apiaceae (1 species) Asteraceae (17 species) Brassicaceae (1 species) Caprifoliaceae (1 species) Crassulaceae (1 species) Fabaceae (2 species) Lamiaceae (6 species) Malvaceae (1 species) Polemoniaceae (1 species) Ranunculaceae (1 species) Rosaceae (1 species) Saxifragaceae (1 species) Scrophulariaceae (1 species)	13	11	Apiales (1 species) Asterales (17 species) Brassicales (1 species) Dipsacales (1 species) Saxifragales (2 species) Fabales (2 species) Lamiales (7 species) Malvales (1 species) Ericales (1 species) Ranunculales (1 species) Rosales (1 species)	7	orange (2 species) pink (13 species) red (1 species) various (2 species) violet (7 species) white (4 species) yellow (6 species)	deep (1 species) medium (11 species) shallow (23 species)
Aglais urticae	10	Asteraceae (3 species) Boraginaceae (1 species) Brassicaceae (1 species) Crassulaceae (1 species) Fabaceae (1 species) Lamiaceae (2 species) Scrophulariaceae (1 species)	7	6	Asterales (1 species) Boraginales (1 species) Brassicales (1 species) Saxifragales (1 species) Fabales (1 species) Lamiales (3 species)	4	orange (1 species) pink (4 species) violet (4 species) white (1 species)	medium (6 species) shallow (4 species)

Aphantophus hyperantus	14	Asteraceae (9 species) Brassicaceae (1 species) Fabaceae (3 species) Lamiaceae (1 species)	4	4	Asterales (9 species) Brassicales (1 species) Fabales (3 species) Lamiales (1 species)	5	pink (5 species) violet (3 species) white (1 species) white+yellow (1 species) yellow (4 species)	medium (4 species) shallow (10 species)
Araschnia levana	12	Apiaceae (2 species) Asteraceae (6 species) Brassicaceae (1 species) Caryophyllaceae (1 species) Crassulaceae (1 species) Lamiaceae (1 species)	5	5	Apiales (2 species) Asterales (6 species) Brassicales (1 species) Caryophyllales (1 species) Saxifragales (1 species) Lamiales (1 species)	4	pink (3 species) violet (2 species) white (4 species) yellow (3 species)	deep (1 species) medium (2 species) shallow (9 species)
Argynnis paphia	9	Apiaceae (1 species) Asteraceae (5 species) Brassicaceae (1 species) Fabaceae (1 species) Lamiaceae (1 species)	5	5	Apiales (1 species) Asterales (5 species) Brassicales (1 species) Fabales (1 species) Lamiales (1 species)	3	pink (2 species) violet (3 species) yellow (4 species)	medium (2 species) shallow (7 species)
Boloria dia	4	Asteraceae (1 species) Brassicaceae (2 species) Fabaceae (1 species)	3	3	Asterales (1 species) Brassicales (2	2	white (1 species) yellow (3 species)	medium (1 species) shallow (3

					species) Fabales (1 species)			species)
Brenthis ino	2	Asteraceae (2 species)	1	1	Asterales (2 species)	2	pink (1 species) violet (1 species)	shallow (2 species)
Coenonympha glycerion	4	Asteraceae (1 species) Brassicaceae (1 species) Fabaceae (1 species) Plantaginaceae (1 species)	4	4	Asterales (1 species) Brassicales (1 species) Fabales (1 species) Lamiales (1 species)	2	violet (2 species) white (2 species)	medium (1 species) shallow (3 species)
Coenonympha pamphilus	13	Apiaceae (1 species) Asteraceae (5 species) Boraginaceae (1 species) Brassicaceae (2 species) Fabaceae (1 species) Rosaceae (2 species) Rubiaceae (1 species)	5	5	Apiales (1 species) Asterales (5 species) Boraginales (1 species) Brassicales (2 species) Fabales (1 species) Rosales (2 species) Gentianales (1 species)	5	blue (1 species) pink (2 species) violet (1 species) white (4 species) white+yellow (1 species) yellow (4 species)	medium (2 species) shallow (10 species)
Issoria lathonia	6	Apiaceae (1 species) Asteraceae (3 species) Fabaceae (1 species) Lamiaceae (1 species)	4	4	Apiales (1 species) Asterales (3 species) Fabales (1	3	pink (4 species) violet (1 species) white (1 species)	medium (2 species) shallow (4 species)

					species) Lamiales (1 species)			
Lasiommata megera	2	Asteraceae (2 species)	1	1	Asterales (2 species)	2	pink (1 species) yellow (1 species)	shallow (2 species)
Maniola jurtina	21	Asteraceae (11 species) Brassicaceae (1 species) Caryophyllaceae (1 species) Crassulaceae (1 species) Fabaceae (2 species) Lamiaceae (3 species) Oleaceae (1 species) Scrophulariaceae (1 species)	8	6	Asterales (11species) Brassicales (1 species) Caryophyllales (1 species) Saxifragales (1 species) Fabales (2 species) Lamiales (5 species)	5	orange (1 species) pink (9 species) violet (5 species) white (3 species) yellow (3 species)	medium (8 species) shallow (13 species)
Melanarghia galathea	11	Asteraceae (9 species) Fabaceae (1 species) Lamiaceae (1 species)	3	3	Asterales (9 species) Fabales (1 species) Lamiales (1 species)	4	pink (6 species) violet (2 species) white (1 species) yellow (2 species)	medium (2 species) shallow (9 species)
Polygonia c-album	8	Asteraceae (4 species) Brassicaceae (1 species) Lamiaceae (3 species)	3	3	Asterales (4 species) Brassicales (1 species) Lamiales (3 species)	5	orange (1 species) pink (3 species) various (1 species) violet (2 species) white (1 species)	medium (3 species) shallow (5 species)
Vanessa atalanta	6	Asteraceae (1 species) Fabaceae (1 species) Lamiaceae (2 species) Malvaceae (1 species)	5		Asterales (1 species) Fabales (1 species)	4	pink (2 species) various (1 species) violet (2 species)	medium (4 species) shallow (2 species)

		Scrophulariaceae (1 species)			Lamiales (3 species) Malvales (1 species)		yellow (1 species)	
Vanessa cardui	16	Asteraceae (7 species) Boraginaceae (2 species) Brassicaceae (2 species) Fabaceae (1 species) Lamiaceae (2 species) Malvaceae (1 species) Rosaceae (1 species)	7		Asterales (7 species) Boraginales (2 species) Brassicales (2species) Fabales (1 species) Lamiales (2 species) Malvales (1 species) Rosales (1 species)	5	blue (1 species) pink (5 species) violet (4 species) white (3 species) yellow (3 species)	medium (5 species) shallow (11 species)

Analysis of similarity in plant family interests demonstrated two major groups of species. First cluster grouped butterflies that were associated mostly with Asteraceae, Fabaceae and Brassicaceae, but were also visiting flowers of Lamiaceae and Boraginaceae. The second group of species was visiting mostly flowers of Asteraceae, Fabaceae and Brassicaceae. More detailed ecological affinities between butterfly species can be seen in the similarity analysis based on plant species. Three groups (cluster 1, 2 and 3) of flower generalists (in majority visiting flowers of several or more species of plants) were recorded at 40-50% similarity. First one was associated with species like *Centaurea stoebe*, *Jasione montana*, *Trifolium pratense*, *Origanum vulgare* but large majority of species were also visiting flowers of *Cirsium arvense* and *Echium vulgare*. The second cluster grouped species associated with almost the same group of plants including *Jasione montana*, *Cirsium arvense*, *Origanum vulgare* and *Centaurea stoebe* but were never recorded on *Echium vulgare* and *Trifolium pratense* and only one of them (*Pontia edusa*) was observed on *Lavendula officinalis*. At the same time most of them were observed on *Achillea vulgaris*. The third cluster of the generalists grouped only two butterflies that differ strongly in number of visited plants (*A. io* – 35 species, *P. brassicae* – 17 species) but both of them avoided *Jasione montana* and *Echium vulgare* and were observed on ornamental garden plants, namely *Agastache mexicana*, *Phlox* and *Aster*. Six other small clusters grouped various species that were observed on low number of plants or species that were rather rarely observed in the city and low number of their observations on flowers is most probably associated with their overall rarity on observed sites.

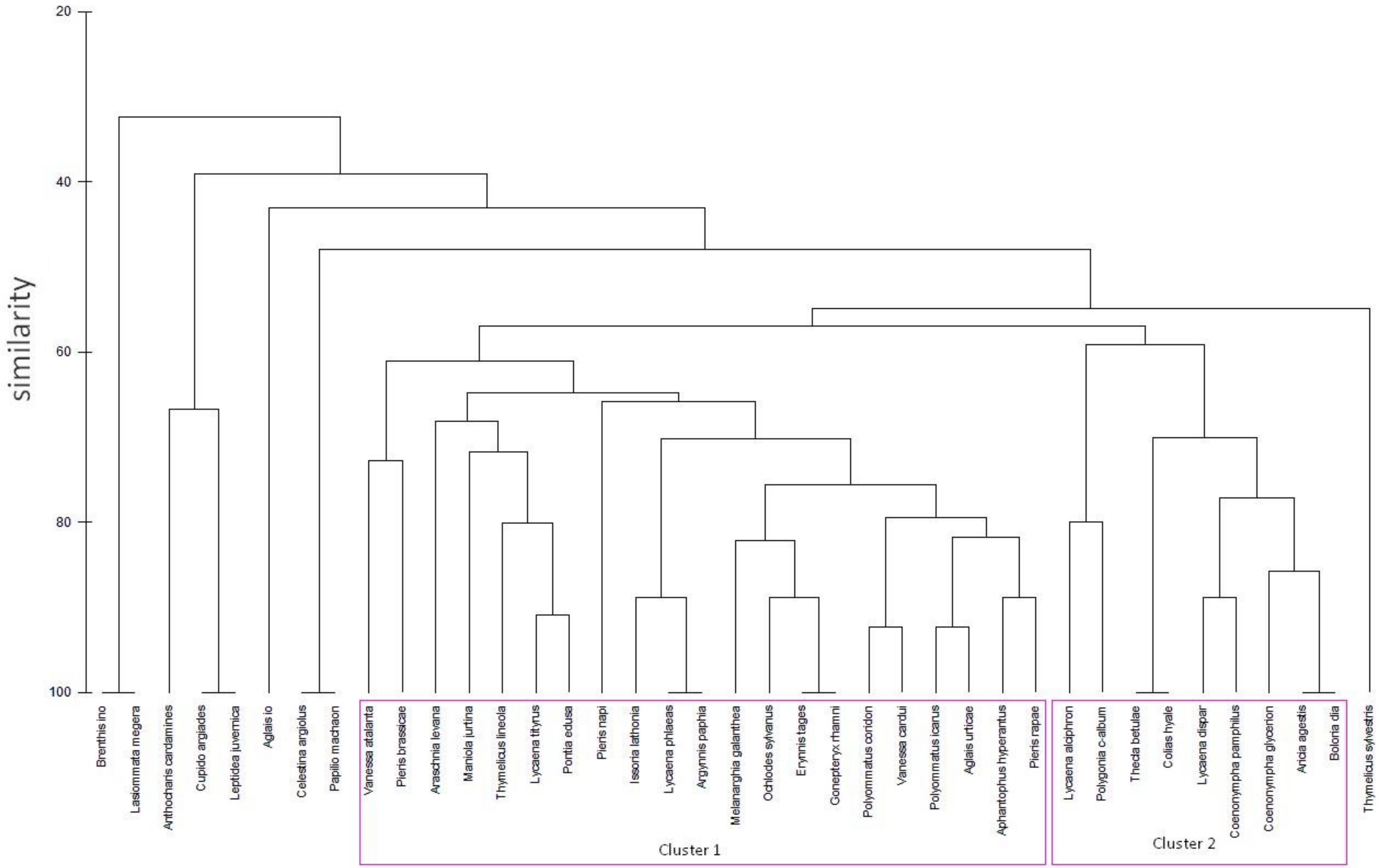

Fig 12 Bray-Curtis similarity of butterflies based on plant families

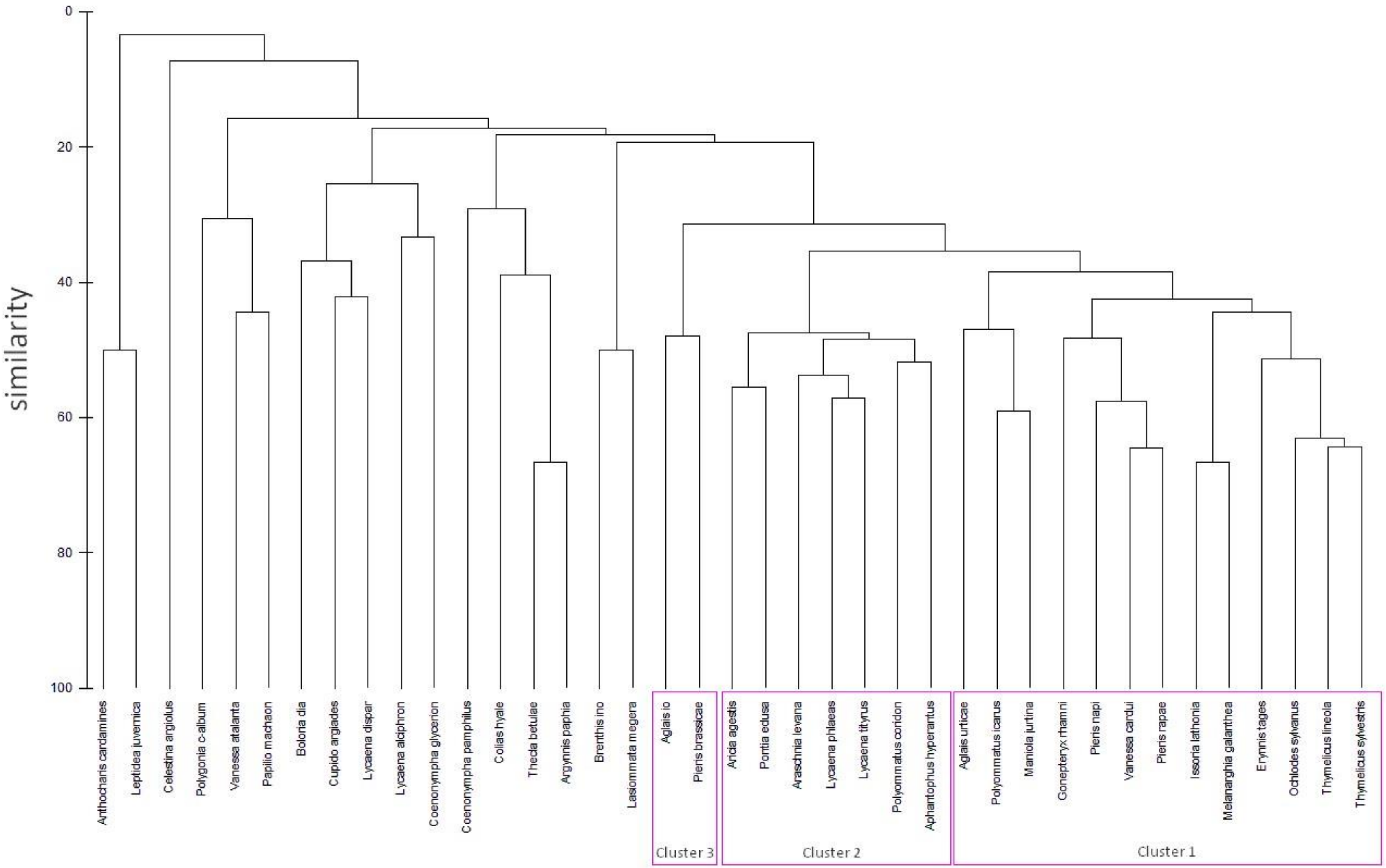

Fig 13 Bray-Curtis similarity of butterflies based on plant species

Quantititative analysis of flower visits showed that the highest mean number of individuals visiting the clump of plants within the 4 hour period was recorded on *Centaurea stoebe* with 196 ± 99 Individuals (Fig. 1). The species richness and Shannon index on that plant had also the highest values, accordingly S= 7±2 and H'=1,3±0,1 (Fig. 2, 3). Altogether 14 species of butterflies were recorded on this plant. The second plant with very high number of observed individuals and high richness and diversity was *Senecio jacobaea* (N=48±47 S=3±2 H=0,8±0,5). Lower but still relatively high abundance and diversity was also observed on *Cirsium arvense* (N=26±23 S=4±2 H=0,8±0,5), *Echium vulgare (*N=20±13 S=2±1 H=0,4±0,3*), Trifolium pratense* (N=18±19 S=4±3 H=0,8±0,8)*, Jasione montana* (N=24±19 S=4±3 H=0,7±0,6)*, Knautia arvensis* (N=31±14 S=3±1 H=0,6±0,5)*, Tanacetum vulgare* (N=13±17 S=3±2 H=0,5±0,6) and *Origanum vulgare* (N=35±14 S=6±2 H=1±0,3) (Fig 1, 2, 3). The number of butterfly species visiting the flowers during quantitative observations varied strongly between the plants. Species like *Hieracium pilosella* and *Trifolium repens* attracted only one species *Polyommatus icarus,* while plants like *Jasione montana, Centaurea stoebe, Cirsium arvense, Trifolum pratense* and *Origanum vulgare* attracted more than 10 species (Table 3). No butterflies were observed on clumps of *Helichrysum arenarium* (2 samples), *Daucus carrota* (3 samples), *Erigeron strigosus* (6 samples), *Cerastium tomentosum* (3 samples), *Securigera* varia (2 samples), *Potentilla* sp. (3 samples), *Oenothera* sp. (3 samples).

Table 3 Plants and butterflies observed on their flowers (quantitative analysis).

Plant	**Butterfly species observed on targetted clamps**
Hieracium pilosella	*Polyommatus icarus*
Trifolium repens	*Polyommatus icarus*
Berteroa incana	*Aricia agestis* *Inachis io* *Lycaena phlaeas* *Lycaena tityrus* *Maniola jurtina* *Pieris brassicae* *Pieris rapae* *Polyommatus coridon* *Polyommatus icarus* *Pontia edusa* *Thymelicus lineola*
Jasione montana	*Aphantophus hiperantus* *Aricia agestis* *Coenonympha pamphilus* *Erynnis tages* *Hyponephele likaon* *Issoria lathonia*

	Lycaena phlaeas *Lycaena tityrus* *Maniola jurtina* *Pieris rapae* *Polyommatus coridon* *Polyommatus icarus* *Pontia edusa* *Thymelicus lineola* *Vanessa cardui*
Echium vulgare	*Coenonympha pamphilus* *Erynnis tages* *Ochlodes sylvanus* *Pieris rapae* *Polyommatus coridon* *Polyommatus icarus* *Thymelicus lineola*
Centaurea jacea	*Aphantopus hyperantus* *Inachis io* *Maniola jurtina* *Melanargia galanthea* *Pieris brasicace* *Pieris rapae* *Polyommatus icarus*
Centaurea stoebe	*Aphantopus hyperantus* *Aricia agestis* *Boloria dia* *Erynnis tages* *Maniola jurtina* *Melanarghia galanthea* *Ochlodes sylvanus* *Pieris brasicace* *Pieris napi* *Pieris rapae* *Polygonia c-album* *Polyommatus icarus* *Thymelicus lin/syl* *Vanessa cardui*
Anchusa officinalis	*Aricia agestis* *Erynnis tages* *Polyommatus coridon* *Thymelicus lineola*
Solidago gigantea/canadensis	*Aricia agestis* *Inachis io* *Lycaena phlaeas* *Pieris napi* *Polyommatus icarus*
Cirsium arvense	*Aphantopus hyperantus* *Gonepteryx rhamni* *Inachis io* *Lycaena phlaeas* *Lycaena tityrus* *Maniola jurtina* *Melanargia galanthea* *Pieris brassicae* *Pieris napi* *Pieris rapae* *Pontia edusa* *Thymelicus lineola*
Trifolium pratense	*Cupido argiades* *Gonepteryx rhamni*

	Inachis io *Maniola jurtina* *Melanarghia galanthea* *Ochlodes sylvanus* *Pieris brassicae* *Pieris rapae* *Polyommatus icarus* *Thymelicus lineola* *Vanessa cardui*
Medicago xvaria violet	*Erynnis tages* *Pieris rapae* *Polyommatus icarus* *Thymelius lineola*
Lotus corniculatus	*Aricia agestis* *Erynnis tages* *Polyommatus icarus*
Achillea millefolium	*Maniola jurtina* *Melanarghia galanthea* *Polyommatus icarus* *Thymelicus lineola*
Senecio jacobaea	*Aphantopus hyperantus* *Araschnia levana* *Celastrina argiolus* *Lycaena phlaeas* *Maniola jurtina* *Melanarghia galanthea* *Pieris napi* *Polygonia c-album* *Thymelicus lineola*
Knautia arvensis	*Aphantopus hyperantus* *Inachis io* *Lycaena phlaeas* *Maniola jurtina* *Melanarghia galanthea* *Pieris rapae* *Polyommatus coridon* *Thymelicus lineola*
Tanacetum vulgare	*Aphantopus hyperantus* *Aricia agestis* *Coenonympha pamphilus* *Lycaena tityrus* *Maniola jurtina* *Polyommatus icarus*
Origanum vulgare	*Aglais urticae* *Aphantopus hyperantus* *Araschnia levana* *Aricia agestis* *Inachis io* *Issoria lathonia* *Maniola jurtina* *Melanarghia galanthea* *Ochlodes sylvanus* *Pieris brasicace* *Pieris napi* *Pieris rapae*

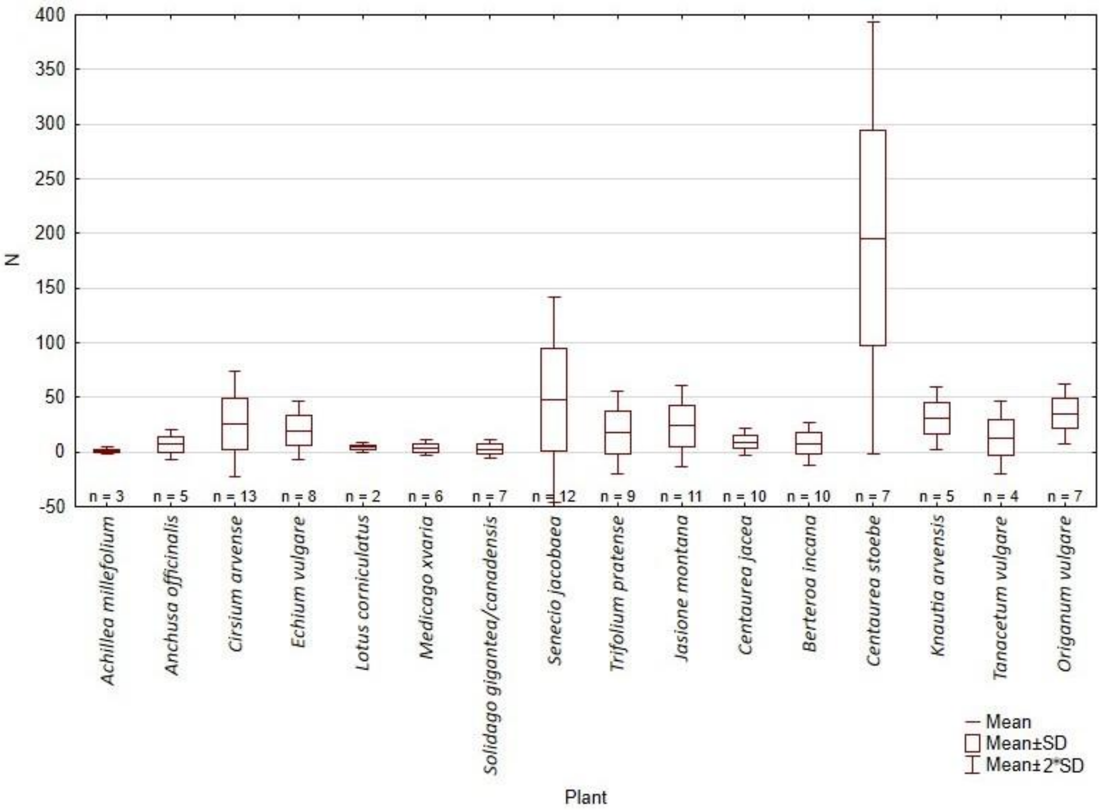

Fig 14 Mean abundance of butterflies recorded on different species of plants

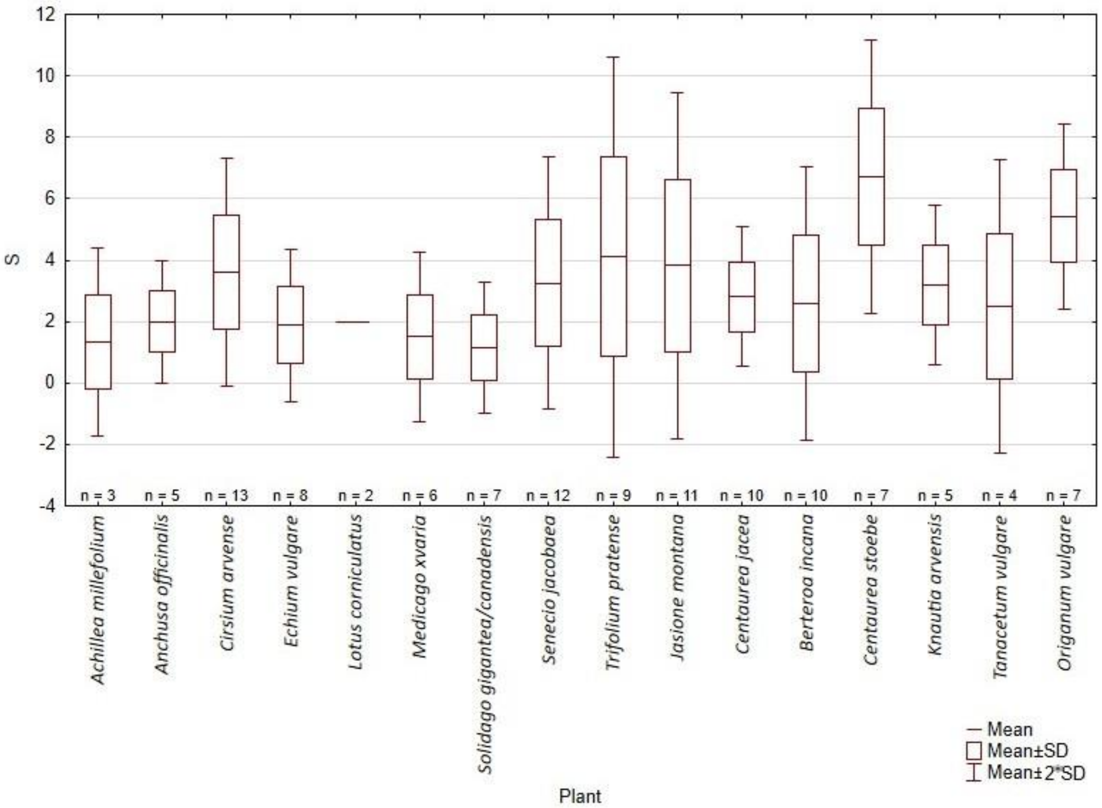

Fig 15 Mean species richness of butterflies recorded on different species of plants

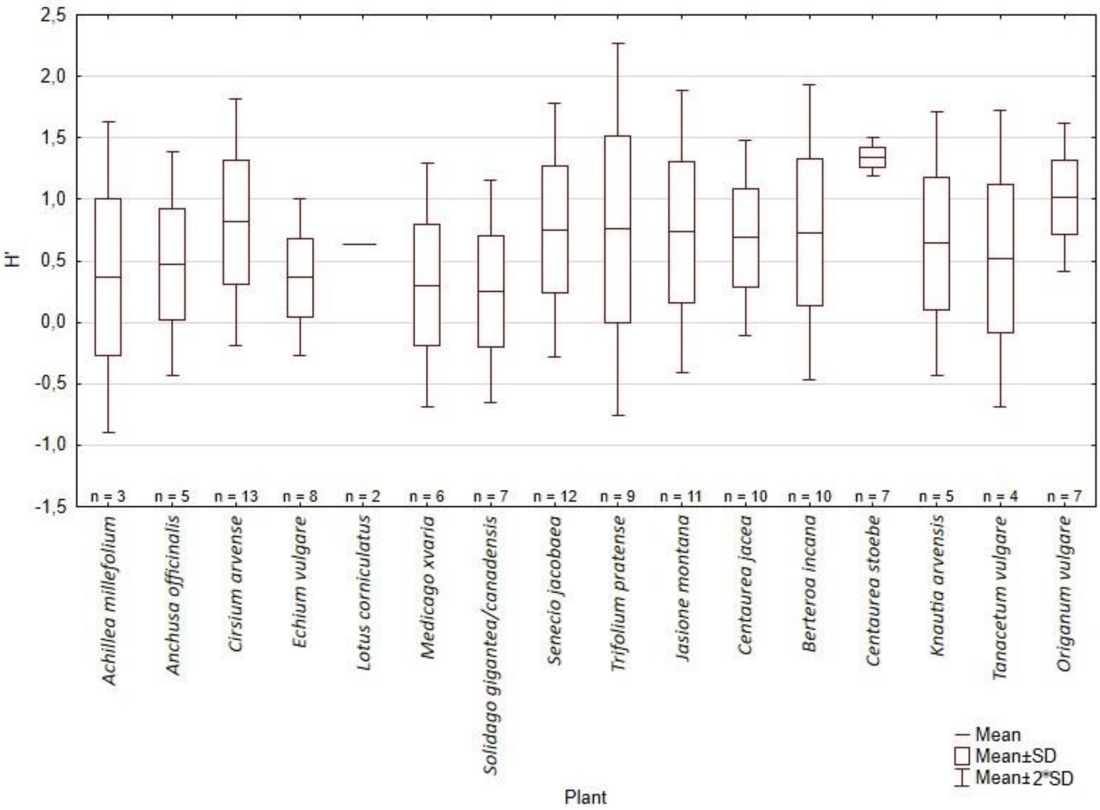

Fig 16 Mean values of Shannon index on different species of plants

Discussion

Over a half (24 species) of butterflies observed on large wastelands in Łódź were flower generalists, and their wide feeding preferences are also linked with their generally high abundance and/or frequency of occurrence in the city (Pietrzak and Pabis unpublished manuscript 01), which is generally consistent with common notion that generalists are better adapted to fragmented and disturbed urban landscape (Clark et al. 2007, Mauro et al. 2007, Callaghan et al. 2021). Moreover, majority of species visited plants (Table 1, 2) that are not used by their caterpillars (Sielezniew and Dziekańska 2010, Buszko and Masłowski 2008), which increases their environmental plasticity, and probably also a range of habitat used in the adult stage. Majority of species recorded in Łódź also did not display strong flower colour preferences, a factor that may limit distribution of some butterflies (Tiple et al. 2006), although all were associated with shallow and medium depth flowers which can not constitute a limiting factor because such species are common in Łódź (Witosławski 2006). Nevertheless, it is difficult to assess how important are feeding preferences of the adults for their survival in the city. Other functional traits and elements of the life cycle are probably crucial for common urban dwellers. This include for example mobility, dispersal abilities, or availability of caterpillar host plants (Börschig et al. 2013, Kőrösi et al. 2022, Pla-Narbona et al. 2021), and earlier analysis of butterfly communities in Łódź also demonstrated that combination of various traits might be very important for distribution and/or co-occurrence of butterfly species in urban areas (Pietrzak et al. unpublished manuscript 02), with flowers as not the most important element influencing butterfly distribution in the cities (Bergerot et al. 2010). Nevertheless, feeding preferences of the adults might certainly be an important factor structuring diversity and distribution of butterfly communities (Steffan-Dewenter and Westphal 2008, Thomas et al. 2011, Curtis et al. 2015, Martinez-Adriano et al. 2018). On the other hand not all of the most common species in Łódź were recorded on high number of plants. For example, one the most abundant species *C. pamphilus* was observed on 10 species of plants and avoided common urban flowers like *Jasione monatana*, *Knautia arvensis*, *Cirsium* or *Cantaurea stoebe* or ornamented garden plants like *Lavendula officinalis*, despite the fact that it was already observed feeding on those plants in natural habitats or gardens (Buszko and Masłowski 2008). Other common butterflies like *M. jurtina*, *A. hyperanthus*, and *L. phleas* utilized large number of plants but over a half represented one family (in this case Asteraceae), which are known as good nectar source for butterflies (Tudor et al. 2004, Shihan and Kabir 2015, Buszko and Masłowski 2008, Venjakob et al. 2021) and are generally common in Łódź (Witosławski 2006), and other urban areas (Nikolić and Stevović 2015, Dubois and Cheptou 2017, Géron et al. 2021). Their pollen is rarely exploited by generalist bees, probably as a result of chemical defence (Vanderplanck et al. 2020), but nectar is rich in amino acids essential for pollinators and rich in hexoses (Venjakob et al. 2021). On the other hand species that are true flower generalists like *A. io* or *A. urticae* and were observed on many species representing different families or orders of plants were not so abundant in the city (Pietrzak and Pabis unpublished manuscript 01). Therefore, the flower preferences were probably not crucial for their distribution, because they can actively search for resources over a large distances (Bartonova et al. 2014). It is also worth mentioning that species recorded on small number of flowers are not necessarily flower specialists. Most of them where recorded so rarely in Łódź that number of their feeding events is probably strongly biased by limited number of observations, except of species like *P. aegeria* and *A. ilia*, which rarely visit flowers (Buszko and Masłowski 2008).

It is very difficult to compare our results with earlier studies, because only one European research of flower preferences was based on long term observations, performer in a large distance from Łódź and in completely different habitats (Tudor et al. 2014). Earlier data from Poland are also not linked with particular habitats (Sielezniew and Dziekańska 2010, Buszko and Masłowski 2008). None of the previous analysis was done in urban areas, except of studies performed in the city gardens (Di Mauro 2007, Marquardt et al. 2021). Nevertheless, our results extended the knowledge about flower preferences of almost all recorded butterflies, even if compared with diet know for Polish flora (Sielezniew and Dziekańska 2020, Buszko and Masłowski 2008). For example, earlier long term studies suggested that *A. paphia* is a flower specialist associated with *Rubus* (Tudor et al. 2004), while in Poland it was noticed on *Anthriscus sylvestris, Centaurea, Cirsium, Eupatorium cannabinum* or *Knautia arvensis*, while in Łódź it was observed on 9 species of plants representing 5 families, including species never mentioned previously as part of its diet, like: *Tanacetum vulgare, Allium, Solidago canadensis* and *S. gigantea* (Appendix 1). Narrow flower preferences were also recorded earlier for *A. hyperanthus, G. rhamni* and even *A. io* in the Wyre Forest nature reserve on British Isles (Tudor et al. 2004), which might suggest that flower preferences are strongly dependant on the habitat type, because at least *A. io* is generally common on wide variety of flowers (Buszko and Masłowski 2008). What is more important at least some butterflies may display a flower constancy and prefer the species that they already visited previously (Goulson and Cory 1993, Goulson et al. 1997, Janovský et al. 2017), for example the species of plants that are the most common and abundant on particular location, which suggest that preferences might be strongly site specific even on a very small scale, like on restricted urban wastelands.

Urban garden plants were often mentioned amongst the main flower resources for butterfly in the cities (Di Mauro 2007, Marquardt et al. 2021) but those species are often planted in the strict city centers, botanical gardens or larger parks, areas that are not necessarily a perfect habitat for butterflies. It is mostly dew to intensive management practice, regular moving and lack of caterpillar host plants (Öckinger et al. 2009, Aguilera et al. 2019). Similar observation were done in Łódź, where butterfly fauna of large parks was less speciose (Sobczyk et al. 2017), than faunas associated with small wastelands (Pietrzak and Pabis unpublished manuscript 01, Pietrzak et al. unpublished manuscript 02). Even the number of butterfly species recorded in Łódź botanical garden, a large site with high number of ornamented flowering plants was lower than number of butterfly species recorded on much smaller wastelands (Sobczyk et al. 2017, 2018, Pietrzak and Pabis unpublished manuscript 01). Our study demonstrated that such habitats are becoming a blooming urban table that can attract various species of butterflies to plants that are often neglected in management of the urban areas, even if the municipal authorities are trying to maintain biodiversity of insects within the city borders to enhance wellbeing of the citizens according to latest recommendations (Bellamy et al. 2017, Samways et al. 2020). Therefore, our result might change the common practice in management of urban green spaces, pointing at possible new directions and more extensive protection of wastelands or ruderal sites as important resources for pollinators. Moreover, recent studies demonstrated that many garden plants that are available in garden centers are unattractive to flower-visiting insects (Garbuzov et al. 2017). Some other studies suggested that urban green spaces are hot spots of diversity of floral resources but not quantity of nectar supplies (Tew et al. 2021). On the other hand some of the horticulturally modified plants are more or equally attractive to insects (Garbuzov and Ratnieks 2014, Marquardt et al. 2021). Nevertheless, our results showed that we do not need ornamented plants to attract butterflies into the cities and we already know that preferences for exotic flower do no promote urban affinities of European butterflies (Bergertot et al. 2010). Our results should be also viewed in the light of planning of urban meadows or urban green spaces in general, while seed mixes often contain seeds of *T. pratense, L. corniculatus* or *Centaurea*, that were often visited by butterflies in Łódź, but sometimes also various alien species which should be avoided (Hicks et al. 2021). Communities of native ruderal plants might constitute good alternative or supplement to saled seed mixes. Therefore, we postulate a greater selection of plants in urban green spaces, and use of species that are already present in the cities, attract many species of butterflies, but at the same time might be attractive to humans, like for example: *Jasione montana, Knautia arvensis* or *Berteroa incana*. Such planning could probably also include selection of flower colors. Studies of butterflies from India and Nepal demonstrated that butterflies might prefer blue, yellow, red, and violet flowers over the white and pink flowers (Tiple et al. 2005, Subedi et al. 2021) while studies from Turkey demonstrated preference for yellow and pink flowers and avoidance of red flowers (Yurtsever et al. 2010), but we did not record such patterns in Łódź, which is congruent with growing evidence that tight colour-based plant–pollinator associations are generally rare, because most of the pollinators are flower generalists (Reverte et al. 2016) and flower color preferences, even when observed are not accompanied by constancy (Pohl et al. 2011). Only a few of the most common (and therefore more often recorded on flowers) butterflies observed in Łódź demonstrated narrower preferences to flower color. For example *G. rhamni* and *M. galathea* were found on violet and pink flowers, while majority of other species were color generalists.

The largest number of species was recorded on plants representing Asteraceae, some of them like *Centaurea stoebe* were visited by over 20 species of butterflies. Several species of plants attracted more than 10 species of butterflies and the urban table was generally dominated by Asteraceae Fabaceae, Brassicaceae, Lamiaceae and Boraginaceae. The list of the most often visited species of flowers differed from observation performed in woodland habitats on British Isles, where the larger number of flower visits was recorded on *Cirsium*, yellow Asteraceae, *Rubus fruticosus, Ajuga reptans* and *Calluna vulgaris* (Tudor et al. 2004). Nevertheless butterfly-flower associations observed in Łódż might be explained by features of utilized plants. Species like *Lotus corniculatus* or *Tripholium pratensis* have very high carbohydrate concentrations and are attractive to pollinating insects, moreover families like Lamiaceae, Asteraceae and Fabaceae have high carbohydrate-amino acids rations 19:1, 6:1 and 5:1 respectively (Venjakob et al. 2022), which supports our findings that they are main sources of food for many butterflies. Recent studies conducted in Poznań (western Poland) also showed that plants representing Boraginaceae, Asteraceae, and Lamiaceae are important for pollinators (Dylewski et al. 2020), although authors did not analyse specific preferences of butterfly species. Brassicaceae are important food source for many pollinators (mostly bees and hoverflies) but rarely butterflies (Badenes-Pérez 2022), although their presence in diet of European butterflies is not surprising (Buszko and Masłowski 2008).

Interesting questions arose during our attempt for quantitative analysis of flower visits. In contrast to studies carried out in gardens or on experimentally prepared research plots

(Shackleton and Ranieks 2016, Wijesinghe et al. 2020, Marquardt et al. 2021), where observer can at least indirectly control the number of flowers and/or the size of clumps during plant observations, we were bound to the irregularity of clumps and their random (or uniform) distribution. This is a key inconvenience that needs to be addressed when attempting to perform methodologically consistent study. On the other hand some of those problems were already noticed during observations performed on garden plants, and it is generally difficult to propose fully reliable field methods for measuring plant attractiveness to pollinators (Wijesinghe et al. 2020, Erickson et al. 2022a, Erickson et al. 2022b). For example, in case of some particular plant species (e.g. *Solidago*, *Centaurea stoebe*, or *Berteroa incana*), locating a single, well-separated clump can pose difficulties when those plants densely cover large areas. We have also observed disproportions between total number of species observed on particular species of plant during long term qualitative observations, and number of species observed during quantitative studies conducted in the restricted period of time. For instance, *Centaurea stoebe* was generally visited by 23 species of butteflies, *Berteroa incana* by 22 species and *Solidago* by 10 species, while only 14, 11 and 5 species respectively were documented during observations of selected clumps. Such differences may result from composition of local species pools, or may illustrate problems in observations of naturally less abundant species (Haddad et al. 2008). Therefore, those two datasets should be viewed together in order to provide a comprehensive picture.

Another problem was associated with heterogeneity of clumps of the same species, and interspecific differences in plant morphology, their high, type of the inflorescence, density of flowers or size of the flowers. Earlier studies suggested that at least some of those features e.g. plant high might be important for distribution of butterflies (Dylewski et al. 2019), although it is difficult to say to which extent they can influence particular feeding events of particular individual. The problems of relations between composition of pollinator assemblages and flower integration might also be important (Ordano et al. 2008, González et al. 2015). Adopting an uniform and comparable unit that reflects the clump's attractiveness measured in number of resources (e.g. number of flowers on a given surface) is almost impossible. For example, the inflorescence of *Trifolium pratense* consists of a small head composed of tubular flowers, while the inflorescence of *Solidago* is huge and covered with hundreds of flowers. Therefore, conclusions drawn from the comparisons of different plants should be treated with particular cautiousness. On the other hand it is worth mentioning that large inflorescence of *Solidago*, or inflorescence of *Achillea millefolium* attracted only 5 and 4 species respectively, while plants with small inflorescences like *Centaurea stoebe, Cirsium* *arvense* and *Senecio jacobea* attracted not only higher number of species but also considerably higher number of individuals.

The microhabitat characteristics (e.g. level of moisture, shading and other factors that may change tempo of plant growth) (LeBeau et al. 2017) and co-occurrence of different less or more attractive flowering plants on a particular location can probably also influence decisions of particular butterfly individuals, although it is impossible to avoid such problems in natural conditions, and there are no studies analysing similar patterns. In other words, do plants become less visited if something better is blooming nearby? Comprehensive, answer to this question probably requires small scale mark-release recapture studies and involvement of larger group of observers accompanied by high quality movies.

The quality of resources probably depends also on flowering phenology. Plant attractiveness during the period of flowering peak may differ from the attractiveness at the end of the season, when nectar resources are depleted (Langenberger and Davis 2002), also the nectar production may depend on pollinator abundance (Ratnieks and Balfour 2021). Moreover, temperature differences during each season and/or different cities may at least to some point affect synchronization of optimal flowering, peak and butterfly abundance, like in case of relationships with caterpillar host plants (Navarro-Cano et al. 2015, Posledovich et al. 2017), leading to differences in number of visits in different parts of the season. The number of flower visits on particular site depends also on general butterfly abundance (which may vary depending on habitat type, level of disturbance or availability of caterpillar host plants), therefore low number of visits does not have to mean lower attractiveness of particular plants. This results in question if we need to calibrate observation method (e.g. length of the observation period, and number/resolution of counts during one visit) depending on general abundance of butterflies at given site or in different habitats?

Conclusions

Majority of earlier data about flower preferences of European butterflies are not based on regular monitoring of particular habitats, but rather occasional observations, most probably conducted in natural habitats (e.g. Sielezniew and Dziekanska 2010, Buszko and Masłowski 2008). Moreover, such data are generally rare, highly scattered and are often neglected, even in identification field guides to European butterflies (e.g. Tolman 1997, Lafranchis 2007). As a result the knowledge on flower preferences is not accessible for wider group of butterfly watchers, rarely catalogued, even by specialists and can not be used in conservation actions, especially in altered ecosystems like large cities. There is also a great need for quantitative studies focuses on particular species of plants in different habitats, although our study demonstrated that it is difficult to apply the counting methods to wild plants that are rarely growing in clearly separated clumps, like in case of garden plants (Shackleton and Ratnieks 2016). Despite those problems such quantitative approach seem to be highly desirable and will allow to collect comprehensive data on butterfly flower preferences. Although we certainly need field test of various methodological approaches. Finally it is very important to link this knowledge with management of the urban green spaces or in planning of the conservations strategies on larger regional scale.

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Appendix 4 Flower-butterfly relationships observed in Łódź (Lycaenidae, Papilionidae, Pieridae)

					Lycenidae										Papilionidae	Pieridae							
Flower colour	Flower depth	Plant order	Plant family	Plant species	*Aricia agestis*	*Celestina argiolus*	*Cupido argiades*	*Lycaena alciphron*	*Lycaena dispar*	*Lycaena phlaeas*	*Lycaena tityrus*	*Polyommatus coridon*	*Polyommatus icarus*	*Thecla betulae*	*Papilio machaon*	*Anthocharis cardamines*	*Colias hyale*	*Gonepteryx rhamni*	*Leptidea juvernica*	*Pieris brassicae*	*Pieris napi*	*Pieris rapae*	*Pontia edusa*
white	shallow	Apiales	Apiaceae	*Daucus carota*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Apiales	Apiaceae	*Pastinaca sativa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Asterales	Asteraceae	*Achillea vulgaris*	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	0	0	1
pink	shallow	Asterales	Asteraceae	*Arctium tomentosum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
various	shallow	Asterales	Asteraceae	*Aster sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
orange	shallow	Asterales	Asteraceae	*Calendula sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	shallow	Asterales	Asteraceae	*Carduus acanthoides*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
pink	shallow	Asterales	Asteraceae	*Centaurea stoebe*	1	0	0	0	0	1	0	1	1	0	0	0	0	1	0	1	1	1	1
pink	shallow	Asterales	Asteraceae	*Knautia arvensis*	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	1	1
white	shallow	Asterales	Asteraceae	*Centaurea stoebe**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	shallow	Asterales	Asteraceae	*Cirsium arvense*	1	0	0	0	0	1	1	0	1	1	0	0	0	1	0	1	1	1	1
violet	shallow	Asterales	Asteraceae	*Echinacea sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	shallow	Asterales	Asteraceae	*Jasione montana*	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	1	1	1
white+yellow	shallow	Asterales	Asteraceae	*Erigeron annuus*	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Helichrysum arenarium*	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Heliopsis helianthoides*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Hieracium pilosella*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0
pink	shallow	Asterales	Asteraceae	*Centaurea jacea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Inula helenium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white+yellow	shallow	Asterales	Asteraceae	*Leucanthemum vulgare*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	shallow	Asterales	Asteraceae	*Liatris spicata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Senecio vulgaris*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Solidago canadensis/gigantea*	1	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	1	0	0
yellow	shallow	Asterales	Asteraceae	*Solidago virgaurea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
orange	shallow	Asterales	Asteraceae	*Tagetes*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
yellow	shallow	Asterales	Asteraceae	*Tanacetum vulgare*	1	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Taraxacum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

				officinale																			
yellow	shallow	Asterales	Asteraceae	*Senecio jacobaea*	0	1	0	0	0	1	1	0	0	1	0	0	1	0	0	0	1	0	0
various	shallow	Asterales	Asteraceae	*Zinnia sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
blue	medium	Boraginales	Boraginaceae	*Anchusa officinalis*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
blue	medium	Boraginales	Boraginaceae	*Echium vulgare*	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0
violet	medium	Boraginales	Boraginaceae	*Phacelia*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
white	shallow	Brassicales	Brassicaceae	*Alliaria petiolata*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
violet	shallow	Brassicales	Brassicaceae	*Allium sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Brassicales	Brassicaceae	*Barbarea vulgaris*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
white	shallow	Brassicales	Brassicaceae	*Cardaminopsis arenosa*	0	0	0	0	1	1	0	0	1	0	0	1	0	0	1	0	0	0	0
white	shallow	Brassicales	Brassicaceae	*Berteroa incana*	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1
yellow	shallow	Brassicales	Brassicaceae	*Raphanus raphanistrum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
pink	medium	Dipsacales	Caprifoliaceae	*Kolkwitzia amabilis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Caryophyllales	Caryophyllaceae	*Dianthus deltoides*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	deep	Caryophyllales	Caryophyllaceae	*Saponaria officinalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
white	shallow	Caryophyllales	Caryophyllaceae	*Stellaria sp*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Solanales	Convolvulaceae	*Convolvulus arvensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
pink	medium	Saxifragales	Crassulaceae	*Hylotelephium spectabile*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
pink	medium	Fabales	Fabaceae	*Lathyrus latifolius*	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
pink	medium	Fabales	Fabaceae	*Trifolium pratense*	0	0	1	0	1	0	0	0	1	1	1	0	1	1	0	1	1	1	0
pink	medium	Fabales	Fabaceae	*Vicia sativa*	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Fabales	Fabaceae	*Medicago ×varia (violet)*	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	1	1	1	0
violet	medium	Fabales	Fabaceae	*Viccia cracca*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
violet	medium	Fabales	Fabaceae	*Vicia villosa*	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0	0	1	0	0
white	medium	Fabales	Fabaceae	*Melilotus alba*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	medium	Fabales	Fabaceae	*Melilotus officinalis*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
grey	medium	Fabales	Fabaceae	*Trifolium arvense*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
yellow	medium	Fabales	Fabaceae	*Trifolium campestre*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
white	medium	Fabales	Fabaceae	*Trifolium repens*	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0
yellow	medium	Fabales	Fabaceae	*Lotus corniculatus*	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0
yellow	medium	Fabales	Fabaceae	*Medicago ×varia (yellow)*	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0
pink	medium	Geraniales	Geraniaceae	*Geranium molle*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
pink	medium	Geraniales	Geraniaceae	*Geranium robertianum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
pink	medium	Lamiales	Lamiaceae	*Agastache mexicana*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
violet	medium	Lamiales	Lamiaceae	*Ballota nigra*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Lamiales	Lamiaceae	*Origanum vulgare*	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	0

pink	medium	Lamiales	Lamiaceae	*Lamium purpureum*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
violet	medium	Lamiales	Lamiaceae	*Lavendula officinalis*	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	1	1	1
violet	medium	Lamiales	Lamiaceae	*Mentha sp*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
violet	medium	Lamiales	Lamiaceae	*Hyssopus officinalis*	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	0
pink	medium	Lamiales	Lamiaceae	*Prunella grandiflora*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
pink	medium	Lamiales	Lamiaceae	*Stachys officinalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
yellow	shallow	Malvales	Malvaceae	*Tilia sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Lamiales	Oleaceae	*Ligustrum vulgare*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Lamiales	Plantaginaceae	*Plantago lanceolata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	medium	Lamiales	Plantaginaceae	*Linaria vulgaris*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	deep	Ericales	Polemoniaceae	*Phlox*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
white	shallow	Ranunculales	Ranunculaceae	*Actaea europaea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Rosales	Rosaceae	*Potentilla sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Rosales	Rosaceae	*Prunus serotina*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
red	shallow	Rosales	Rosaceae	*Rosa sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Rosales	Rosaceae	*Rubis sp.*	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Gentianales	Rubiaceae	*Galium album*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	shallow	Saxifragales	Saxifragaceae	*Astilbe japonica*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Lamiales	Scrophulariaceae	*Buddleja davidii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Appendix 5 Flower-butterfly relationships observed in Łódź (Hesperiidae, Nymphalidae)

					Hesperiidae				Nymphalidae															
Flower colour	Flower deepness	Plant order	Plant family	Plant species	*Erynnis tages*	*Ochlodes sylvanus*	*Thymelicus lineola*	*Thymelicus sylvestris*	*Aglais io*	*Aglais urticae*	*Aphantophus hyperantus*	*Araschnia levana*	*Argynnis paphia*	*Boloria dia*	*Brenthis ino*	*Coenonympha glycerion*	*Coenonympha pamphilus*	*Issoria lathonia*	*Lasiommata megera*	*Maniola jurtina*	*Melanarghia galanthea*	*Polygonia c-album*	*Vanessa atalanta*	*Vanessa cardui*
white	shallow	Apiales	Apiaceae	*Daucus carota*	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
yellow	shallow	Apiales	Apiaceae	*Pastinaca sativa*	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Asterales	Asteraceae	*Achillea vulgaris*	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0
pink	shallow	Asterales	Asteraceae	*Arctium tomentosum*	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
various	shallow	Asterales	Asteraceae	*Aster sp*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
orange	shallow	Asterales	Asteraceae	*Calendula sp*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	shallow	Asterales	Asteraceae	*Carduus acanthoides*	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1
pink	shallow	Asterales	Asteraceae	*Centaurea stoebe*	1	1	1	1	1	0	1	0	0	1	1	0	0	1	1	1	1	1	0	1
pink	shallow	Asterales	Asteraceae	*Knautia arvensis*	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0	1
white	shallow	Asterales	Asteraceae	*Centaurea stoebe**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
violet	shallow	Asterales	Asteraceae	*Cirsium arvense*	0	0	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	1
violet	shallow	Asterales	Asteraceae	*Echinacea sp*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
violet	shallow	Asterales	Asteraceae	*Jasione montana*	1	1	1	1	0	1	1	1	0	0	1	1	1	1	0	1	1	0	0	1
white+yellow	shallow	Asterales	Asteraceae	*Erigeron annuus*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Helichrysum arenarium*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Heliopsis helianthoides*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Hieracium pilosella*	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	1
pink	shallow	Asterales	Asteraceae	*Centaurea jacea*	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
yellow	shallow	Asterales	Asteraceae	*Inula helenium*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white+yellow	shallow	Asterales	Asteraceae	*Leucanthemum vulgare*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
pink	shallow	Asterales	Asteraceae	*Liatris spicata*	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Senecio vulgaris*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Solidago canadensis/gigantea*	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Solidago virgaurea*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
orange	shallow	Asterales	Asteraceae	*Tagetes*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Tanacetum vulgare*	0	0	0	0	1	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0
yellow	shallow	Asterales	Asteraceae	*Taraxacum officinale*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					Hesperiidae				Nymphalidae															
Flower colour	Flower deepness	Plant order	Plant family	Plant species	*Erynnis tages*	*Ochlodes sylvanus*	*Thymelicus lineola*	*Thymelicus sylvestris*	*Aglais io*	*Aglais urticae*	*Aphantophus hyperantus*	*Araschnia levana*	*Argynnis paphia*	*Boloria dia*	*Brenthis ino*	*Coenonympha glycerion*	*Coenonympha pamphilus*	*Issoria lathonia*	*Lasiommata megera*	*Maniola jurtina*	*Melanarghia galanthea*	*Polygonia c-album*	*Vanessa atalanta*	*Vanessa cardui*
yellow	shallow	Asterales	Asteraceae	*Senecio jacobaea*	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0
various	shallow	Asterales	Asteraceae	*Zinnia sp*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
blue	medium	Boraginales	Boraginaceae	*Anchusa officinalis*	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
blue	medium	Boraginales	Boraginaceae	*Echium vulgare*	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
violet	medium	Boraginales	Boraginaceae	*Phacelia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Brassicales	Brassicaceae	*Alliaria petiolata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	shallow	Brassicales	Brassicaceae	*Allium sp*	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
yellow	shallow	Brassicales	Brassicaceae	*Barbarea vulgaris*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
white	shallow	Brassicales	Brassicaceae	*Cardaminopsis arenosa*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Brassicales	Brassicaceae	*Berteroa incana*	0	0	1	0	1	0	1	1	0	1	0	1	1	0	0	1	0	1	0	1
yellow	shallow	Brassicales	Brassicaceae	*Raphanus raphanistrum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Dipsacales	Caprifoliaceae	*Kolkwitzia amabilis*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Caryophyllales	Caryophyllaceae	*Dianthus deltoides*	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
white	deep	Caryophyllales	Caryophyllaceae	*Saponaria officinalis*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Caryophyllales	Caryophyllaceae	*Stellaria sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Solanales	Convolvulaceae	*Convolvulus arvensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Saxifragales	Crassulaceae	*Hylotelephium spectabile*	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0
pink	medium	Fabales	Fabaceae	*Lathyrus latifolius*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
pink	medium	Fabales	Fabaceae	*Trifolium pratense*	0	1	1	1	1	1	0	0	1	0	0	0	1	1	0	1	1	0	1	1
pink	medium	Fabales	Fabaceae	*Vicia sativa*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Fabales	Fabaceae	*Medicago ×varia (violet)*	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Fabales	Fabaceae	*Viccia cracca*	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
violet	medium	Fabales	Fabaceae	*Vicia villosa*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	medium	Fabales	Fabaceae	*Melilotus alba*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	medium	Fabales	Fabaceae	*Melilotus officinalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
grey	medium	Fabales	Fabaceae	*Trifolium arvense*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	medium	Fabales	Fabaceae	*Trifolium campestre*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	medium	Fabales	Fabaceae	*Trifolium repens*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	medium	Fabales	Fabaceae	*Lotus corniculatus*	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

					Hesperiidae				Nymphalidae															
Flower colour	Flower deepness	Plant order	Plant family	Plant species	*Erynnis tages*	*Ochlodes sylvanus*	*Thymelicus lineola*	*Thymelicus sylvestris*	*Aglais io*	*Aglais urticae*	*Aphantophus hyperantus*	*Araschnia levana*	*Argynnis paphia*	*Boloria dia*	*Brenthis ino*	*Coenonympha glycerion*	*Coenonympha pamphilus*	*Issoria lathonia*	*Lasiommata megera*	*Maniola jurtina*	*Melanarghia galanthea*	*Polygonia c-album*	*Vanessa atalanta*	*Vanessa cardui*
yellow	medium	Fabales	Fabaceae	*Medicago ×varia (yellow)*	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
pink	medium	Geraniales	Geraniaceae	*Geranium molle*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Geraniales	Geraniaceae	*Geranium robertianum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Lamiales	Lamiaceae	*Agastache mexicana*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Lamiales	Lamiaceae	*Ballota nigra*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Lamiales	Lamiaceae	*Origanum vulgare*	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	0	1
pink	medium	Lamiales	Lamiaceae	*Lamium purpureum*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Lamiales	Lamiaceae	*Lavendula officinalis*	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0	1	1	1
violet	medium	Lamiales	Lamiaceae	*Mentha sp*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Lamiales	Lamiaceae	*Hyssopus officinalis*	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
pink	medium	Lamiales	Lamiaceae	*Prunella grandiflora*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	medium	Lamiales	Lamiaceae	*Stachys officinalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
yellow	shallow	Malvales	Malvaceae	*Tilia sp*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
white	shallow	Lamiales	Oleaceae	*Ligustrum vulgare*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
white	shallow	Lamiales	Plantaginaceae	*Plantago lanceolata*	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
yellow	medium	Lamiales	Plantaginaceae	*Linaria vulgaris*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pink	deep	Ericales	Polemoniaceae	*Phlox*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Ranunculales	Ranunculaceae	*Actaea europaea*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow	shallow	Rosales	Rosaceae	*Potentilla sp*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
white	shallow	Rosales	Rosaceae	*Prunus serotina*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
red	shallow	Rosales	Rosaceae	*Rosa sp*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Rosales	Rosaceae	*Rubis sp.*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white	shallow	Gentianales	Rubiaceae	*Galium album*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
pink	shallow	Saxifragales	Saxifragaceae	*Astilbe japonica*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
violet	medium	Lamiales	Scrophulariaceae	*Buddleja davidii*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0

Manuscript 3: Blooming urban table – flower resources and preferences of butterflies on fragmented wastelands of the large European city

AUTHORSHIP CONTRIBUTION AND ORDER OF AUTHORS

Sylwia Pietrzak (70%) concept of the paper (main contribution), taxonomic analysis of plants and butterflies, field studies, methodology planning, methodology testing in the field, main part of literature research, preparation of dataset for analysis, performing of data analysis, interpretation of the results, preparation of figures, tables and graphics, writing of the manuscript (main draft), manuscript editing, coresponding author

Krzysztof Pabis (30%) supervision of the research, concept of the paper, planning of the field methodology and data analysis, literature research, involvement in manuscript writing and interpretation of the results, manuscript editing

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....

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....

Conclusions

1. Urban wastelands are a habitat for diverse and abundant butterfly communities that strongly reflected composition of the regional species pool of the Central Poland, wastelands are small scale diversity hot spots for butterfly fauna as a result of high microhabitat diversity and high availability of host plants.

2. Phenological changes were stable at all sites and during both seasons, only *Anthocharis cardamines* displayed phenological shifts, probably associated with urban heat island effect.

3. Urban communities were numerically dominated by moderately good dispersers characterized by high fertility, cryptic solitary caterpillars, hidden close to the ground and often displaying nocturnal activity.

4. Butterfly fauna of urban wastelands was dominated by flower generalists utilizing mainly plants representing families Asteraceae, Fabaceae and Lamiaceae, and shallow or medium depth pink, yellow and white flowers.

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Summary

Butterflies are considered good indicators of disturbance associated with urbanization. Despite an increasing number of studies of European butterfly fauna our knowledge about diversity, functional traits and distribution patterns of communities associated with large cities is still insufficient. There are large gaps in our knowledge, especially long term quantitative studies. General understanding of processes structuring urban insect communities is also geographically biased and Central Europe is largely neglected in ecological research. There is particular lack of studies of urban westlands, habitats that may potentially host high variety of resources for diverse and abundant communities of pollinators. Presented thesis aims to analyze species richness, abundance, functional diversity, phenological changes and flower preferences of butterfly communities associated with five urban westlands located in Łódź, a large Central European postindustrial city. Quantitative material was collected during two seasons. Altogether 214 Pollard walks were conducted between April and September of 2019 and 2020. Analysis of flower preferences was conducted in 2021 and 2022. Fauna of all five westlands was homogenous, although diverse (46 species), due to co-occurence of butterflies representing different ecological requirements. Moreover, composition of butterfly communities at small scale restricted urban green spaces strongly reflected the composition of the regional species pool of Central Europe. Observed patterns resulted from high microhabitat diversity and availability of plants for highly plant dependent insects like butterflies. Majority of butterflies recorded in Łódź can be considered generalists, although more specialized taxa like wetland species *Lycaena dispar* and *Polyommatus coridon* - facultative myrmecophile associated with calcareous grassland were also observed in the city. Fauna was numerically dominated by moderately good dispersers characterized by high fertility, cryptic solitary caterpillars hidden close to the ground and often displaying nocturnal activity. Dominance of those butterflies may result from cultivation practice and other types of disturbance typical for unstable, isolated and highly fragmented urban habitat patches. Majority of species were flower generalists utilizing mostly species representing Asteraceae, Fabaceae and Lamiaceae. Flower visits of 39 butterflies on 81 species of plants, representing 19 families were recorded. In general species recorded in the city were visiting shallow or medium depth pink, yellow and white flowers. Obtained results provide new insights into knowledge about urban pollinators and can be used in urban management planning.

Streszczenie

Motyle dzienne są uważane za doskonałe indykatory zmian związanych z urbanizacją. Jednak pomimo rosnącej liczby badań, nasza wiedza na temat różnorodności, zróżnicowania funkcjonalnego i rozmieszczenia zgrupowań europejskich motyli związanych z dużymi miastami jest nadal niewystarczająca. Szczególnie duże braki dotyczą długoterminowych badań ilościowych oraz niektórych rejonów kontynentu, między innymi Europy Środkowej. Jednymi z najczęściej pomijanych siedlisk są miejskie nieużytki, stanowiące bogate źródło zasobów dla zgrupowań owadów zapylających. Niniejsza praca ma na celu analizę bogactwa gatunkowego, rozmieszczenia, różnorodności funkcjonalnej, zmian fenologicznych i preferencji pokarmowych motyli związanych z pięcioma miejskimi nieużytkami zlokalizowanymi w Łodzi, dużym, środkowoeuropejskim postindustrialnym mieście. Badania ilościowe zostały przeprowadzone w czasie dwóch sezonów badawczych. Dane zebrano na 214 transektach Pollarda w okresie od kwietnia do września roku 2019 i 2020. Preferencje pokarmowe owadów dorosłych były także analizowane w roku 2021 i 2022. Faunę miejskich nieużytków charakteryzowała homogeniczność połączona z wysokim bogactwem gatunkowym oraz zróżnicowaniem ekologicznym. W czasie badań odnotowano 46 gatunków. Zgrupowania motyli związane z niewielkimi, miejskimi terenami zielonymi silnie odzwierciedlały faunę regionalną typową dla Europy Środkowej. Zaobserwowane wzorce rozmieszczenia wynikały z dużego zróżnicowania mikrosiedlisk i wysokiej dostępności roślin pokarmowych. Motyle występujące w Łodzi można określić jako gatunki ubikwistyczne. Stwierdzono jednak także obecność bardziej wyspecjalizowanych motyli. Znalazł się wśród nich *Lycaena dispar* (gatunek związanym z wilgotnymi siedliskami) oraz *Polyommatus coridon* - fakultatywny myrmekofil związany murawami rosnącymi na podłożu wapiennym. Faunę zdominowały ilościowo gatunki o umiarkowanie dobrych zdolnościach dyspersyjnych, charakteryzujące się wysoką płodnością, samotnymi gąsienicami żerującymi przy powierzchni ziemi i często wykazującymi aktywność nocną. Rozmieszczenie motyli w mieście może być związane z wpływem zabiegów pielęgnacyjnych oraz innych zaburzeń typowych dla niestabilnych, izolowanych i pofragmentowanych siedlisk miejskich. Większość odnotowanych motyli miała szeroki preferencje w wyborze roślin kwiatowych. Wykorzystywały głównie gatunki roślin z rodziny Asteraceae, Fabaceae i Lamiaceae. Stwierdzono żerowanie 39 gatunków motyli na 81 gatunkach roślin z 19 rodzin. Motyle obserwowano przede wszystkim na płytki i średniej głębokości kwiatach w kolorze różowym, żółtym i białym. Uzyskane wyniki przynoszą wiele nowych informacji na temat ekologii żyjących w mieście zapylaczy i mogą zostać wykorzystane w zarządzaniu zielenią miejską.