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Community structure of flower-visiting insects in different grassland types in Southwestern Germany*

(Hymenoptera Apoidea, Lepidoptera, Diptera)

Von **Anselm Kratochwil**

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The communities of flower visitors (Hymenoptera: Apoidea, Lepidoptera: Rhopalocera, Hesperiidae, Zygaenidae, Diptera: Syrphidae) in different plant communities and vegetation complexes (Xerobrometum, Mesobrometum, Molinietum, Arrhenatheretum) have been studied since 1983 in 10 hectares of the nature reserve "Taubergießen" in southwestern Germany. The aim of this investigation is the registration of the different communities of flower visitors based on a detailed phytosociological characterization of the study area. Different methods are used to identify the degree of habitat preferences: collection of flower visitors in definite areas throughout the vegetation period, transect method and determination of corbicular pollen of bumblebees. Different flower visitors prefer specific grassland communities which can be characterized by phytosociological relevés. The various causes for the preferences are discussed. In the studied vegetation mosaic it is possible to show a differentiated pattern of plant species and their flower visitors in the light of their area-geographical distribution.

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Introduction

Since 1983 a flower ecological research project has been carried out by our working group from the University of Freiburg (FRG) (Kratochwil 1987). 16 participants have assisted in this study. The aim of this investigation is the registration of the different communities of flower visitors based on a detailed characterization of the ecology and phytosociology of the vegetation of the study area.

The questions addressed within the scope of this project are the following:

1) What is the composition of the community of flower-visiting insects (Hymenoptera, Lepidoptera, Diptera) based on a detailed phytosociological characterization of the study area?

2) Do flower visitors prefer specific grassland communities which can be characterized by phytosociological relevés or relevés of vegetation complexes?

3) Which habitat structures, requisites and resources are necessary or quite obligatory for certain flower visitors?

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4) Is it possible to name the causes for the spatial mosaic pattern of flower visitor groups which coincide with the pattern of plant communities?

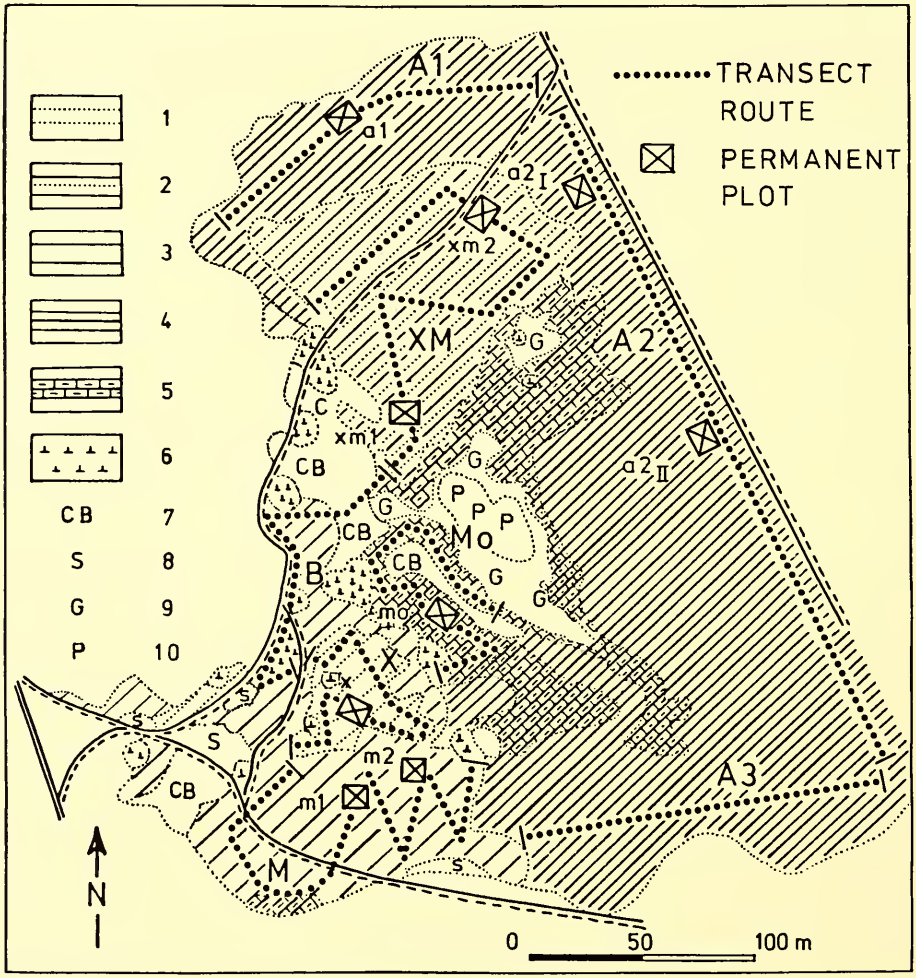


Fig. 1. The study site in the nature reserve "Taubergießen" / southern Rhine plain: vegetation mosaic, permanent plots and transect routes.
1 = Xerobrometum, 2 = mosaic of Xero- and Mesobrometum, 3 = Mesobrometum, 4 = Arrhenatheretum, 5 = Molinietum, 6 = site dominated by shrubberies, 7 = *Calamagrostis epigejos, Brachypodium pinnatum*, 8 = *Solidago gigantea*, 9 = high sedges, 10 = *Phragmites communis*. The locality of the study site in Europe is marked in Fig. 3.

Methods and Materials

The survey area is situated in the southern Rhine plain between Basle and Strasbourg in the nature reserve "Taubergießen" (Fig. 1), and covers an area of about 100000 square meters.

All vegetation types have been mapped on the scale 1:1700 (Schall & Lutz 1982, Lutz 1983). The grassland communities can be differentiated into 5 different types, reflecting on the one hand spatially changing geomorphological factors and on the other hand anthropogenic influences.

1) Xerobrometum (xerophytic limestone grassland)

The Xerobrometum can be found on the driest sites; it has not been influenced by man, and there are scattered shrubberies in the study site in and around this community.

2) Mesobrometum (mesoxerophytic grassland)

The Mesobrometum occurs in sites with deeper weathered soils. It is anthropogenically influenced by occasional mowing.

3) Molinietum (*Molinia* meadow)

The Molinietum is restricted to periodically wet soils, which become very dry during several months. The community is anthropogenically influenced by mowing.

4) Arrhenatheretum, cut once per year (tall oatgrass meadow)

5) Arrhenatheretum, cut twice per year (tall oatgrass meadow)

These fertilized meadow communities grow on deeper, weathered soils, which are mown once or, if fertilized intensively, twice a year. They can be typified as Arrhenatheretum grassland.

In the study area we applied – among others – the following methods:

1) All observations on the flower-visiting entomofauna were included within the whole vegetation period in permanent plots of the different plant communities which were 200 square meters large (Fig. 1); information on their behaviour, for example flower-visiting, was noted.

2) Quantitative phenological inventories of flower and inflorescence numbers were made in 10 by 10 meter plots within the sample squares at weekly intervals (method: Kratochwil 1983, 1984). Data from 120 entomophilous plant species collected in 5 years have been made available (Kratochwil 1989).

3) Measurements of the microclimate within the defined plant communities were carried out by means of thermohygrographs; the analysis of vegetation structure was recorded by measuring transmitted infrared light impulses from different vegetation layers (Federschmidt 1988, Oppermann 1989).

4) In order to register flower visitors of high mobility (for example bumblebees, butterflies) we used a transect method: We noted bumblebees and butterflies with the help of a standardized questionnaire within a visible section of the transects; information about the behaviour of the insects was included. The transect stripe passed defined vegetation types (Fig. 1), and the course was standardized (Steffny et al. 1984).

5) Finally a very exact pollen analytical method has been used in the study area to analyse the preferred plant species for pollen collecting. This method was verified with individually marked bumblebee workers of different species which had been kept in special nest boxes. The collected corbicular pollen was determined on plant species level, and it was possible to draw conclusions concerning the visited plant communities (Kratochwil & Kohl 1988, Kohl 1989).

Results and Discussion

1. Degree of binding certain dominant flower visitors to certain plant communities and some causes of habitat preferences

At first we did not expect to ascertain clear preferences of the flower visitors because numerous flower visitors are excellent flyers and the plant communities sometimes form small patches. Nevertheless it was possible to find differences using the mapped phytosociological units. Three types of Hymenoptera Apoidea and Syrphidae can be differentiated according to the grade of stenotopy (Fig. 2 a, b):

1) species which are specific for a certain plant association in the study area,
2) species with a concentration in a certain plant association in the study area,
3) indifferent species.

a) HYMENOPTERA APOIDEA

		XERO-BROM.	MESO-BROM.	ARRH. twice cut	ARRH. once cut	MOL.
(I)	*Tetralonia salicariae*	■				+ + +
	Andrena humilis			■	+	
	Andrena nitidiuscula	+	+	▩	+ + +	
	Andrena minutuloides		░		▩	░
(II)	*Eucera tuberculata*	▓	+ + +	+ + +	+ + +	
	Lasioglossum villosulum	▓	░	+	+	+ + +
	Halictus tumulorum	▓	+	░	+	+ + +
	Andrena falsifica	▓				▓
	Lasioglossum zonulum	░	▓	+	+	░
	Lasioglossum morio	░	▓	+		+ + +
	Lasioglossum albipes	░	▓	+	+	+ + +
	Lasioglossum interruptum	░	░		▓	
	Lasioglossum major		░	+	░	▓
	Lasioglossum politum	+ + +	+ + +	+	░	▓
(III)	*Halictus maculatus*	░	+ + +	+	+ + +	░
	Lasioglossum pauxillum	░	░	+ + +	+ + +	░
	Lasioglossum leucozonium	░	░	+	+	░
	Andrena ovatula	░	░	░	+	+
	Lasioglossum calceatum	░	░	░	+	+ + +
	Halictus simplex	░	+	░	░	+ + +
	Andrena flavipes	+ + +	░	░	░	+ + +

b) DIPTERA: SYRPHIDAE

		XERO-BROM.	MESO-BROM.	ARRH. twice cut	ARRH. once cut	MOL.
(I)	*Paragus tibialis*	▩	░			
	Microdon latifrons		▩			░
	Syrphus vitripennis			■		+
	Eristalis tenax		+	▩	+	+ + +
	Platycheirus angustatus				▩	+ + +
	Neoascia dispar					■
	Eumerus tuberculatus					■
(II)	*Syritta pipiens*	+	▓	░	+ + +	
	Episyrphus balteatus	+	+ + +	░	+ + +	+ + +
	Eoseristalis arbustorum		+ + +	▓	+	░
	Pipizella varipes		░	▓	+ + +	+
	Pipizella virens		+ + +	░	▓	+ + +
	Myathropa florea	+	+ + +	+	▓	+ + +
	Platycheirus clypeatus	+	+	+	░	▓
	Platycheirus fulviventris		+	+ + +	░	▓

Ⅲ	*Metasyrphus corollae*	░	++	░	++	++
	Scaeva pyrastri	+	░	░	░	++
	Melanostoma mellinum	++	+	░	++	++

+	++	░	▒	▓	█
≤10%	11-20%	21-40%	41-60%	61-80%	81-100%

	c) LEPIDOPTERA: RHOPALOCERA, ZYGAENIDAE, HESPERIIDAE	shrubb. domin. sites	*XERO-BROM.*	*XERO-/MESO-BROM*	*MESO-BROM.*	*ARRH.* twice cut	*ARRH.* once cut	*MOL.*
Ia	*Pararge aegeria*	█						
	Apatura ilia	▓	░					
	Callophrys rubi	+	█		+			
	Aricia agestis		█	+	++			
	Clossiana dia		+	+	▓	+		++
	Cynthia cardui			░		▓		+
	Cupido minimus	+	+	░			▓	
	Melanargia galathea	+	░		+			▓
	Maculinea nausithous							█
Ib	*Aphantopus hyperantus*	▓	++		+			++
	Anthocharis cardamines			+	++	++	▓	+
Ⅱ	*Gonepteryx rhamni*	▒		+	++	++	+	+
	Ochlodes venatus	▒	+		+	++	++	
	Coenonympha hero	▒	░		+		+	
	Thymelicus sylvestris		▒				░	░
	Lysandra coridon	+	▒	░	++	+	+	+
	Minois dryas	++	░	+	░	+	+	+
	Lysandra bellargus		++	▒	+	+	++	
	Papilio machaon	+		▒	+	░		
	Hesperia comma			▒	▒			
	Zygaena filipendulae	+	+	░	░	++	++	+
	Erynnis tages		++	++	░	+	░	
	Maniola jurtina	+	+	++	++	▒	++	+
	Polyommatus icarus		+	++	+	▒	++	+
	Colias australis/hyale		+	++	+	▒	++	+
	Leptidea sinapis	+	+	+	+	░	░	░
	Everes argiades				+	++	▒	░
Ⅲ	*Artogeia rapae/napi*	++	+	++	+	░	+	░
	Coenonympha pamphilus	+	++	++	+	░	++	+

	d) HYMENOPTERA APOIDEA: BOMBUS	shrubb. domin. sites	*XERO-BROM.*	*XERO/MESO-BROM.*	*MESO-BROM.*	*MESO-BROM/ARRH.*	*ARRH.* twice cut	*ARRH.* once cut	*MOL.*
Ⅰ	*Bombus terrestris*			+		+	⁺⁺	●	
	Bombus lapidarius			+		+	░	●	
	Bombus lucorum			+		+	+	█	
Ⅱ	*Bombus pratorum*			░		●	+		
	Bombus humilis			░		▒		+	
	Bombus hortorum			+		▒	+	░	
Ⅲ	*Bombus pascuorum*	+	+	+	+	▒	⁺⁺	░	+
	Bombus silvarum	+	+	⁺⁺	+	⁺⁺	░	░	+

+	⁺⁺	░	▒	●	█
≤10%	11-20%	21-40%	41-60%	61- 80%	81- 100%

Fig. 2. Characteristic species of bees (a), hoverflies (b), butterflies (c) and bumblebees (d) of the study site and their grade of stenotopy in the studied plant communities (b. modified after Schanowski 1985; c, d. modified after Steffny et al. 1984).

I: species which are specific for a certain plant association in the study area,
II: species with a concentration in a certain plant association,
III: indifferent species.

Various causes for these relatively clear preferences of group 1 or 2 can be found. The habitat preferences of many flower-visiting insects are based on specific requisites and structures (Kratochwil 1987):

1) Presence of specific nectar and pollen plants.

Andrena falsifica Perk., for example, only visits flowers in the plant communities Xerobrometum and Molinietum. This species is specialized on the genus *Potentilla* (Rosaceae), the females collect pollen on *Potentilla tabernaemontani* Aschers. and *P. heptaphylla* L. in the Xerobrometum, and on *Potentilla erecta* (L.) Räusch. in the Molinietum. Among the Syrphidae *Cheilosia albitarsis* (Meig.) prefers flowers of *Ranunculus* (Ranunculaceae). In the study area this syrphid flies in the Mesobrometum.

2) Presence of specific blossom types.

Different plant communities offer qualitatively and quantitatively different blossom "equipment" or blossom types. This fact may be the reason for the observed concentration of flower-visiting insects in certain plant communities. For example, the halictid bee *Lasioglossum politum* (Schck.) prefers simple blossoms with radial symmetry and many anthers. This insect is able to cling to the filaments in order to remove pollen from the anthers. The same method of pollen extraction also works well for this bee on *Hypericum perforatum* L. (Hypericaceae) and thus its concentration in the Molinietum and Arrhenatheretum can be explained. However, *L. politum* (Schck.) can be observed in the Xerobrometum and Mesobrometum as well, but less frequently, where it visits *Helianthemum nummularium* (L.) Mill. (Cistaceae) with a blossom type analogous to *Hypericum perforatum* L.

The syrphid *Eristalis tenax* (L.) was observed in the study area mostly in the Arrhenatheretum. This is due to the presence of certain blossom types too in this case head shaped blossoms, e. g. Asteraceae, are decisive. But there are two other factors which must be mentioned concerning of

E. tenax (L.). These are discussed below (3 and 4), and are factors which are as important for other species.

3) Dominance of specific blossom colours.

   Kugler (1950) and Kay (1976) were able to demonstrate a spontaneous preference for yellow blossom colour in experiments with *Eristalis tenax* (L.). In the study area this species also showed this colour constancy. But colour constancy for a dominant species is only possible in plant communities which offer seasonally predominating colour aspects, as in the Arrhenatheretum.

4) Occurence of high blossom density of one or few plant species.

   The individuals of *Eristalis tenax* (L.) confine themselves to certain plant species, whose flowers are easily handled by experience, and so it is possible to collect a high amount of pollen without high energy expense. Blossom fidelity as a possible foraging strategy is only profitable in plant communities with a lot of florescence dominating species. These conditions are especially offered by the type of meadows from Arrhenatheretum.

The concentration of insects visiting flowers in specific plant communities can be explained even by other important factors, for instance, microclimate, larval habitats, etc. Examples from the study area are given.

It is possible to describe the habitat of specific flower-visiting insects using the phytosociological pattern. This can be shown even for very active insects such as butterflies and bumblebees (Figs 2 c, d) (Kratochwil 1987, Kratochwil 1989, Kohl & Kratochwil 1988).

Fig. 3. The locality of the study area in Central Europe with reference to different geoelements.

2. Area-geographical and historical interpretation of the spatial pattern of plant communities and their flower visitors

The question arises as to the causes for this distribution pattern of different communities of flower visitors in the different plant communities. These causes are not to be found only on the species level but on the community level too. Subsequently it should be conceivable to give an area-geographical interpretation of the spatial mosaic pattern of plant and insect communities with regard to biogeographical aspects:

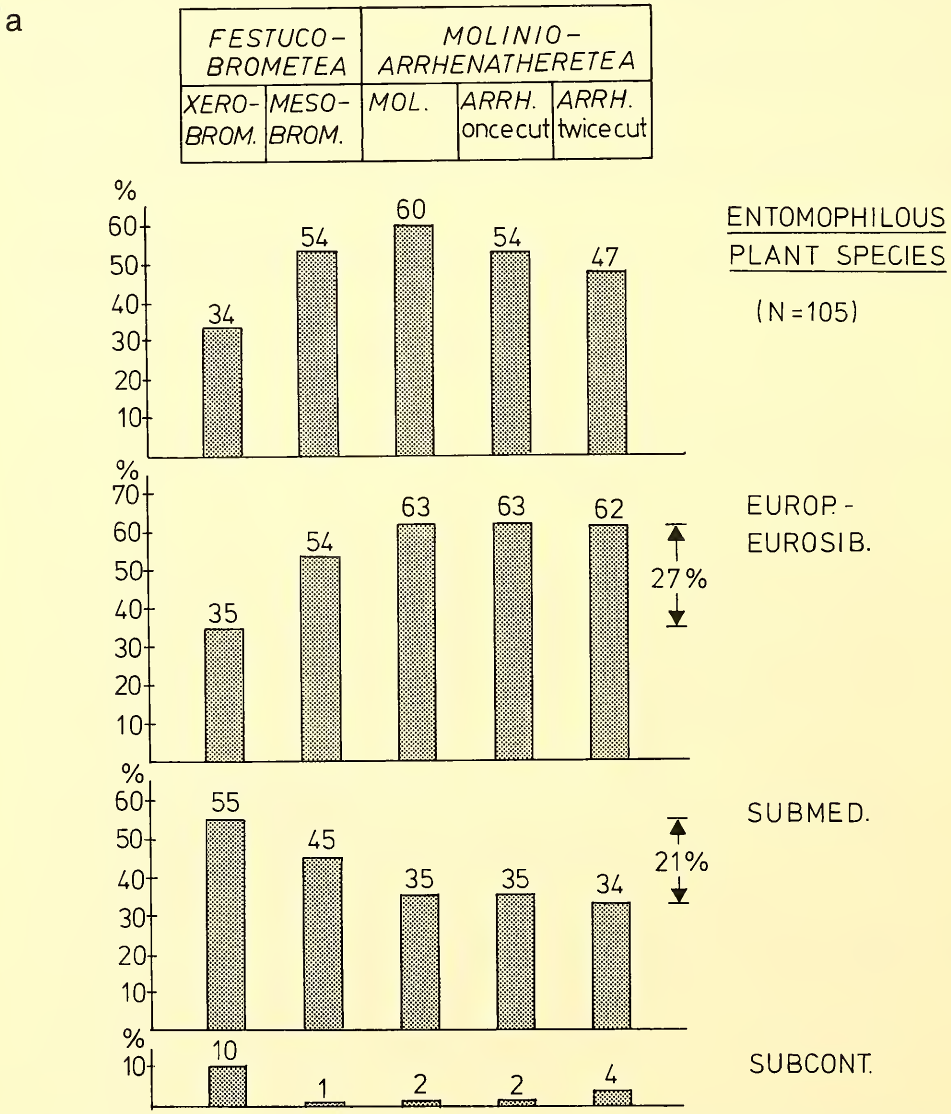
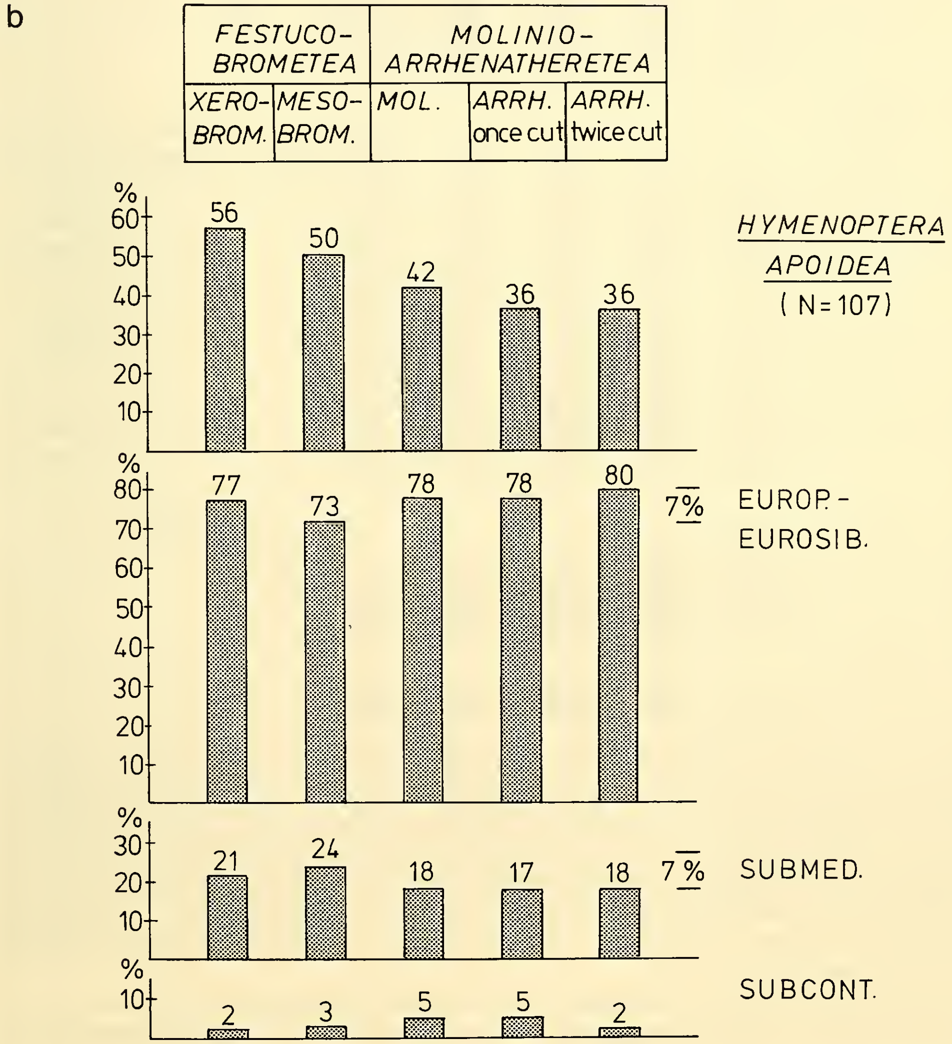
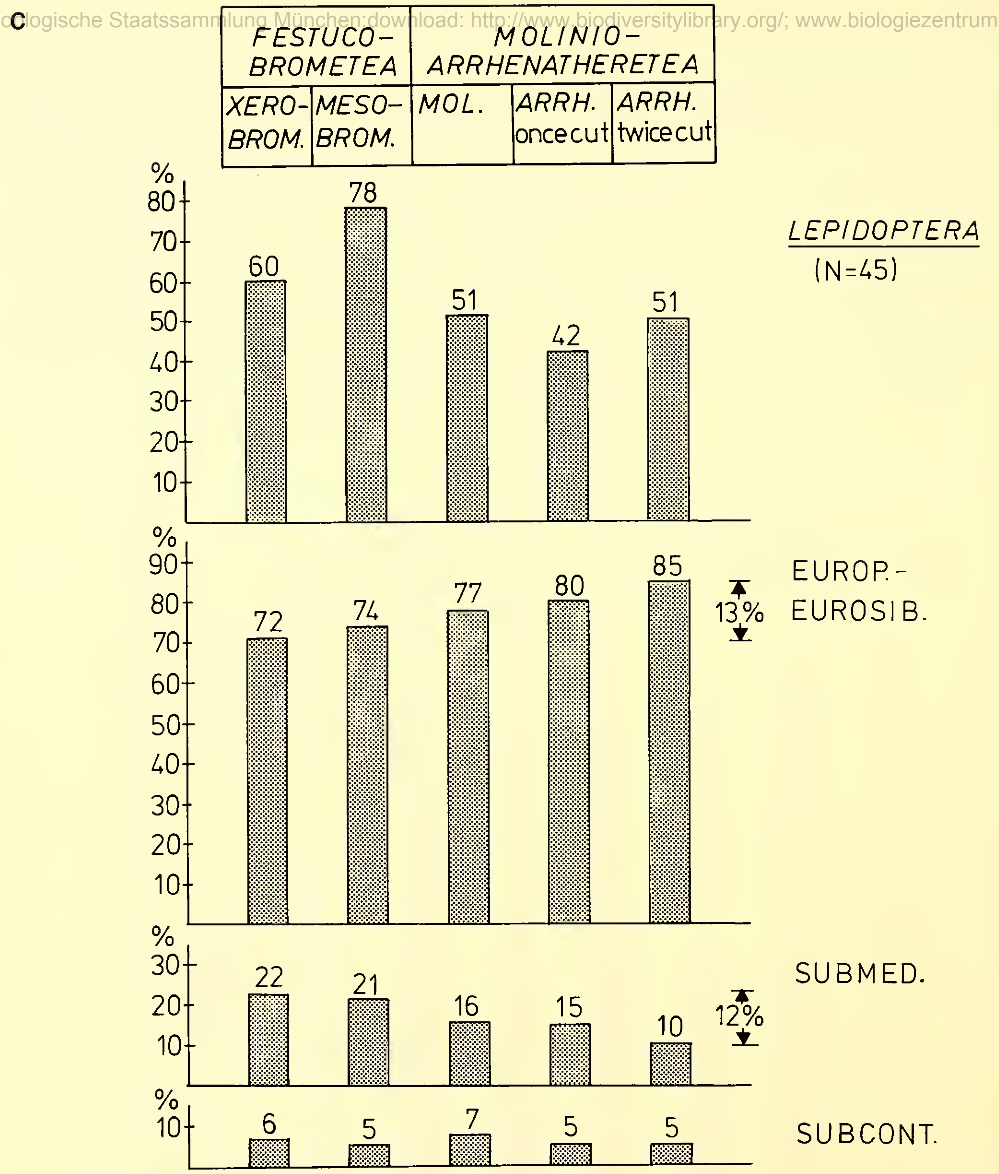


Fig. 4. Percentage of entomophilous plant species (a), butterfly (b), bee (c) and hoverfly (d) in the studied plant communities belonging to different geoelements.

The flora and fauna of Central Europe is dominated by the European-Eurosiberian geoelement, in addition, there are also some Submediterranean and Subcontinental species (Fig. 3). The occurence of Submediterranean and Subcontinental species in Central Europe can only be understood in the light of the history of flora and fauna of the postglacial period: In the last Wuerm glacial period Continental steppe species migrated to Central Europe; then in the postglacial warm period Submediterranean species followed. The Submediterranean and Subcontinental species now exist in Central Europe only in microclimatically favoured habitat islands (Kratochwil 1988).

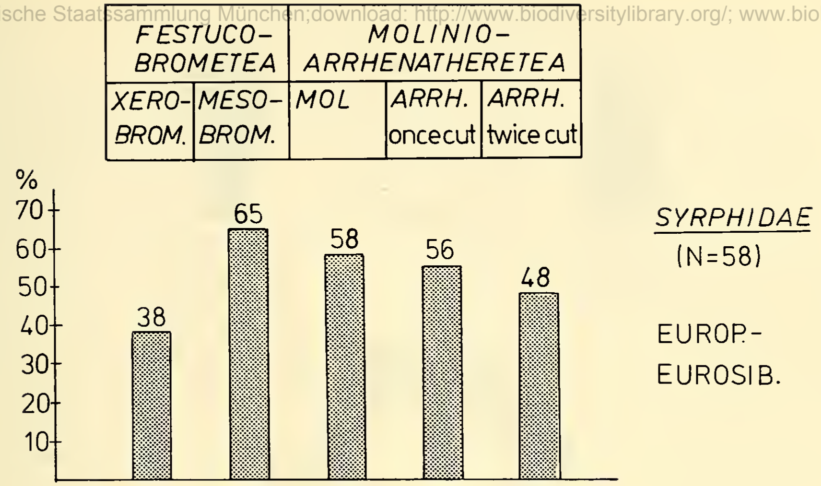
Certain plant communities differ from each other concerning the percentage of species belonging to these geoelements, even if the communities grow within a mosaic such as in the study area (Fig. 4a). The Xerobrometum and the Mesobrometum have a higher portion of Submediterranean plant species as the Molinietum and the Arrhenatheretum; conversely, the Xerobrometum has only a few species of the European-Eurosiberian element. The question arises whether or not we can infer a similar area-geographical pattern referring to the flower visitor community as well.





Thus it is very remarkable that the highest species diversity and flower-visiting activity of bumblebees can be observed in the meadows of the Arrhenatheretum type (Fig. 2c). From an area-geographical point of view this means that the occuring bumblebees – all of them are spread over Northern/ Central Europe and Eurosiberia – prefer exactly the plant community with the highest percentage of plant species of this geoelement. The foraging strategies of many bumblebees are correlated with a specific blossom type spectrum and a vegetation pattern with high florescence density of few species and with certain microclimatic conditions. All these requirements are fulfilled by the Arrhenatheretum (Kratochwil & Kohl 1989).

The plant species as well as the bumblebees and even the butterflies show a good correlation regarding the percentage of different area-geographic elements. The butterfly species with Submediterrad



nean distribution have their highest portion in the Xerobrometum, those with Eurosiberian distribution in the Arrhenatheretum (Fig. 4b).

Regarding bees – except the genus Bombus – the coincidence is not so clear (Fig. 4c). Given the thermophilic and xerophilic habitat conditions of most of the bee species they will prefer such plant communities offering the best micro- and mesoclimatical conditions provided there are adequate nectar and pollen resources. Considering this, it is understandable why the Xerobrometum is of great importance for these bees. It has the highest species diversity.

Regarding the syrphids with only Eurosiberian distributed species in the study area it can be stated that this group avoids the Xerobrometum due to microclimatic reasons (Fig. 4d). The highest percentage rates of the syrphids are found in the Molinietum und Arrhenatheretum, and even in the Mesobrometum although the latter is characterized by a high percentage of Submediterranean plant species. In the case of Mesobrometum the high blossom diversity has certainly a considerable influence.

In summary the following conclusions can be drawn:

Even in a vegetation mosaic it is possible to show a differentiated pattern of plant species and their flower visitors in the light of their area-geographical distribution (Fig. 5). The different percentage rates of the Eurosiberian and Submediterranean elements are especially remarkable. It is certainly possible that there is a seasonal gradation regarding flowering time and flower visitor activities according to their area-geographical centre in one biocoenosis, for instance, the flower visitor community of the Mesobrometum (Kratochwil 1987). However, the actual portions of these geoelements change in the different plant communities studied. We can demonstrate that flower visitors often prefer plant species for collecting pollen which belong to the visitors geoelement (Kratochwil 1987).

The area-geographical pattern of entomophilous plant species and flower visitors is on the one hand the result of the spatial changing habitat types with different resources, microclimate, etc., and on the other hand the result of postglacial processes of recolonization of Central Europe.

The results demonstrate that there is a coincidence between plant and flower visitor communities according to the area-geographical point of view indicating the mutual history of the vegetation and fauna of different subbiocoenosis.

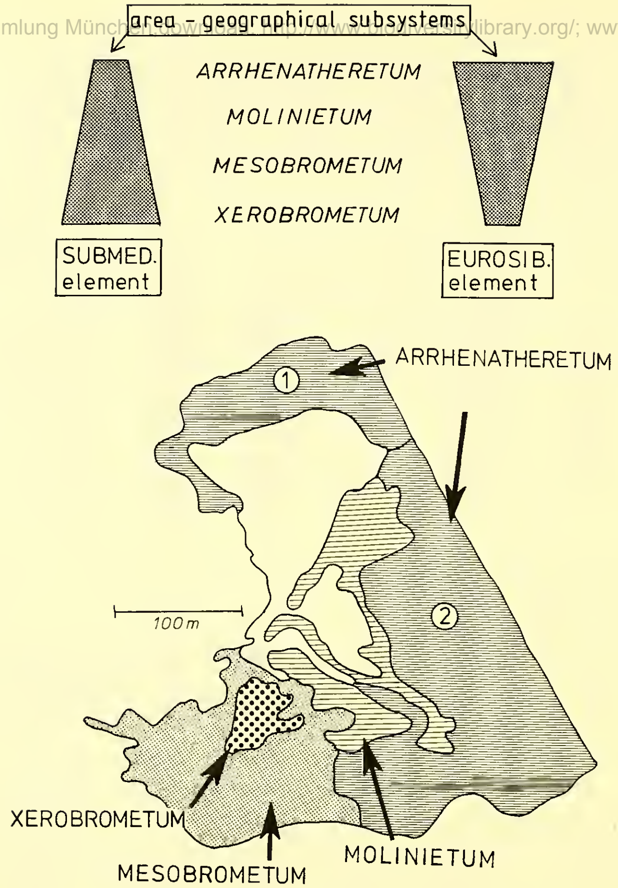


Fig. 5. The correlation between the Submediterranean and European-Eurosiberian flora- and fauna-elements according to the flower visitor communities of different plant communities in the study area.

Tab. 1. List of the dominant flower visitors from the study area in the nature reserve "Taubergießen" (SW-Germany):

Hymenoptera: Apoidea

- *Andrena falsifica* Perkins, 1915
- *Andrena flavipes* Panzer, 1799
- *Andrena humilis* Imhoff, 1832
- *Andrena minutuloides* Perkins, 1914
- *Andrena nitidiuscula* Schenck, 1853
- *Andrena ovatula* (Kirby, 1802)
- *Halictus maculatus* Smith, 1848
- *Halictus simplex* Blüthgen, 1923
- *Halictus tumulorum* (Linnaeus, 1758)
- *Lasioglossum albipes* (Fabricius, 1781)
- *Lasioglossum calceatum* (Scopoli, 1763)
- *Lasioglossum interruptum* (Panzer, 1798)
- *Lasioglossum leucozonium* (Schrank, 1781)
- *Lasioglossum major* (Nylander, 1851)
- *Lasioglossum morio* (Fabricius, 1793)
- *Lasioglossum pauxillum* (Schenck, 1853)
- *Lasioglossum politum* (Schenck, 1853)
- *Lasioglossum villosulum* (Kirby, 1802)
- *Lasioglossum zonulum* (Smith, 1848)
- *Eucera tuberculata* (Fabricius, 1793)
- *Tetralonia salicariae* (Lepeletier, 1841)
- *Bombus hortorum* (Linnaeus, 1761)
- *Bombus humilis* Illiger, 1806
- *Bombus lapidarius* (Linnaeus, 1758)
- *Bombus lucorum* (Linnaeus, 1761)
- *Bombus pascuorum* (Scopoli, 1763)
- *Bombus pratorum* (Linnaeus, 1761)

Bombus silvarum (Linnaeus, 1761)
Bombus terrestris (Linnaeus, 1758)

Lepidoptera: Rhopalocera, Hesperiidae, Zygaenidae

Papilio machaon Linnaeus, 1758
Artogeia napi Linnaeus, 1758
Artogeia rapae Linnaeus, 1758
Leptidea sinapis Linnaeus, 1758
Gonepteryx rhamni Linnaeus, 1758
Colias australis Verity, 1911
Colias hyale Linnaeus, 1758
Anthocharis cardamines Linnaeus, 1758
Melanargia galathea Linnaeus, 1758
Aphanthopus hyperanthus Linnaeus, 1758
Maniola jurtina Linnaeus, 1758
Coenonympha hero Linnaeus, 1761
Coenonympha pamphilus Linnaeus, 1758
Minois dryas Scopoli, 1763
Pararge aegeria Linnaeus, 1758
Apatura ilia Schiffermüller, 1775
Cynthia cardui Linnaeus, 1758
Clossiana dia Linnaeus, 1767
Callophrys rubi Linnaeus, 1758
Cupido minimus Fuessli, 1775
Everes argiades Pallas, 1771
Aricia agestis Schiffermüller, 1775
Polyommatus icarus Rottemburg, 1775
Lysandra bellargus Rottemburg, 1775
Lysandra coridon Poda, 1761
Maculinea nausithous Bergsträsser, 1779
Erynnis tages Linnaeus, 1758
Thymelicus sylvestris Poda, 1761
Ochlodes venatus Bremer & Grey, 1853
Hesperia comma Linnaeus, 1758
Zygaena filipendulae Linnaeus, 1758

Diptera: Syrphidae

Paragus tibialis (Fallen, 1817)
Platycheirus angustatus (Zetterstedt, 1843)
Platycheirus clypeatus (Meigen, 1822)
Platycheirus fulviventris (Macquart, 1828)
Melanostoma mellinum (Linnaeus, 1758)
Scaeva pyrastri (Linnaeus, 1758)
Syrphus vitripennis Meigen, 1822
Metasyrphus corollae (Fabricius, 1794)
Epistrophe balteata (De Geer, 1776)
Neoascia dispar Meigen, 1822
Pipizella varipes (Meigen, 1822)
Pipizella virens (Fabricius, 1805)
Eristalis tenax (Linnaeus, 1758)
Eoeristalis arbustorum (Linnaeus, 1758)
Myatropa florea (Linnaeus, 1758)
Eumerus tuberculatus Rondani, 1857
Microdon latifrons Loew, 1856
Syritta pipiens (Linnaeus, 1758)

Zusammenfassung

Seit 1983 werden in verschiedenen Pflanzengesellschaften und Pflanzengesellschafts-Komplexen (Xerobrometum, Mesobrometum, Molinietum, Arrhenatheretum) auf einer Fläche von 10 ha Blütenbesucher-Gemeinschaften (Hymenoptera: Apoidea, Lepidoptera: Rhopalocera, Hesperiidae, Zygaenidae, Diptera: Syrphidae) im Naturschutzgebiet „Taubergießen" (Südliche Oberrheinebene) untersucht. Ein Ziel der Untersuchungen liegt in der Abgrenzung verschiedener Blütenbesucher-Gemeinschaften auf der Basis des pflanzensoziologischen Rasters. Hierbei kommen verschiedene Methoden zum Einsatz: Blütenbesucher mit einem geringen Aktionsraum werden in einzelnen Dauerbeobachtungsflächen verschiedener Pflanzengesellschaften erfaßt, Arten mit größerer Mobilität auf Transektstrecken in homogenen Pflanzenbeständen. Als eine weitere Methode zur Feststellung der Pollensammel-Präferenzen diente die Analyse von Corbicularpollen verschiedener in künstlichen Nestern gehaltener Hummelarten und die Rekonstruktion der besuchten Pflanzengesellschaften. Verschiedene Blütenbesucher zeichnen sich durch die Bevorzugung bestimmter Rasengesellschaften aus. Einige Ursachen für die Habitatbindung werden an Beispielen vorgestellt. Die verschiedenen Pflanzengesellschaften und ihre jeweiligen Blütenbesucher-Gemeinschaften besitzen ein für sie charakteristisches Arealtypen-Spektrum. Das „biogeographische Verteilungsmuster" eines solchen kleinflächigen Vegetationsmosaiks und seiner Blütenbesucher-Gemeinschaften wird aufgezeigt und diskutiert.

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