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Life Sciences
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The Natural Roof (NADA) -

Research Project Report on the Use of Extensive Green Roofs by Wild Bees

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The translated version was edited by Dusty Gedge.

Summary

Earlier investigations (Riedmiller & Schneider 1993, Riedmiller 1994, Mann 2005) established that wild bees make use of replacement habitats on buildings as much as other species do. However, questions about the importance of substrate, vegetation and structure of green roofs for their use by wild bees needed answering.

Some wild bee species make their nests in holes in the ground; hence the question whether substrates made from natural earth or sand and gravel provide suitable nesting conditions.

The following investigation shows that green roofs are systematically used as habitats by wild bees. On average sedum roofs attracted only half the number of bee species compared with green roofs planted with multiple forms of vegetation (herbaceous roofs). The number of blossom visits is even more marked: on sedum roofs it was only one fifth of the number of visits counted on herbaceous roofs. An extended investigation would probably produce an even greater difference. The reason for this is simple: sedums have a shorter flowering period, which minimises their usefulness as feeding grounds.

Ten endangered wild bee species (red listed category 3 in Switzerland) have been identified. Green roofs of a more natural character invited a higher number of bee species than those with less variety (i.e. planted predominantly with sedums).

It has been found that even green roofs situated in city centres and at relatively high altitudes attract wild bees. Even large bees, such as masonry bees have been sighted on the tallest roof included in this investigation, the *Klinikum 1* in Basel.

The results show that in terms of potential habitat for wild bees there is hardly any difference between a nature-like green roof with substrates from the region (a mix of sand and clay) and the ground. Green roofs such as the *Klinikum 2* in Basel could be planted with a greater variety of plants that could provide food throughout the growing season. As extensive green roofs do not suffer any disturbance once installed, the dead plant matter provides ideal habitats during the winter for spiders and insects. In urban areas such undisturbed conditions are hardly available on the ground and difficult to provide by design, as parks and gardens are constantly maintained. On the ground there is also more competition from other species. Extensive green roofs can improve conditions for wild bees by providing additional feeding grounds in built-up areas; they can therefore count as ideal extensions to the natural conditions on the ground.

Further investigations about frequency of wild bee visits comparing sedum roofs with herbaceous roofs are planned for 2006 at Wädenswil University in order to create statistics. The resulting figures regarding the protection of endangered species on extensive green roofs will

emphasise their ecological significance and be used to inform Guidelines, Planning Control and Execution Control. The provision of suitable habitats for as many endangered species as possible would have to become a requirement.

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1. Starting point and Introduction

Extensive green roofs provide living conditions for plants as well as animal species that live in the vegetation and in the soil, species that can adapt to extreme conditions. These species need to be sufficiently mobile in order to reach the roof area. Surveys of invertebrates on green roofs in Basel and Luzern have shown that green roofs offer a compensatory solution for the protection of species (Brenneisen 2003). A gradual increase in the number of rare and endangered invertebrates has been observed in Switzerland (Brenneisen 2003) and Germany (Pozzi et al 1998). (Fig.1)

The functionality of specially designed surfaces incorporating small mounds and a variety of substrate materials has also been detected. Areas that remain constantly humid during dry periods offer refuge to soil fauna resulting in a significant increase in the number of species compared with levelled locations.

A variety of sample roofs have been installed in Basel (Photos 1 and 2) following older examples from Basel (Photos 3 – 5) and Luzern (SUVA, Migros Würzenbach). These sites will also be investigated as to their functionality.

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(Skipped: see German Paper)

[Fig.1 Green roofs sampled in 1999 as to the age, coverage and variety of plants and the number of spiders and beetles (Brenneisen 2003, modified)]

[Photos 1 and 2 : Experimental area *Nordtangente*]

[Photos 3 -5): Green roof *Rhypark* on the Rhine]

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1.1 Wild bees on green roofs

Earlier research conducted by Riedmiller & Schneider 1993, Riedmiller 1994, Mann 2005 proved that wild bees belong to the group of species that make use of replacement habitats provided on buildings. Now an investigation into the significance of substrates, vegetation and structural diversity with regard to their usefulness to wild bees was called for.

Bees (*Apoidea*) belong to the order of *Hymenoptera*. Bees found preserved in amber prove their existence since 80 million years. In the course of 100 million years a great variety of bees developed as a result of the evolution of flowering plants. It is estimated that there are 30,000 species worldwide; about 1,000 species are known in Europe alone, whereby the name "wild bees " is used for all but the honeybee (*Apis melllifera*). In Switzerland 585 types of wild bees have been identified (Steinmann 1993).

Most bees are solitary. The female builds the nest on her own and feeds the brood alone. Social structures such as that of the honeybees have only been seen in bumblebees and burrowing bees (Müller 1990).

Some species build their nests in the form of cavities in the ground. This fact prompted important questions about the usefulness of substrates containing natural soil or sandy gravel as nesting grounds for wild bees.

2. Target and choice of locations to be investigated

The primary objective was to establish the impact of various forms of roof vegetation on the number of blossom visits performed by wild bees. The specific aims were:

- To refine the argument in favour of the significance of green roofs for wild bees in general
- To compare the variety of ways in which bees use and frequent green roofs given different types of green roofs
- To investigate how different substrates are used for nesting.

For a countrywide comparison investigations took place in the regions of Basel, St.Gallen, Luzern and Zurich (Tab. 1)

Table 1. List of locations of surveyed areas with description of type of vegetation and substrates

Location		Type of vegetation and substrate	Area	Age
Surveyed area				
Basel				
Universitätsspital Klinikum 1	1	Scant vegetation, mainly sedums with meadow-like areas incorporating small mounds (h 20cm); substrate: gravel (*Wandkies*) + fine soil	2000 m^2	5 yrs
Universitätsspital Klinikum 2	2	Partly scant vegetation, partly large meadow with mixed areas between; various substrates: sand + gravel, shingle , topsoil	3000 m^2	5 yrs
Messehalle	3	Scant sedum growth; substrate: pumice	10000 m^2	7 yrs
Planted slopes Nordtangente „Earth“	4	Alternating open areas of mosses, herbs, grasses; substrate: layer of shingle topped with thin layer of fine brown soil (*Braunerdehorizont)*	10000 m^2	7 yrs
Planted slopes Nordtangente „Shingle“	5	Mainly open areas without vegetation with some solitary plants, sedums; substrate: shingle	10000 m^2	7 yrs
Saalbau Rhypark	6	Scant vegetation, mounds with small shrubs, areas with grasses, mosses or free of vegetation; substrates: sandy gravel, broken up chalk, mix of gravel and soil	500 m^2	13 yrs
University Hospital Rossetti-Bau	7	Scant vegetation, hilly areas with a variety of herbs, areas of grass, open mossy areas, some large stones; substrate: a mix of sand clay and gravel	1500 m^2	5 yrs
Schwarzpark	8	60% coverage with vegetation of mixed sedum – herbs – grasses on natural topsoil taken from the woodland on which the structure stands.	200 m^2	5 yrs
Luzern				
Maihof	9	Semi-intensive character. Open areas with sedum – grass – herbs alternating with various shrubs on thicker substrate layers	2000 m^2	15 yrs
SUVA	10	Meadow-like vegetation. Some humid areas with plants that tolerate varying degrees of humidity (orchids). Substrate: ca 15cm unsorted gravel with a small amount of soil	2000 m^2	15 yrs
Würzenbach	11	Fully covered with vegetation. Varying humidity. The initial stage of a wetland meadow (*Pfeifengraswiese)*	1500 m^2	30 yrs
St. Gallen				
Baudepartement	12	Low coverage with mainly sedums interspersed with only a few herbs. Substrate: pumice	1000 m^2	8 yrs
Botanic Garden	13	Sloping green roof with mainly sedums mixed with herbs. Substrate: pumice	600 m^2	10 yrs
Cemetery Bruggen	14	A rich diversity of plant species such as on a meadow. Substrate: gravel – sand with some compost	300 m^2	12 yrs
Cemetery Feldli	15	A rich diversity of plant species; some humid areas. Substrate: Gravel with leaf mould	150 m^2	4 yrs
Kanton Hospital	16	Relatively dense vegetation. Substrate: pumice / expanded slate (*Blähschiefer)*	1500 m^2	20 yrs
School building Grossacker	17	Sparse vegetation, mainly sedum. Substrate: pumice	1000 m^2	5 yrs
Steinach	18	Ground location on a river bank (Steinach) with extensive management of a meadow and trees	10000 m^2	?
Zürich				
Seewasserwerk Moos	19	Rich diversity of vegetation, meadow with varying degrees of humidity. Substrate: topsoil	10000 m^2	90 yrs

Table 2. List of additional locations surveyed in 2005 with description of vegetation and substrates.

Location	Type of vegetation and substrate	Area	Age
Surveyed area			
Additional roofs			
Basel			
University Hospital Klinikum 2, (9th floor)	Mixed sedum and herb roof with areas of grass. Substrate: expanded slate (*Blähschiefer)*	2000 m^2	12 yrs
Basel-Land			
IKEA	Predominantly sedum; substrate: pumice	8000 m^2	6 yrs
Sieffert AG	Sedum – herbs - grass. Substrate: broken chalk and pumice	150 m^2	10 yrs
Zurlinden Grube	Conservation area in disused gravel pit.	10000 m^2	?
St. Gallen			
Stadttheater	Small area of vegetation ranging from open to relatively dense meadow. Substrate: Gravel (*Wandkies*), leaf mould	120 m^2	1 yr
Heimstätten Wil	Sedum – herb vegetation. Substrate:: sand / clay / gravel mix	1000 m^2	3 yrs

3. Methods and execution

In 2004, the first year of survey the so-called 'yellow dish method' (*Gelbschalenmethode*) was employed, that intended to attract the species to the green roof in order to obtain data. In the second year of the survey, 2005 this was extended to counting the number of blossom visits by wild bees.

The first survey year 2004

Wild Bees were caught in yellow 6 litre buckets, one bucket per survey location. The bait was a 1:10 dilution of acetic acid. The traps were put in place at the beginning of April and checked and emptied at 14-day intervals until the end of October.

The second survey year 2005

Different green roofs were monitored on two separate dates (end of April and mid June) for one hour at a time. At nine different locations (three each in Basel City, Basel Region, St.Gallen) the number of bees visiting a 1m x 1m area of green roof were counted.

4. Results

The collection of *Apidae* during project NADA resulted in 1551 adult animals, of which 478 were honeybees (*Apis mellifera*). 77 species belonging to 18 genera were found (Tab. 3). The species were identified by Mike Edwards, a London entomologist working with Dr. G. Kadas of Royal Holloway College on her long term study of green roofs and invertebrates, who both collaborated in this project. Tables 3a to 3c show the distribution of individuals among the surveyed sites. The figures refer to the number of bees collected per year. The total number of species and of individual specimens and the diversity values are given at the end of the tables.

Approximately one third of collected specimens were honeybees. 15 identified species (19.5% of a total of 77 species) belong to the genera *Lasioglossum* (burrowing bees). In terms of specimens 20.9% of collected individuals were burrowing bees. The second most common species belong to the genera *Andrena* (sand bees) (13 species = 16.9%) which constituted 9.8% of collected specimen. The third most common bees collected were *Bombus* (bumblebees) (12 species = 15.6%). At 27.3% bumblebees constituted a high number of specimens, only surpassed by honeybees (31.1%).

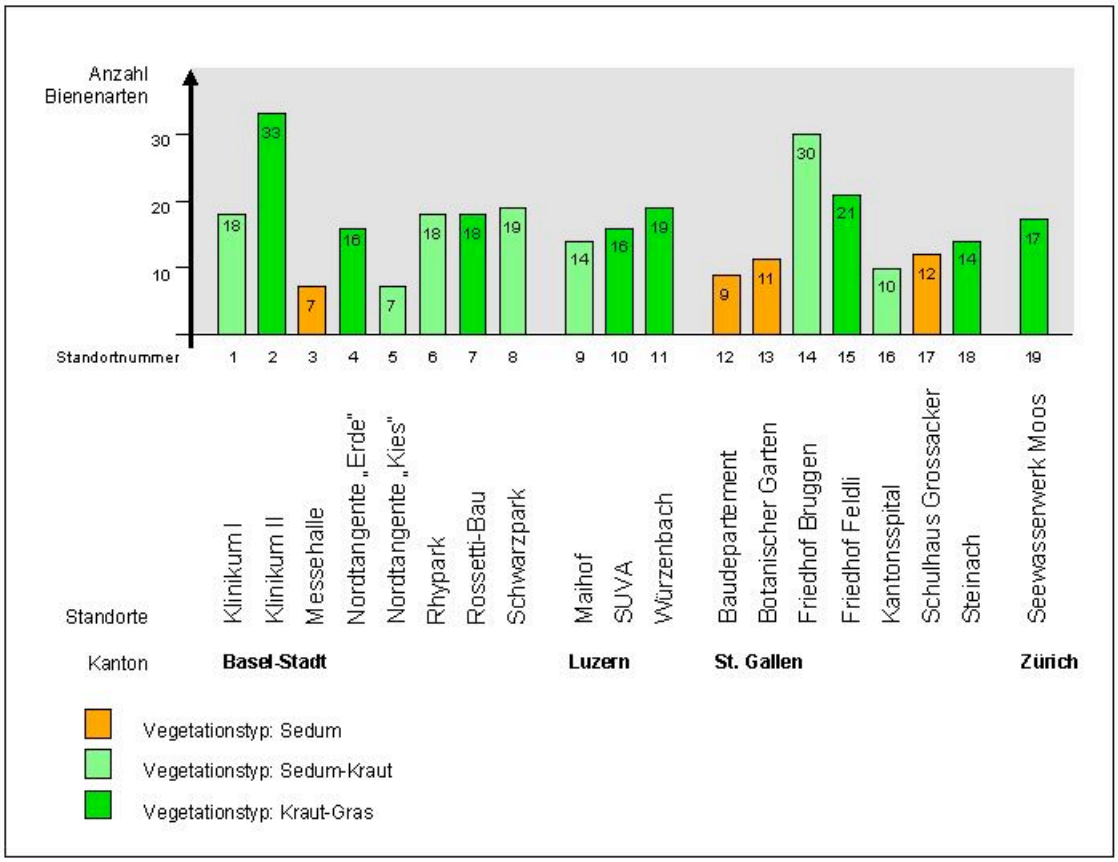

Fig. 2: Number of bee species (Anzahl Bienenarten) collected at each surveyed location (Standort) and type of vegetation (Vegetation

***Apidae* (Bienen)**	**Schutz**	**Ökologie**			**Standorte**																				
	Rote Liste CH	Lebensraum	Nistweise	Blüten-besuch	Basel								Luzern			St. Gallen							ZH	
Gattung und Art					Klinikum 1	Klinikum 2	Messehalle	Nordtangente ("Erde")	Nordtangente ("Kies")	Rhypark	Rossetti-Bau	Schwarzpark	Maihof	SUVA	Wurzenbach	Baudepartement	Botanischer Garten	Friedhof Bruggen	Friedhof Feldli	Kantonsspital	Schulhaus Grossacker	Steinach	Seewasserwerk Moos	Summe
Standortnummer					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
***Andrena* (Sandbienen)**																								
Andrena spec.		-	-	-	2	3		5	1		1	3	4		4		6	6				4	39
Andrena bicolor		U	E	p		2				1		2						2	1					8
Andrena chrysoceles		tF, S, H, W, F, R, W, Si, aW	E	p											1		1							2
Andrena cineraria	**3**	**W, tF, H, Sa, K, Si,**	**E**	**p**		**5**		**2**				**1**												**8**
Andrena flavipes		U	E	p	1	16	2	5		2	3	4	3	2	7		1	1		1			2	50
Andrena fulva		IW, W, H, aW, Si, G	E	p		2																		2
Andrena haemorrhoa		U	E	p		1												1			17			19
Andrena minutula		U	E	p		6				2		1												9
Andrena minutuloides		W, Ka, Fe, S, H	E	p							1													1
Andrena nitida		U	E	p												1		3		1		1	1	7
Andrena scotica (=carantonica)		?														1					1			2
Andrena subopaca		W, Fe, tF, aW, Fel, M, R	E	p		1						1						1				1		4
Andrena viridescens	**3**	**tF, S, H, Bö, M, aW**	**E**	**o, V**																			**1**	**1**
***Anthidium* (Harz- und Wollbienen)**																								
Anthidium manicatum		G, T, aW, W, L, I, B	vH	p		1		1						1				1						4
Anthidium strigatum		Fl, W, Wi, M, aW, K, St	Fr	p														1						1
***Anthophora* (Pelzbienen)**																								
Anthophora spec.		-	-	-			1																	1
Anthophora furcata		W, Wi, Ka, S, O	sH	o, L					1															1
***Apis* (Honigbienen)**																								
Apis mellifera		verschiedene Rassen			6	26	11	50	45	7	10		1	29	22	24	96	98	5	24	4	7	13	478
***Bombus* (Hummeln)**																								
Bombus spec.		-	-	-																		1		1
Bombus alpestris		?																			1			1
Bombus campestris		?																1						1
Bombus horotrum		W, S, H, Si	vM, V, Ge	p														2	1					3
Bombus humilis	**3**	**oG, W, S, Si**	**Kr, Mo, vM**	**p**											**1**									**1**
Bombus hypnorum		IW, W, Si	Ba, Fs, Ge	p		1		1		1	1				2			11	1		4	2		24
Bombus lapidarius		W, aW, S, M, Si	vH	p	18	3		4	1	3	5		3	4	11	2	13	4	1	2	22	6	4	106
Bombus pascuorum		U	vM, Mo, Kr, vH	p									2	3	2			43	2	4	2	14	1	73
Bombus pratorum		IW, oG, Si	Ges, Mo, Ge, vM	p														2						2
Bombus soroeensis		W, oG, IW, Sa,	vM	p				1										1				1		3
Bombus sylvestris		?			1													1						2
Bombus terrestris/lucorum		U	vM, Ge,	p	26	29	2	15	6	5	55	3	5	4	4	2	3	18	1	6	14	10	1	209
***Chelostoma* (Scherenbienen)**																								
Chelostoma campanularum		W, Wi, S, aW, Si	vHo	o, C															1					1
Chelostoma rapunculi		?																2	1					3

Tabelle 3a: Aktivitätsdichten der erfassten Bienenarten nach Untersuchungsstandort, mit Angaben zur Ökologie und Schutzstatus.

***Apidae* (Bienen)**	**Schutz**	**Ökologie**			**Standorte**																				
	Rote Liste CH	Lebensraum	Nistweise	Blüten-besuch	Basel								Luzern			St. Gallen								ZH	
Gattung und Art					Klinikum 1	Klinikum 2	Messehalle	Nordtangente ("Erde")	Nordtangente ("Kies")	Rhypark	Rossetti-Bau	Schwarzpark	Maihof	SUVA	Wurzenbach	Baudepartement	Botanischer Garten	Friedhof Bruggen	Friedhof Feldli	Kantonsspital	Schulhaus Grossacker	Steinach	Seewasserwerk Moos	Summe
Standortnummer					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
***Colletes* (Seidenbienen)**																								
Colletes spec.		-	-																1					1
Colletes daviesanus		K, L, St, F, aW, Ka, Si	sHo	o, A																			1	1
***Eucera* (Langhornbienen)**																								
Eucera nigrescens		?							1					15	1									17
***Halictus* (Furchenbienen)**																								
Halictus spec.		-	-	-														1						1
Halictus aff. eurygnathus		keine genauen Angaben				2		2																4
Halictus rubicundus		W, S, H, M, aW, Ka, K, L, Si	E	p										1	1	1	1		1					5
Halictus scabiosae	**3**	**R, L, K, W, H,**	**E**	**p**				**1**					**1**											**2**
Halictus subauratus	**3**	**M, H, K, R**	**E**	**p**	**3**	**1**				**5**	**1**													**10**
Halictus tumulorum		U	E	p		1				1	1	1	2		1			3	3	1				14
***Heriades* (Löcherbienen)**																								
Heriades truncorum		W, Wi, Ka, S, He, Fe, aW, Si	tH, P	o, A															2					2
***Hylaeus* (Maskenbienen)**																								
Hylaeus brevicornis		Au, Wi, Ka, Fe, K, L, St, S, R, Si	Z, tH	p												2								2
Hylaeus confusus		W, Ka, S, H, Sc, Sa, K, aW, R	tH, Z	p														1	1			5		7
Hylaeus communis		U	vH	p		1						1												2
Hylaeus hyalinatus		K, L, W, R, Si, Tro, Lö	Hö	p	1	2		1			1	1		2	2		1	4	7		1	2		25
Hylaeus nigritus		K, L, St, Tro, Lö, R, Si	Gs	o, A	4	3					2		1	1										11
Hylaeus styriacus		Wi, Ka, W, Fe, aW, R	tH, P	p								1												1
Hylaeus taeniolatus		?				1																		1
***Lasioglossum* (Furchenbienen)**																								
Lasioglossum albipes		W, S, M, aW, H	E	p				1							1			1					1	4
Lasioglossum calceatum		U	E	p		1						1	1			1		3	1		2	2	4	16
Lasioglossum fulvicorne		U	E	p	3	8				1		17	1	1	6			1	1				12	51
Lasioglossum laticeps		W, aW, L, R, Si	E	p	1	9		2		1	1	21	1	4	18		1						5	64
Lasioglossum lativentre	**3**	**W, S, M, R**	**E**	**p**			**1**																	**1**
Lasioglossum leucopus		K, M, Ka, Wi, W, Si	E	p	1							1												2
Lasioglossum leucozonium		U	E	p		1				8	1							1						11
Lasioglossum malachurum		L, K, Lö, F, W, Si	E	p																			1	1
Lasioglossum minutissimum		L, K, M, Ka, Si, R	E	p		2																		2
Lasioglossum morio		U	E	p	4	40	1	1	4	14	10	17		3	3			11	11	1	1		2	123
Lasioglossum parvulum	**3**	**Ka, T, aW, S, K**	**E**	**p**																**1**				**1**
Lasioglossum pauxillum		U	E	p	2	2					2	5	1	1	2									15
Lasioglossum politum		Ka, H, M, aW, K, Si	E	p		1					1	14												16
Lasioglossum smeathmanellum		keine genauen Angaben			1	3					2	1	1	2					2					12
Lasioglossum villosulum		U	E	p	1	4				2										1				8

Tabelle 3b: Aktivitätsdichten der erfassten Bienenarten nach Untersuchungsstandort, mit Angaben zur Ökologie und Schutzstatus.

***Apidae* (Bienen)**	**Schutz**	**Ökologie**			**Standorte**																				
	Rote Liste CH	Lebensraum	Nistweise	Blüten-besuch	Basel								Luzern			St. Gallen								ZH	
Gattung und Art					Klinikum 1	Klinikum 2	Messehalle	Nordtangente ("Erde")	Nordtangente ("Kies")	Rhypark	Rossetti-Bau	Schwarzpark	Maihof	SUVA	Wurzenbach	Baudepartement	Botanischer Garten	Friedhof Bruggen	Friedhof Feldli	Kantonsspital	Schulhaus Grossacker	Steinach	Seewasserwerk Moos	Summe
Standortnummer					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
***Megachile* (Mörtel-/Blattschneiderbienen)**																								
Megachile centuncularis		Wi, W, aW, R, Fe, Si	tH, P	p						2														2
Megachile rotundata	**3**	**K, L, T, Bö, H, W, Si, R**	**th, P, Hö**	**p**		**2**																		**2**
Megachile willughbiella		W, Wi, aW, Si	sH, tH	p						2												2		4
***Nomada* (Wespenbienen)**																								
Nomada spec.		-	-	-															1				1	2
Nomada striata		keine genauen Angaben														1								1
***Osmia* (Mauerbienen)**																								
Osmia adunca		Fl, K, St, aW, B, Bö, R, Si	tH, P,	o, E						2														2
Osmia cornuta		Si	vH	p		1																		1
Osmia leucomelana		W, Wi, Ka, Fe, Sc, Si	Z	p																		1		1
Osmia rufa		W, Wi, Ka, S, Fe, aW, Si	vH	p		12		1						2	1		1	9	1		1		2	30
***Panurgus* (Zottelbienen)**																								
Panurgus calcaratus	**3**	**R, K, H, F, I, B, Si**	**E**	**o, A**	**1**					**1**		**1**												**3**
***Sphecodes* (Blutbienen)**																								
Sphecodes ephippius		keine genauen Angaben															1							1
Sphecodes ferruginatus		keine genauen Angaben																1						1
***Xylocopa* (Holzbienen)**																								
Xylocopa violacea	**3**	**S, G, Si**	**sH**	**p**	**1**																			**1**
Total Anzahl Individuen					77	193	18	93	59	60	99	96	27	75	90	35	125	235	46	42	70	55	56	1551
Total Anzahl Arten					18	33	6	16	7	18	18	19	14	16	19	9	11	30	21	10	12	14	17	77
Diversität mit *Apis mellifera*					2,2	2,7	1,4	1,7	0,9	2,5	1,7	2,3	2,4	2,1	2,4	1,3	0,9	2,2	2,6	1,5	1,9	2,2	2,4	
Diversität ohne *Apis mellifera*					2,0	2,7	1,7	2,2	1,5	2,4	1,6	2,3	2,4	2,3	2,4	2,0	1,7	2,6	2,6	1,9	1,7	2,1	2,4	

Tabelle 3c: Aktivitätsdichten der erfassten Bienenarten nach Untersuchungsstandort, mit Angaben zur Ökologie und Schutzstatus.

Legenden

Lebensräume

aW: alte Weinbergbrachen
Au: lichte Auenwälder
B: Bahndämmen
Bö: Böschungen
F: Feldfluren
Fe: Feldhecken
Fel: Feldraine
Fl: Felshänge
G: Gärten
H: Hochwasserdämme
He: Hecken
I: Industriehalden
K: Kies- und Sandgruben
Ka: Kahlschläge
L: Lehm- und Tongruben
Lö: Lösswände
lW: lichte Wälder
M: Magerrasen
O: Obstgärten
oG: offenes Gelände
R: Ruderalstellen
S: Streuobstwiesen
Sa: Sandheiden
Sc: Schilfröhrricht
Si: Siedlungsbereich
St: alte Steinbrüche
T: Trockenhängen
tF: trockene Fettwiesen
Tro: Trockenmauer
U: Ubiquist (in allen möglichen Lebensräumen)
W: Waldränder
Wi: Waldlichtungen

Nistweise

Ba: Baumhöhlen
E: selbstgegrabene Hohlräume in der Erde
Fr: Freibauten
Ge: Gebäude
Ges: Gestrüpp
Gs: Gesteinsspalten
Hö: Höhlen (Sand, Kies, Lehm)
Kr: Krautschicht
Mo: Moospolster
P: hohler Pflanzenstengel
sH: selbstgenagte Gänge im morschen Holz
sHo: selbstgegrabene Hohlräume im Stein
tH: Höhlungen im toten Holz
V: Vogelnester
vH: vorgefundene Hohlräume verschiedenster Art
vHo: vorhandene Hohlräume im Holz
vM: verlassene Mauslöcher
Z: dürre Zweige von Brom- und Himbeeren

Blütenbesuch

A: Asteracea spezialisierte Art
C: Campanula spezialisierte Art
E: Echium spezialisierte Art
L: Lamiaceae spezialisierte Art
o: oligolektische Art
p: polylektische Art
V: Veronica spezialisierte Art

Rote Liste

0: ausgestorben
1: vom Aussterben bedroht
2: stark gefährdet
3: gefährdet
4: potentiell gefährdet
-: nicht autochthon vorkommend
n= nicht gefährdet

Lebensräume, Nistweise und Blütenbesuch nach:
Westrich, Paul (1989): Die Wildbienen Baden-Württembergs, 2. Band Gattungen und Arten. Ulmer GmbH & Co, Stuttgart.

Legenden zu Tabellen 3a-3c Aktivitätsdichten der erfassten Bienenarten nach Untersuchungsstandort, mit Angaben zur Ökologie und Schutzstatus.

4.1 Comparison between surveyed locations

(Summary)

The comparison between the number of species collected on green roofs and on ground sites could not be done satisfactorily because of insufficient data available from two of the ground sites in St. Gallen (*Stadttheater* and *Bildweiher*) where traps were disturbed and specimens lost. The remaining site (*Steinach*) showed no significant difference between ground and roof sites.

Unfortunately losses occurred on the green roof at *Maihof* in Luzern during the main flying season. However, the 27 individuals caught here belong to 14 species, which constitutes a rich diversity. The vegetation on the roof of *Maihof* compares well with the ground at *Rhypark* in Basel where 60 collected specimens belonging to 18 different species were collected. One can therefore assume that a greater number of samples would have resulted in an even greater diversity of species at *Maihof*.

Most species (33) were caught on the Biodiverse green roof of *Klinikum 2* in Basel. Similarly, on the small green roof at *Bruggen cemetery* in St.Gallen 30 species were caught, where the traps probably attracted bees from the cemetery grounds. The number of species caught on other green roofs with denser planting but less diverse habitats was lower: between 14 and 21. The least number of species (7 – 12) was found on classic sedum roofs with sparser coverage. The two sedum roofs at *Grossacker* school and at the *Botanic garden* had 11 – 12 species, probably due to the surrounding gardens and fields. Fewer were found on inner city sedum roofs such as at *Messehalle* in Basel and at the *Baudepartement* in St. Gallen.

The results must be treated with caution and the influence of the surrounding landscape taken into account, especially on a small roof where the traps may attract bees that would not normally visit the green roof.

Surprisingly, relatively few species were found at the *Seewasserwerk Moos* in Zurich, despite the rich vegetation, while a high number were found at *Klinikum 2* in Basel in the centre of the city. The reason could be the variety of substrate levels at the latter, where the diverse vegetation offers a longer flowering season. One can assume that in the course of the seasons more species will be attracted to such a diverse roof (*Klinikum* 2) than to a uniform roof meadow (*Seewasserwerk Moos*). Different bee species have different flying/feeding times in the course of a year, therefore more species will profit if green roofs provide more diverse flowering periods.

(Photographs:)

[Photo 6: Green roof *Messehalle* Basel, typical sedum planting]

[Photo 7: Green roof University hospital *Klinikum 2* Basel, 9th floor, typical sedum planting]

[Photo 8: Green roof *Baudepartement* St.Gallen, typical sedum planting]

[Photos 9, 10: The green roof with the most diverse vegetation in this study: University hospital Basel, *Klinikum 2.* Top: in 2003 when a variety of substrate levels were installed. Bottom: First vegetation period.]

4.2. Recorded blossom visits

Time limits did not allow an in-depth study. However, some important indications will help towards the continuation of this quantitative study of blossom visits by wild bees, planned for 2006.

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Fig. 3: Number of blossom visits at selected sites during two survey periods (May, June 2005)

4.3 Differences between locations

(Summary)

Seasons in St. Gallen are usually two weeks behind Basel. This explains the low number at the end of April. Clearer results were obtained in June. The more diversely meadow-like green roofs are visited more frequently than the sedum roofs.

The altitude of the roof seems of secondary importance up to a point. The survey done on 17.06.05 showed the same number of visits on *Klinikum 1* and *Klinikum 2* (3rd floor). *Klinikum 2* (9th floor) however only had 6 visits. This one survey is not enough for a serious statistic but it indicates that the height of the building is of less importance.

4.4 Quantitative – mathematical comparison of locations

The similarity of species has been analysed in a dendogram using Sorensen's Index (Fig.4). It roughly shows the linkage between locations situated in the same area. The green roofs no. 9-11 in Luzern (refer to names and locations in Fig.2) form a cluster, as does a group of green roofs in St.Gallen (nos. 14,15,17,18) and in Basel (1,7, and 2,6,8). The sedum roofs with sparse vegetation (nos. 3,5,12,16) form another cluster irrespective of their geographical location. The same occurs with green roofs with denser vegetation (nos. 4,13,19). Evidently the ground location *Steinach* (16) blends in with the surveyed green roofs.

[Fig. 4 Dendogram of bee fauna at the surveyed sites according to similarity of species (after Sorensen)]

The Renkonen Index has been used for the analysis of species dominance (Fig.5). It clearly shows the link between similar habitats independent of the geographical region. Green roofs with sparse vegetation (12,13,5) form a cluster, as do green roofs with dense vegetation (1,7,9 and 2,6,15). Green roofs 11 and 19 with varying degrees of dampness form another group; similarly numbers 10 and 14 that are planted as dry meadows.

[Fig. 5 Dendogram of bee fauna at the surveyed sites according to dominance of species (after Renkonen)]

4.5 Description of rare and endangered species collected

Ten species that are red-listed in Switzerland (according to Amiet 1994) have been identified.

Categories

0	extinct or missing	0 species
1	threatened with extinction	0 species
2	severely endangered	0 species
3	endangered	10 species
4	potentially endangered	0 species
n	not endangered	67 species

Category 3, endangered species

Andrena cineraria (LINNAEUS 1758)

A typical mining bee that builds her nest where there is not too much vegetation and no interference from tidy gardeners; in favourable conditions several hundred nests can be spotted. *A. cineraria* live in gravel pits and on housing estates. This species has only been found on green roofs with substrates containing subsoil (*Nordtangente "Erde", Rosetti-Bau, Klinikum 2).*

[Photo 11: Typical nest of *Andrena cineraria*]

Photo 12: *Andrena cineraria* building her nest]

Andrena viridescens (VIERECK 1916)

Very small sand bee, feeding on speedwell: *Veronica chamaedris,* also *Veronica teucrium* (strictly *oligolectic*). Builds her own ground nests. The species has only been found on the roof of *Seewasserwerk Moos* in Zurich because the required plants grow there.

Bombus humilis (ILLIGER 1806)

The species prefers nesting above ground in the vegetation layer, under clumps of grass or moss. In this study it was only seen on the roof *Würzenbach* in Luzern.

Halictus scabiosae (ROSSI 1790)

This rare burrowing bee is found in dry habitats such as sand pits, clay pits and rubble heaps. They dig their nests (13-20 cm deep in spring; 20-33 cm deep in summer) in slightly sloping ground with sparse vegetation. Found at Basel *Nordtangente "Erde"* and in Luzern on the roof of *Maihof.* There are small mounds on both these sites and these bees are known to dig deep nests.

Halictus subauratus (ROSSI 1792)

This rare burrowing bee digs its nest in rough sandy soil and feeds on plants that grow on rough ground. It was only found in Basel on the roofs of *Klinikum 1* and *Klinikum 2,* and at *Rhypark* and *Rosettibau.* All these green roofs provide habitats that resemble rough ground.

Lasioglossum lativentre (SCHENK 1853)

Only one individual of this species has been found, and this on the roof of the *Messehalle* in Basel. It is also a ground-nesting bee. The substrate on this roof contains pumice, which is not known to occur in their natural habitat. As only one individual has been found it can only be assumed that the bee may be using the roof as a feeding ground.

Lasioglossum parvulum (SCHENK 1853)

Here again only one such individual has been caught, on the green roof of *Kantonspital* in St.Gallen. Therefore we are faced with the same methodical analysis problems as in the previous sample.

Megachile rotundata (FABRICIUS 1784)

The alfalfa leaf cutter bee builds her nest out of leaf cuttings. The nectar is taken from papilionaceae and compositae. This species is used by farmers for the purpose of pollination like the honeybee. It was found at *Klinikum 2* in Basel where the green roof is a diverse meadow, including the plants this species depends on. It was not found elsewhere in this survey.

Panurgus calcaratus (SCOPOLI 1763)

This solitary bee prefers a dry habitat and lives in nature holes in the ground created by large stones. It was found on the green roofs at *Klinikum 1, Rhypark* and *Schwarzpark* in Basel.

Xylocopa violacea (LINAEUS 1758)

This carpenter bee has only been found on the roof of *Klinikum 1* in Basel.

5. Discussion of results

Relevance regarding the provision of extensive green roofs

It has been shown that green roofs are being used as feeding grounds by wild bees. On typical sedum roofs only half the number of bee species have been caught, compared with green roofs with diverse vegetation. The number of blossom visits showed an even greater discrepancy: only one fifth of visits were recorded on sedum roofs compared with green roofs with herbaceous vegetation. It can be assumed that a longer study would show an even more obvious divergence. The reason is simple: green roofs planted predominantly with sedums have only a short flowering season, thus providing only a short period of nourishment. In addition it became evident that even during flowering the sedum roofs were visited less frequently by bees than the herbaceous roofs. It is important to continue the study to verify the statistics as the figures obtained in this survey are limited.

Further studies about the frequency of blossom visits are needed in order to verify the existing figures and to be able to perform an in depth comparison between sedum roofs and herbaceous roofs.

In the survey a total of ten endangered wild bee species have been identified (Swiss Red Data Category 3). Most were caught at Basel, with three species each found at *Klinikum 1* and *Klinikum 2.* As has been shown in a previous study of invertebrates on green roofs (Brenneisen 2003) a high number of xerothermophilous species are present in the warm and dry area of Basel. From this can be deduced that there may be a correlation between this fact and the high number of endangered bee species found here.

The Swiss nature conservation act NHG ('Natur- und Heimatschutzgesetz', section 3) dictates that the indigenous flora and fauna must be protected within residential areas as well as elsewhere. The NHG emphasizes the need to protect endangered species and their habitats. The findings regarding the ecological significance of extensive green roofs as contributors to the protection of nature and species can inform planning guidelines and standards. The requirement for extensive green roofs should be to set them up as replacement habitats for as high a number of endangered species as possible.

It follows that flat roofs should consistently and extensively be executed as green roofs in line with the concept of ecological urban planning. Ideally incentives and measures for implementation should be put in place. This is especially important where significant natural habitats are being built over. In these circumstances the provision of greenery to match the surrounding natural environment needs to be enforced.

Substrates and regional soils for nature-like green roofs

The provision of green roofs that recreate a nature-like environment is a challenge but it is achievable. The layering and siting of soils and substrates is essential, as are the logistics of the design. Subsoil suitable for green roofs is usually derived from established meadow lands or from woodlands. Soils from agricultural lands are often too loamy, as these are mixed with B-horizon soil types (containing dissolved products of weathering) and are unsuitable for use on green roofs because they tend to silt up.

Nowadays processed substrates (that can be pumped onto the roof) consisting of a mixture of soils and gravel are used to create a nature-like environment.

A desirable side effect of using subsoil is its inherent reservoir of seeds. As can be seen at *Klinikum 2* (see photos 9 and 10) this has resulted in a 60-70% primary vegetation coverage already during the first vegetation period.

The provision of green roofs can promote wild bees by offering them suitable feeding and nesting grounds.

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6. Bibliography and references

(See full German Paper)
