BEES FOR POLLINATION

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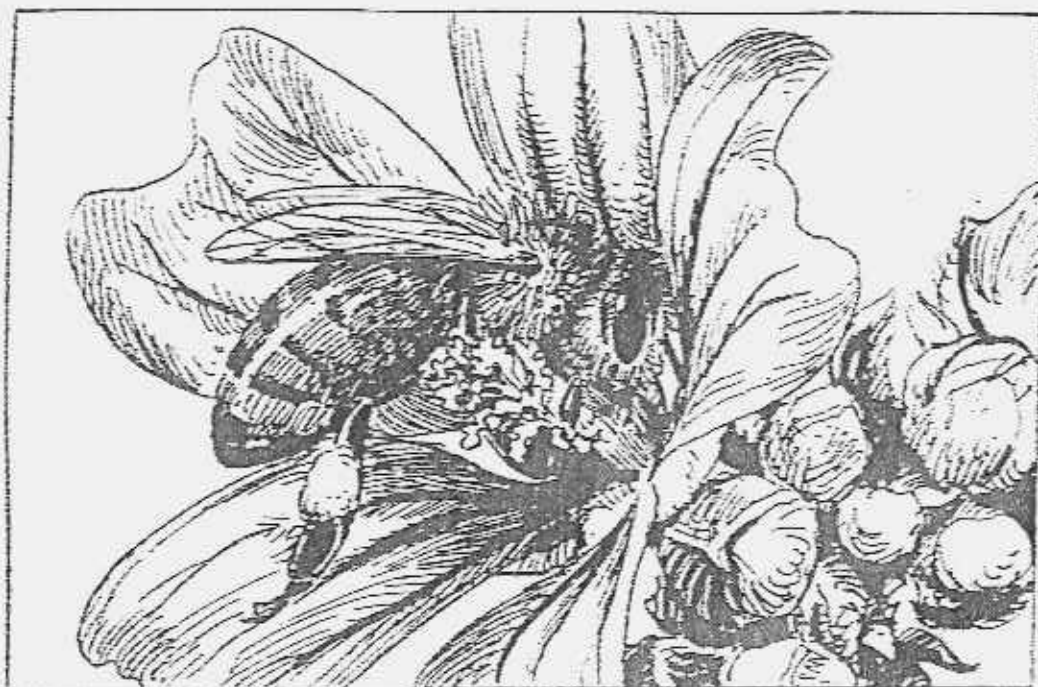
GROUP II

PRESENT AND FUTURE USE OF

POLLINATION INSECTS

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THE FAUNISTIC DRIFT OF APOIDEA IN BELGIUM

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ABSTRACT

The authors studied the faunistic drift in Apoidea of Belgium by comparing the relative number of species before and 1950 onwards. The change in the abundance was estimated by the Stroot & Depiereux (1989) method. On 360 species, 91 are decreasing (25,2%), 145 are stable (40,2%), 39 are expanding (10,8%), and 85 have an indeterminable status (rare species : 23,5%). This regression cannot be attributed to a lack of observations as they are more numerous in the second period. The authors compare different hypotheses that could explain this global regression. As the most important one affects species with a long tongue, it is likely due to the fall in availability of plants with long corollae (e.g. Lamiaceae, Fabaceae, Scrophulariaceae). The strong relative regression of cleptoparasites could be seen as the result of an absolute numerical decrease of all Apoidea. The relative regression of species nesting in ground could be the evidence of the lacking availability or suitability of open areas through afforestation, urbanization or agricultural intensification. The regression which strongly affects long tongue species seriously threatens the maintain of an appropriate pollination level of wild and cultivated plants.

INTRODUCTION

Among the Apoidea, only bumblebees were subjected to a quantitative estimation of the faunistic drift (Williams et al., 1991) and this, just in two European areas : Great Britain (Williams, 1985, 1986), Belgium and North of France (Rasmont, 1988; Rasmont & Mersch, 1988). An estimation of this faunistic drift for solitary bees is so missing.

Leclercq et al. (1980) points out 13 species of Apoidea among the ones that make up their "first red list of threatened insects in the Belgian fauna". However, the method used then to determine the status of the populations of these species does

not include the abundance criterion. This short list is just the outcome of the consideration of the geographical spreading of taxa. A species was added to this "first red list" only if the number of occupied 10 km UTM squares since 1950 indicates a regression of 10 units in relation with the number of squares occupied before this year. This criterion allowed the useful determination of the 13 most threatened species. Nonetheless, the examination of old documents and the comparison of entomologists' recollections indicate that the Apoidea entomofauna has been much more deeply modified. Very often, the regression of a species isn't marked by a heavy fall in its distribution but by a decrease in its relative frequency.

Moreover, something can be added : the fact that a great part of the fauna is decreasing while another one is expanding can be seen as quite normal. The regression and expansion phenomena could be just the expression of a random variation of the fauna.

Therefore, it is very important to study not only the geographical distribution but also the numerical variations of the species : the faunistic drift.

By "faunistic drift" we mean any modification of the relative specific composition of local faunae along time. This change is, in general but not always, linked to variations in the geographical distribution of species. "Faunistic drift" is a locution which has the advantage of being presumptively neutral, unlike the words "expansion" or "regression". Moreover, it reminds, by analogy with "genetic drift", that a great part of the population changes estimation can be stochastic or comes out of a sampling bias.

Thanks to a recent update of the Gembloux and Mons faunistic data bank, an estimation of the faunistic drift of Apoidea in Belgium can be provided.

MATERIAL AND METHODS

The Gembloux faunistic data bank has encoded all the data concerning Apoidea of Belgium, Luxembourg, the North of France and neighbouring areas till 1988. Since then, the University of Mons-Hainaut is also taking part in this collection of information.

The data are managed by the Microbanque faunique 2.0 (Rasmont & Barbier, 1991) software.

For Belgium alone, 48.654 data on 79.765 solitary bees specimens of the 1900-1991 period are now available. The main authors of these data are: J.Leclercq, A.Jacob-Remacle, A.Pauly, V.Lefeber, P.Mathot, J.Petit, K.Janssens, C.Thirion,

L.Verleysen and P.Rasmont. The other authors are (in decreasing order of contribution) K.Warncke, Liongo Ii Enkulu, M.Schwarz, A.Ruwet, G.Vander Zanden, L. et C.Verlinden, H.M.Warlet, H.Wiering, D.Gryffroy, J.J.Pasteels, Y.Barbier, C.Verstraeten, G.Pagliano, J.Decelle, J.Van Schepdael, C.Burgeon, C.Luyts, P.M.F.Verhoeff, J.Beaulieu and C.Gaspar.

Only data including at least the year and the province are taken into account.

Origin of data	before 1900 or without date	before 1950	since 1950
field	9	3	1.214
litterature	1.583	1.495	728
collection	6.210	12.573	63.752
Total number of specimens	7.802	14.071	65.694
Data of the present study	79.765		

Table I. Solitary Apoidea studied

All distribution maps of solitary bees of Belgium were published from 1971 to 1982 (Jacob-Remacle, 1982; Leclercq & Rasmont, 1985; Leclercq, 1971, 1972a,b, 1982; Liongo Ii Enkulu, 1982; Mathot, 1982; Pauly, 1978,1982a,b,c). Those of Apidae Bombinae were published by Rasmont (1988).

We use the Stroot & Depiereux (1989) method to estimate the faunistic drift. This method is very attractive as it puts forward an objective estimation criterion which takes into account differences of sampling effort during the different periods.

For bumblebees (Apidae Bombinae), the data of Rasmont & Mersch (1988) are reinterpreted thanks to the Stroot & Depiereux (1989) method. However, the estimation criterion for this family is the number of specimens in collection and not the number of occurrences.

Origin of data	before 1950	since 1950
field	20	2.284
litterature	914	324
collection	78.003 *	12.282
Total number of specimens	78.937	14.890

* all specimens are not yet encoded but they have been all identified and counted.

Table II. Apidae Bombinae data from Rasmont & Mersch, 1988

The *Apis mellifera* (L.) case has not at all been considered here as it is known in Belgium just as a domestic insect. Therefore, Apidae include here bumblebees (Bombinae) only.

The data cover is detailed in the tables I and II. The survey seems to have been comprehensive for both periods (fig.1), except for the West-Vlaanderen province and the Gent surroundings.

For each species, the status calculated by the Stroot & Depiereux (1989) method is compared with the distribution map of the species. This lead first to the correction of the status of most species determined as " significantly" (*) or "highly significantly decreasing" (**) then, to the conclusion that they are "more or less stable". Are particularly concerned the species which are very confined and whose number of occupied UTM squares did not decrease nor increase by more than 25% (apparently stable distribution). The explanation of this systematic bias is that because of the sharp increase in the total number of occurrences for the second period, such a stability has been computed as a relative regression.

In the opposite, all species in significant (*) or highly significant (**) expansion actually indicate a distinct increase in the number of occupied UTM squares (more than 25% increase).

Incontestably all species computed as very highly significantly decreasing or increasing (***) present respectively a sharp regression or expansion (at least 25% of difference in the observed UTM squares number).

	observed estimator			expected estimator			
	before 1950	since 1950	TOTAL	before 1950	since 1950	chi^2	trend
species 1	p_{11}	p_{12}	$T_{1.}$	e_{11}	e12	I_1	(-)
species 2	p_{21}	p_{22}	$T_{2.}$	e_{21}	e22	I_2	+
species 3	p_{31}	p_{32}	$T_{3.}$	e_{31}	e32	I_3	=
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
species I	p_{i1}	p_{i2}	$T_{i.}$	e_{i1}	ei2	I_i	.
TOTAL	$T_{.1}$	$T_{.2}$	T	$T_{.1}$	$T_{.2}$		

Table III. Estimating faunistic drift using the Stroot & Depiereux (1989) method

population estimator can be:
- number of specimens in collections
- number of lines in data bank
- number of grid squares
- number of sample units
- number of occurrences (1 occurrence = at least one observation of the taxa in a given grid square during a given year).

Expected   estimator

$$E_{ij} = \frac{T_{i.} * T_{.j}}{T}$$

$$I_i = \sum_{j=1}^{2} \frac{(p_{ij} - e_{ij})^2}{e_{ij}}$$

The value I_i is compared with the value of chi^2 distribution (1 d° of freedom).

- : species in relative regression
= : species in relative status quo
+ : species in relative expansion
() : species with an expected estimator < 5 for the "since"
period.

For the present study, the population estimators are
- occurrences by UTM (10km) * year, for the solitary Apoidea;
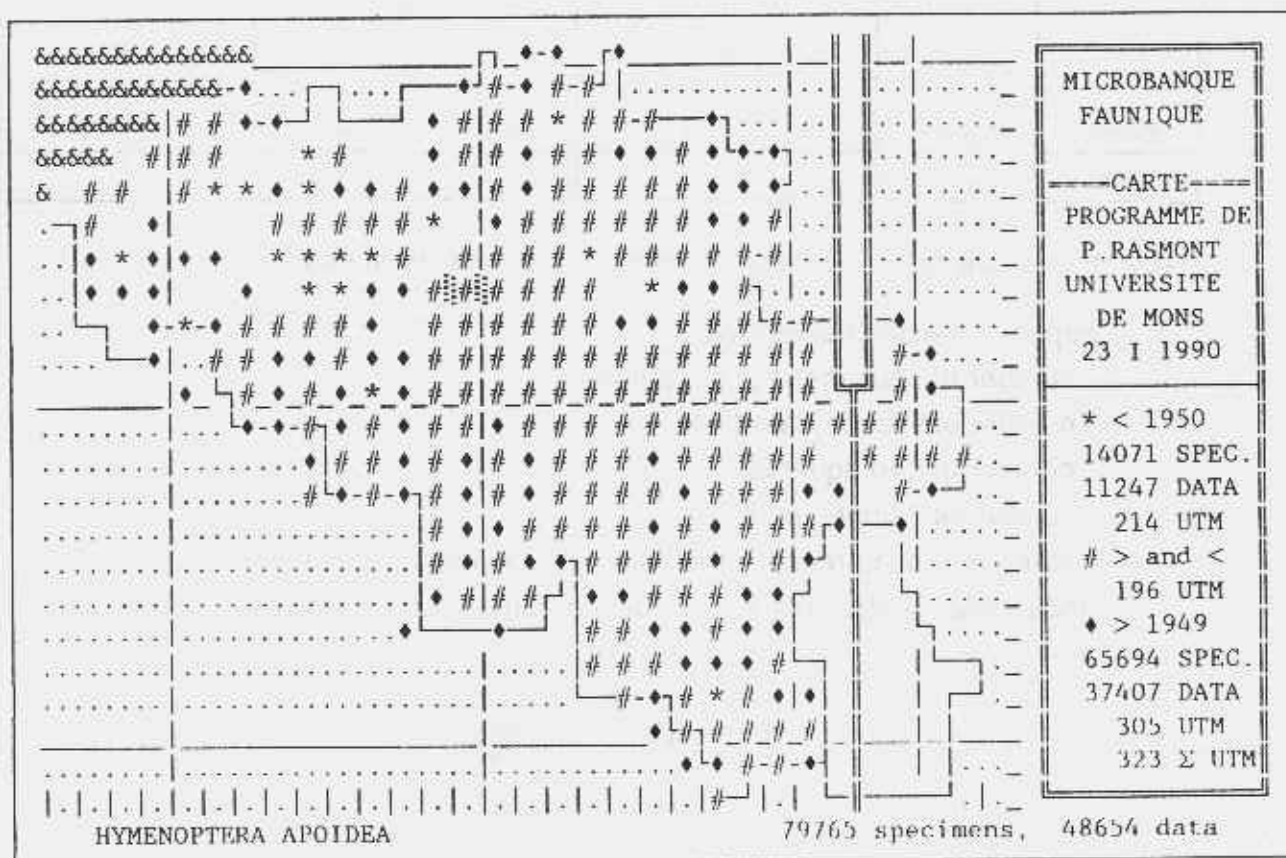- number of specimens, for the bumblebees.

Figure 1. Solitary Apoidea of Belgium; covering of the survey 1.III.1992
(// localisation of Brussels)

RESULTS

330 species of solitary Apoidea are observed in Belgium for the 1900-1992 period.
Rasmont & Mersch (1988) point out for the same period 30 species of bumblebees.
The detailled list of taxa is annexed.

On the 360 Apoid species known in Belgium for the studied period, 91 are decreasing (25,2%), 145 are more or less stable (40,2%), 39 are expanding (10,8%), and 85 are in an undetermined situation (rare species: 23,5%) (fig.2).
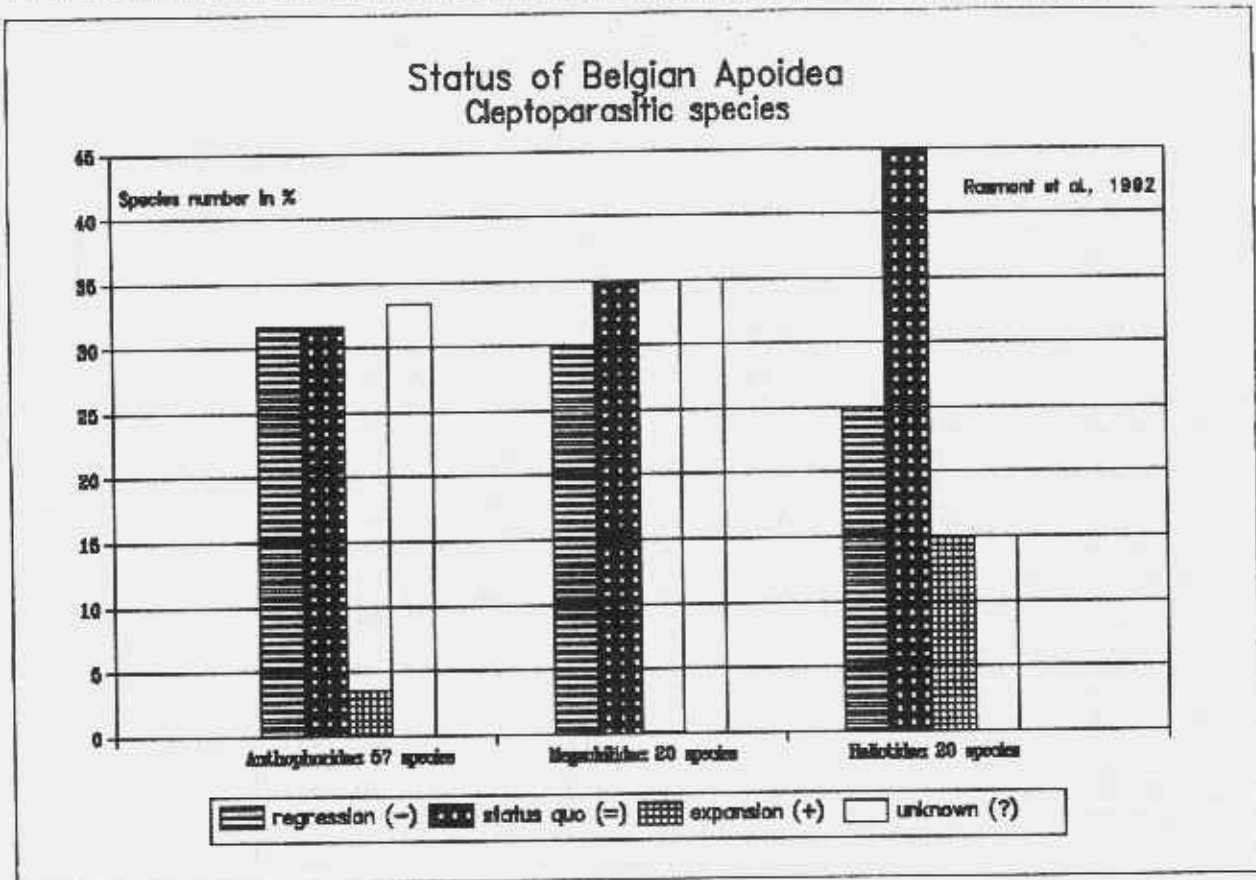

Status of Belgian Apoidea
Cleptoparasitic species

Figure 2.

DISCUSSION

The present study confirms the status of the 13 species pointed as decreasing by Leclercq et al. (1980).

For solitary bees, the relative regression of species cannot be explained by a shortage in the observations (14.071 specimens before 1950 and 65.694 since 1950).

Besides, the regression rate of bumblebees is probably a bit overestimated (19 taxa in regression on 28 studied: 68%). According to Rasmont (1988) and Rasmont &

Mersch (1988), the regression is less pronounced than following the present criteria (14 taxa in regression on 28: 50%) (table IV).

Table IV.
Apoidea Bombinae: comparison between the trend estimated by the Stroot & Depiereux method and the trend estimated by Rasmont & Mersch, 1988

| | estimator | | | | chi2 | trend | Rasmont & |
	observed		expected				Mersch,1988
Psithyrus rupestris	590	14	509	95	82.24	-***	-
Psithyrus vestalis	867	38	762	143	91.17	-***	-
Psithyrus bohemicus	245	166	346	65	187.67	+***	+
Psithyrus campestris	1417	181	1346	252	23.70	-***	=
Psithyrus barbutellus	669	17	578	108	91.20	-***	.
Psithyrus quadricolor	1	0	1	0	0.19	(-)	?
Psithyrus sylvestris	688	531	1027	192	709.19	+***	+
Psithyrus norvegicus	4	24	24	4	103.17	(+)	+
Confusibombus confusus	153	1	130	24	26.50	-***	-
Bombus s.s.*	20791	3330	20318	3803	69.75	-***	=
Alpigenobombus wurfleini	3	0	3	0	0.56	(-)	.
Pyrobombus hypnorum	1384	772	1816	340	652.15	+***	+
Pyrobombus pratorum	3603	3597	6065	1135	6339.15	+***	+
Pyrobombus jonellus	286	25	262	49	13.98	-***	=
Pyrobombus lapidarius	10714	971	9843	1842	489.05	-***	-
Pyrobombus cullumanus	9	0	8	1	1.68	(-)	-
Pyrobombus soroeensis	526	49	484	91	22.72	-***	-
Megabombus ruderatus	2504	8	2116	396	451.33	-***	-
Megabombus hortorum	5529	865	5386	1008	24.09	-***	-
Megabombus subterraneus	338	16	298	56	33.71	-***	-
Megabombus distinguendus	796	3	673	126	142.50	-***	-
Megabombus pomorum	400	1	338	63	72.69	-***	-
Megabombus sylvarum	622	35	553	104	53.90	-***	-
Megabombus veteranus	3786	31	3215	602	642.66	-***	-
Megabombus ruderarius	1599	185	1503	281	39.10	-***	-
Megabombus muscorum	1003	8	852	159	170.70	-***	-
Megabombus humilis	857	27	745	139	107.55	-***	-
Megabombus pascuorum	20176	3995	20359	3812	10.60	+**	=
	79560	14890	79561	14890			

* Bombus terrestris auct., B.lucorum (L.), B.cryptarum (Fabr.) and B.magnus Vogt are not separated for this study.

The regression is not equal for the different taxa (fig. 3).

The regression is sharp for Apidae and Anthophoridae (species with a long tongue preferring zygomorphic flowers with a long corolla) : the number of decreasing species is prevailing and is far more greater than the number of stable or expanding ones. The regression is also sharp for Megachilidae (medium to long tongue) : almost 25% of species are decreasing. However, almost 50% of the species are stable.

For Halictidae (short tongue), the regression is sharper than the expansion. Above all, however the majority of species are stable.

For Andrenidae and Colletidae (very short to short tongue), many species are stable and the number of increasing species is greater than the number of

decreasing ones. In Melittidae (7 taxa with short tongue) and Rasmont & Mersch (1988), species are stable, except *Macropis europaea* which is distinctly decreasing (this has already been noticed by Leclercq et al., 1980).
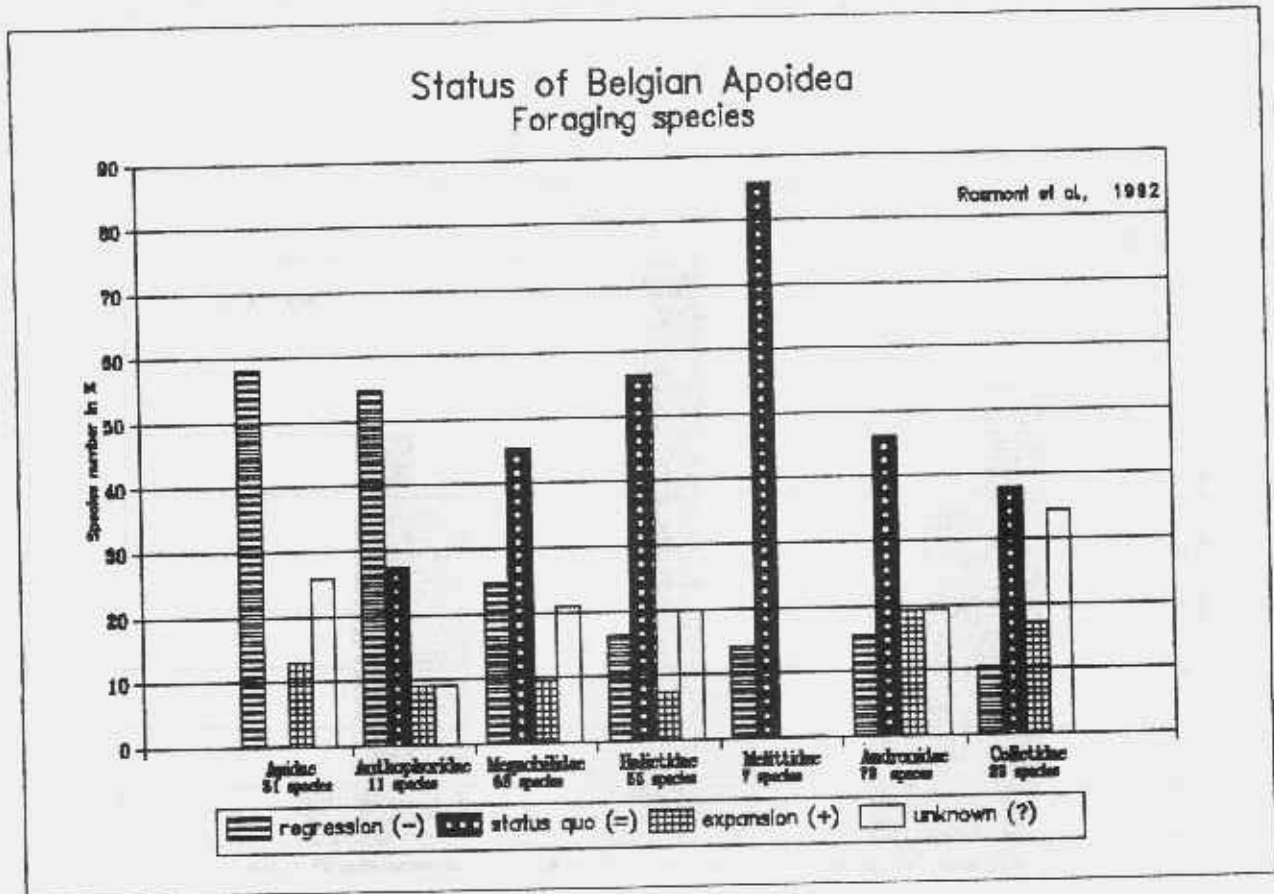

Figure 3.

It seems so that the foraging taxa with a long tongue show a relative decrease particularly in comparison with species with a short one. The latter seem to be more or less stable or even in a relative small increase. The number of decreasing species is smaller than the number of increasing ones but the most important fact is that the stable species have a clear majority. This appears clearly in fig.4 where taxa have been gathered in three categories : species with a medium to a long tongue, species with a very short to a short tongue, and cleptoparasitic species.

This leads us to believe that the Apoidea regression is due first of all to the loss of floral resources which would be particularly marked for plants with long corollae (Fabaceae, Lamiaceae, Scophulariaceae, Boraginaceae). Rasmont (1988) and

Rasmont & Mersch (1988) have already noticed that the decrease of legume crops (Fabaceae) seems enough to explain the regression of most bumblebees species in Belgium (table V). The study of the data on the other wild Apoidea confirms this hypothesis. It must be added the excessive maintenance and erasing of embankments, side roads and public areas, which are privileged locations for Lamiaceae (e.g. *Lamium* spp., *Ballota nigra*) and Boraginaceae (e.g. *Echium vulgare, Symphytum officinale*).
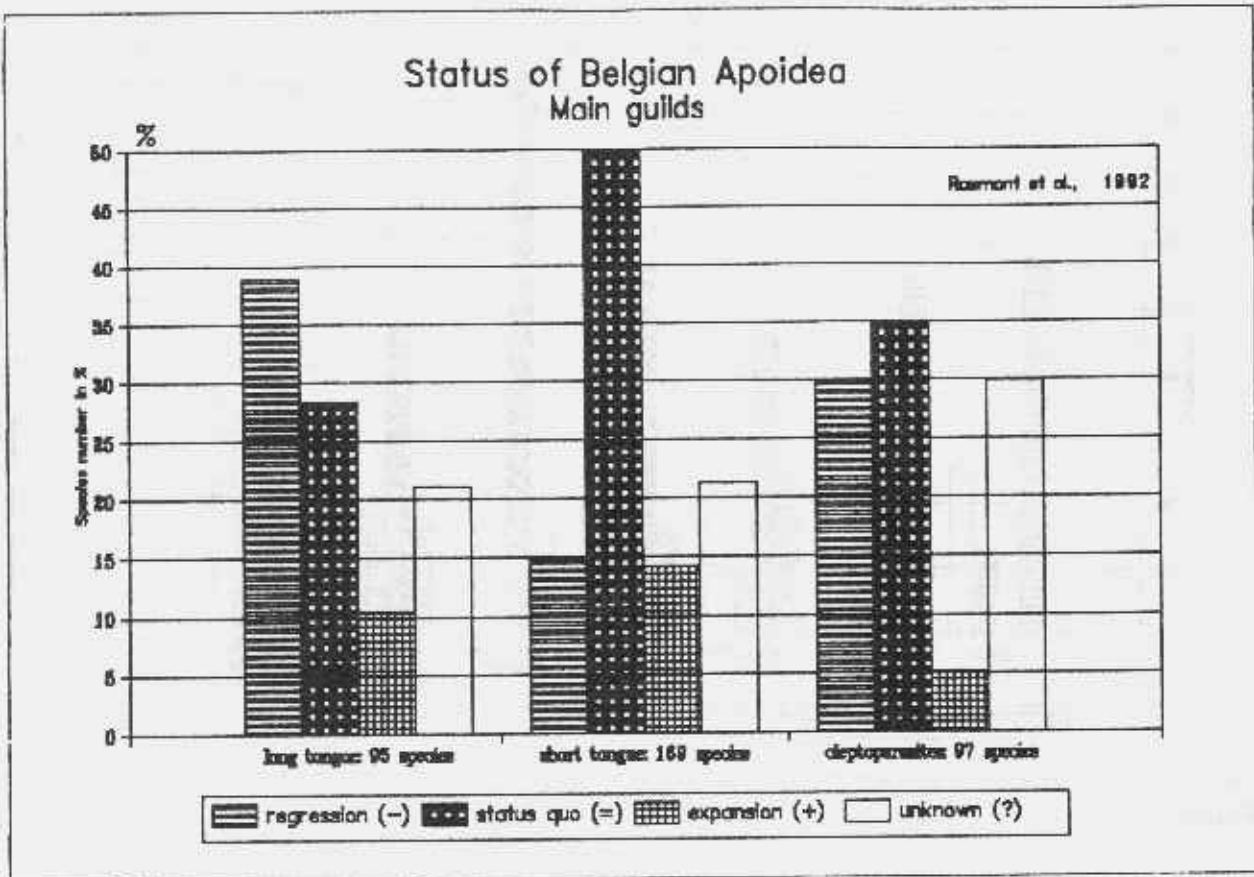

Figure 4.

Table V							
Cultivated area of legumes in Belgium							
(thousands ha)	1908	1913	1929	1950	1959	1970	1985
Alfalfa (*Medicago sativa*)	13,9	13,3	7,6	13,0	8,7	6,1	1,3
Clovers (*Trifolium* spp.)	141,9	128,6	78,1	31,5	29,1	7,0	1,1
Sainfoin (*Onobrychis viciifolia*)	7,9	5,2	2,2	0,4	0,1	0,0	0,0
Pea (*Pisum sativum*) and bean (*Vicia faba*)	14,5	13,3	10,2	9,7	11,1	5,6	0,8
Total area	178,2	160,4	98,1	54,6	49,0	18,7	3,2

Sources: Statistique de la Belgique, 1910, 1914; Office central de la Statistique, 1937; Institut National des Statistiques, 1953, 1961-1964, 1976, 1986.

The very sharp regression of most of cleptoparasitic species (fig.5) is noticed too, especially in Megachilidae and Anthophoridae. This is curious since Anthophoridae parasite especially Andrenidae and Colletidae, taxa with short tongue, stable or in relative increase. The only hypothesis that could be put forward to explain this cleptoparasites regression is that it probably expresses an absolute numerical decrease of the hosts. Indeed, the survival of a cleptoparasitic species needs that the populations of its host are numerous. In case of a numerical regression of the host, even if its geographical distribution is not affected, its cleptoparasitic species would undergo a more than proportional decrease. Besides the relative regression of the long tongue species, an absolute regression of whole Apoidea superfamily must be feared.
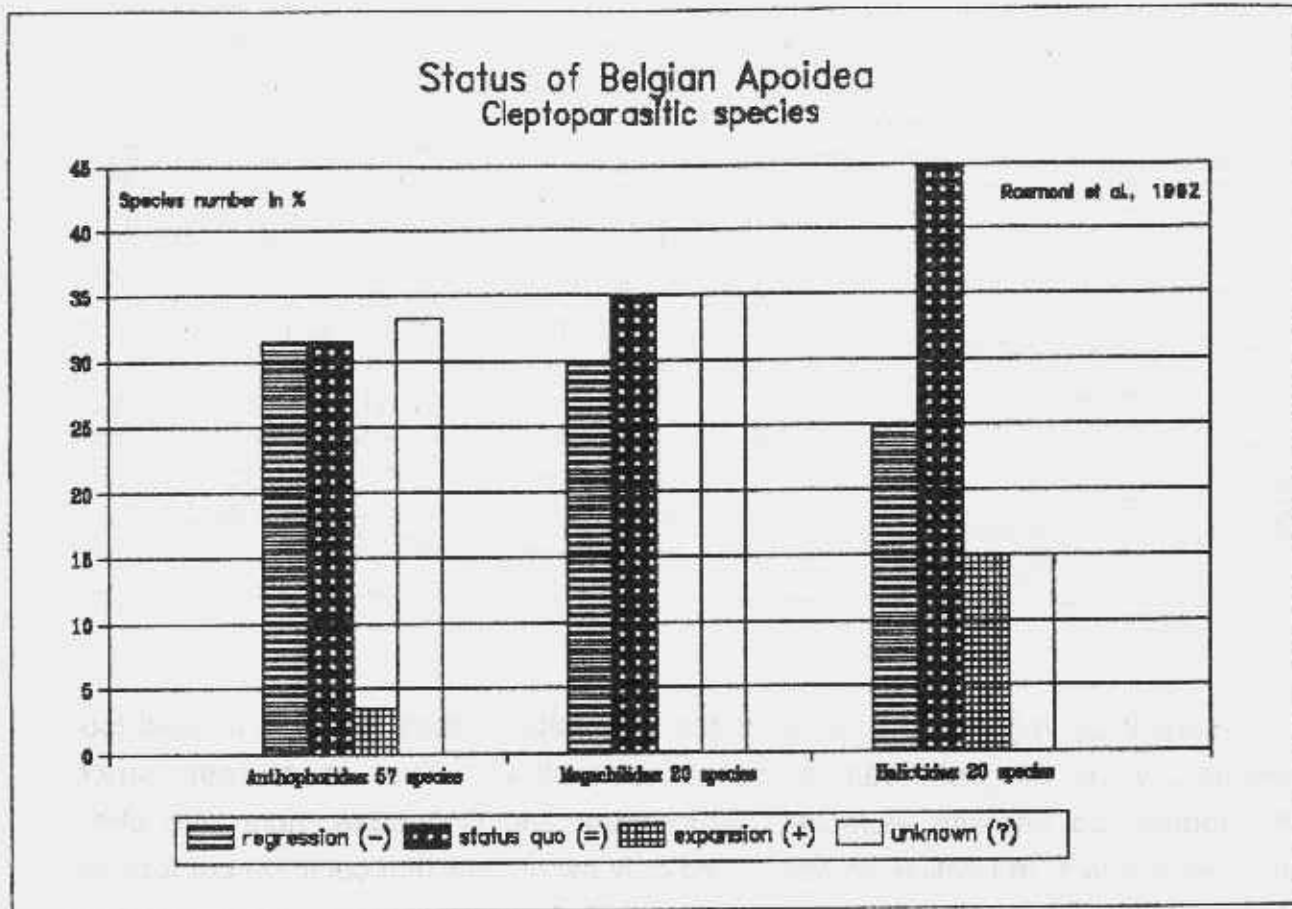
Figure 5.

Some nesting habits (listed by Westrich, 1990) seem to be correlated to the regression (fig.6). The few Belgian species nesting in snail shells are not worth discussing here as their number is too small. Species with nests in ground holes seem to be more threatened than the ones nesting in wood or plant stems, what had already been noticed by Westrich (1989). Michener (1979) point out that the nidification in ground holes would be an adaptation to open or xeric areas. In the opposite, species which are nesting in wood or in plant stems are rather adapted to woody or wet environments, as the nesting out of the ground avoids a great part of the mortality due to cryptogamic diseases in wet conditions. This relative regression of ground nesting species can be interpreted as a increasing lack of the availability or suitability of the open areas. Several mechanisms can be relied on this: afforestation, which was very important in some areas of Belgium (particularly in the province of Namur, where the greatest part of chalkland grasses, formerly used for cattle is now planted with pine woods); weeding of crops; conversion of lands into housing areas.

Among the factors whose role is difficult to estimate, the one of insecticides, herbicides and fungicides seems to be particularly problematic. The acute poisoning does not seem to have played a big role apart from local and limited cases. However, nearly nothing is known about the chronic intoxication and the influence of sublethal doses. The latter could have brought selective pressure variations in different ways. As generations of wild bees are short, small interspecific differences in the selective pressure could have led in few years to the replacement of sensitive species by others.

Status of Belgian Apoidea
Foraging species: nesting habits

Figure 6.
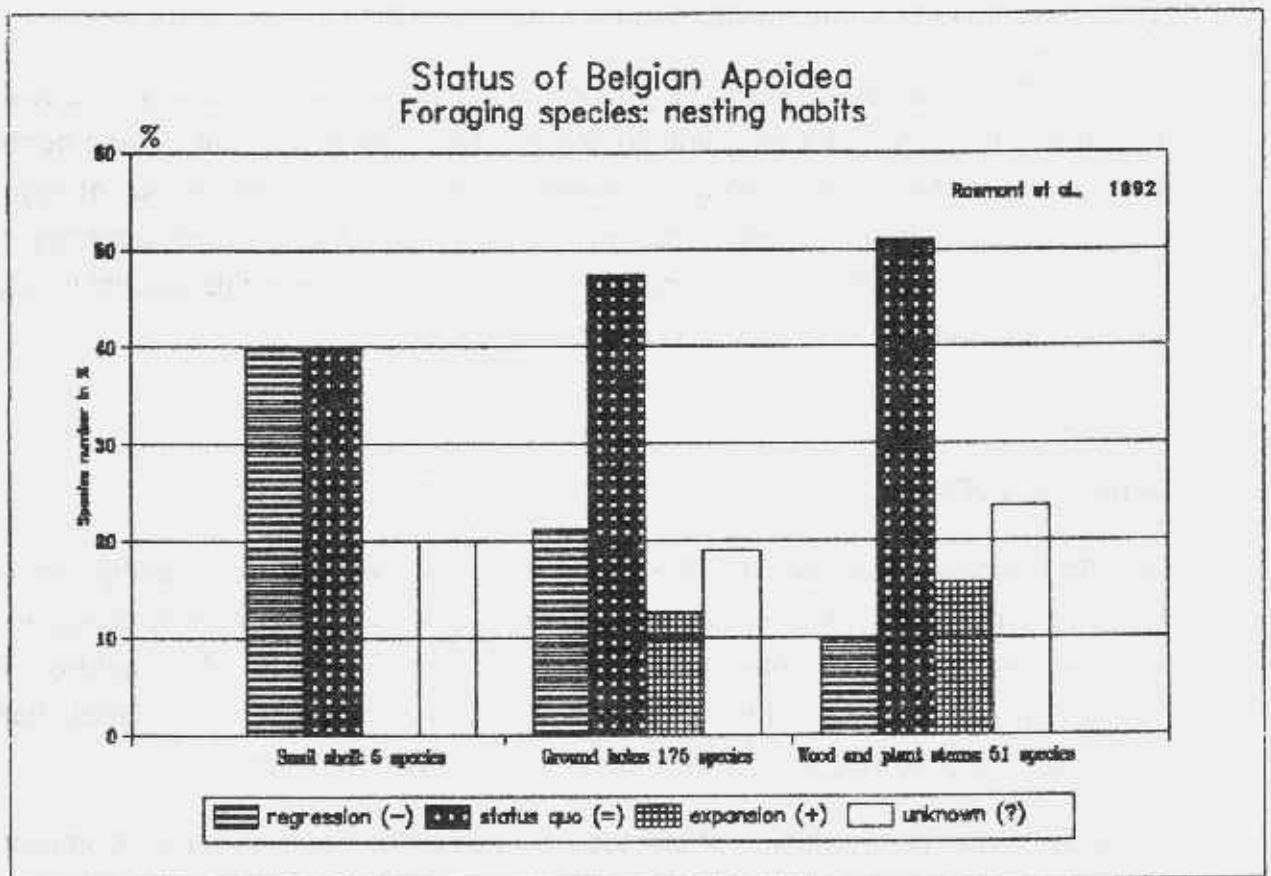
The conclusions of this study strongly remind those of Corbet et al.(1991), Osborne et al. (1991) and Williams et al. (1991), whereas these authors studied especially the case of the honey bee and bumblebees (Apidae). So it seems that the regression phenomenon of Apidae affects all kinds of wild bees too. Even short tongue species seem to undergo a regression despite their relative number

increases. The whole regression phenomenon affects more strongly species with a long tongue. This must be considered as being serious as they are the most efficient and specialised pollinators. In an untouched wild bee fauna, the isolated regression of a long tongue species could probably be ecologically compensated thanks to the spontaneous substitution of competing species. However, in the present situation, it is the whole guild which is threatened. Therefore, we can fear that the linked regression of species will not allow a spontaneous replacement. It is likely that the density and the diversity of these pollinators fall under the population level needed to insure the pollination requirement of many agricultural and horticultural productions. There is another big danger: the regression of key species would lead to the disappearance of great parts of the wild flora.

Very few European countries have a long tradition to collect and study Apoidea. It is therefore unlikely that a long and constant survey - as in Belgium - could become widespread in the whole Europe. However, the progressive dying out of legume crops, breeding intensification, afforestation of agricultural areas economically marginal and urbanization are general in Europe. Therefore, this faunistic drift of the Apoidea fauna should also appears everywhere.

CONCLUSIONS

On 360 species observed in Belgium since 1900, 25% are decreasing and only 11% are expanding. This regression especially affects long tongue species, which are precious specialised pollinators, auxiliaries of agriculture and horticulture. This can be seen as the result of the dying out of legume crops and of the destruction of wild long corolla flowers like labiate, borage and figwort families.

The strong relative regression of cleptoparasites can be seen as the outcome of an absolute numerical decrease of the whole Apoidea superfamily.

The relative regression of the species nesting in ground holes can be interpreted as a consequence of a lacking availability or suitability of open areas through afforestation, urbanization and agriculture intensification.

The general wild bees regression, which strongly affects long tongue species, seriously threatens the maintain of an adequate pollinating level of wild and cultivated plants.

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Annex

List of solitary bee of Belgium observed during the period 1900-1992 and estimation of their status

Nesting habits :
- g = nest in ground hole
- w = nest in wood
- p = nest in plant stem
- h = nest in snail shell

		Foraging Anthophoridae						
		number of occurences					computed	corrected
		observed		expected			trend	trend
nest	species	befor	sinc	befor	sinc	chi^2		
g	Anthophora aestivalis Schenck	24	1	7	18	55.63	- ***	
g	Anthophora bimaculata (Panzer)	23	6	8	21	36.53	- ***	
g	Anthophora furcata (Panzer)	56	32	25	62	54.53	- ***	
g	Anthophora plagiata (Illiger)	6	2	2	6	8.44	- **	-
g	Anthophora plumipes (Pallas)	104	634	211	527	76.02	+ ***	
g	Anthophora quadrimaculata (Panzer)	52	51	29	74	24.17	- ***	
g	Anthophora retusa (L.)	51	51	29	73	22.89	- ***	
p	Ceratina cyanea (Kirby)	27	60	25	62	0.25	-	
g	Eucera longicornis (L.)	26	56	23	59	0.39	-	
g	Eucera nigrescens Pérez (=tuberculata)	19	23	12	30	5.70	- *	-
p	Xylocopa violacea (L.)	0	2	1	1	0.80	- (=)	
		Foraging Megachilidae						
	Anthidium diadema Latreille	0	1	0	1	0.40	= (-)	=
g	Anthidium manicatum (L.)	50	79	37	92	6.53	- *	=
g	Anthidium oblongatum Illiger	11	10	6	15	5.82	- *	=
g	Anthidium punctatum Latreille	28	26	15	39	14.30	- ***	
p	Anthidium strigatum (Panzer)	14	23	11	26	1.55	=	
g	Chalicodoma ericetorum (Lepeletier)	38	71	31	78	2.10	=	
	Chalicodoma rufescens Lichtenstein	0	1	0	1	0.40	+ (=)	
w	Chelostoma campanularum (Kirby)	35	110	41	104	1.41	-	
w	Chelostoma distinctum (Stöckhert)	15	41	16	40	0.09	-	
w	Chelostoma florisomme (L.)	35	101	39	97	0.54	-	
w	Chelostoma fuliginosum (Panzer)	37	183	63	157	14.94	+ ***	+
w	Heriades truncorum (L.)	30	127	45	112	6.92	+ **	
w	Megachile alpicola Alfken	11	29	11	29	0.02	-	
g	Megachile analis Nylander	3	0	1	2	7.49	- (-)	
p	Megachile buyssoni Pérez	1	2	1	2	0.03	(-)	
w	Megachile centuncularis (L.)	66	149	61	154	0.47	-	
g	Megachile circumcincta (Kirby)	35	33	19	44	17.43	- ***	
g	Megachile lagopoda (L.)	12	2	4	10	22.37	- ***	
w	Megachile lapponica Thomson	0	13	4	9	5.21	+ *	
g	Megachile leachella Curtis	7	15	6	16	0.11	-	
w	Megachile ligniseca (Kirby)	41	25	19	47	36.33	- ***	
w	Megachile maritima (Kirby)	13	10	7	16	8.79	- **	-
g	Megachile pilidens Alfken	0	2	1	1	0.80	= (=)	
g	Megachile pyrenaea Pérez	23	7	9	21	33.95	- ***	
w	Megachile rotundata (Fabricius)	0	1	0	1	0.40	- (=)	
w	Megachile versicolor Smith	23	45	19	49	0.91	=	
w	Megachile willughbiella (Kirby)	28	63	26	65	0.21	=	

Foraging Megachilidae (continued)

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi²	computed trend	corrected trend
w	Osmia adunca (Panzer)	48	54	29	73	17.03	- ***	
h	Osmia andrenoides Spinola	0	5	1	4	2.00	= (-)	
g	Osmia anthocopoides Schenck	22	5	8	19	36.99	- ***	
h	Osmia aurulenta (Panzer)	51	54	30	75	20.52	- ***	
h	Osmia bicolor (Schrank)	15	55	20	50	1.76	=	
w	Osmia brevicornis (Fabricius)	0	1	0	1	0.40	= (-)	
w	Osmia caerulescens (L.)	50	87	39	98	4.19	- *	=
p	Osmia claviventris (Thomson)	24	34	17	41	4.64	- *	=
w	Osmia cornuta (Latreille)	92	348	126	314	12.73	+ ***	
w	Osmia fulviventris (Panzer)	35	53	25	63	5.38	- *	=
g	Osmia inermis (Zetterstedt)	1	0	0	1	2.50	= (-)	
w	Osmia leaiana (Kirby)	17	25	12	30	2.90	=	
p	Osmia leucomelana (Kirby)	23	42	19	46	1.47	-	
g	Osmia mitis Nylander	1	0	0	1	2.50	- (=)	
g	Osmia mustelina Gerstäcker	2	0	1	1	4.99	- (-)	
w	Osmia papaveris (Latreille)	25	6	9	22	41.13	- ***	
w	Osmia parietina (Curtis)	5	14	5	14	0.05	=	
g	Osmia pilicornis (Smith)	20	5	7	18	32.35	- ***	
w	Osmia ravouxi Pérez	11	40	15	36	1.23	=	
h	Osmia rufa (L.)	93	620	204	509	84.45	+ ***	
h	Osmia rufohirta Latreille	22	23	13	32	9.08	- **	-
w	Osmia spinulosa (Kirby)	22	18	11	29	13.66	- ***	
g	Osmia uncinata Gerstäcker	9	19	8	20	0.17	-	
g	Osmia villosa (Schenck)	16	10	7	19	13.82	- ***	
g	Osmia xanthomelana (Kirby)	18	3	6	15	33.56	- ***	
g	Trachusa byssina (Panzer)	17	22	11	28	4.29	- *	=

Foraging Halictidae

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi²	computed trend	corrected trend
g	Dufourea dentiventris (Nylander)	16	35	15	36	0.19	=	
g	Dufourea inermis (Nylander)	2	9	3	8	0.58	-	
g	Dufourea minuta Lepeletier(=halictula)	4	1	1	4	6.47	- (-)	
g	Dufourea vulgaris Schenck	6	2	2	6	8.44	- **	(-))
g	Halictus confusus Smith	26	71	28	69	0.15	=	
g	Halictus eurygnathus Blüthgen	4	3	2	5	2.79	- (=)	
g	Halictus leucaheneus Ebmer	22	19	12	29	12.61	- ***	
g	Halictus maculatus Smith	26	28	15	39	10.11	- **	-
g	Halictus quadricinctus (Fabricius)	17	7	7	17	20.97	- ***	
g	Halictus rubicundus (Christ)	86	227	90	223	0.19	-	
g	Halictus scabiosae (Rossi)	5	15	6	14	0.13	-	
g	Halictus sexcinctus (Fabricius)	48	19	19	48	60.80	- ***	
g	Halictus simplex Blüthgen	15	5	6	14	21.09	- ***	
g	Halictus tetrazonianellus Strand	1	0	0	1	2.50	= (-)	
g	Halictus tomentosus (Eversmann)	12	24	10	26	0.40	=	
g	Halictus tumulorum (L.)	70	296	105	261	16.07	+ ***	
g	Lasioglossum albipes (Fabricius)	82	706	82	206	0.00	-	
g	Lasioglossum brevicorne (Schenck)	6	10	5	11	0.62		
g	Lasioglossum breviventre (Schenck)	1	0	0	1	2.50	(-)	
g	Lasioglossum calceatum (Scopoli)	144	444	168	420	4.85	+ *	+
g	Lasioglossum costulatum (Kriechbaumer)	3	1	1	3	4.22	- (-)	
g	Lasioglossum fratellum (Pérez)	21	36	16	41	1.90	=	
g	Lasioglossum fulvicorne (Kirby)	88	215	87	216	0.03	=	
g	Lasioglossum interruptum (Panzer)	1	0	0	1	2.50	- (=)	
g	Lasioglossum laeve (Kirby)	2	0	1	1	4.99	- (-)	
g	Lasioglossum laevigatum (Kirby)	29	42	20	51	5.22	- *	-
g	Lasioglossum laticeps (Schenck)	56	113	48	121	1.71	-	
g	Lasioglossum lativentre (Schenck)	62	35	28	69	59.27	- ***	
g	Lasioglossum leucopus (Kirby)	28	98	36	90	2.51	=	
g	Lasioglossum leucozonium (Schrank)	102	187	83	206	6.35	- *	=
g	Lasioglossum lineare (Schenck)	4	13	5	12	0.71	-	
g	Lasioglossum lucidulum (Schenck)	6	19	7	18	0.26	=	

Foraging Halictidae (continued)

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi^2	computed trend	corrected trend
g	*Lasioglossum malachurum* (Kirby)	40	69	31	78	3.50	-	
g	*Lasioglossum minutissimum* (Kirby)	15	45	17	43	0.38	-	
g	*Lasioglossum minutulum* (Schenck)	15	21	10	26	3.01	=	
g	*Lasioglossum morio* (Fabricius)	97	237	96	238	0.03	-	
g	*Lasioglossum nitidiusculum* (Kirby)	28	66	27	67	0.07	=	
g	*Lasioglossum nitidulum* (Fabricius)	49	274	92	231	28.51	+	***
g	*Lasioglossum parvulum* (Schenck)	47	102	43	106	0.63	-	
g	*Lasioglossum pauxillum* (Schenck)	35	56	26	65	4.34	-	*	-
g	*Lasioglossum politum* (Schenck)	0	5	1	4	2.00	=	(=)
g	*Lasioglossum prasinum* (Smith)	7	8	4	11	2.40	=	
g	*Lasioglossum punctatissimum* (Schenck)	25	102	36	91	4.94	+	*	+
g	*Lasioglossum pygmaeum* (Schenck)	12	6	5	13	12.78	-	***
g	*Lasioglossum quadrinotatulum* (Schenck)	26	53	23	56	0.72	-	
g	*Lasioglossum quadrinotatum* (Kirby)	13	12	7	18	6.71	-	**	-
g	*Lasioglossum rufitarse* (Zetterstedt)	29	72	29	72	0.00	-	
g	*Lasioglossum semilucens* (Alfken)	13	51	18	46	2.15	-	
g	*Lasioglossum sexnotatum* (Kirby)	68	47	33	82	52.52	-	***
g	*Lasioglossum sexstrigatum* (Schenck)	35	108	41	102	1.19	-	
g	*Lasioglossum tarsatum* (Schenck)	2	1	1	2	2.13	=	(-)
g	*Lasioglossum villosulum* (Kirby)	64	189	72	181	1.35	=	
g	*Lasioglossum xanthopus* (Kirby)	36	21	16	41	33.35	-	***
g	*Lasioglossum zonulum* (Smith)	68	139	59	148	1.84	=	
g	*Rophites quinquespinosus* Spinola	2	1	1	2	2.13	-	(=)

Melittidae (all foraging species)

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi^2	computed trend	corrected trend
g	*Dasypoda hirtipes* (Fabricius)	26	56	23	59	0.39	-	
g	*Macropis europaea* Warncke	26	42	19	49	3.10	=	
g	*Macropis fulvipes* (Fabricius)	13	16	8	21	3.74	-	
g	*Melitta haemorrhoidalis* (Fabricius)	47	98	41	104	1.04	-	
g	*Melitta leporina* (Panzer)	22	20	12	30	11.64	-	***
g	*Melitta nigricans* Alfken	13	19	9	23	2.27	=	
g	*Melitta tricincta* Kirby	19	31	14	36	2.17	=	

Andrenidae (all foraging species)

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi^2	computed trend	corrected trend
g	*Andrena agilissima* (Scopoli)	27	19	13	33	20.41	-	***
g	*Andrena angustior* (Kirby)	38	222	74	186	24.89	+	***
g	*Andrena anthrisci* Blüthgen	1	2	1	2	0.03	-	(-)
g	*Andrena apicata* Smith	5	19	7	17	0.71	-	
g	*Andrena argentata* Smith	8	24	9	23	0.20	-	
g	*Andrena barbilabris* (Kirby)	29	150	51	128	13.47	+	***
g	*Andrena bicolor* Fabricius	65	367	124	308	38.84	+	***
g	*Andrena bimaculata* (Kirby)	0	3	1	2	1.20	=	(=)
g	*Andrena carbonaria* (L.)	28	28	16	40	12.57	-	***
g	*Andrena chrysopyga* Schenck	10	2	3	9	17.61	-	***
g	*Andrena chrysosceles* (Kirby)	37	242	80	199	32.13	+	***
g	*Andrena cineraria* (L.)	39	90	37	92	0.17	-	
g	*Andrena clarkella* (Kirby)	29	103	38	94	2.84	-	
g	*Andrena coitana* (Kirby)	12	21	9	24	0.98	-	
g	*Andrena combinata* (Christ)	22	20	12	30	11.64	-	***
g	*Andrena curvungula* Thomson	7	6	4	9	4.06	-	*	-
g	*Andrena denticulata* (Kirby)	28	9	11	26	40.17	-	***
g	*Andrena dorsata* (Kirby)	11	39	14	36	1.07	-	
g	*Andrena falsifica* Perkins	8	6	4	10	5.59	-	*	-
g	*Andrena ferox* Smith	3	2	1	4	2.42	-	(-)
g	*Andrena flavipes* Panzer	70	326	113	283	23.12	+	***
g	*Andrena florea* Fabricius	37	79	33	83	0.62	-	
g	*Andrena fucata* Smith	29	136	47	118	9.81	+	**	+
g	*Andrena fuligula* Warncke	0	1	0	1	0.40	-	(-)
g	*Andrena fulva* (Müller)	66	672	211	527	139.54	+	***

Andrenidae (continued)

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi^2	computed trend	corrected trend
g	Andrena fulvago (Christ)	24	36	17	43	3.82	-	
g	Andrena fulvida Schenck	11	5	5	11	12.64	- ***	
g	Andrena fuscipes (Kirby)	36	78	33	81	0.50	-	
g	Andrena gelriae van der Vecht	1	1	1	1	0.45	- (=)	
g	Andrena glabriventris Alfken	2	6	2	6	0.05	=	
g	Andrena gravida Imhoff	46	94	40	100	1.25	-	
g	Andrena haemorrhoa (Fabricius)	101	854	273	682	151.86	+ ***	
g	Andrena hattorfiana (Fabricius)	53	87	40	100	5.88	- *	=
g	Andrena helvola (L.)	41	224	76	189	22.35	+ ***	
g	Andrena humilis Imhoff	42	129	49	122	1.36	-	
g	Andrena intermedia Thomson	3	1	1	3	4.22	- (-)	
g	Andrena labialis (Kirby)	39	55	27	67	7.65	- **	=
g	Andrena labiata Fabricius	24	37	17	44	3.45	=	
g	Andrena lapponica Zetterstedt	26	41	19	48	3.42	-	
g	Andrena lathyri Alfken	52	97	43	106	2.90	-	
g	Andrena limata Smith	4	1	1	4	6.47	- (-)	
g	Andrena marginata Fabricius	25	10	10	25	31.45	- ***	
g	Andrena minutula (Kirby)	41	189	66	164	13.06	+ ***	
g	Andrena minutuloides Perkins	9	34	12	31	1.24	-	
g	Andrena mitis Schmiedeknecht	8	32	11	29	1.45	-	
g	Andrena nana (Kirby)	1	0	0	1	2.50	= (=)	
g	Andrena nigriceps (Kirby)	2	1	1	2	2.13	= (-)	
g	Andrena nigroaenea (Kirby)	56	205	75	186	6.51	+ *	+
g	Andrena nitida (Müller)	75	311	110	276	15.88	+ ***	
g	Andrena nitidiuscula Schenck	1	0	0	1	2.50	- (=)	
g	Andrena niveata Friese	5	1	2	4	8.80	- (-)	
g	Andrena nycthemera Imhoff	0	6	2	4	2.40	- (-)	
g	Andrena ovatula (Kirby)	85	111	56	140	20.95	- ***	
g	Andrena pandellei Pérez	9	14	7	16	1.25	-	
g	Andrena polita Smith	4	18	6	16	1.17	=	
g	Andrena potentillae Panzer	0	4	1	3	1.60	- (=)	
g	Andrena praecox (Scopoli)	35	69	30	74	1.30	=	
g	Andrena proxima (Kirby)	29	47	22	54	3.40	-	
g	Andrena rosae Panzer	21	11	9	23	21.49	- ***	
g	Andrena ruficrus Nylander	17	48	19	46	0.19	=	
g	Andrena sabulosa (Scopoli)	76	512	168	420	70.71	+ ***	
g	Andrena schencki Morawitz	45	15	17	43	63.28	- ***	
g	Andrena semilaevis Pérez	34	116	43	107	2.58	-	
g	Andrena similis Smith (=ocreata)	30	40	20	50	6.97	- **	=
g	Andrena spreta Pérez	3	10	4	9	0.19	=	
g	Andrena strohmella Stöckhert	14	26	11	29	0.80	-	
g	Andrena subopaca Nylander	64	302	105	261	22.12	+ ***	
g	Andrena synadelpha Perkins	3	25	8	20	4.38	+ *	+
g	Andrena tarsata Nylander	20	4	7	17	35.22	- ***	
g	Andrena thoracica (Fabricius)	5	1	2	4	8.80	- (-)	
g	Andrena tibialis (Kirby)	27	95	35	87	2.50	=	
g	Andrena vaga Panzer	15	33	14	34	0.17	-	
g	Andrena varians (Rossi)	27	92	34	85	2.03	-	
g	Andrena ventralis Imhoff	13	24	11	26	0.78	-	
g	Andrena wilkella (Kirby)	48	147	56	139	1.51		
g	Panurgus banksianus (Kirby)	14	44	17	41	0.56		
g	Panurgus calcaratus (Scopoli)	37	41	22	56	13.56	- ***	
g	Panurgus dentipes Latreille	2	1	1	2	2.13	- (-)	

Colletidae (all foraging species)

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi^2	computed trend	corrected trend
g	Colletes cunicularius (L.)	8	3	3	8	10.49	- **	-
g	Colletes daviesanus Smith	34	213	71	176	26.60	+ ***	
g	Colletes fodiens (Fourcroy)	6	9	4	11	0.96	=	
g	Colletes halophilus Verhoeff	0	12	3	9	4.81	+ *	+
g	Colletes marginatus Smith	1	5	2	4	0.42	= (-)	

Colletidae (continued)

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi²	computed trend	corrected trend
g	*Colletes similis* Schenck	2	1	1	2	2.13	- (-)	
g	*Colletes succinctus* (L.)	22	63	24	61	0.31	-	
p	*Hylaeus angustatus* (Schenck)	0	2	1	1	0.80	= (-)	
p	*Hylaeus annularis* (Kirby)	9	51	17	43	5.43	+ *	+
p	*Hylaeus bifasciatus* (Jurine)	1	0	0	1	2.50	- (-)	
p	*Hylaeus bipunctatus* (Fabricius)	48	114	46	116	0.08	-	
p	*Hylaeus bisinuatus* Förster	17	13	9	21	11.58	- ***	
p	*Hylaeus brevicornis* Nylander	38	101	40	99	0.11	=	
p	*Hylaeus clypearis* (Schenck)	1	0	0	1	2.50	- (=)	
p	*Hylaeus communis* Nylander	48	194	69	173	9.10	+ **	+
p	*Hylaeus conformis* Förster	10	9	5	14	5.38	- *	-
p	*Hylaeus cornutus* Curtis	4	10	4	10	0.00	-	
p	*Hylaeus difformis* (Eversmann)	1	1	1	1	0.45	= (-)	
p	*Hylaeus gibbus* Saunders	54	180	67	167	3.49	=	
p	*Hylaeus gracilicornis* (Morawitz)	1	0	0	1	2.50	- (-)	
p	*Hylaeus Hyalinatus* Smith	56	219	79	196	9.13	+ **	+
p	*Hylaeus nigritus* (Fabricius)	0	2	1	1	0.80	- (=)	
p	*Hylaeus pectoralis* Förster	2	7	3	6	0.18	-	
p	*Hylaeus pictipes* Nylander	38	76	33	81	1.25	=	
p	*Hylaeus punctulatissimus* Smith	20	42	18	44	0.41	-	
p	*Hylaeus rinki* (Gorski)	4	21	7	18	1.94	=	
p	*Hylaeus sinuatus* (Schenck)	0	1	0	1	0.40	= (-)	
p	*Hylaeus styriacus* Förster	1	3	1	3	0.03	- (-)	
p	*Hylaeus variegatus* (Fabricius)	17	10	8	19	15.62	- ***	

Cleptoparasitic Anthophoridae

nest	species	observed befor	observed sinc	expected befor	expected sinc	chi²	computed trend	corrected trend
g	*Ammobates punctatus* (Fabricius)	10	2	3	9	17.61	- ***	
g	*Biastes truncatus* (Nylander)	1	6	2	5	0.70	= (-)	
g	*Epeoloides caecutiens* (Fabricius)	5	1	2	4	8.80	- (-)	
g	*Epeolus cruciger* (Panzer)	17	53	20	50	0.64	-	
g	*Epeolus variegatus* (L.)	7	5	3	9	5.20	- *	-
g	*Melecta albifrons* (Förster)	21	155	50	126	23.93	+ ***	
g	*Melecta luctuosa* (Scopoli)	29	4	9	24	56.80	- ***	
g	*Nomada alboguttata* Herrich-Schäffer	37	81	34	84	0.44	-	
g	*Nomada argentata* Herrich-Schäffer	2	0	1	1	4.99	- (-)	
g	*Nomada armata* Herrich-Schäffer	10	6	5	11	9.01	- **	-
g	*Nomada baccata* Smith	1	2	1	2	0.03	= (-)	
g	*Nomada bifasciata lepeletieri* Pérez	26	14	11	29	25.96	- ***	
g	*Nomada castellana* Dusmet (=baeri)	0	1	0	1	0.40	- (=)	
g	*Nomada conjungens* Herrich-Schäffer	6	9	4	11	0.96	=	
g	*Nomada distinguenda* Morawitz	20	11	9	22	19.59	- ***	
g	*Nomada emarginata* Morawitz	5	18	7	16	0.53	-	
g	*Nomada fabriciana* (L.)	78	168	70	176	1.17	=	
g	*Nomada femoralis* Morawitz	23	18	12	29	15.19	- ***	
g	*Nomada ferruginata* (L.)	10	14	7	17	2.01	-	
g	*Nomada flava* Panzer	104	573	194	483	58.06	+ ***	
g	*Nomada flavoguttata* Kirby	38	117	44	111	1.26	-	
g	*Nomada flavopicta* Kirby	53	37	26	64	40.45	- ***	
g	*Nomada fucata* Panzer	64	78	41	101	18.88	- ***	
g	*Nomada fulvicornis* Fabr. (=lineola)	57	31	25	63	56.41	- ***	
g	*Nomada fulvicornis* Fabricius	27	100	36	91	3.35	-	
g	*Nomada furva* Panzer	1	5	2	4	0.42	= (-)	
g	*Nomada fuscicornis* Nylander	16	11	8	19	12.43	- ***	
g	*Nomada glabella* Thomson	9	9	5	13	4.04	- *	-
g	*Nomada goodeniana* Kirby	62	85	42	105	13.28	- ***	
g	*Nomada guttulata* Schenck	3	4	2	5	0.70	- (=)	
g	*Nomada integra* Brullé(=cinctiventris)	28	30	17	41	11.00	- ***	
g	*Nomada lathburtiana* Kirby	26	35	17	44	5.88	- *	-
g	*Nomada leucophthalma* Kirby	41	25	19	47	36.33	- ***	
g	*Nomada marshamella* Kirby	55	174	65	164	2.35	-	

Cleptoparasitic Anthophoridae (continued)

nest	species	observed befor	sinc	expected befor	sinc	chi^2	computed trend	corrected trend
g	Nomada melathoracica Imhoff	7	5	3	9	5.20	- *	(-)
g	Nomada mutabilis Morawitz	3	1	1	3	4.22	- (-)	
g	Nomada mutica Morawitz	2	0	1	1	4.99	- (-)	
g	Nomada obscura Zetterstedt	1	8	3	6	1.35	=	
g	Nomada obtusifrons Nylander	0	5	1	4	2.00	- (=)	
g	Nomada opaca Alfken	0	1	0	1	0.40	= (=)	
g	Nomada panzeri Lepeletier	62	105	48	119	5.95	- *	=
g	Nomada piccioliana Magretti	1	1	1	1	0.45	+ (=)	
g	Nomada pleurosticta Herrich-Schäffer	0	1	0	1	0.40	- (=)	
g	Nomada rhenana Morawitz	2	5	2	5	0.00	- (=)	
g	Nomada roberjeotiana Panzer	31	1	9	23	73.07	- ***	
g	Nomada roberjeotiana Panzer	0	2	1	1	0.80	- (=)	
g	Nomada ruficornis (L.) (=bifida)	102	106	59	149	42.57	- ***	
g	Nomada rufipes Fabricius	47	69	33	83	8.08	- **	=
g	Nomada sexfasciata Panzer	30	13	12	31	35.70	- ***	
g	Nomada sheppardana Panzer	47	61	31	77	11.78	- ***	
g	Nomada signata Kirby	52	26	22	56	55.37	- ***	
g	Nomada similis Morawitz	17	15	9	23	9.43	- **	=
g	Nomada stigma Fabricius	0	1	0	1	0.40	- (=)	
g	Nomada striata Fabricius	47	77	35	89	5.26	- *	=
g	Nomada villosa Thomson	1	6	2	5	0.70	= (-)	
g	Nomada zonata Panzer	2	1	1	2	2.13	= (-)	
g	Thyreus orbatus (Lepeletier)	14	1	4	11	30.79	- ***	

Cleptoparasitic Megachilidae

nest	species	observed befor	sinc	expected befor	sinc	chi^2	computed trend	corrected trend
	Coelioxys afra Lepeletier	0	3	1	2	1.20	= (-)	
	Coelioxys alata Förster	3	0	1	2	7.49	- (-)	
	Coelioxys aurolimbata Förster	25	16	12	29	21.05	- ***	
	Coelioxys conoidea Klug	16	1	5	12	35.74	- ***	
	Coelioxys elongata Lepeletier	6	13	5	14	0.08	=	
	Coelioxys emarginata Förster	2	0	1	1	4.99	- (-)	
	Coelioxys inermis (Kirby)	28	32	17	43	9.60	- **	-
	Coelioxys mandibularis Nylander	6	6	3	9	2.69	=	
	Coelioxys quadridentata (L.)	19	19	11	27	8.53	- **	=
	Coelioxys rufescens Lepeletier	29	11	11	29	37.76	- ***	
	Coelioxys rufocaudata Smith	0	1	0	1	0.40	- (=)	
	Dioxys tridentata Nylander	0	2	1	1	0.80	- (-)	
	Stelis breviuscula (Nylander)	22	48	20	50	0.28	=	
	Stelis minima Schenck	0	3	1	2	1.20	- (=)	
	Stelis minuta Lep.& Serv.	1	8	3	6	1.35	=	
	Stelis odontopyga Noskiewicz	0	1	0	1	0.40	= (-)	
	Stelis ornatula (Klug)	10	6	5	11	9.01	- **	=
	Stelis phaeoptera (Kirby)	25	25	14	36	11.22	- ***	
	Stelis punctulatissima (Kirby)	12	10	6	16	7.26	- **	
	Stelis signata (Latreille)	6	2	2	6	8.44	- **	-

Cleptoparasitic Halictidae

nest	species	observed befor	sinc	expected befor	sinc	chi^2	computed trend	corrected trend
g	Sphecodes albilabris (Fabricius)	7	3	3	7	8.40	- **	-
g	Sphecodes alternatus Smith	0	2	1	1	0.80	= (-)	
g	Sphecodes crassus Thomson	7	47	15	39	6.46	+ *	+
g	Sphecodes ephippius (L.)	52	107	45	114	1.32	=	+
g	Sphecodes ferruginatus von Hagens	10	31	12	29	0.36	-	
g	Sphecodes geoffrellus (Kirby)	11	65	22	54	7.42	+ **	+
g	Sphecodes gibbus (L.)	34	68	29	73	1.12	=	
g	Sphecodes hyalinatus von Hagens	12	40	15	37	0.78	-	
g	Sphecodes longulus von Hagens	16	39	16	39	0.01	=	
g	Sphecodes marginatus von Hagens	4	27	9	22	3.74	-	
g	Sphecodes miniatus von Hagens	8	38	13	33	2.83	-	
g	Sphecodes monilicornis (Kirby)	33	111	41	103	2.27	-	

nest	species	number of occurences				chi^2	compu ted trend	corre cted trend
		observed		expected				
		befor	sinc	befor	sinc			
g	*Sphecodes niger* von Hagens	1	5	2	4	0.42	= (-)	
g	*Sphecodes pellucidus* Smith	15	77	26	66	6.81	+ **	+
g	*Sphecodes puncticeps* Thomson	19	48	19	48	0.00	=	
g	*Sphecodes reticulatus* Thomson	23	23	13	33	10.32	- **	-
g	*Sphecodes rubicundus* von Hagens	15	2	5	12	29.61	- ***	
g	*Sphecodes rufiventris* (Panzer)	4	2	2	4	4.26	- (-)	
g	*Sphecodes scabricollis* Wesmael	12	3	4	11	19.41	- ***	
g	*Sphecodes spinulosus* von Hagens	11	3	4	10	17.13	- ***	

TOTAL number of occurences for the period before 1950: 7791
TOTAL number of occurences for the period since 1950: 19453
GRAND TOTAL : 27244

Table title: Cleptoparasitic Halictidae (continued)

NECESSARY RESEARCH TO IMPROVE POLLINATION TECHNOLOGY

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ABSTRACT
One of the main outcomes of the P.A.C. reform is the necessity of intensifying and diversifying the cultures in E.E.C. To attain this. the european farmers have to rely on new cultivars, new hybrids or even traditional cultures which can be entirely unknown in certain regions. In many cases, pollination and specially cross pollination are necessary to obtain correct harvest from these cultures. A certain amount of research seems necessary for pollination to become a really useful tool for european agriculturists.

1. TECHNICO-ECONOMICAL RESEARCH

1.1. Independant advisory boards on pollination should be put in place to meet the needs of farmers. These organisms should be pluridisciplinary, established nationally or regionally they should have at least one entomologist, one agronomist, one agricultural technician, one beekeeping technician. These people could explain to the demanding farmers which pollinators and which pollinating technology to use because these may vary according to the plants and even to the climatic conditions.

1.2. Economic incidences of pollination
It is also necessary to install in different regions of Europe precise experiments to evaluate the economic gain realised by a well studied pollination. This gain is not only a result of bettering the quality and quantity of the harvest, but also economy of fertilisers and plant protection products. Such tests should convince farmers to use pollinating insects under certain conditions to obtain a much better reward per acre.

2. SUGGESTIONS FOR TECHNICAL IMPROVEMENT RESEARCH

2.1. Systematic studying of the loss of germinating power of pollens collected by the bees should enable considerable progress to be made in pollen dispensers

technology. Works done on the washing of the pollen balls to get rid of the oils which make them stick together should find an easier way to use the pollen in its redistribution by bees or mechanical means. It is true that other ways of harvesting pollen other than through the bees seem to be making progress (electro mechanical device ?)

2.2. Further research should be continued on the products which help to make Unattractive plants more easely pollinated. Through the knowledge on kairomones has made a lot of progress, the practical results in spraying the plants or training the bees, are still non significant.

2.3. To enable the beekeepers to build strong colonies in the early spring when they are badly needed for pollination, more studies must be made on the bees feeding and defining of some specific food.

3. POLLINATION IN GLASS-HOUSES

3.1. We should investigate more thoroughly in the use of queenless package bees with or without pheromone dispensers. These colonies could be delivered in cheap cardboard boxes which would be burnt after use.

3.2. More attention should be given to produce bees resistant to glass houses or plastic tunnels. Everyone who has worked with bees in tents or glass houses, mainly during plant-protection products research, knows that some colonies do not stand the enclosed space. The bee mortality may be high and varies with the different colonies. Therefore it is important to set up some tests to allow the beekeepers to chosse the more "resistant" colonies before delivering them to green houses farmers.

DEVELOPMENT OF SOLITARY BEES AS CROP POLLINATORS

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INTRODUCTION

The value of pollination to agriculture and horticulture is very difficult to estimate. Nevertheless much have been written on this subject and a recent article (Gill, 1991) reviews former and recent attempts to evaluate the benefits attributed to the pollinating activities of honey bees. Although most of these attempts to evaluate pollination has been based on, to some degree, predictions and insupportable premises, they have clearly demonstrated that bees are and will be vital in maintaining the productivity in agricultural and horticultural environments.

In the temperate regions the honey bee is the most important pollinator, but the dependence on one species for crop pollination sometimes creates problems which are now being experienced in Denmark. In Denmark there is not enough colonies of honey bees available to meet the needs for adequate pollination. The total numbers of colonies have declined from 240.000 in 1950 to about 80.000 in 1990. In the same period the need for pollinators has increased. Rape fields (ca. 200.000 ha) alone requires 400.000 colonies to maximize the seed production. Thus it is in fact impossible to assure adequate pollination of cultivated crops in Denmark with the available honey bees alone.

The decline in number of honey bees is just one side of a very serious pollinating problem. The agricultural and horticultural environments have changed dramatically the last 50 years and there are several aspects associated with these changes that are threatening the global pollinating system. This problem has recently been reviewed and discussed in articles by Kevan (1991) and Torchio (1991).

The decline in number of pollinators, honey bees and non-honey bee species, has been caused by three major factors : 1) PESTICIDES - which have caused rapid decline in number of pollinators, 2) DESTRUCTION OF HABITATS - first and

foremost elimination of nesting areas previously used by non-honey bees and destruction of food resources, and 3) DISEASES AND PARASITES IN HONEY BEES - first and foremost the parasitic mite *Varroa jacobsonii* Oud. (Kevan, 1991; Torchio, 1991).

Much can be done to avert the potential decline in agricultural and horticultural productivity caused by pollinator problems. Use of pesticides can be reduced, habitat reduction can be avoided and habitats for wild pollinators can be augmented, and the decline in number of honey bee colonies can be avoided. Furthermore the number of wild pollinators (solitary and social bees) within agricultural and horticultural environments can be increased fairly rapidly in two ways.

A : The "natural method" - increase numbers of wild pollinators through establishment of habitat management programs.

B : The "artificial method" - development of additional wild bee species as managed pollinators of specific crops within intensively farmed agricultural areas (or in greenhouses).

The value of several solitary bee species as pollinators on specific crops have already been demonstrated, i.e. *Megachile rotundata* (Fab.) and *Nomia melanderi* Ckll. on alfalfa in USA, *Osmia cornifrons* (Rad.) in Japan and *Osmia lignaria propinqua* Cr. in USA on orchard crops and recently *Rhophitoides canus* Ev in Poland on alfalfa (Richards, 1986; Torchio, 1987; Maeta & Kitamura, 1974; Torchio, 1991; Ptacek, 1991). These species have been developed and utilized successfully as an alternative to honey bee pollination. The results clearly demonstrate that the pollinating problem can partly be solved by increasing the numbers of non-honey bee species through the "artificial method". I n Spain and Yugoslavia active efforts are now in progress to establish *Osmia cornuta* Latr. as an alternative pollinator of orchard crops (Asensio, 1983; Krunic et al, 1991) and in Denmark the species *Osmia rufa* L. has recently been developed and utilized as an alternative pollinator of orchard crops.

The purpose of this paper is only to review some of the results from a research program that started in Denmark in 1984 (the results will be published in more details elsewhere). The aim of the program is to investigate the possibilities in

developing and utilizing the solitary bee *Osmia rufa*. as an alternative commercial pollinator. This paper reports on following research topics; 1) occupation of artificial nests, 2) reproduction, 3) hibernation, 4) sex-ratio and 5) mortality and control of parasites.

MATERIAL AND METHODS

In the period 1984-1988 following experiments were carried out.

In 1984,1985 and 1986, *Osmia rufa* cocoons were collected in nest traps from a natural population. The nest traps were constructed of 10 mm chipboard box and filled with grooved boards (Fig. 1). Two different nesting materials were tested. The tunnels had different diameter (6 and 8 mm) and nest traps were placed in such a way that the tunnels were either vertical or horizontal. The nest traps were different regarding the access to the tunnel-openings.
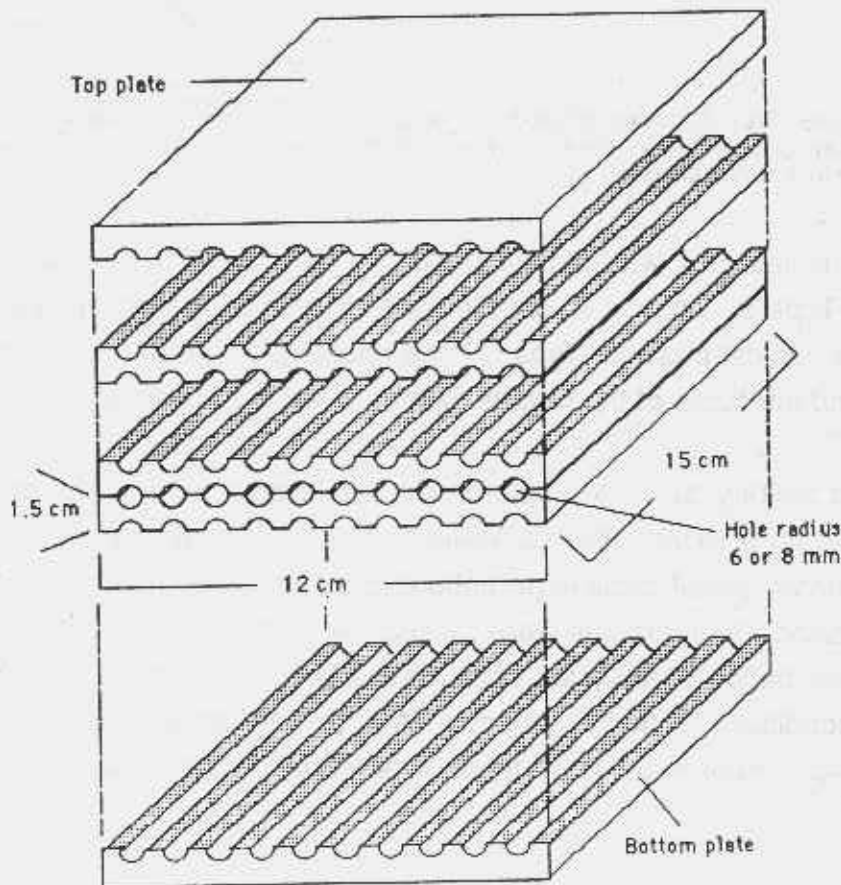
Figure 1. Grooved boards used as a nesting material. The boards made of wood had 8 grooves and boards made of pressed plant fibers 10 groovers.

Type A - the opening of the nest tunnels facing each other inside the nest box, with a 7 cm distance between the faces, thus forming a small cavity. The cavity was closed with a wooden plate with 6 holes (3 cm in diameter) in a row, allowing the bees to fly in and out of the cavity (Fig. 2).

A small room (cavity) between the boards

Grooved boards facing each other

Holes 3 cm in diameter
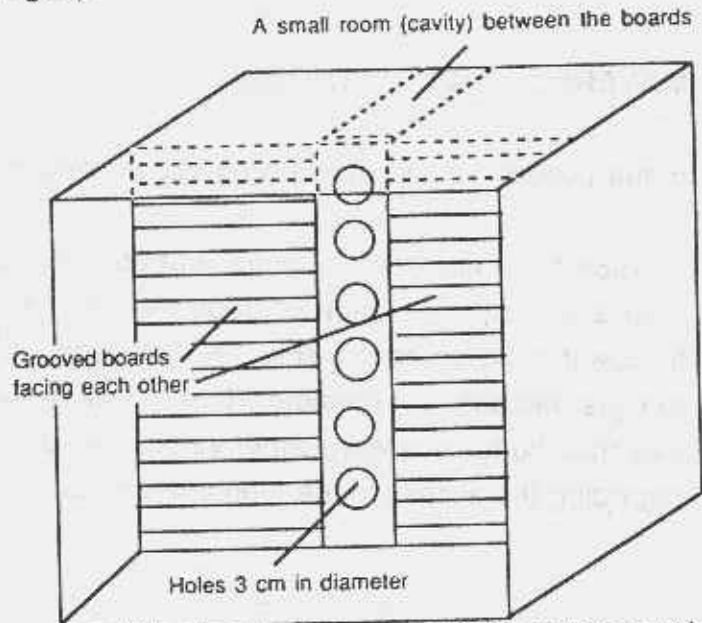
Figure 2. Nest type A, demonstrate the 6 holes which allow the bees access to the nesting tunnels which are laying horizontally. Nest type B was identical, but the tunnels were in a vertical position and the 6 holes in a horizontal one.

The whole nest box was placed in such a way that the tunnels had a horizontal position. Type B - as type A, but the nest box placed in such a way that the tunnels were in a vertical position. Type C - the opening of the tunnels facing outwards (no cavity) and the faces of the boards painted black with contrasting blue figures.

To use a solitary bee on a commercial basis as a pollinator it must increase its population fairly rapidly. Free & Williams (1970) and Holm (1973) have shown that O. rufa nests gregariously in greenhouses as well as in nature and rapidly increase its population. Experiments were carried out in 1986, 1987 and 1988 to investigate further occupation of artificial nests and the possibility of reproducing O. rufa under Danish conditions, both in a greenhouse and in an orchard. For these experiments, O. rufa (rufa) from trap nests and O. rufa (cornigera) imported from Germany were used.

When using bees for pollination on a commercial basis, it is necessary to have detailed information on the pattern of emergence and factors involved. The

influence of the hibernating temperature, the incubation temperature and the length of the diapause on the emergence of *O. rufa* was investigated. Bees (in cocoons) were hibernated in a refrigerator at different temperatures, for different periods of time and incubated at different temperatures.

To maintain a population of a wild bee species on a commercial basis for pollination, one of the requirements the populations have to fulfill is to produce progeny of favorable sex-ratio, i.e., a sex-ratio near to unity (1:1). The greater a number of females per male there are in a population the greater is the pollinating efficiency of the population as a unit. he sex-ratio and the sex distribution in nests were examined.

One of the major problems in rearing wild bees for pollination purposes is mortality of immature stages due to diseases and infestation of parasites. A large population of nesting bees concentrated in a small area easily attracts dipterous and hymenopterous parasites, and as soon the parasites have established themselves in the population they might become a serious problem in only a few years. Although only few parasites have been recorded as serious pests in nests of *O. rufa*, their number will probably rise where the species will be reared in great numbers. During the period from 1984-1988, nest traps and nests used in reproduction programs were dismantled and the mortality of immatures and the infestation of parasites were recorded. Dead immatures (eggs and larvae) were divided into two groups; 1) Dead larvae after defecation and 2) dead eggs and larvae before defecation. The distributions of dead immatures in the tunnels were also recorded.

RESULTS

Occupation of artificial nests

Results obtained on number of occupied tunnels per nest type revealed a wide variation (table 1).

NEST TYPE	1984 NUMBER OF CELLS	NUMBER OF COCOONS	NEST TYPE	1985 NUMBER OF CELLS	NUMBER OF COCOONS	NEST TYPE	1986 NUMBER OF CELLS	NUMBER OF COCOONS
A	7	1	A	50	8	C	31	9
A	10	0	A	22	3	C	107	46
A	47	8	A	33	15	C	18	1
A	28	6	A	0	0	C	243	109
A	532	297	B	5	2	C	43	23
B	2	2	B	0	0	C	0	0
B	5	1	C	574	226			
B	0	0	C	52	17			
C	247	109	C	2424	1468			
C	0	0						
TOTAL	878	424		3160	1739		442	109

Table 1. Results of nesting in nest trap - Taastrup, Zealand, 1984, 1985 and 1986. Empty cells = number of empty cells not including vestibular cells. The different nest types are described in text.

Number of closed tunnels (tunnels with terminal plug) in each type of nest box and average number of cells per tunnel is showed in table 2.

NEST TYPE	1984 NO. OF CLOSED TUNN.	CELLS PER TUNN.	NEST TYPE	1985 NO. OF CLOSED TUNN.	CELLS PER TUNN.	NEST TYPE	1986 NO. OF CLOSED TUNN.	CELLS PER TUNN.
A	65	8.03	A	21	4.14	C	62	5.50
C	24	7.33	C	392	7.08			
AVERAGE		7.84			6.92			5.50

Table 2. Number of closed tunnels in each type of nest box and average number of cells per tunnel.

A chi-square test (2 nest boxes in 1984) did not reveal significant difference in the selection between 6 and 8 mm tunnels ($x^2 = 1.401$, df = 1, p = 0.2366). In these two nest boxes 57 of 6 mm and 67 of 8 mm tunnels were occupied, but greater numbers of constructed cells were found in 8 mm tunnels.

A highly significant difference was recorded between the selection of the two different nesting materials, all nests included. Number of cells recorded in wooden boards and boards made of pressed plant fibers is demonstrated in figure 3 for two nest boxes in 1985 and for all nest boxes in 1986.
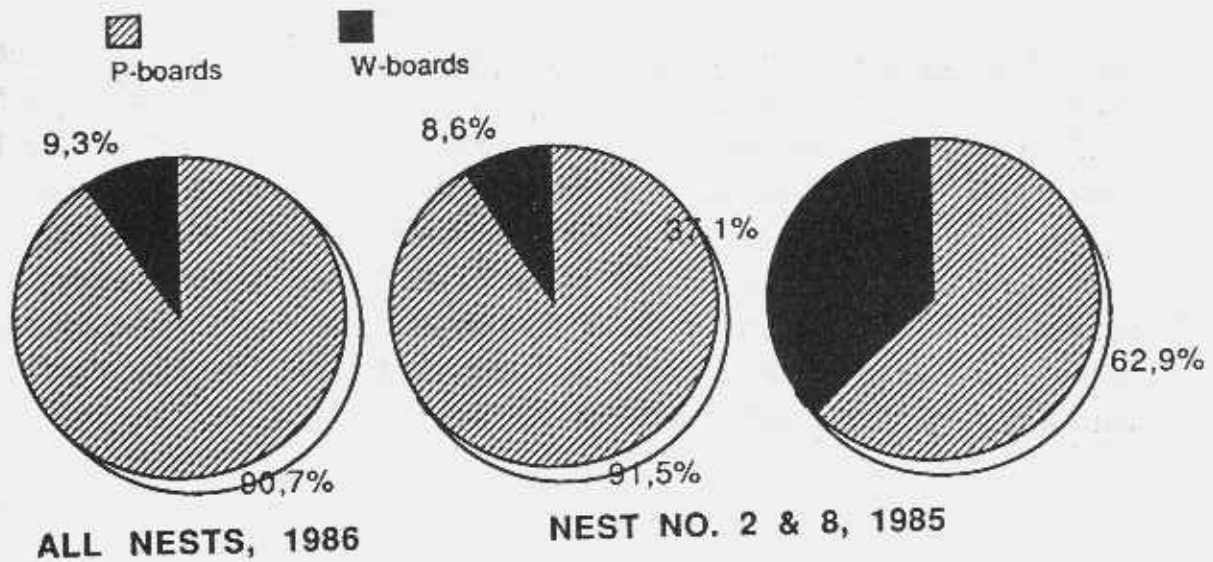
Figure 3. Percentage number of cells recorded in tunnels made of grooved wooden boards (W-boards) and boards made of pressed plant fibers (P-boards) in Taastrup 1986 (all nest boxes included) and in Taastrup 1985 (nest box N° 2 and 8).

REPRODUCTION

In the greenhouse in 1986 a total of 1008 bees emerged from the 1200 cocoons incubated. The first male emerged on the 12th of May and the first female on 17th of May. During a 2-month nesting period, a total of 788 cells were constructed in 273 tunnels. Dead immatures were recorded in 193 cells (24.5% immature mortality) and 81 (10.28%) empty cells were found. A total of 514 cocoons were collected (table 3). The population of life bees therefore decreased by 49%.

1986			1987			1988		
NEST NO.	NUMB. OF CELLS	NUMBER OF COCOONS	NEST NO.	NUMB. OF CELLS	NUMBER OF COCOONS	NEST NO.	NUMB. OF CELLS	NUMBER OF COCOONS
1	19	10	1	0	0	1	1762	1443
2	651	429	2	53	28	2	2502	2138
3	118	75	3	109	59	3	2521	2142
			4	617	439	4	2293	1993
			5	21	6	5	2636	2344
			6	79	62			
			7	102	74			
TOTAL	788	514		981	668		11714	10060

Table 3. Results of nesting in the greenhouse 1986 and in the orchard 1987 and 1988.

In 1987 in the orchard a total of 2552 bees emerged from the 2870 cocoons incubated. The first male emerged on 21st of May. On the 3d of June the first nesting female was observed. The last bee emerged on the 16th of June. The first closed tunnel observed was as late as on the 6th of July. The last flying female was recorded on the 10th of July. During the 37 days nesting period, a total of 981 cells were constructed in 312 tunnels, in 6 out of 7 nest boxes. Dead immatures were recorded in 249 cells (26.5% immature mortality) and empty cells were 53 (5.40%). In the remaining 668 cells, cocoons were found (table 3). The population of life bees was therefore decreased by 75%.

In 1988 in the orchard a total of 3130 bees emerged from the 4000 cocoons incubated. The first male emerged on the 24th of May. The bees completed their emergence on the 7th of June. Already on 26th of May the first female was observed nesting, and the following day, 100-150 females were observed returning from the field with mud pellets, indicating that they had found a tunnel to nest in and started to construct the first cell. The first closed tunnel was recorded on the 29th of May and the last one the 1st of July. (Figure 4), which show the numbers of tunnels closed per day, demonstrate roughly the nesting activity of the population during the nesting period. The last flying female was observed on the 4th of July. During the 1 month nesting period, a total of 11714 cells were constructed in 1453 tunnels (table 3). Dead immatures were recorded in 1529 cells (10.72% immature mortality) and 53 (3.24%) empty cells were found. In a total of 10060 cells, cocoons were recorded. The population of life bees therefore increased by 221%, or tripled.
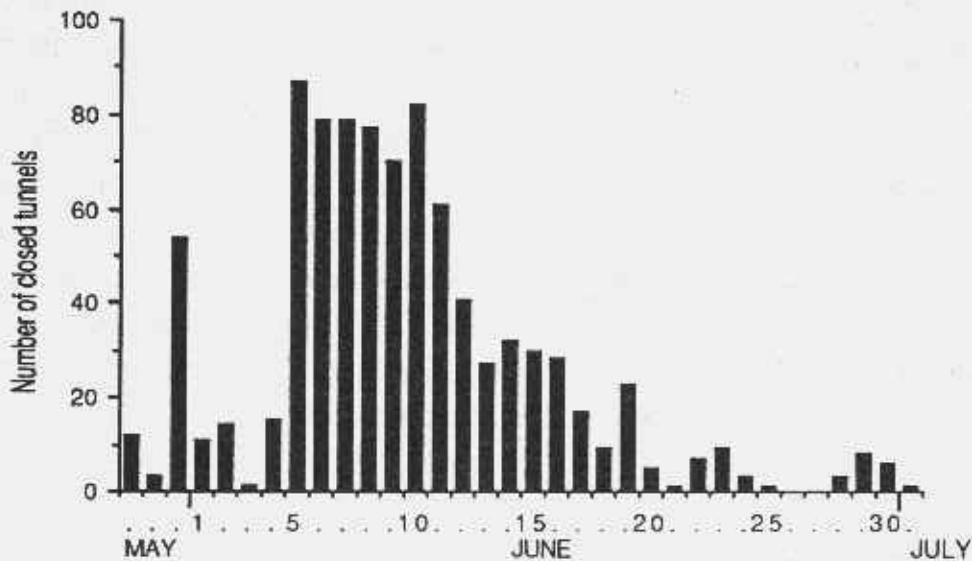
Figure 4. The nesting activity of *O. rufa* during the season, expressed as number of tunnels closed per day, in the orchard 1988.

Results obtained on number of occupied tunnels per material revealed a wide variation (see table 4). In the greenhouse in 1986 a total of 268 closed tunnels were recorded out of 273 occupied tunnels. A total of 270 occupied tunnels (98.9%) were recorded in boards made of pressed plant fibers and only 3 in wooden boards. In the orchard in 1987 only 39 closed tunnels were recorded out of 312 occupied tunnels, and a total of 303 occupied tunnels were recorded in boards made of pressed plant fibers and 9 in wooden boards. In 1988 in the orchard there was very little difference in number of occupied tunnels between the

five nest boxes. A total of 1355 tunnels (96.79% of available tunnels) were occupied in the sections with boards made of plant fibers, and only 98 tunnels (12.25% of available tunnels) were recorded occupied in sections with wooden boards. A total of 903 tunnels were closed, i.e., 62% of occupied tunnels.

YEAR	PLANT FIBERS (8 mm)			WOOD (8 mm)			WOOD (6 mm)		
	AVAIL. TUNN.	OCCUP TUNN.	CLOSED TUNN.	AVAIL. TUNN.	OCCUP TUNN.	CLOSED TUNN.	AVAIL. TUNN.	OCCUP TUNN.	CLOSED TUNN.
1986	840	270	265	240	0	0	240	3	3
1987	1960	303	33	560	2	2	560	7	4
1988	1400	1355	838	400	58	39	400	40	26

Table 4. Results on number of occupied tunnels and closed tunnels per material and diameter in greenhouse 1986 and in the orchard 1987 and 1988

In the greenhouse in 1986, the average number of constructed cells per closed tunnel was very low, on average 2.9. The lowest number in a single nest box was 1.2 cells per tunnel and highest 3.0 cells per tunnel. The average number of cells per closed tunnel in 1987 (only tunnels in plant fiber boards) was 6.8 cells per tunnel, ranging from 5.3 to 8.6 in a single nest box. In 270 open tunnels, a total of 750 constructed cells were recorded, thus the average number of cells in open tunnels were 2.8 cells per tunnel. In 1988 the average number of constructed cells per closed tunnel was 9.5, ranging from 9.1 to 9.9 in a single nest box. The average number of cells per open tunnel was 5.9. The largest number of cells recorded in a closed tunnel was 13 cells and the lowest 1 cell.

HIBERNATION AND EMERGENCE

The diurnal emergence of Danish and German (imported) O. rufa at three different incubation temperatures is shown in (figure 5 and figure 6). The Danish bees began to emerge on the 6th day of incubation at 30°C, on the 10th day at 23°C and on the 16th day at 15°C, respectively. Because the majority of emerged bees were males, the emergence pattern of females was not clarified.
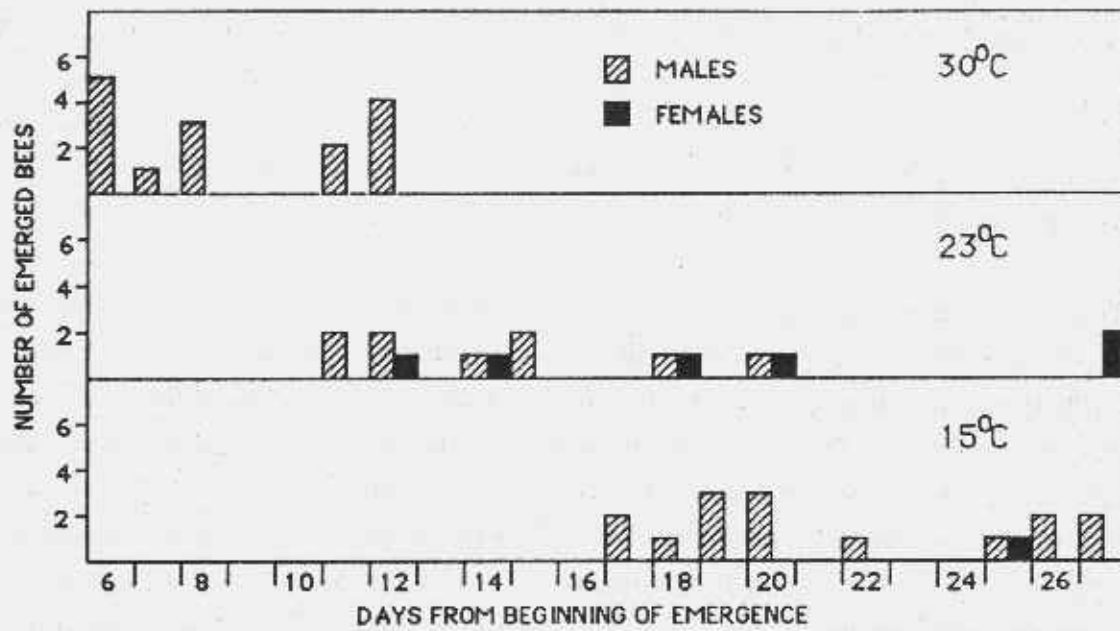
Figure 5. Daily emergence of Danish *O. rufa (O,rufa)* at three different temperatures, expressed as number of emerging bees per day (1987).
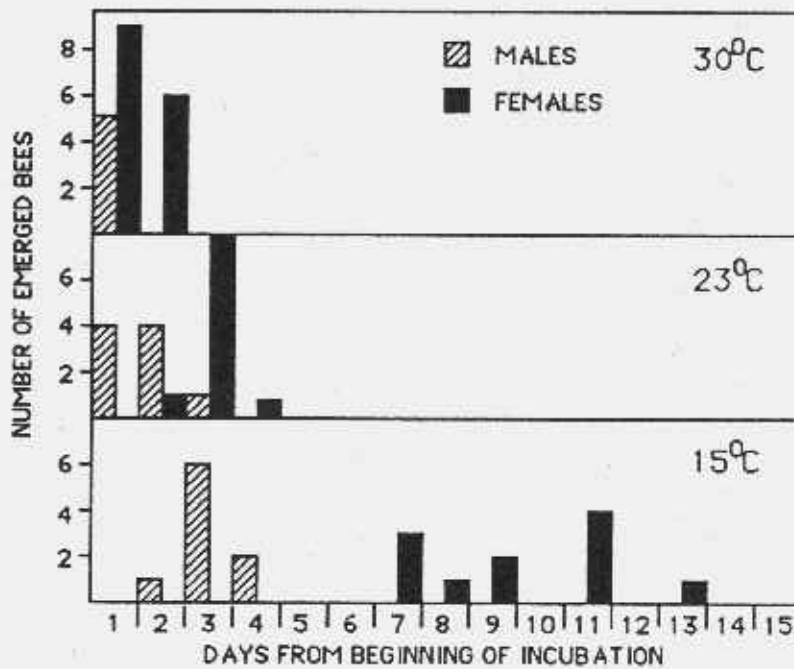
Figure 6. Daily emergence of German *O. rufa (O. r. cornigera)* at three different temperatures, expressed as number of emerging bees per day (1987).

The bees from Germany began to emerge on the first day of incubation at 30°C and 23°C, and on the 3rd day at 15°C. The higher the temperature was, the shorter was the total emerging period. Approximately 70% of the bees emerged on the first day of emergence at 30°C, but at 15°C same percentage of bees emerged over a period of 8 days. The bees originating from Germany emerged sooner and over a shorter period of time than those from Denmark.

The diurnal emergence of *O. rufa*, retained for different length of hibernation period at 4° and 6-8°C and incubated at 23°C, is shown in figure 7. The longer the hibernation period was, the greater was the rate of emergence. After a hibernating period of 155 days the first bees emerged on the 7th day of incubation, but after a period 234 days the bees started to emerge as soon as they were taken out from the cold store. Bees hibernating at 4°C emerged earlier than those hibernated at 6-8°C. At 4°C, some males had already emerged inside the refrigerator when the cocoons were taken out for incubation. After a period of 234 days one male had already emerged inside the refrigerator and four males after 283 days.
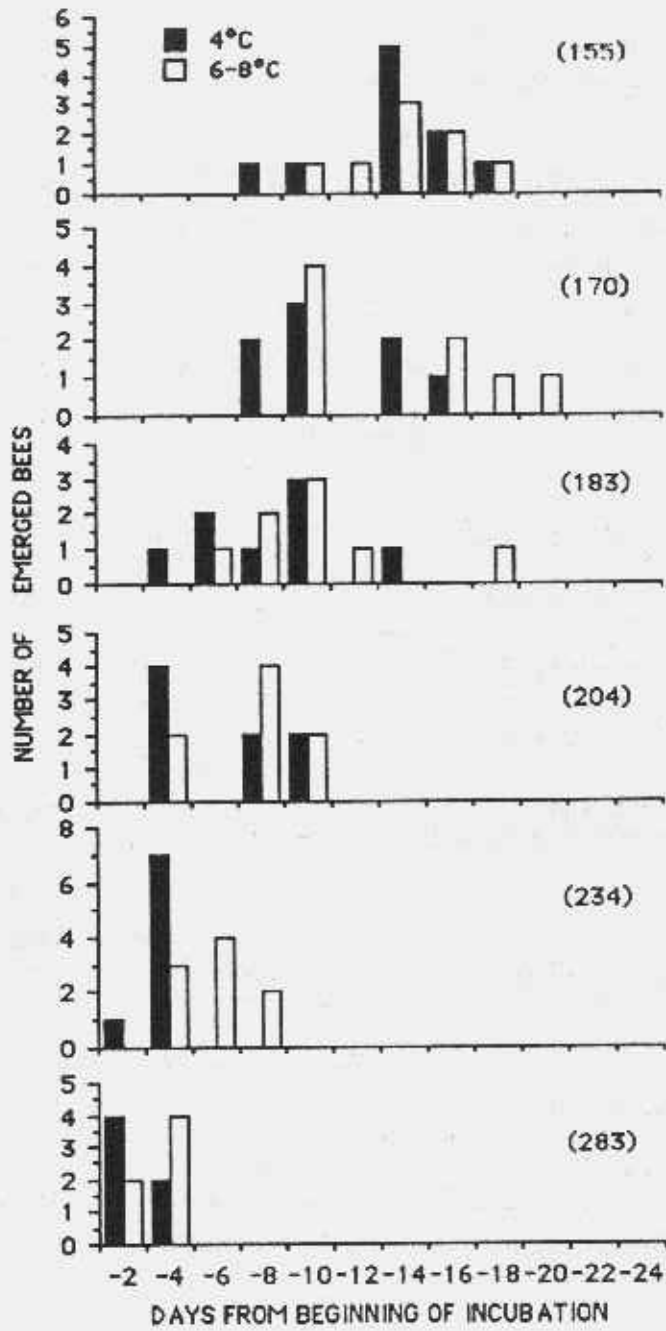
Figure 7. Daily emergence of *O. rufa* hibernated in 6 different length of periods and incubated at 23°C. Length of hibernation period in bracktes.

The sex-ratio and sex distribution

The sex-ratio is summerized for all four populations in table 5. In the two nest trap populations the sex-ratio (females:males) was nearly identical, 1:1.5 in 1985 and 1:1.4 in 1986. In the orchard the sex-ratio 1:2.2 was biased towards more number of males. The most unfavorable sex-ratio 1:8.7 was recorded in the greenhouse population. The sex-ratio in 6 mm tunnels was more biased towards male than in 8 mm tunnels, see table 6. A chi-square test revealed a significant difference between the two diameters (X^2=4.123, df=1, p=0.0423).

YEAR	POPULATION	NO. OF TUNNELS	NO. OF COCOONS	NO. OF FEMALES	NO. OF MALES	SEX RATIO
1985	Trap nests	81	522	208	314	1:1.5
1986	Trap nests	20	110	45	65	1:1.4
1986	Greenhouse	56	166	17	149	1:8.7
1987	Orchard	45	314	108	233	1:2.2

Table 5. The sex-ratio (females : males) of *O. rufa* in tunnels from nest traps 1985 and 1986, from greenhouse in 1986 and the orchard in 1987.

MM AND MATERIAL	NO. OF TUNNELS	NO. OF COCOONS	NO. OF FEMALES	NO. OF MALES	SEX RATIO
6 and wood	17	110	29	81	1:2.8
8 and wood	20	129	50	79	1:1.6
8 and Fibers	44	283	129	154	1:1.2

Table 6. The sex-ratio (females : males) of *O. rufa* in 6 and 8 mm tunnels from nest traps in Taastrup 1985.

The sex distribution in the tunnels is summerized in table 7 according to four types of distribution. In the Taastrup population and the orchard population the type c was clearly the most common one, i.e., most tunnels had females in innermost cells and males in the outer ones. Approximately 57.8-65.5% of tunnels were recorded of type c. As a contrast, only 33.9% of tunnels in the greenhouse nests had females in innermost cells or type c, and the number of tunnels with only male (type b) was extremely high (33.2%), see table 7.

YEAR	POPULATION	TYPE A	TYPE B	TYPE C	TYPE D	NO. OF TUNNELS
1985	Trap nests	3.7%	11.3%	67.5%	17.5%	81
1986	Trap nests	5.0%	15.0%	65.0%	15.0%	20
1986	Greenhouse	12.5%	33.2%	33.9%	20.4%	56
1987	Orchard	8.9%	15.5%	57.8%	17.8%	45

Table 7. Sex distribution of *O. rufa* in nesting tunnels according to four types of distribution. Type A = only female/females in tunnels, Type B = only male/males in tunnels, Type C = female/females in innermost cells, Type D = irregular siting.

MORTALITY

The mortality of immature stages is summerized in table 8.

YEAR	POPULATION	LARVAE	EGGS & LARVAE	CACOX. INDIGATOR	APHOMIA. SOCIELLA.	TOTAL
1984	TRAP NESTS	13.8%	20.3%	16.7%	-	50.8%
1985	TRAP NESTS	14.4%	15.6%	12.3%	0.7%	43.0%
1986	TRAP NESTS	27.8%	12.0%	14.9%	-	54.7%
1986	GREENHOUSE	5.5%	19.0%	-	-	24.5%
1987	ORCHARD	1.8%	23.6%	1.1%	-	26.5%
1988	ORCHARD	0.2%	9.5%	0.2%	1.1%	11.0%

Table 8. Immature mortality in *O. rufa* nests in 1984-1988, expressed as percentage number of dead immatures of total progeny produced. Larvae = dead larvae after defecation, and eggs and larvae = dead eggs and larvae before defecation. *Cacoxenus indigator* is a small sarcophagid fly of the family Drosophilidae. *Aphonia sociella* is the wax-moth of the gamily Pyralidae.

The highest mortality percentage was recorded in the nest traps in 1984 and 1986, i.e., 50.8% in 1984 and 54.7% in 1986. Both years the mortality of eggs and larvae were accordingly highest, i.e., 34.1% (13.8 + 20.3) in 1984 and 39.8% (27.8 + 12.0) in 1986. The lowest mortality percentage, 9.9%, was recorded in the orchard nests in 1988. Mortality due to infestation of the fly *Cacoxenus indigator* Loew was recorded in all years except in the greenhouse in 1986. In the nest traps the mortality due to infestation of *C. indigator* was relatively high, i.e., 16.7% in 1984, 12.3% in 1985 and 14.9% in 1986. Highest mortality percentage of eggs and young larvae (larvae before defecation) was recorded in the orchard 1987 and of older larvae (after defecation) in nest traps in 1986.

The mortality of hibernating bees is summerized in table 9, for the years 1985, 1986 and 1987.

YEAR	POPULATION	FULLY DEVEL - OPED BEES	PUPAE AND LARVAE	TOTAL
1985	TRAP NESTS	5.0%	1.3%	6.3%
1986	TRAP NESTS	5.6%	0.7%	6.3%
1987	ORCHARD	15.1%	1.8%	16.9%

Table 9. Mortality of hibernating bees, expressed as percentage number of dead bees of the total progeny produced each year.

SUMMARY AND CONCLUSIONS

The main purpose of present studies, was to investigate the possibilities of using the solitary bee *Osmia rufa* L. as a pollinator of cultivated crops in Denmark. In order to exploit these possibilities, following studies were carried out :

1) Nest trap experiments; - different types of nest boxes and different types of nesting material were tested to exploit the most favorable artificial nests for *O. rufa.*

2) Reproduction experiments; - were carried out, both in an orchard and in a greenhouse, to exploit the best way of reproducing populations of *O. rufa.*

3) Hibernation and emergence experiments; - were carried out to exploit the possibilities of controlling the hibernation and the emergence of *O. rufa.*

4) Investigations on the sex-ratio and sex distribution; - were carried out to exploit the factors involved in determining the sex-ratio in a population of *O. rufa.*

5) Investigations on mortality and parasites; - were carried out to exploit the immature mortality and mortality of hibernating bees and factors involved, and determine parasites and possibilities of controlling them.

Results obtained from nest trapping studies demonstrate that: (1) *O. rufa* can easily be traped in nature; (2) the species readily accept artificial nests; (3) the bees prefer to nest in horizontal tunnels; (4) the bees prefer to nest in tunnels constructed of grooved boards made of pressed plant fibers, when given the choice between plant fibers and wood; (5) tunnels of 8 mm in diameter are more frequently selected by the females than tunnels of 6 mm.

Results obtained from reproduction studies demonstrate that: (1) under favorable weather conditions and "correct" placement of nest boxes, it is possible to reproduce a population of *O. rufa* in the field; (2) protection of nest boxes against wind, rain and direct sunlight is important in order to gain high reproduction percentage; (3) *O. rufa* can be forced to visit different species of plants under greenhouse conditions, but under such conditions the population would not always reproduce it self;

Results obtained from hibernation and emergence studies demonstrate that: (1) the length of the hibernating period effects the emergence, i.e., the longer the hibernating period is, the sooner the bees will emerge; (2) the lower the hibernating temperature is, the sooner the bees will emerge; (3) the higher the incubation temperature is, the sooner the bees will emerge and the shorter is the emergence period; (4) the bees can be successfully hibernated in airtight plastic bags at a temperature of 4-8°C.

Results obtained from studies on the sex-ratio and sex distribution in the nest demonstrate that: (1) the sex-ratio in a population of *O. rufa* is close to 1:1, and is influenced by factors such as high immature mortality, small tunnel diameter, inclement weather, high temperature and flower dearth, which causes the ratio to be biased towards more males; (2) the females lay fertilized eggs primarily in the innermost cells in the tunnels, and unfertilized eggs in the outer one, which is the most common distribution of the sexes in the nest tunnels.

Results obtained from studies on the mortality and parasites demonstrate that: (1) under favorable weather conditions the immature mortality is low; (2) the mortality is probably also effected by the placement of nest boxes, i.e., when nest boxes are well protected against wind, rain and direct sunlight, the percentage of immature mortality is lower; (3) mortality of hibernating bees is low, when stored in airtight plastic bags; (4) Infestation due to diptereous and hymenopterous parasites can be serious, but is fairly easy to control when grooved boards are used as nesting material and cocoons are collected (harvested) prior to hibernation.

The results obtained from present studies (summerized above) suggest that *O. rufa* can be developed into an important pollinator of cultivated crops in Denmark, especially of orchard crops. Furthermore greenhouse experiments indicate that the species can be used as an effective pollinator of other plant species as well. The

species fulfill all demands required in order to use it as a commercial pollinator. It nests gregariously, it readily accepts artificial nest, it can be reproduced fairly easily in the field, control of hibernation and emergence is possible and of parasites as well, the bees are adapted to the Danish climate, i.e., they are active at a relatively low temperature and in cloudy weather, and the overall work with the bees - incubation, hibernation and control of parasites - is simple and not at all time demanding.

In order to solve some of the pollinating problems described earlier, and to increase the availability of pollinators, steps have to be taken, not only within the scientific world but, more importantly, within the political world. Within Europe important decisions have to be taken at both the scientific and political level if a potentially disastrous decline in horticultural and agricultural productivity is to be averted because of an insufficiency in the numbers of effective pollinators. On the basis of the results presented here, and through the establishment of co-operative international research programmes, it should be possible to establish *O. rufa* as one of the most important pollinators of cultivated crop plants in Europe, in the same way as *O. cornifrons* and *O. lignaria propinqua* have been established in Japan and USA.

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CONSIDERATIONS WHEN PICKING OUT A "NEW" COMMERCIAL BEE

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ABSTRACT

Commercial use a "new" pollinating insect might be started before proper knowledge of rearing technics and of impacts on the environments is achieved. The present rearing of bumblebees is viewed as an example of this. Only one bumblebee species is being reared and the rearing suffers from low efficiency, this influences the environment as well as the profitability of bumblebees use. From the bumblebee example points are extracet - which should be considered when "new" bees (semisocial, solitary) are picked out for rearing for pollination purposes.

Small scale domestication trials with solitary bees and bumblebees have been carried out for many years. In recent years a few "new" bees have been subject to large scale trials and bumblebees have been subject to commercial use for pollination.

The present bumblebee rearing suffers from very low efficiency which is compensated for by capturing great numbers of wild bumblebee queens - some of which are transported from the Southern Hemisphere to Europe.

Commercialization of a bee species may cause :

A. THREATS TO WILD POPULATION

1) Deprivation of individuals
- low breeding effiency (in lab.) demands continued capture of specimens
- mishandling of captured specimens demands capture of even more specimens

2) Changes in composition of gene pool
- increased by introduction of not-local genotypes (e.g. changes in adaption to duration of winter or to "flowering calendar".
- increased by selective capture ? (e.g. capture of early de-hibernating specimens)
- increased by restoration ? (of populations having been devastated by commercial exploitation or by environmental changes)

3) Introduction of new parasites and of new genotypes of parasites (e.g. Nosema)

B. THREATS TO OTHER SPECIES (ANIMALS/PLANTS)

1) Changes in selective pressure (e.g. increased competition for nesting sites may influence pollination of wild flowers)
2) Introduction of new (facultative) parasites (e.g. *Melittobia* attacking bumblebee brood as well as honeybee brood)
3) Introduction of new "attending" fauna/flora (e.g. the mite *Scutacarus acarorum* living in bumblebee nests feeding on *Histoplasma* (mould) that grows saprophytically in soil contaminated with faeces of rodents and grows parasitically in soil rodents, whose nests are frequently used as nesting sites by bumblebees that act as phorecy-hosts to *S. acarorum*; HISTOPLASMOSIS in humans may cause death)

GENERAL CONSIDERATION AND LINES OF ACTION WHEN PICKING OUT A "NEW" COMMERCIAL BEE

Is a suitable local bee present ?
May a rearing technique be adapted to this local bee/genotype ?

IF SO : Contact authorities for co-operation in
- evaluation of harm done to the population* (means to restore the harm*)

IF NOT : Before commercial rearing af a not-local bee is started
- contact authorities for co-operation in
- evaluation of harm done to donor population* (means to restore the harm*)
- evaluation of riscs to local species/genotypes when introducing* the new bee (means to minimize*)
- evaluation of riscs of introducing new pests* (means to minimize*)
- evaluation of riscs to others* than hymenopteras (incl. humans*)

* = regulation by law ? CITES ?

HOW TO MAKE A GOOD TOMATO POLLINATOR FROM A COMMON EARTH-BUMBLE BEE SOLVED AND UNSOLVED PROBLEMS IN BUMBLE BEE BIOLOGY IN RELATION TO THE USE OF BUMBLE BEES IN AGRICULTURE

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ABSTRACT
A description is given about the history and the solved and unsolved problems in bumble bee biology in relation to the use of bumble in agriculture.

HISTORY

In 1912 Sladen described the biology and domestication of the bumble bee. In connection with domestication there were initially three problems: colony initiation, mating and hibernation. He discovered that a queen that is caught in the field has to be stimulated before she begins to lay eggs. This stimulation can be performed by another queen or by young workers placed beside the queen. But the problems of mating and hibernation were not yet solved.

Later on, several researchers who investigated colony development in bumble bees developed rearing methods that allowed bumble bee culture to be continued throughout the year . Röseler discovered that CO_2 anaesthesia can be used to break the diapause of young queens; such queens initiate a colony without hibernation; queens that were not used immediately for colony initiation were overwintered in glass jars with moist paper in a refrigerator (Röseler, 1985). He had already been using these methods for several years prior to 1980. A more natural method for making queens hibernate, based on experiments done by Pouvreau (Pouvreau 1970), was described in 1985 (Duchateau, 1985) : the queens can dig themselves into peat dust in boxes which are later placed in the refrigerator at 6 °C. Mating was described in 1985 as well : if queens about 6 days old and males 4-20 days old are placed in a flightcage a high percentage of mated queens will be obtained. Mating was found to be more frequent in the morning than in the afternoon.

Although initiation, mating and hibernation were no longer problems in the 1980s commercial rearing for pollination still seemed impossible. Rearing of bumble bee colonies is labour-intensive and therefore too costly. As soon as De Jonghe showed (in 1987) that tomato plants in greenhouses could be succesfully pollinated by bumble bees, the cost of commercial rearing became reasonable compared to the cost of hand pollination of tomato flowers. In 1988 two companies started commercial bumble bee rearing and grew into big enterprises. They were followed by several other firms, each of which uses its own rearing methods. Thus several methods are used for breaking the 9-month diapause, for initiation and for hibernation. Unfortunately no data are available about the success of these combinations of methods. No comparative research has been published so far.

PROBLEMS OF COLONY QUALITY

The unpredictable output of the colonies is still a problem in commercial rearing. Bumble bee colonies vary tremendously with regard to the size of the worker population and the production of queens. Some of the reared colonies cannot be used for pollination because they contain such a small numbers of workers. Not all colonies produce queens and are therefore useless for queen rearing. The tomato grower requires colonies with a good pollination performance. In other words, it is very important that a more uniform type of colony could be produced. To achieve this, more knowledge is needed about the factors that regulate colony development.

PATTERN OF COLONY DEVELOPMENT

In colony development Bombus terrestris show a distinct pattern of egg laying by the queen : there are 3 separate broods, the first of which consists of a few eggcups laid in a couple of days and containing about 10 eggs in all (see also figure 1). From these eggs workers develop, developmental time being about 21 days. The second brood is started at the moment the larvae of the first brood pupate. This second brood, consisting of on average 35 workers, is laid in about 7 eggcups. The time needed for development. within the second brood varies between about 21 and 25 days. The third brood is the largest, and consists of a continuous series of eggcups. Each eggcup contains about 8 eggs. The number of eggcups produced

daily by the queen depends on the rearing conditions. The third brood ends abruptly about 30 days after the emergence of the first workers. This is due to the fact that some of the workers are preparing for their own reproduction. Not only do they construct eggcups for themselves, but they also destroy eggcups made and oviposited by the queen or other workers. We refer to the onset of this kind of worker behaviour as the competition point. Not many of the eggs laid after this moment develop into adults. In fact, the competition point is decisive with regard to the final colony size. We assume that the competition point occurs when the queen loses pheromonal control of the colony.
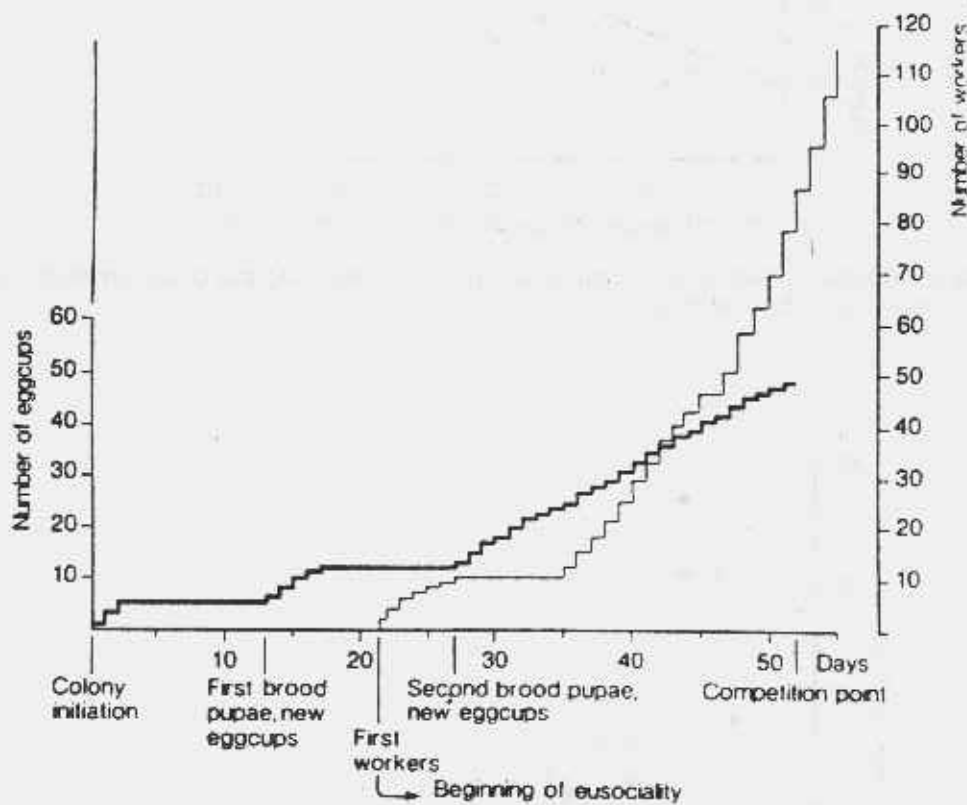
Figure 1. The average pattern of development of 21 *B. terrestris* colonies, as revealed by the cumulative number of eggcups produced per day by the queen and by the resulting number of emerged workers.

In the third brood the queen switches abruptly from the laying of fertilized eggs to the laying of haploid eggs, and consequently after 25 days almost only males will emerge. If the switch takes place early in the third phase, the worker population will remain rather small, and many males will be produced. It may also occur late in

the third phase, near the competition point. In that case, there will be a large worker population and only a small number of males will be produced.

There is a strong correlation between the moment the competition point is reached and the moment the rearing of queens is initiated (r=0.805, n=32, p<<0.01) figure
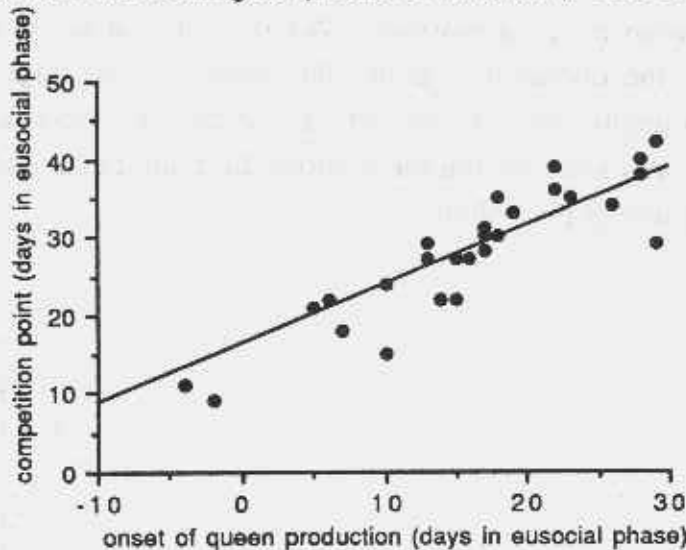
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Figure 2. Relation between the onset of queen production and the occurrence of the competition point (colonies of 1989 and 1990).
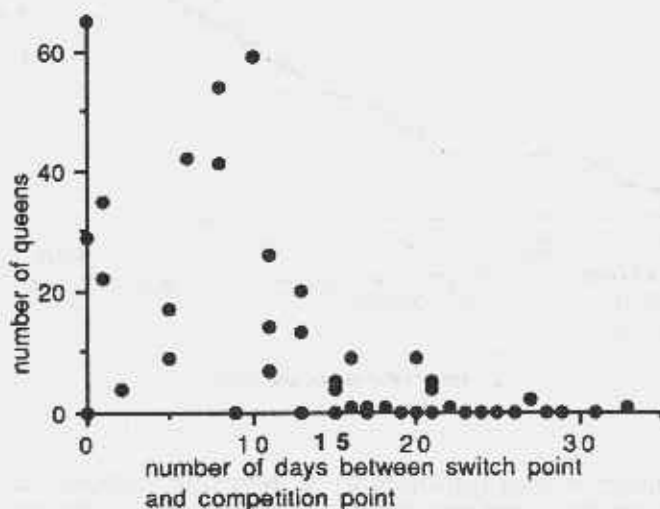

Figure 3. Relation between the time-interval separating the switch point from the competition point and the number of queens produced (colonies of 1989 and 1990).

This correlation is an argument for assuming the existence of pheromonal control. It has been established earlier (van Honk et al.1980) that egg laying by workers is pheromonally inhibited by the queen. It is possible, therefore, that the same pheromone source is responsible for regulating both aspects.

However, queens can only be reared if diploid eggs are present at the moment of the pheromonal change. If the period of time between the switch point and the competition point is not longer than 15 days (figure 3) colonies can produce queens. If this period of time is longer, almost no queens are reared. The few queens that are produced in these colonies derive from diploid eggs that happen to have been laid after the switch point. It is therefore concluded that the moment at which the switch point and the competition point occur is the main factor that determines the number of workers, males and queens are produced (cf. Duchateau and Velthuis 1988).

STANDARDIZATION

The large variability in bumble bee colony composition needs to be reduced if the colony is to provide a good pollination service. To pollinate tomatoes one needs a large worker population from a colony that forages for a large number of larvae. On the basis of information about colony development it might be possible to obtain a large worker population :
1. increasing the egg laying rate of the queen, especially in the third brood;
2. delaying the switch point;
3. postponing the competition point.

ad 1. In the third brood our free-flying colonies produced on average 2 eggcups per day and colonies in confinement produced 1 eggcup per day. The main difference between free-flying colonies and colonies in confinement (but connected to flight cages) was the food factor. The free-flying colonies collected their own pollen in the field. The colonies in confinement had continuous access to pollen. This pollen was collected by the honeybees and was stored, for a time, possibly after some initial drying, in the freezer. So food quality, in the sense of pollen originating from a different spectrum of flowers visited by honeybees and bumblebees, and in the sense of quality loss through storage could have influenced the egg laying rate of the queen. We therefore carried out some studies on this quality aspect.

ad 2 and 3. Contrary to what is suggested in the literature the switch point and the competition point are not correlated. This means that different factors are involved or that factors have different influences. If we knew what determines the occurrence of the switch point and the competition point, then it would perhaps be possible to

manipulate the colonies in such way that worker or male production reaches the required level. The variability we observed could be due to the genetic difference in queens, environmental factors, or a combination of genes and environment. Is the early production of males (and the abandonment of queen production) a result of stress? or is it a different reproductive strategy determined mainly by the genetic background of the queen?

Social stress factors like the number of workers, agonistic behaviour (Duchateau, 1989) and ovarian development of the workers (Duchateau and Velthuis, 1989) were not found to be correlated with the queen's switch and with the occurrence of the competition point.

A stress factor that could be important is the occasional emergence of males even in the first brood. This occurs if CO_2 is used as an anaesthetic to breake the diapause. Apparently the queen's control over the fertilization of the eggs is affected. In inbred colonies too males emerge from the first brood onwards. Such males are diploid and are not the result of queen's lack of control over fertilization. The fact that early males are produced at the expense of the worker force, might reduce the amount of help the queen receives in rearing the following broods. As indicated already, food (quality, quantity and the frequency of feeding larvae) can also operate as a stress factor.

Factors operating in the solitary phase of the queen like the conditions during natural hibernation and the duration of the solitary phase after queens were collected in the field were slightly correlated with the moment of the switch point. I n addition to such environmental aspects a genetic factor may be involved. The repeated occurrence of early and late switching queens under the same rearing conditions points to a genetic factor.

QUEEN REARING

For the continuation of commercial rearing, without burdening nature, queen-producing colonies are required. It may be possible to obtain queen producing colonies by postponing the switch point in relation to the competition point. However, it is not sufficient to have adequate numbers of queens, they must also be of good quality. We have observed important differences between groups of queens, descending from a separate queen (or colony) : they may differ in the

success of initiating a new colony (the average is about 50%), in the acceptance of males for mating (about 80%) and in hibernation (about 70%). We are of the opinion that improvement of the quality of the queens has to do with environmental aspects, food being an important factor. When colonies were fed with a pollen mixture of reduced quality, especially the young queens were affected; they emerged with a lower body weight (M. Ribeiro, unpublished). There are still many questions to be answered before standardized colonies and queens of good quality can be obtained. Further fundamental research should help to solve a number of problems.

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NEW REGIONAL STRUCTURES TO IMPROVE POLLINATION SERVICES USING HONEY BEES AND OTHER SPECIES IN FRANCE

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France

ABSTRACT

Pollination of entomophilous crops in France has traditionally been managed with honey bees, *Apis mellifera* L., provided by individual beekeepers. The production of honey or other bee products remained the prime activity while crop pollination consisted mainly of moving beehives around as a side business to improve cash flow. Colonies were delivered with little regard to the crop to pollinate and growers were often not fully satisfied. In the midst of intense competition due the fall of honey prices, ten commercial beekeepers heavily involved in commercial pollination started the GRAPP (Groupement des Apiculteurs Pollinisateurs Professionnels) Midi-Pyrénées in the fall of 1990. The bylaws of this original non-profit association set strict guidelines for the pollination service of its members. One of its goals is to improve the quality of pollination service by (1) enhancing the technical knowledge and skills of its members to be able to provide services tailored to the pollination needs of each crop, (2) monitoring the foraging activity of the colonies and evaluating the pollination results with the clients to promote dialog, and (3) improving efficiency using modern technology such as electronic network (Minitel™). This first GRAPP has now grown to 14 members covering a large region and it has over 4 500 honey-bee colonies available for service and the use of another insect species as pollinators was started this year. Another regional GRAPP was created in 1992 in Provence-Alpes-Côte d'Azur and the emergence of a national structure is foreseen. In this report, the development and current functioning of the first GRAPP are examined along with possible consequences for crop pollination services.

INTRODUCTION

Across most of Europe, the native pollinator guild must often be augmented or supplemented in order to reach the pollination intensity — the number of pollen grains per stigma — needed to produce satisfactory yields of fruit, nuts or seeds of good quality (Corbet et al. 1991). Yet, few growers realize just how important adequate pollination is to achieve their production goal in quantity and quality, and even fewer are aware that pollination by insects can be managed just like irrigation or fertilization. Though honey bees are still better known for their honey than for their pollinating activity, *Apis mellifera* L. remains a key species. Indeed, until very

recently it was the only one used to provide reliable and effective pollination for most crops because their managed colonies reach large size and can be moved readily by beekeepers wherever and whenever needed (Free 1970; Mc Gregor 1976; Robinson et al. 1989). This use of honey bees, and more recently of bumble bees, *Bombus terrestris* L., does not reflect a lack of importance of other species in the pollinator guild. Indeed, the pollinating efficiency of some wild bees on some plant species can greatly exceed that of single *Apis* foragers on an individual basis (Westerkamp 1991). But, due to natural population fluctuations and modern agricultural practices, populations of native bees are usually too low, too unpredictable or simply not available to reliably pollinate the surfaces of entomophilous monocultures grown in the open or in enclosures throughout Europe. The temporary importation of honey-bee colonies for the purpose of pollinating a crop should not be seen as necessarily conflicting with the use and survival of the wild bee fauna as they can be quite complementary (Berger et al. 1986; Vaissiere 1991a). Honey bees are native from the Old World and their limited impact on native apoid species may be associated with their polylecty and centralized, information-based foraging strategy (Seeley 1985).

The pollination effectiveness of a honey-bee colony has both a social component, namely the size of its foraging population, and an individual component, that is the pollination efficiency associated with the foraging behavior of individual bees. Factors such as colony size (Waller et al. 1985), presence of the queen and age-structure of the population (Free 1967), and management practice (Goodwin & Houten 1991; Moriya 1966) can affect the size of the population foraging on a target crop. On the other hand, the level of competition experienced by foragers and the type of resource they forage (nectar, pollen, or both) can alter dramatically the foraging area and pollination effectiveness of individual bees (Weaver 1957; Robinson 1979; Vaissiere 1991b). Finally, because of the social foraging strategy, the population of workers foraging on a target crop and issued from colonies left nearby all year around is often much less than that from colonies imported purposefully at the onset of flowering of the target crop (Gary 1979).

Management usually done by the beekeeper will determine the intrinsic characteristics of the colonies used for pollination. On the grower's side, it is a prerequisite that viable and compatible pollen must be available in abundance for the bees to be able to transfer it onto stigmas. The farmer will also have to provide a safe environment for the insects to forage such as managing crop pests without harming the bees. Besides these responsibilities, the farmer and beekeeper are

left with mainly three basic tools at their disposal to achieve the effective pollination of the target crop: (1) the schedule of colony delivery and removal, (2) the spatial distribution of the colonies, and (3) the stocking rate, that is the number of imported colonies per unit area of target crop to pollinate.

It is therefore clear that pollination management using honey bees implies far more than the mere renting and moving of bee boxes around fields. Good colonies are not enough nor is an abundant supply of viable and compatible pollen enough to insure the satisfactory pollination of every crop every year. Clearly the pollination of crops with honey bees involves two partners and both beekeepers and growers must be well aware of the constraints, limits, and goals of the pollination service. Though it is often overlooked, the establishment of a good working relationship between the beekeeper and the grower is therefore critical if the best technical and economic decisions are to be made.

1. THE EMERGENCE OF GRAPP

Pollination services of entomophilous crops in France has traditionally been done by individualistic beekeepers who rented their colonies for a fee or in exchange for bee yards. For growers, dealing with a single beekeeper is risky since the flowering of many crops lasts only a few days and precise timing of colony delivery is critical for adequate pollination and seed set. Individual beekeepers are also limited by the size of their operation as to the number of colonies they can provide, and farmers or associations with large surface of entomophilous crops may have to contract with several beekeepers. It is also very hard for individual beekeepers, even if they are interested in pollination, to keep abreast of the new development and research findings in pollination techniques as well as the pollination requirements of all entomophilous crops in their surroundings, especially in a rapidly changing agricultural environment. Individual beekeepers often have little visibility in the farming community and it is noteworthy that, while considerable progress had been made in most crop production practices in recent years, insect pollination using honey bees remains an area where amazingly little has happened at the producer's level.

Despite these problems, there was often little cooperation or even coordination among the beekeepers renting colonies for pollination to define a pollination service. Indeed, the production of honey or other bee products remained the prime activity while commercial pollination was usually regarded as a side business. In

this context, it is symptomatic that the beekeeper association which claims to represent most of the commercial beekeepers calls itself the Syndicat des Producteurs de Miel Français ("French Honey Producers Association") with no mention at all of pollination. As a result of this lack of steady interest, the colonies rented to growers varied considerably among beekeepers and from season to season, depending upon the expected nectar flow and the price of honey. Colonies were usually managed with little regard to the crop to pollinate and there was little, if any, monitoring of the foraging activity at hive entrance or in the target crop once the colonies were delivered.

This lack of coordination and serious interest in pollination from most commercial beekeepers involved in pollination service was not favorable for the establishment of a solid working relationship between beekeepers and growers. In this context, colonies were rented and stocking rate established based solely on the price per hive, with little regard to the colony inside or advance notice to the beekeeper. Beekeepers often complained that the rental fees were too low to justify any special effort and that farmers did not seem very appreciative of the importance of the pollination service rendered by their colonies. At the same time, growers were often not fully satisfied of the pollination service and concerned farmers could not find beekeepers with whom they could share their practical experience and interest in the pollination of their crops to develop a reliable working relationship.

The stake at hand for the grower is often considerably higher than it is for the beekeeper, and growers do not always succeed in making beekeepers understand that he would be ready to pay a higher price if only he could be sure that he would get the pollination service he is counting on. This is especially true for crops with a high market value such as fruits grown in greenhouses and horticultural seeds. While farmers had little alternatives when beekeepers were alone on the pollination market, the advent of bumble bee colonies available commercially year around in southern France since 1989 changed this situation radically.

Bumble-bee companies started to provide their colonies for the small but lucrative market of greenhouse-grown tomatoes. These companies used a dynamic commercial strategy, developed sleek brochures for the growers and their pollination service included a continuous monitoring with the replacement of the defective colonies and a follow-up of the foraging activity throughout the contract period. The fee structure was established per month and per unit area of crop to pollinate rather than per colony of insects. The rates were much higher than

anything beekeepers had ever charged (8 000.00 FF per ha and per month in the winter of 1989-1990), but the flowering of the tomato crop was followed and the stocking rate (colony/ha) adjusted accordingly to maintain an adequate density of pollinators. Thus, despite high prices which also went down with increased competition, the use of bumble bees rapidly spread and *B. terrestris* now pollinate most tomatoes grown commercially in greenhouses in France.

In the winter of 1990, with the price of honey falling, a number of beekeeping operations found themselves short of cash and considered renting colonies for pollination to alleviate their financial problems. Since the pollination service was so undefined, the quality of service, not solely the price per hive, could not be effectively used in commercial discussions with growers. The "département" of Tarn & Garonne (Fig. 1) has large areas planted in orchards and melons, and beekeepers from sometimes far away came to offer their colonies at cut-away prices to a level where local commercial beekeepers heavily involved in pollination would not have survived. It was also clear that these price-cutting practices only further degraded the image of pollination as a serious and manageable production factor in the eyes of growers.

At the same time, a survey started by the veterinary services of Tarn & Garonne to monitor the movement of colonies and coordinate the purchase of fluvalinate to treat all recorded colonies for *Varroa* also played a catalyst role. In this context, 10 commercial beekeepers mainly in Tarn & Garonne (Fig. 1) got together in the fall of 1990 to address the demand of the veterinary services, better coordinate their pollination activities for the next season and try to find solutions to fight the competition. These beekeepers all knew each other fairly well and they were all individually involved in commercial pollination to a large extent and brought colonies in a well defined geographical area. After a few meetings which took place in the span of two months, they decided to take action and organized into a Groupement des Apiculteurs Pollinisateurs Professionnels — GRAPP — Midi-Pyrénées in November of 1990. This original non-profit organization was legally born in January 1991. GRAPP members coordinated their efforts with those of the veterinary services for their survey and they also petitioned for and received a small grant of 40 000 FF from the Conseil Général du Tarn & Garonne to develop their association and improve pollination service among fruit growers and seed producers.

2. THE GRAPP AND HOW IT WORKS.

GRAPP is first a 'groupement', that is an association. As such, its founding members established a set of bylaws providing strict guidelines for the pollination services and each new member has to agree in writing to comply with these bylaws. For example, the maximum time span for delivery and removal of colonies after the notification of a client is 48 hours, and the client is assured that the service will be provided by the GRAPP even if the contracting beekeeper is personally unable to deliver it. This guarantee extends to the sanitary condition and minimum colony size of the stock delivered. At its start, the 10 members of the GRAPP Midi - Pyrénées were operating a total of 4 000 colonies managed for pollination and a large park of vehicles of all types to move colonies rapidly and deliver them across most fields (Appendix 1). During 1991, 2 000 colonies were used for pollination service.

Secondly, the first P in "GRAPP" implies that its members are 'pollinisateurs', that is involved in commercial pollination. While there is no minimum figure for the number of colonies actually used in pollinating crops, all GRAPP members must share a strong interest in pollination and a demonstrated will to improve their knowledge and skills in this area. In practice, members use from 50% to nearly all of their colonies in pollination service. GRAPP members do not foresee their activities with honey bees only, however, and contacts were made in 1991 with bumble-bee companies to distribute colonies of *Bombus terrestris* and thus be able to offer a choice of pollinators adapted to a wider array of crops and growing conditions.

Finally, GRAPP is an association of 'professionnels" meaning only full-time commercial beekeepers can belong. This policy was adopted because GRAPP members insist on their professional image and they feel that part-time keepers of honey bees will always have a different outlook on the beekeeping business than full-time beekeepers. Also, the pollination business requires lots of moving of hives and other heavy equipment at night and in poor weather conditions very often, and members feel that they cannot afford partners who would not be 100% reliable. There is no required minimum number of colonies for membership, but in practice a full-time beekeeper cannot survive economically with less than 300 colonies. New potential members must be introduced by 2 members and the final decision of membership is dependent upon approval of the governing board which has 5

members (the president, two vice-presidents, the treasurer and the secretary). The decision of the governing board is final and it does not have to justify its decision.

GRAPP Midi-Pyrénées uses marketing approaches which could be hardly possible for an individual beekeeper. For example, for the New Year in 1992, a mailing was sent throughout the region to all potential clients. This mailing consisted of a folded card which on one side presented the GRAPP, its activities and its goals, while the other side consisted of a coupon which could be torn off and mailed to GRAPP to receive a free evaluation of the pollination need and current practice of the farming operation. The return from this mailing was good and many new potential customers were contacted in the process. An example of an earlier brochure used in 1991 is given in Appendix 1. The GRAPP also set up an electronic bulletin board using the Minitel™ network whereby growers can order directly colonies as well as ask various questions regarding the pollination of their crop. GRAPP has a booth at several agricultural fairs as well as at the international show on fruit and vegetable in Agen (SIFEL : on April 5 - 7). GRAPP members also organize regularly several visits with the technical advisers of several grower associations and co-operatives, and they give interviews to several journalists. As a result, several articles were published in farming as well as local newspapers to explain the creation of GRAPP, its status and its goals. New customers contacted by Minitel™, mailings, or otherwise are dispatched to the members by the secretary based solely on their geographical location : the nearest member gets first choice to provide the pollination service. For Minitel™ orders, the client is always recontacted within 24 h by the secretary of the association with the address of the nearest GRAPP member that he should contact. If this member cannot fulfill the order, he can pass it on to another member he chooses.

Each member joins GRAPP with its own customer base and these customers remain his property for as long as the beekeeper so desires and regardless of the geographic location of these clients. Unless he decides otherwise, the fees from these personal customers are not assessed to support the activities of the association or research on pollination. As a non-profit structure, GRAPP does not do any direct billing. All members use a standard contract and billing form with a flier identifying them individually and a copy of each of these is sent to the office of the GRAPP. Interestingly, each bill has an area at the bottom where customers can write their evaluation of the pollination service and make suggestions on how to improve it. Based on the bills, a fee is voluntarily assessed to support the activities of the association (5,00 FF/colony in 1991 and 6,00F/colony in 1992) and to support

research on entomophilous pollination (1,00 FF/colony in 1991 and 1992). The funds of the association are used to employ a part-time secretary and to pay for various technical and public relation materials. For example, in 1991, the GRAPP Midi-Pyrénées edited several technical sheets on the pollination of entomophilous crops important in their area. These sheets were compiled from the literature and they were aimed at GRAPP members as well as clients.

The fee structure is decided by majority vote at a meeting of the general assembly (all GRAPP members). The general assembly meets 4 or 5 times a year, usually between October and the end of March, while the board meets independently about 10 times a year. There is a base fee for a standard service to which extras such as feeding or placing pollen traps can be added at extra cost (Table 1). This fee structure was designed to generate questions among the growers as to the precise meaning of the various options and the relative advantage of their use. GRAPP members also acknowledge that the current rates are not very profitable, but they believe that it is a necessary step until the level of awareness of the growers regarding pollination has been raised.

3. FROM THE REGIONAL TO THE NATIONAL LEVEL

During 1991, the name GRAPP, its bylaws and its logo (Appendix 1) were registered by the GRAPP Midi-Pyrénées with INPI (Institut National de la Propriété Industrielle) so that other similar associations will have to endorse the bylaws if they want to use the name or logo. The bylaws specify in particular that there shall be only one GRAPP per administrative region (there are 22 such regions in France). GRAPP members must agree to the definition of a pollination service adapted for each crop which includes compliance with (1) minimum standards of quality, (2) monitoring of foraging activity and pollination after colony delivery, and (3) use of a base fee per hive to which specific fees can be added for particular extras (Table 1). These rules shall apply regardless of the species of pollinating insects distributed by GRAPP members. Any GRAPP can support any research it deems appropriate and in collaboration with any institution , but the results must be shared with other GRAPPs. Apart from this and other important rules described in the previous section, every GRAPP can decide freely upon its precise organization and set of internal rules. For global coherence and also to protect the work of each association, only the use of GRAPP documentation is allowed for advertising purposes. Finally, every association which signs the current set of bylaws must thereby agree to take part as early as 1992 in a national body of GRAPPs, the

purpose of which will be to harmonize the language, service and rates used for the pollination service.

Table 1. Rental fee structure used by the GRAPP Midi-Pyrénées.

TYPE OF POLLINATION SERVICE	CROP	NUMBER OF COLONIES IN CONTRACT		
		12 to 48	49 to 100	over 100
		1992 rental rates (French Francs/colony)		
Delivery within 48 hours of strong colonies with sanitary certificate and monitoring of foraging activity (**BASE SERVICE**)	Apple pear plum	130	120	115
	Melon	150/month	140/month	125/month
	Sunflower (seed production)	150	140	125
Base service + feeding	Kiwifruit	150	140	125

OPTIONS :

Pollen trap	+ 25% of the base rate
Feeding with a full feeder of syrup following hive delivery	+ 25% of the base rate
"Flash-pollination" (for apple trees in particular, where colonies are removed within 24 hours following the request by the client)	+ 30% of the base rate

The previously described situation of the pollination service in France and the associated problems are not very different from those found in other parts of the world with similar agriculture and climate. Yet, the creation and development of a GRAPP appears to be fairly original solution. In California, for example, the link between beekeepers and growers is often provided by private pollination consultants such as Pollen Bank™ in Bakersfield and there is no specific association of beekeepers involved in commercial pollination. In the Pacific Northwest, there are currently no pollination consultants, but the idea of a middlemen had some appeal and was seriously considered in 1991 by large vegetable seed processing companies though the beekeepers opposed it. About 3 years ago, 3 beekeepers in central Washington State tried to set up an Association of Beekeepers for Commercial Pollination, but they failed to generate much interest among the rest of the beekeepers. However, the Washington State Department of Agriculture has a program where individual farmers or orchardists can ask for the

Figure 1. Geographical distribution of the GRAPPs (Groupement des Apiculteurs Pollinisateurs Professionnels) in France as of March 1, 1992.

CONCLUSIONS & PERSPECTIVES

As long as honey bees will be used to pollinate crops in enclosures or in the open, the availability of the pollination service will likely rest on beekeepers who can manage their colonies accordingly and move them whenever and wherever needed. This is even more so with the spread of *Varroa jacobsoni* across continental Europe since this parasite has wiped out feral populations of honey bees as well as other untreated colonies. The ability to provide this pollination service should be regarded as a great opportunity for commercial beekeepers to interact with growers and become fully integrated with the rest of the farming community. Yet, to this date, pollination service is often the cause of a latent misunderstanding between farmers and beekeepers. The establishment of a good working relationship between the user and the provider of bee colonies should nearly be a prerequisite in any pollination strategy using honey bees. For this working relationship to take place, it is essential that the pollination service be clearly defined and understood by both parties so that it could then be evaluated objectively and rewarded accordingly. Past experience shows that this is unlikely to be achieved by individual beekeepers alone. The gathering of commercial beekeepers involved in pollination into regional GRAPP structures constitutes an original approach to improve the situation. The increased exposure and visibility enables the GRAPP to provide orchard growers as well as fruit and seed producers with a basic working knowledge of the pollination process so that they can better

appreciate and properly plan for an adequate pollination service rather than try to pollinate an expensive crop with empty wood boxes (beehives) in an attempt to save money. GRAPP also provides a forum for its members to harmonize their management practices and clearly define the pollination service. For the farmers who contract a pollination service through GRAPP, it provides a guaranty that a well-defined service will be delivered and that properly managed and disease-free colonies will be delivered on time.

It is noteworthy that companies which offer pollination service using bumble bee colonies charge by the unit area for tomatoes under greenhouses, but per colony for crops grown in the open. Charging by per-unit-area has the distinct advantage of focusing on what the pollination service is really about rather than on the stocking rate which is only a means to achieve pollination. This is an important step because the relationship between forager density (bees/100 flowers) and pollination intensity can be measured with a good level of accuracy in any given pollination system, while the relationship between forager density and stocking rate can fluctuate considerably with the distribution and abundance of floral resources in the 4-5 km radius surrounding the target crop. Perhaps, as they gain experience in monitoring colony activity and forager density (bees/100 flowers), beekeepers who deal with greenhouse crops will also start charging pollination service per unit area. As long as the price of the pollination service is established on a colony basis and therefore set with the stocking rate, a practical solution will be needed to guard against large fluctuations in the environment. "Saturating" the target area with imported pollinators is the only practical solution currently available, but it is costly for both farmers and beekeepers. Also, farmers may not understand very well why a neighbor got a good crop one year using one colony per ha while the beekeeper is recommending the use of 5 colonies per ha for the same pollination service. Finally, the saturation approach totally ignores the native pollinator guild and may backfire in cases where an over-pollination can be detrimental as with apple or peaches where chemicals are then needed to increase natural fruit drop. An alternative strategy would be to monitor the pollinator density and flowering phenology of the target crop and import honey-bee colonies accordingly based on the relationship between pollinator density and pollination intensity. Such a scenario is foreseeable because structures such as GRAPPs also provide a forum for the fruitful exchange between pollination scientists, beekeepers, and growers. Research priorities can be defined and new developments to improve the use and pollination efficiency of bee colonies can be readily presented, tested on a commercial scale, and evaluated and discussed based on scientific data rather than empirical observation.

In conclusion, with adequate support, structures such as GRAPPs have the potential to significantly improve crop pollination in the European Community and to implement real pollination management as an important part of integrated production strategies more respectful of the environment.

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HISTORICAL REVIEW, PRESENT SITUATION AND NEAR FUTURE PROJECTS ABOUT THE USE OF POLLINATING INSECTS IN SPAIN

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ABSTRACT

A brief historical review about research on pollinating insects in Spain is given. In addition, the author presents the results obtained in southern Spain in recent years as well as the forecasts for next few years. A proposal of cooperation in order to study the imports of foreign bumblebees, their adaptation and their possible effects on the native fauna is made.

INTRODUCTION

Due to its condition as a Mediterranean country and point of contact between Central European and African faunas, Spain has one of the richer insect communities in Europe. If we focus on pollinating insects, more concretely on bees, two factors cause a very high diversity in our fauna : the climate, basically Mediterranean, and the large variety of ecosystems (MICHENER, 1979).

Unfortunately that situation has not always been accompanied by extensive studies about any aspect related to Apoidea, but mainly as pollen vectors. Moreover, attempts to coordinate research into this matter have been usually lacking.

Now we want to give an overview of the investigations throughout the present century. For that purpose we first will summarize what has been published about bees until the sixties (basically taxonomic and faunistic topics); the second part will deal with the research on bees and pollination from the seventies until the nineties; the third part will detail the investigations in southeastern Spain; and finally, current programmes as well as projects for near future will be exposed.

TAXONOMIC AND SYSTEMATIC RESEARCH

Mr José Maria Dusmet was the first author who devoted a lot of time to the studies on Spanish Apoida. He published a lot of articles about some himenopterous groups in the first half of this century. His main contribution to the knowledge of Spanish bees was carried out between 1905 and 1935 (DUSMET, 1905, 1906a,1906b,1908,1913,1915,1921a,1921b,1923,1926,1935). These papers focused on taxonomy, but they also gave some information about nesting habits, flowers visited and phenology.

Additional data by Spanish authors appeared dispersely until the fifties and sixties. At that time CEBALLOS (1956,1959,1964) made a catalogue wich compiled records of around 1,200 bee species in Spain.

New important contributions by Spanish authors were not made until the eighties. A new impulse has been undergone since then, and several specialists are giving numerous records of distribution in Spain (see for example CASTRO,1989; ESPESO & GAYUBO, 1988; ORNOSA, 1984; ORTIZ & JIMENEZ, 1991; PEREZ-INIGO, 1980). So even though an update of Ceballos catalogue has not been undertaken, there are some regional studies and taxonomic revisions. For instance, our own estimations place the number of bee species in the province of Almeria (southeastern Spain) at 300.

RESEARCH ON INSECT POLLINATION

A few works on pollinating insects in Spain before the sixties were published (see for example ARCHIMOWITSCH, 1952, about sugar beet).

More significant research started in 1967, when Dr ASENSIO began his survey in the region of Castilla-Leon (ASENSIO & RODRIGUEZ, 1980). There Dr Asensio's team dealt with several programmes related to the adaptation of different bee species for the pollination of lucerne and fruit trees (ASENSIO, 1978; ASENSIO & RODRIGUEZ, 1980). In the last case the experiments were also carried out in other Spanish regions as Murcia and Andalusia (ASENSIO, 1984). Moreover, populations of the bee *Osmia Cornuta* (Latr.) collected in those regions were succesfully introduced in the U.S. in order to study the pollination of almond and

apple orchards in the conditions of that country (TORCHIO & ASENSIO, 1985; TORCHIO et al., 1987). Dr Lacasa extended this work in Murcia, where it continues nowadays.

The efforts devoted to research on insect pollination in Spain were greatly increased in the middle of the past decade. At that time, several research teams began to work in different parts of Spain :

- Dr Gayubo, under the management of Dr Asensio, began some projects on the biology of the pollinating bee fauna in the University of Salamanca (Gayubo et al., 1987).

- The University of Barcelona focused its research on Mediterranean flora. A a team of botanists and entomologists studied the pollination biology of a rosemary shrub (*Rosmarinus officinalis* L.) (BOSCH, 1986). Those studies have been continued by others about the nesting biology and multiplication of *Osmia* Pz. bees as well as their effect on fruit tree production.

- Another team is working in Sevilla, in the Donana Biological Station. This team is led by Drs. Herrera, and their work is being carried out on floral biology, floral rewards and pollination of different plant species in natural conditions (see for example J. HERRERA, 1985; C.M. HERRERA, 1987).

- Other works have been dispersely undertaken in recent years in Andalusia. Perhaps one on the pollination of custard apple (*Annona cherimolia* Mill.) is of great interest. This crop occupies in Andalusia an area of approximately 3,100 Ha (99,6 % over the total of Spain) and it yields about 33,000 tons. The director of these works is Dr FARRE, and they began two decades ago. Due to of the high costs of handpollination this colleague is trying to develop another fertilizer method. He discovered that the honeybee is not the adequate vector of pollen and so, he continued to look for other possible pollinating species. He found that *Orius* sp. hemipterous are abundant in flowers of custard apple and that they can be an appropiate vector if it is possible to artificially maintain high population levels near the orchards (FARRE,1991).

RESEARCH IN THE UNIVERSITY OF GRANADA

Our work began in 1986. In that year a programme of research on insect pollination in eastern Andalusia was established. The first step comprised of the study of almond and sunflower pollination. The results of such a study constituted a Doctoral Thesis (ORTIZ, 1990). We subsequently started the study of pollination in protected crop conditions.

General objectives :

1) To know the fauna related to the flowering and pollination of the crops and to quantify its densities and rhythm of activity.

2) To evaluate the effect of pollinating fauna on production.

3) To start a selection programme of wild bee species able to accept artificial shelters for their multiplication and later use as pollinators.

RESULT

Almond

In the province of Granada we captured insects belonging to 74 species in different parts of almond trees and flying between them. Only 47 species were found probable role as pollinators. The Apoida were the main group (49 % of the total of species) followed by Diptera (28 %) and Lepidoptera (11 %).

Studying complete flowering cycles in almond orchards which had the support of apiaries, the fauna of potential pollinators was almost solely composed of honeybees (94.9 to 99.6 % over the total number of individuals). These bees displaced the wild fauna to other blossoms and only *Xylocopa violacea* (L.) reached some importance in almond flowers (up to 2.5 %).

The experiment on production carried out in the previously described conditions proved that almond trees which had received insect visits yielded 6 times more than others isolated from them.

In a geographic study throughout Granada's province, we noted some differences in the composition of the potentially pollinating fauna :
* The number of species constituting this fauna increases towards the interior of the province. Wild Apoidea and other groups cause this increase, but the number of species of social Apoidea does not vary.

* From a quantitative point of view we have the same situation : in localities near the sea the fauna is almost completely made up of individuals of *Apis mellifera* L. and *Bombus terrestris* (L.), but these two species gradually become less important towards places more inland, where almond trees blossom later.

* The typical community of potential pollinators of almond in Granade was made up of 4 Apoidea species (*Andrena nigroaenea* (K.), *Xylocopa violacea* (L.), *Bombus terrestris* (L.) and *Apis mellifera* (L.), 2 of Diptera (*Eristalis tenax* (L.) and *Calliphora vicina* Rob.) and one of Lepidoptera (*Vanessa cardui* L.).

Regarding the occupation of artificial shelters by wild bees, we have obtained positive results. 40 % of shelters and 9 % of available pipes in them were used. The more abundant species were *Osmia cornuta* (Latr.) (79 % of all occupied pipes) and *Osmia tricornis* Latr. (15 %). The level of parasitism was relatively low : the 8 % of the occupied shelters and the 26 % of occupied pipes suffered parasitism. *Osmia cornuta* (Latr.) was the only host species and *Monodontomerus* sp. (Hypenoptera, Chalcididae) and *Cacoxenus* sp. (Diptera, Drosophilidae) were the parasites.

The conclusion related to the use of bees for almond pollination in Granada are evident : to look for alternative species to honeybees is needed, mainly in sites near the coast, where almond blossoms earlier and its pollination is almost exclusively dependent on the availability of beehives. The main candidates to carry out this role are *Osmia cornuta* (Latr.) and *O. tricornis* Latr. The cycle of the first species is coincides fully with almond blossom. The second one shows a later cycle but, because of its relatively flexibility, it will be able to be used for almond pollination (LACASA, pers. com.). We have not studied the nesting biology of *Bombus terrestris* (L.). However its artificial employment must be taken into account, mainly in inner localities where it appears later in nature.

Sunflower

150 arthropod species have been found to be related in some ways to sunflower blossoms in Granada. If we take into account only those wchich remain active in the heads, concretely 103, the community of potential pollinators is constituted, in number of species, of Apoidea as the main group (48 %), followed by Diptera (15 %), Formicidae (9 %) and Coleoptera (8 %).

The fauna related to sunflower has shown to be more diverse than that related to almond. So, in fields with support of honeybees due to the presence of apiaries, *Apis mellifera* L. was the most abundant species, but much lesser than in almond (55.4 %); the other Apoidea reached up to 27.3 % and Diptera up to 13.4 %.

In the described conditions we recorded an average of 7.2 insects per 100 sunflower heads. However heads which received insect visits did not yield more seeds than those wchich remained isolated from them. Moreover we did not find differences in either the height of the total seeds yielded per head or in their fatty acid content.

These results lead us to believe that the sunflower cultivar studied, Viky, shows a self-compatibility rate of 100 %.

After a geographic study throughout Granada's province, we established that the typical fauna of sunflower potential pollinators is constituted of 5 Apoidea species *Lasioglossum discum* (Sm), *Lasioglossum malachurum* (K.), *Halictus scabiosae* Ross., *Osmia signata* Erich. and *Apis mellifera* L.), one of Vespidae (*Polistes gallicus* (L.)) and one of Diptera (*Eristalis arbustorum*) (L.)).

Studies related to the use of artificial nests by wild bees were positive on this occasion too, but they were lower than in the case of almond. Concretely, 17 % of shelters and only 3 % of available pipes were occupied. 50 % of these pipes were occupied by *Megachile versicolor* Sm., 19 % by *Megachile pilidens* Alfk. and 19 % by *Osmia signata* Erich. 31 % of the occupied pipes (all belonging to *Megachile versicolor* Sm.) were parasitized by *Coelioxys inermis* (K.) (Megachilidae).

As general conclusions from the use of bees for sunflower pollination in southeastern Spain, we first must emphasize that this crop is of little apicultural

interest in that region. So the presence of apiaries is not always guaranteed. In addition, and due to the existence of an increasingly large number of cultivars with high rate of self-compatibility, a previous study on the need for vectors of pollen will be necessary in each case. 4 Megachilidae species were found nesting in artificial shelters. Their biology must be studied in order to start further programmes on their use as commercial pollinators.

Protected crops

An extension of approximately 48,000 Ha is occupied by protected crops in Andalusia. The chief crops are watermelon (9,600 Ha), green bean (9,100 Ha), strawberry (6,000 Ha), melon (6,503 Ha) and pepper (5,828 Ha) (ANONYMOUS, 1991). Our work has been carried out in the province of Almeia. This province has half the greenhouse surface in Andalusia, and the yearly production is about 800,000 tons. The most important crops in the province are pepper (5,500 Ha), green bean (3,500 Ha), melon (3,000 Ha), tomato (2,290 Ha) and watermelon (2,000 Ha) (Anonymous, 1987).

The concrete objectives proposed in this occasion were :

1) To study the potential pollinating fauna in the areas around greenhouses.
2) To select candidate bee species to be captured in the field, multiplied, and subsequently released into protected crops.
3) To study honeybee activity in greenhouses conditions.
The results obtained were the following :

39 insect especies were selected as potential pollinators around greenhouses. Most of them were Apoidea (71.8 %), followed by Coleoptera (17.9 %) and Diptera (7.7 %).

We placed artificial shelters between greenhouses, and the nesting results were : 40 % shelters and 6.7 % available pipes were occupied. *Hoplitis adunca contraria* Tkalcu and *Hoplitis anthocopoides* (Schck.) were the species collected in this way. No parasitism was detected at that moment.

Moreover, fertilized females belonging to these two species were collected in the field, hibernated along the way, and released again in greenhouses 1 to 2 days

later. In this case the results were negative : bees did not feed on the available sources (watermelon, melon and bean) and they quickly left the greenhouses without visiting any flower. Similarly we studied the feeding comportment of these species in cages, but bees did not feed on plants different to *Echium* spp., their natural source.

The crops previously referred to were used to monitor honeybee activity. The average number of bees during the flowering period were : watermelon, 3.5 bees per 100 flowers; melon, 1.2; and bean, 0.06.

The reason for this preference was caused by flower shape and nectar secretion. So, despite its concentrated nectar, and due to the form of its papilionaceus corolla, bean flower was the least visited. The flowers of the other two species have practically the same shape and equally concentrated nectar. However, honeybees preferred watermelon because of its more abundant nectar.

The results of the experiments in protected crops once again demonstrated the manageability of *Apis mellifera* L., but as honeybees showed different preferences for each crop, we recommended not cultivating several crops in the same greenhouse at the same time in order to avoid low pollination rates in the less attractive ones.

With regard to the use of other bee species, further research should go in two ways :

a) To look for non specialist Megachilidae species;
b) For non accessible corolla flowers, select bees with longer tongue (bumblebees for instance);
c) To study the possible adaptation of *Hoplitis* spp. to horticultural exploitations.

PRESENT SITUATION AND NEAR FUTURE FORECASTS

The following projects are currently being carried out in Spain :

- Adaptation of *Osmia* species (*cornuta* (Latr.), *rufa* (L.) and *tricornis* Latr.) to be used for pollination of fruit trees. This work is mainly being carried out in Barcelona and Murcia, and will be concluded this year.

- Another project involving the majority of Spanish teams begins this year. It deals with the adaptation of *Osmia* species *(rufa* (L.) and *tricornis* Latr.) to conditions of protected crops.

In southern Spain we would like to focus our work in two directions :

1. To study the floral biology and pollination of *Anthyllis cytisoides* L. (Leguminosae). This wild plant yields a very important monofloral honey, but it is also important as a source of forage and for preventing the advance of desertification in arid lands of southeastern Spain.

2. To study the biology and use of Apoidea species untested by us so far. In particular we are worried about the introduction by foreign enterprises of bumblebee colonies (*Bombus terrestris terrestris* (L.)) for pollinating protected crops. These colonies are mainly directed to tomato pollination because the fertilization of its flowers is very problematic in the conditions of our greenhouses. Nevertheless this technique has two risks : on one hand, a subspecies different from the autoctonous is introduced and it means a danger of the displacement of the Spanish subspecies or the hybridization with it (Ortiz, in press); on the other hand, these bumblebees may not adapt to climatic conditions different from those their regions of origin and therefore, not produce the expected results.

In this situation we are very interested in dealing with the problems which the introduction of these bumblebees might produce. Fortunately this pollination technique has been introduced very recently into our region and we have not seen foreign bumblebees in the surroundings of cultivated areas where they were moved to. We think that a study of the use of our subspecies (*Bombus terrestris ferrugineus* Schmied.) will be most beneficial. This is therefore a challenge that we would like to face with our European colleagues in whose countries this practice has been used for many years.

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