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Effects of flower abundance and colour on pan-trap catches

Hilda-Linn Berglund

Examinator, Anders Hargeby
Tutor, Per Milberg

LINKÖPINGS UNIVERSITET

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Författare
Author

Hilda-Linn Berglund

Sammanfattning
Abstract

Pollinating insects are important for many plants and for the human population. To be able to monitor pollinators and assess improvements made for them, it is important to get information about pollinator population changes. Therefore, it is essential that the methods used to collect data are accurate (i.e. that they represent the pollinator fauna). One commonly used method is pan-traps, but this method is suggested to be affected by the abundance of surrounding flowers. The results in the present study showed that catches in pan-traps can be affected by flower cover and the colour of the flowers, depending on which colours are preferred by the insects. The effects differed when looking at a larger scale (2-6 ha) and a smaller scale (25 m^2) around the pan-traps. When comparing cover of flowers with catches in pan-traps in the small scale there were some results that showed linear positive correlations (expected), but also, negative linear and quadratic correlations. In contrast, in the large scale there were no significant positive linear correlations. When comparing catches in hand-net and pan-traps, only in one out of six taxonomical groups there were a correlation. The results in this study show that catches in pan-traps can be misleading if catches are done to survey pollinator population fauna and the cover of flowers is not considered.

Nyckelord Blomflugor, bin, humlor, guldbaggar, blombockar, humlebaggar, färgskålar, håvning, blomfärger

Keyword Syrphidae, Apoidea, Bombus, Cetoniidae, Lepturinae, Trichius, pan-trap, hand-netting, flower colour

Content

1 Abstract

Pollinating insects are important for many plants and for the human population. To be able to monitor pollinators and assess improvements made for them, it is important to get information about pollinator population changes. Therefore, it is essential that the methods used to collect data are accurate (i.e. that they represent the pollinator fauna). One commonly used method is pan-traps, but this method is suggested to be affected by the abundance of surrounding flowers. The results in the present study showed that catches in pan-traps can be affected by flower cover and the colour of the flowers, depending on which colours are preferred by the insects. The effects differed when looking at a larger scale (2-6 ha) and a smaller scale (25 m^2) around the pan-traps. When comparing cover of flowers with catches in pan-traps in the small scale there were some results that showed linear positive correlations (expected), but also, negative linear and quadratic correlations. In contrast, in the large scale there were no significant positive linear correlations. When comparing catches in hand-net and pan-traps, only in one out of six taxonomical groups there were a correlation. The results in this study show that catches in pan-traps can be misleading if catches are done to survey pollinator population fauna and the cover of flowers is not considered.

2 Introduction

Pollinating insects are important for many plants and for the human population. They contribute to plant reproductions and to agricultural yields (Aizen et al. 2009, Gallai 2008). However decreases in pollinator fauna have been seen (Fitzpatrick et al. 2007, Kluser and Peduzzi 2007). Agricultural land use has changed markedly during the last 50-100 years (Potts et al. 2010). The changes in agricultural land use has led to fragmentation of the land and almost all of the unimproved grasslands have been lost, and hence the continuity of an abundance of flowers required for pollinators to survive (Goulson 2005, Hooftman & Bullock 2012). Pesticides used in agriculture do not only affect the target species, but also pollinators (Rundlöf et al. 2015).To be able to monitor and assess improvements made for pollinators, it is important to get information about pollinator population changes. Therefore, it is essential that the methods used to collect data accurately represent the pollinator fauna.

Different methods are used to survey pollinator populations, for example Malais-traps, suction-traps, pan-traps, transect-walks (bumblebees) and hand-netting in transect-walks. Malais-traps and suction traps catch a large number of insects, of which only a small proportion are pollinators (Campbell et al. 2007). While transect-walks work for larger flying insects like *Bombus*. Pan-traps are specifically targeting pollinators and is a method where pollinators are collected in pans containing a liquid of some sort. Pan-traps can be used in slightly different ways. Some variations include different colours of the pans, placed on the ground or higher up in the vegetation or with different types of pans. With the hand-netting method pollinators are caught with a hand-net, usually while the person is walking along a transect.

All insect sampling methods has at least some degree of selectivity. Studies have shown that the pan-traps catch less species than hand-netting (Cane et al. 2000, Roulston et al. 2007), while another found no difference in catches between the methods (Westphal et al. 2008). As written above, the pan-trap method can be executed in different ways and this could have an effect on the results.

There are advantages and disadvantages with both hand-netting and pan-traps. Hand-netting is time consuming and requires trained collectors (Cane 2001). In contrast, passive catching methods like pan-traps are less time consuming, and do not need trained collectors (Westphal et al. 2008). Pan-traps are not as weather-dependent as hand-netting since you do not need to be at the place in person when the favourable weather occurs. This makes it possible to make catches at several places at the same time when pan-trapping. Pan-traps can attract pollinators even if there are no flowers and can be good at sampling small species that can otherwise be hard to catch with hand-netting (Westphal et al. 2008). However, pan-traps can under-sample large species (Cane 2001) that may escape the traps more easily (Westphal et al. 2008). Pan-traps also catch non-targeted insect species and we cannot calculate the population density, only a relative measure per catching-effort.

Studies suggest that the number of flowers surrounding pan-traps can affect the catches of insects, with less catches when there are more flowers around (Cane 2000, Roulston et al. 2007, Wilson et al. 2008, Baum 2011), while others have shown the opposite (Wood et al. 2015). Different colours on the pans are preferred by different species (Toler et al. 2005, Campbell & Hanula 2007, Cane et al 2000, Wilson et al. 2008) and blue, white and yellow are frequently used colours (Saunders & Luck 2013, Toler et al. 2005, Wilson et al. 2008, Campbell & Hanula 2007). Therefore it could also be suggested that the colours of the flowers around the pan-traps may affect the catches in the pan-traps. For example if an insect taxon prefers the blue flower over the blue pan. However, Toler et al. (2005) found no effect by the colours of the flowers on the catches. Given the somewhat conflicting reports, it remains unclear if a flower-abundance or flower-colour bias exists and if so how it affects the catches.

Earlier studies have shown that number of pollinator insects increases when density of flowers increases (Franzén & Nilsson 2008, Sjödin 2006, Ebeling et al. 2008). Because of that relationship, we might assume that catches in pan-traps, if unbiased, should be positive linear to density of flowers. In contrast, if there are competition between flowers and the pan-traps, i.e.a bias in catches, the relationship would not be positive linear. Either it could decrease negative linearly when flower density increase, or there might be a quadratic shape to the relationship with less catches when low and high density of flowers (due to fewer available insects when low density and to discrimination of pan-traps when high density). When there is a high density of flowers, the probability of a flower visit might go down, a phenomenon termed pollinator limitation (Pettersson & Sjödin 2000, Steven et al. 2003, Sih & Baltus 1987); a similar effect might be seen in the visits to pan-traps.

The aim of the present study was to relate pan-trap catches to the flower abundance and the colour of the flowers, both in the nearest surroundings of the pan-traps (25 m^2) and on a larger scale (2-6 ha).The study system was clear-cuts in production forest, which were selected to represent a gradient in flower abundance. Six taxonomical groups were considered *Syrphidae*, *Apoidea* (excl. *Bombus*), *Bombus*, *Cetoniidae*, *Lepturinae* and *Trichius*. Pan-traps were also compared to hand-netting to see if there is a correlation in catching-efficiency between the two methods and to what extent hand-netting catches are affected by flower abundance and the colours of the flowers.

3 Material & methods

3.1 Study sites

The study areas are situated in the province of Östergötland, southern Sweden. The landscape consists mainly of coniferous forest, but is mixed with bogs, lakes, small patches of seminatural grasslands and arable fields (Ibbe et al. 2011). Twelve clear-cuts were selected for the study, each had an area of 2-6 ha and had been logged 4-6 years prior to the present study. Six of them were meadows in the 1870s and six of them were coniferous forests. To identify the historical land use, regional economic maps (Häradsekonomiska kartan) produced between 1868 and 1877 was used. Nearby seminatural grasslands are not closer than 300 meters. Since then at least one generation of spruce-dominated forest has grown in these sites, for a minimum of 70 years and a maximum of about 140 years (Ibbe et al. 2011). Sites that had a history as meadows have a higher amount of herbs than clear-cuts which were formerly forests (Jonason et al. 2014, 2016). This range of flower abundances made it possible to examine effects of flower abundance on pollinator-catches across all sites.

3.2 Pollinator catches

3.2.1 Pan-traps

The pans used to collect pollinators was each painted in one of the following colours, blue, white and yellow with UV-reflecting-colour (Soppec, Sylva mark fluo marker, Nersac, France). The pans had a diameter of 8.7cm, a volume of 0.5 L and were filled with propylene glycol (40% concentration), to conserve the pollinators and to decrease the surface tension. A small opening (4 mm in diameter) at the top of each bowl was made to ensure that rainwater could pour out. One set of pan-trap consists of three pans, one in each colour, placed on a steel stick (Figure 2). Four sets of pan-traps were placed at each clear-cut, in the same height as the vegetation and in places that were considered representative for the area. The pans had caps on between the collecting periods. If the pan-traps were overgrown when a new period was about to start, the pan-traps were moved at most 30 cm or some of the vegetation was removed.

The collection with the pan-traps occurred during three periods during the summer, in the beginning of June, July and August. Each period lasting for one week before the bowls was emptied. Each period had at least some days with more than 17 degrees and wind velocity less than four on the Beaufort scale.

In total there were 48 set of pan-traps collecting during each period, but a few set of pan-trap had been knocked down by animals and were therefore excluded. In the first, second and third period there was one, one and two set of pan-traps missing, respectively. Plus one blue pan the second period.

Figure 2.One set of pan-traps painted in blue, yellow and white and mounted on a metal stick.

3.2.2 Hand-netting

During the third collecting-period (beginning of August) all clear-cuts were hand-netted, at most 5 days before or after the period of pan-trap collection. The hand-netting were carried out in transects 25 m apart over the whole clear-cut. The collector walked with a pace of 100 meters in 4 minutes. The transect-walk occurred between 07.00 and 15.00 GMT (9.00-15.00 local Swedish summer time) when it was sunny, at least 17 degrees and the wind strength less than four on the Beaufort scale (Beaufort scale three, only tiny branches and leaf are moving). *Syrphidae*, *Bombus*, *Apoidea* and *Lepturinae* were caught within 1 meter from the transect, while individuals of *Cetoniida* and *Trichius* were only noted. If the sun became covered by clouds, the collector waited until the sun appeared again and then resumed the transect walk.

3.3 Measurement of flower abundance by photos

The clear-cuts were photographed during the collecting-periods. A 1 m^2 square was placed on the ground and photographed from above. Around each pan-trap 25 such 1 m^2 plots were photographed (25 pictures) and an additional 100 pictures (plus some extra) were distributed in transects over the whole clear-cut (Figure 3). This was repeated during all three collecting-periods, at most 5 days before or after the pan-trap-catches.

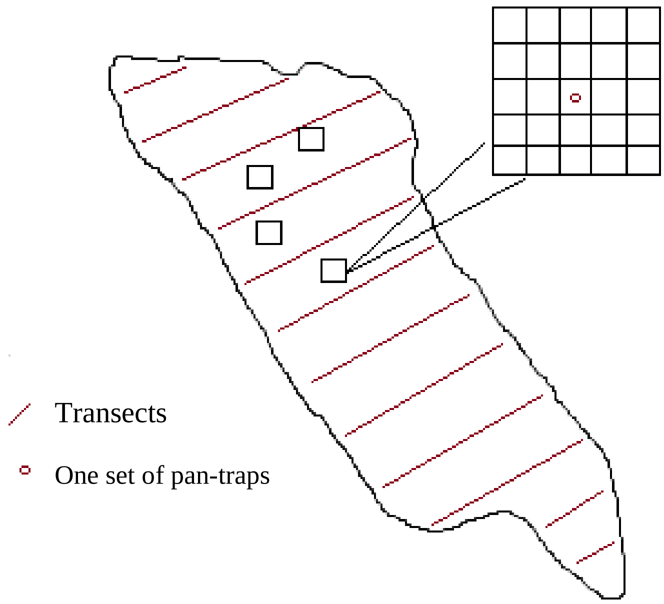

Figure 3. An example of study area with pan-traps and transects indicated. Over the whole clear-cut, there were 100 photos taken along the transects, with an additional 25 photos around each of the four sets of pan-traps. All pictures were photographed over a one-meter square lying on the ground.

3.4 Data analyses

3.4.1 Image analysis

All of the around 7000 pictures were inspected visually to see if they held any flowers within the one meter square and if so of which colours. The colours were grouped in blue, white or yellow. All pictures which contained flowers within the one meter square were cut at the inner edge of the square, hence excluding the area and the vegetation outside of the square from analysis. RGB-values for blue/red, yellow and white were chosen visually in Image J (Rasband 2012) to find the ones that best fit most of the pictures. The values were set to register as many pixels as possible of the flowers and minimize the impact from other vegetation, stones and bolder etc. in the analysis. The proportions of pixels which contained the chosen RGB-values were calculated in the program R (R Core Team 2015) for each picture which held flowers. The script was based on Bellanders script that had been used to analyze colours in paintings (Bellander 2015) and then modified for the present study. The packages readbitmap (Jefferis 2014) and colorspace (Ihaka et al. 2015) were used in the analysis. In the large scale around 100 pictures per clear-cut were analyzed and in the small scale 25 pictures per set of pan-trap.

3.4.2 Statistical analyses

The six taxonomic groups Syrphidae, Apoidea (excl. *Bombus*), *Bombus*, Cetoniidae, Lepturinae and *Trichius* were considered. Correlation between the cover of flowers, per colour, and the average number of individuals per taxonomic group caught in each colour of the pan-traps were calculated.

Correlations between the colours of the flowers (yellow, blue, white and total) during each time period were calculated by Pearson's correlation coefficient.

One expectation was that of a linear relationship between flower abundance and number of specimens with more individuals with increasing flower abundance (due to larger population sizes). However, if pan traps compete with flower abundance, we might expect the catch to drop with high flower abundance. To evaluate the support for these two expectations in the data, two generalized linear models were compared: one linear and one quadratic. Both with poisson and log link. The quadratic model was chosen to be the best model explaining the data if the model had a negative value and was significant. If not, a linear model, either negative or positive, was considered to explain the model in the best way.

The effects of flower colour on hand-netting catches and the correlation between catches in pan-traps and hand-netting were tested by a linear model in R (the lm-function).

The odds to catch a specimen of a specific taxonomic group in pan-traps as well as when hand-netting were calculated with odds ratios in the software Comprehensive Meta analysis. Calculated like;

Odds = a/(b-a) = a/c

a= number of caught individuals for one taxonomic group
b= total number of caught individuals (in all taxonomic groups)
c= a-b

This was calculated for each clear cut for both pan-traps and hand netting and for each colour of the pan-traps and the total number of pan-traps.

4 Results

The total number of insects counted in this study was 3477, divided among six taxonomic groups. Hand-netting which occurred during the third time period caught 1390 individuals compared to 651 for pan-traps at the same time period (Table 1).

Table 1. Individuals of six taxonomic groups caught per clear-cut with pan-trapping (Pan) and hand-netting (Net) for the time periods, with standard deviation.

	Apoidea (excl. Bombus)	***Bombus***	***Cetoniinae***	***Lepturinae***	**Syrphidae**	**Trichius**
Pan Average (± SD) period 1	5.8± 4.17	4.4± 2.87	29± 14.0	7.8± 5.82	11± 9.95	0
Pan Average (± SD) period 2	9.2± 5.54	3.5± 2.71	5.8± 3.51	37± 23.1	1.4± 1.16	4.6± 4.27
Pan Average (± SD) period 3	8.9± 5.58	3.9± 2.07	0.6± 0.90	34± 15.1	2.7± 2.15	4.6± 5
Net Average (± SD) period 3	24± 19.4	15± 7.80	0	12± 7.88	65± 39.3	0.1± 0.29
Pan Min/max period 1	0-16	0-10	14-57	0-19	2-34	0
Pan Min/max period 2	3-19	0-7	0-12	10-89	0-4	0-12
Pan Min/max period 3	1-18	0-7	0-3	10-62	0-7	0-18
Net Min/max period 3	4-66	6-36	0	3-27	12-143	0-1

Number of individuals caught in the pan-traps varied between the colours of the pan-traps and the taxonomic groups (Table 2).

Table 2. Number of individuals caught in the pan-traps with different colours, summed over three time periods.

Colour of pan-trap, time period	***Apoidea (excl. Bombus)***	***Bombus***	***Cetoniinae***	***Lepturina***	***Syrphidae***	***Trichius***
Blue period 1	10	16	77	43	38	0
Blue period 2	24	13	10	222	0	54
Blue period 3	25	23	0	162	1	52
Yellow period 1	43	25	135	16	75	0
Yellow period 2	58	23	27	47	13	0
Yellow period 3	51	20	5	51	27	2
White period 1	17	12	134	34	23	0
White period 2	28	6	33	175	4	1
White period 3	31	4	2	190	4	1
Blue Total	59	52	87	427	39	106
Yellow Total	152	68	167	114	115	2
White Total	76	22	169	399	31	2

The average of flower cover in the large scale (the whole clear-cut) and in the small scale (25m^2 around each set of pan-trap) was quite similar in period two and three. However in the first period there was a larger difference between the large and the small scale (Table 3).

Table 3. Average cover of flowers (promille) with $CI_{95\%}$ in the large scale (clear-cut) and in the small scale (25 m^2 around the pan-traps) for the time periods.

	Blue flowers	***Yellow flowers***	***White flowers***	***Total***
Small scale				
Average (±$CI_{95\%}$) period 1	0.0730±0.06814	0.0422±0.05895	0.880±2.309	0.878±0.3145
Average (±$CI_{95\%}$) period 2	0.139±0.1303	0.188±0.1463	0.0721±0.1990	0.357±0.08188
Average (±$CI_{95\%}$) period 3	0.173±0.09144	0.347±0.2191	0.0487±0.1268	0.499±0.1063
Min/max period 1	0.00774 - 4.16	0.00 - 5.98	0.00 - 90.4	0.00- 90.4
Min/max period 2	0.00408 – 14.0	0.00 - 31.0	0.00 - 9.10	0.00- 31.1
Min/max period 3	0.00109 - 9.86	0.00 - 48.3	0.000419-5.58	0.00- 48.3
Large scale				
Average (±$CI_{95\%}$) period 1	0.178±0.1957	0.140±0.1570	0.208±0.7236	0.453±0.1298
Average (±$CI_{95\%}$) period 2	0.107±0.07967	0.176±0.08780	0.0962±0.1951	0.330±0.05352
Average (±$CI_{95\%}$) period 3	0.181±0.09018	0.283±0.1170	0.0218±0.1017	0.454±0.06312
Min/max period 1	0.00539 – 19.1	0.000149- 18.4	0.00 - 49.2	0.00- 49.2
Min/max period 2	0.00414 – 5.20	0.00 – 16.8	0.00 - 13.3	0.00- 16.8
Min/max period 3	0.00481 – 9.05	0.00 – 14.8	0.00 - 2.96	0.00- 16.5

The correlations between flower colours differ between time periods and colours (Table 4). In the cases when there was a high correlation between flower colours, it was always positive (Table 4). Unsurprisingly most of the substantial correlations were between a specific colour and the total flower abundance. But even some of the other combinations had quite high correlation to (Table 4).

*Table 4. Correlation of cover of flowers, on a large scale (clear-cut) and on a small scale (25 m^2 around the pan-traps) for the three time periods. There were 12 clear-cuts for each colour and significance marked with *.*

	Blue/Yellow	***Blue/White***	***Blue/Total***	***Yellow/White***	**Yellow/Total**	**White/Total**
Small scale						
Correlation period 1	0.782*	-0.0658	0.00771	0.0375	0.106	0.997*
Correlation period 2	-0.104	-0.0129	0.0787	-0.135	0.0195	0.982*
Correlation period 3	0.609*	0.0298	0.753*	0.159	0.978*	0.195
Large scale						
Correlation period 1	0.497	-0.0360	0.746*	0.216	0.730*	0.586*
Correlation period 2	0.343	0.578*	0.523	0.726*	0.973*	0.842*
Correlation period 3	-0.329	-0.281	-0.0692	0.267	0.963*	0.261

A correlation between preferred colour of the pan-traps and effects of surrounding flower colour were most clear on the small scale for Apoidea (excl. *Bombus*), Syrphidae and Lepturinae (Table 2; Table 5). Apoidea (excl. *Bombus*) and Syrphidae increased in some colours of the pan-traps when the preferred colour of the flowers increased around the pan-traps. While Lepturinae decreased in the pan-traps when the preferred colour increase around the pan-traps.

Table 5. Effects of cover of flower on catches in pan-traps, explained by a linear model or a quadratic model. If a linear model fitted the data better than quadratic model, the column Coefficient^2 is blank. Cover of flower measured in a large scale (clear-cut) and in a small scale (25 m^2 around the pan-traps).=P<0.05.*

	Coefficient (SE)	***Coefficient^2 (SE)***	***Coefficient (SE)***	***Coefficient^2 (SE)***	***Coefficient (SE)***	***Coefficient^2 (SE)***	***Coefficient (SE)***	***Coefficient^2 (SE)***
Taxa, flower colour	***Blue pan***		***Yellow pan***		***White pan***		***Total Pan***	
Smal scale								
Apoidea (excl. Bombus)								
Blue	-0.357 (0.332)		-0.874 (0.334)*		-58.9 (21.8)*		-0.867 (0.195)*	
Yellow	-8.88 (16.2)		1.02 (0.380)*		0.922 (0.352)*		0.933 (0.265)*	
White	-17.5 (9.46)		-0.794 (7.52)		-14.2 (8.26)		-12.0 (5.03)*	
Total	-10.7 (8.39)		1.55 (7.26)		-7.75 (7.42)		-6.64 (4.59)	
Bombus								
Blue	16.9 (27.1)		-0.538 (0.369)		-8.34 (37.9)		-0.312 (0.268)	
Yellow	3.92 (19.2)		11.7 (17.2)		1.25 (0.631)*		11.5 (12.4)	
White	-1.26 (0.733)	-1.08 (0.576)*	-0.890 (0.418)*		-21.3 (16.6)		-24.4 (7.99)*	
Total	-0.873 (0.667)	-1.27 (0.566)*	-8.42 (8.99)		-4.88 (13.3)		-0.628 (0.349)	-0.710 (0.315)*
Cetoniinae								
Blue	-0.949 (0.322)*		-0.438 (0.253)		-0.635 (0.249)*		-0.776 (0.159)*	
Yellow	2.22 (0.312)*		2.47 (0.231)*		1.80 (0.251)*		2.91 (0.173)*	
White	-0.391 (0.332)		0.0174 (0.219)		-2.96 (5.79)		-0.178 (0.149)	
Total	0.537 (0.341)	-0.715(0.337)*	20.4 (4.70)*		0.435 (0.253)	-614±0.253*	0.699 (0.155)*	-0.549 (0.157)*
Lepturinae								
Blue	-1.47 (0.174)*		-86.3 (21.8)*		-0.888 (0.163)*		-1.32 (0.112)*	
Yellow	1.06 (0.176)*		1.98 (0.278)*		1.54 (0.165)*		1.98 (0.127)*	
White	-1.43 (0.214)*		-1.177 (0.354)*		-1.15 (0.213)*		-1.37 (0.142)*	
Total	-0.928 (0.212)*	-0.372(0.191)*	-0.245 (0.352)	-0.682±0.331*	-0.436 (0.204)*	-0.673 (0.189)*	-0.689 (0.139)*	-0.575 (0.126)*
Syrphidae								
Blue	-88.2 (34.3)*		-136 (23.8)*		-84.5 (37.3)*		-136 (18.8)*	
Yellow	-71.4 (25.4)*		0.929 (0.336)*		-0.152 (0.744)		0.626 (0.342)	

White	-37.5 (16.3)*		-0.653 (0.307)*		-41.8 (18.9)*		-1.09 (0.278)*	
Total	-40.7 (15.1)*		-0.549 (0.292)		-35.9 (15.9)*		-1.01 (0.263)*	
Trichius								
Blue	-99.4 (22.9)*		-23.8 (60.1)		-11.0 (59.2)		-97.8 (22.4)*	
Yellow	0.875 (0.365)*		31.7 (39.9)		38.2 (39.6)		1.14 (0.394)*	
White	-61.1 (13.8)*		-1.78 (20.5)		-7.74 (22.0)		-57.0 (12.9)*	
Total	-2.40 (0.892)*	-1.66 (0.666)*	4.36 (19.1)		2.25 (19.5)		-2.40 (0.893)*	-1.80 (0.667)*

	Coefficient (SE)	***Coefficient^2 (SE)***	***Coefficient (SE)***	***Coefficient^2 (SE)***	***Coefficient (SE)***	***Coefficient^2 (SE)***	***Coefficient (SE)***	***Coefficient^2 (SE)***
Taxa, flower colour	***Blue pan***		***Yellow pan***		***White pan***		***Total Pan***	
Large Scale								
Apoidea (excl. Bombus)								
Blue	-2.01 (30.3)		-42.9 (30.1)		-18.3 (27.8)		-24.8 (17.4)	
Yellow	-39.0 (17.6)*		-45.2 (17.2)*		-46.2 (16.2)*		-1.17 (0.233)*	-0.506 (0.198)*
White	-30.0 (20.1)		-22.3 (18.6)		-45.2 (19.9)*		-37.9 (11.9)*	
Total	-25.4 (13.7)		-29.4 (13.5)*		-33.4 (12.8)*		-0.989 (0.227)*	-0.416 (0.207)*
Bombus								
Blue	5.32 (36.6)		7.25 (33.0)		26.2 (50.1)		9.44 (23.4)	
Yellow	-21.1 (20.8)		-1.01 (0.482)*	-1.19 (0.444)*	-5.21 (28.2)		-0.722 (0.301)*	-0.553 (0.278)*
White	-0.814 (0.642)	-0.910(0.459)*	-28.9 (21.8)		-11.3 (30.2)		-29.3 (15.5)	
Total	-17.1 (16.3)		-0.840 (0.462)	-1.13 (0.444)*	-3.61 (22.0)		-0.727 (0.317)*	-0.968 (0.304)*
Cetoniinae								
Blue	-0.367 (0.384)	-0.903±0.379*	0.0214 (0.283)	-0.941 (0.284)*	-3.21 (22.1)		-0.138 (0.176)	-0.811 (0.176)*
Yellow	-0.763 (0.408)	-1.04±0.385*	0.204 (0.289)	-1.09 (0.32)*	-15.4 (12.4)		-0.327 (0.178)	-0.780 (0.177)*
White	-13.2 (17.8)		-0.361 (0.206)		-7.69 (12.8)		0.0142 (0.144)	
Total	-18.7 (13.2)		10.7 (9.36)		-9.14 (9.62)		-5.80 (6.09)	
Lepturinae								
Blue	-22.6 (14.2)		3.15 (26.4)		-17.6 (14.8)		-19.6 (9.53)*	
Yellow	-39.5 (8.14)*		-5.21 (14.7)		-38.8 (8.49)*		-37.8 (5.48)*	
White	-64.9 (11.3)*		-31.6 (17.7)		-0.830 (0.230)*	-0.389 (0.175)*	-51.2 (7.055)*	
Total	-1.00 (0.184)*	-0.359(0.167)*	-10.6 (11.6)		-28.2 (6.68)*		-0.898 (0.122)*	-0.341 (0.112)*
Syrphidae								
Blue	-24.6 (41.6)		-1,21 (0.384)*	-0.880 (0.354)*	-3.89 (45.3)		-59.9 (21.5)*	

Yellow	-54.0 (24.4)*		-31.7 (15.1)*	-45.1 (26.5)	-46.0 (12.2)*	
White	-62.8 (32.7)		-0.54 (0.284)	-65.8 (36.6)	-0.864 (0.270)*	
Total	-40.4 (19.4)*		-30.6 (12.1)*	-35.2 (21.1)	-39.4 (9.78)*	
Trichius						
Blue	-0.379 (0.433)	-2.12 (0.430)*	-5.33 (79.4)	11.5 (78.8)	-0.392 (0.432)	-2.26 (0.431)*
Yellow	-1.77 (0.488)*	-1.87 (0.414)*	-19.4 (44.7)	2.76 (43.6)	-1.75 (0.473)*	-1.86 (0.402)*
White	-115 (27.5)*		-19.2 (49.3)	-8.02 (46.2)	-4.42 (2.15)*	-1.32 (1.00)
Total	-2.75 (0.611)*	-2.85 (0.516)*	-14.9 (35.0)	-1.10 (34.1)	-2.76 (0.598)*	-2.91 (0.508)*

On the small scale, most of the significant correlations were best explained by linear models, most of them negative ones, but also some positive ones. On the large scale however, no positive linear models was significant and there was an equal number of significant negative linear models and quadratic models (Figure 4).

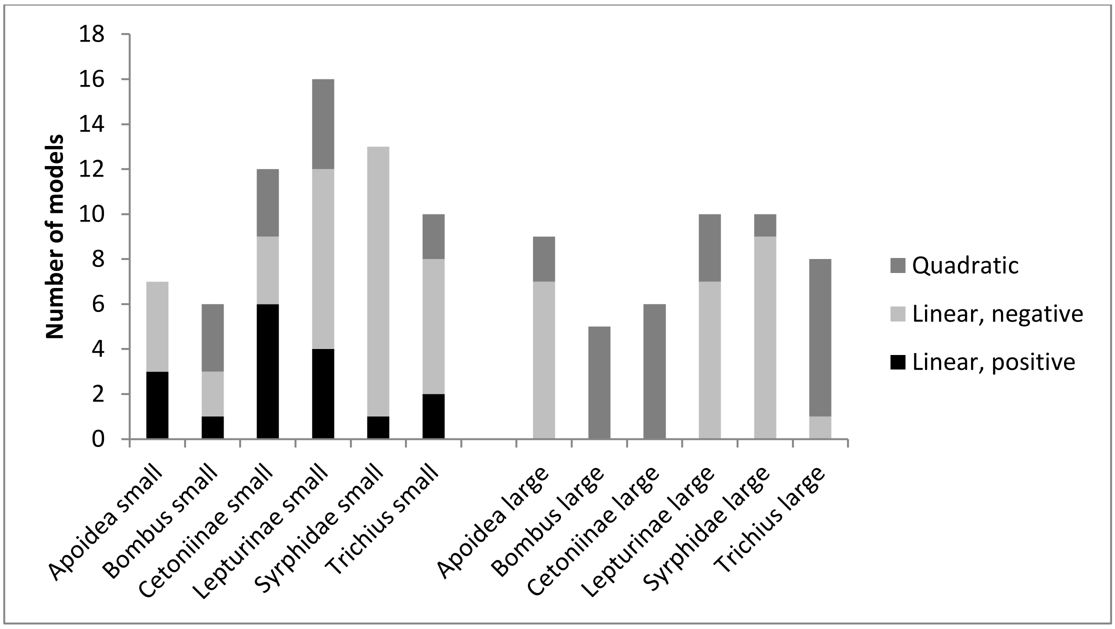

Figure 4. Significant cases of correlations between total flower cover and catches in pan traps, per taxonomic group (six groups) according to the best type of three models evaluated. Left is data from a small scale (25 m^2) and right from a large scale (clear-cut).(Apoidea = exclusive Bombus)

When grouping according to colours of the flowers, only yellow flowers on the small scale had some significant linear positive results. In contrast, blue and white flowers only had linear negative results on the small scale. Nevertheless when looking at total flower abundance there were some quadratic model that best explained the data. While only linear negative and quadratic models are significant in the large scale (Figure 5).

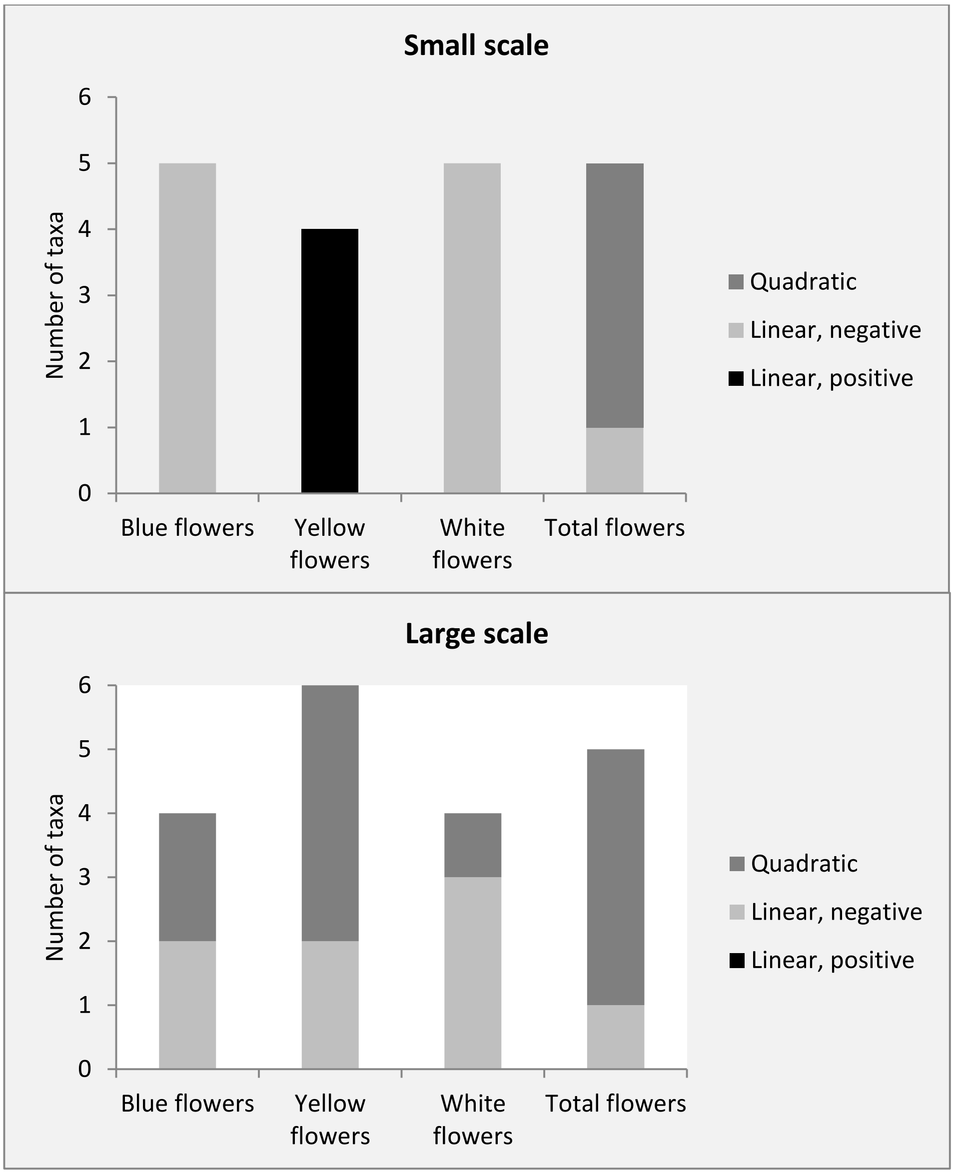

Figure 5. Significant cases of correlations between flower cover and catches in pan traps according to best type of model. Grouped according to the colours of the flowers. Top graph is based on data from a small scale (25 m^2 around the pan-traps) and bottom graph from a large scale (clear-cut).

A correlation between number of caught Apoidea (ecxl. *Bombus*) in pan-traps and hand-netting were recorded, but not for the other taxonomic groups (Table 6). *Trichius* and Cetoniinae are not included due to a small number of individuals noted while hand-netting.

Table 6. Correlation between numbers of caught individuals in pan-traps and hand-netting, per clear-cut (12 clear-cuts) during time period three.

	Apoidea (excl. Bombus)	***Bombus***	***Lepturinae***	***Syrphidae***
Correlation	0.814	-0.0229	0.142	0.00158

For hand-netting, there was a positive correlation for Apoidea (excl. *Bombus*) and blue flower abundance (Table 7). A positive correlation were also seen for Lepturinae and cover of yellow flowers, and a negative correlation for cover of blue flowers (Table 7). Number of Syrphidae also have a tendency to increase when cover of yellow flowers increase.

Table 7. Regression between number of caught individuals per clear-cut in hand-net and cover of flower over the whole clear-cut (12 clear-cuts). Data collected during time period three.

Taxa, flower colour	***Coefficient (+/-SD)***	***t-value***	***p-value***	***Df***
Apoidea (excl. Bombus)				
Blue	11460±4851	2.36	0.0398*	10
Yellow	-2120±16944	-0.125	0.903	10
White	2971±27410	0.108	0.916	10
Total	7577±17504	0.433	0.674	10
Bombus				
Blue	14963±23850	0.627	0.544	10
Yellow	-6248±6517	-0.959	0.360	10
White	-45005±109203	-0.412	0.689	10
Total	-5695±6863	-0.830	0.426	10
Lepturinae				
Blue	-45708±19866	-2.30	0.0442*	10
Yellow	12558±5619	2.24	0.0494*	10
White	10510±10620	0.989	0.3458	10
Total	10176±6406	1.59	0.143	10
Syrphidae				
Blue	7745±122433	0.063	0.951	10
Yellow	55834±29403	1.90	0.0868	10
White	-230195±549844	-0.419	0.684	10
Total	60314±30218	2.00	0.0739	10

The odds to catch Lepturinae in blue and white pan-traps were higher compared with hand-netting (Figure 6). There was a tendency to have less catches of Syrphidae in white pan-traps compared to hand-netting (Figure 6).

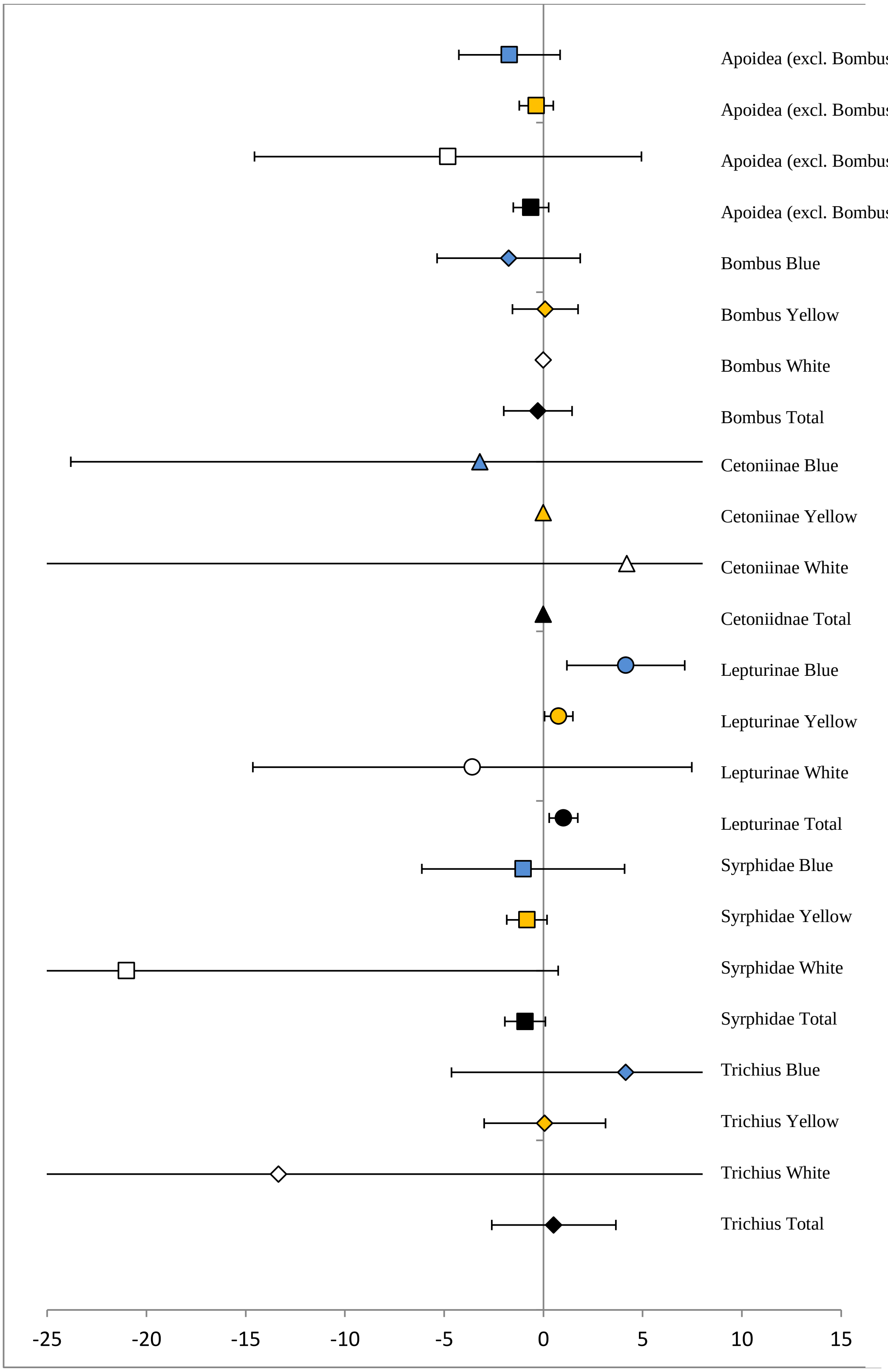

Figure 6. The ln (odds ratio) between the odds of an insect caught belonging to a certain taxonomic group in pan-traps (-) and the corresponding odds in data generated by hand-netting in transects (+). Pan-traps were either blue, yellow or white. Error bars are $CI_{95\%}$.

5 Discussion

5.1 Competition between flowers and pan-traps

The present study show that catches in pan-traps are affected differently by cover of flowers depending on taxonomic group and if surveying on the whole clear-cut or just in the near vicinity of the pan-traps.

Earlier articles have reported that number of insects increase when number of flower increase (Franzén & Nilsson 2008, Sjödin 2006, Ebeling et al. 2008). In that case a positive linear model is the best model describing the relationship between flower abundance and number of insects. However in the present study there were no such significant models in the large-scale flower data, and less than half of the significant models in the small scale. The lack of more results with positive linear regressions could be due to competition between flowers and the pan-traps, which earlier studies have suggested (Cane et al. 2000, Roulston et al. 2007, Wilson et al. 2008).

Two models can indicate competition between flowers and pan-traps, linear negative model or quadratic model. A quadratic model might best describe the data when catches in the pan-traps decrease when it is a low number of flowers on the clear-cuts due to a low number of insects, and also decrease when there are a high number of flowers due to competition between flowers and pan-traps, or less visits to each flower or pan-trap due to pollinator limitation (Pettersson and Sjödin 2000, Steven et al. 2003, Sih & Baltus 1987). In the present study, more of the results were best explained by the quadratic model in the large scale than in the small scale. However it is still less than half of the results which are explained by the quadratic model. Another scenario could be that increasing number of flowers leads to linearly decreasing catches in the pan-traps due to competition between flowers and pan-traps. In that case a negative linear model is the best way to describe the relationship. In the present study, at least half of the significant results were best described by the negative linear model, in both the small and the large scale.

5.2 Preferences for colours

Different taxonomic groups prefer different colours of the pan-traps (Table 2, Toler et al. 2005, Campbell & Hanula 2007, Cane et al 2000, Wilson et al. 2008, Wilhelmsson 2014). In the present study we refer to the catches in the pan-traps when talking about preferred colours for different taxonomical groups.

5.1.1 Small scale

In the small scale there were some taxonomic groups increasing in the pan-traps when the preferred flower colour yellow is around the pan-traps, for example Syrphidae and Apoidea (excl. *Bombus*). This could be explained by a high amount of yellow flowers in a spot attracting more insects to that specific place, which Pettersson and Sjödin (2000) have found for some plant species. This makes it more probable that a higher number of insects lands in the pan-traps.

Other taxa decrease in the pan-traps when the preferred flower colour is around the pan-traps, but increase when the non-preferred colour is around. This is for example noted for Lepturinae. This could be explained by when the preferred flower colour is around the pan-traps, the flowers are chosen over the pan-traps. But when the preferred colour is not around the pan-traps, they are chosen over the flowers.

Other taxa show mixed results, with no clear correlations between preferred colour and surrounding flower colour. Petersson and Sjödin (2000) show that different species of Apoidea could behave differently depending on plant species. For example there were some plant species visited equally in control and density-reduced plots, while other species where less visited in density-reduced plots and in some cases the other way around. In the present study it seems pretty clear that Apoidea (excl. *Bombus*) prefer yellow flowers in high densities. But the behaviour of sometimes preferring denser and sometimes less dense plots of flowers depending on plant species may explain the mixed results for *Bombus* in the present study. This hypothesis, however, cannot be tested within the present data as plant species identity was not noted. The results may also can be explained by insects learning to visit other colours of the flowers than the innate colour preference if it is rewarding for them (Gumbert 2000), which may blur the colour preferences as seen in data. Gumbert (2000) have seen that naive bumblebees more often chose stimuli with a wavelength between 400-410 nm than 450 and 490 nm. This means that if the pan-traps would have another wavelength than in the present study, the results maybe could be slightly different. Different species of Bombus prefer different species of flowers (Mossberg & Cederberg 2012, Söderberg 2013) which may also explain the variation in colour preference in the present study.

5.1.2 Large scale

On the large scale, the general result was that catches decreased when cover of flower increased, either with linear negative or quadratic model best explaining the relationship, regardless of colours of the flowers. Explanations for that could be that when a high amount of the preferred flower colour is present on the clear-cut, the chance to visit the four set of pan-traps is decreasing (hence a pollinator limitation effect). For some taxonomic groups flowers may also be more attractive than the pan-traps (hence a preference).

These results show that when using pan-traps is it important to consider not only the flower cover on the whole clear-cut, but also in the area nearer the pan-traps. It is also important to consider the colours of the flowers around the pan-traps if surveys of the pollinator population fauna are wanted.

5.3 Correlation, hand-net and pan-traps

The only taxonomic group out of six which showed a correlation in number of caught individuals between hand-netting and pan-traps was Apoidea (excl. *Bombus*). Since the two methods do not generate directly comparable data, it is difficult to clarify the nature of the bias and whether, in fact, one of both methods are biased. During the third sampling period, there were 32 Syrphidae and 1 Trichius sampled with the pan-trapping method, while 785 Syrphidae and 55 Trichius where sampled with hand-net (Table 1).

5.4 Hand-netting and cover of flowers

Correlations between number of hand-netted individuals and cover of flowers were mostly non-significant. However, one significant result was that the number of caught Apoidea (excl. *Bombus*) increased when cover of blue flowers increased. This is not the same results as was seen when collecting with pan-traps. Maybe the number of Apoidea (excl. Bombus) increase on clear-cuts containing blue flowers, but they cluster around yellow flowers. Another result was that the number of caught Lepturinae increased when cover of yellow flowers increased, but decreased when cover of blue flowers increased. This means a similar results to that recorded in the pan-traps in the small scale (in the large scale catches decreased in all combinations when cover of flowers increasing). This could indicate that the number of Lepturinae decreased on the clear-cuts when there were much blue flowers, and increased when there were much yellow flowers. But since the catches of Lepturinae can be much higher in blue pans than in the yellow pans (Table 2, Wilhelmsson 2014) and has been recorded to mostly visiting white flowers (Ehnström & Holmer (2007); that also mention some blue flowers), the conclusion on flower preference is only tentative. Maybe other resources as volume and type of substrate suitable for egg laying for Lepturinae and Apoidea (excl.

Bombus) increase at clear-cuts which contain a high cover of yellow and blue flower. Another explanation could be that on clear-cuts which contains a lot of blue or white flowers Lepturinae are more stationary and harder to detect for the collector. While on clear-cuts which contains yellow flowers Lepturinae foraging and moving around make them easier to detect while hand-netting. Lepturinae was captured when flying over the transects several times, but if that was more common on some clear-cuts than others was not noted. A result that was near-significant regarded the number of Syrphidae increasing when cover of yellow flowers increased on the clear-cuts. This result seems quite likely since this taxon has a strong preference for yellow (Table 2, Wilhelmsson 2014), even though the colour preference can change a bit during the aging (Sutherland et al. 1999).

6 Conclusion

Pan-trap catches can be affected by the cover of the flowers in many ways. In the small scale different taxa were affected by colours of the flowers, hence a colour preference. Some taxa increase in number in the pan-traps when the preferred flower colour is around the pan-traps, while other decrease and other do not show any specific pattern. In the large scale, all significant results were negative or quadratic, regardless of preferred colours of the flowers. These results show that catches in pan-traps can give a misleading result for pollinator population fauna when flower cover and composition is not kept constant. If and how flower cover can be used to adjust for bias in catches remains to be established. Some taxa are more likely to be caught in either pan-traps or hand-net, and only Apoidea (excl. *Bombus*) showed a correlation in number of caught individuals between pan-traps and hand-netting, clearly showing that the two methods are fundamentally different prevent meaningful comparison when different methods have been used. This study shows that it is important to choose catching method depending on which taxa that should be surveyed and to think about the flower cover at the site being surveyed. Finally, as both population densities of insect and the abundance of flowers are subject to strong inter-annual variation, pan-traps seems ill-suited for monitoring.

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