Science and Justice 54 (2014) 49–56

Contents lists available at ScienceDirect

Science and Justice

journal homepage: www.elsevier.com/locate/scijus

The spatial and temporal distribution of pollen in a room: Forensic implications

R.M. Morgan [a,b,*], E. Allen [c], T. King [c], P.A. Bull [c]

[a] UCL Department of Security and Crime Science, Jill Dando Institute, 35 Tavistock Square, London, WC1H 9EZ, United Kingdom
[b] UCL JDI Centre for the Forensic Sciences, 35 Tavistock Square, London, WC1H 9EZ, United Kingdom
[c] Oxford University Centre for the Environment, South Parks Road, Oxford, OX1 3QY, United Kingdom

ARTICLE INFO

Article history:
Received 19 April 2012
Received in revised form 20 March 2013
Accepted 21 March 2013

Keywords:
Forensic palynology
Spatial and temporal trends
Indoor setting
Domestic room
Trace evidence protocols
Experimental studies

ABSTRACT

This paper presents two experimental studies that deal with the spatial and temporal distribution of pollen grains within a room of a domestic dwelling. The findings concur with the preliminary work of Morgan et al. [1] and provide greater detail as to the behaviour of pollen grains within indoor locations that are pertinent for forensic investigations. The spatial distribution of pollen in a room exhibits strong distance decay trends, with the majority of pollen recovered within 0.8 m of its source. The pollen was found to persist in increasing quantities during the time the flowers were in the room. This study also shows that 20 days after the flowers were removed, 25–32% of the original pollen was still present within the room. The influence of disturbance was investigated and whilst areas of high disturbance were found to retain less pollen than undisturbed locations, the influence of the proximity to source was a more dominant factor.

These findings have significant implications for forensic investigation protocols, particularly the collection and interpretation phases of trace evidence analysis. The distribution of pollen around a room ensures that viable sources of trace pollen are available for transfer if contact is made between a location in the room and a suspect. The persistence of pollen many days after the flowers have been removed from a room indicates that many rooms in domestic dwellings will have distinctive assemblages that reflect the history of the flowers that have been displayed within that room in the past, and that these assemblages will persist and therefore be available for transfer. These preliminary findings indicate that investigation by forensic palynology in indoor domestic settings may well be an underutilised technique that has the potential to provide accurate and valuable intelligence and evidence for forensic enquiry.

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1. Introduction

It has been well established that trace evidence can provide important intelligence and evidence in forensic investigations [2–7] and that pollen evidence in particular can provide highly valuable spatial and temporal information [8–12]. The majority of cases where pollen evidence has been successfully utilised have been either in the identification of a crime scene based on the pollen assemblages present on a suspect or victim [13] or refuting an alibi by identifying assemblages at a crime scene and on a suspect that could not be excluded from having a common source [14]. To date, it has rarely been used as a means of characterising a particular indoor location. Emberlin et al. [15] is the only study in this broad area (with a primary focus on occupational health issues), yet it but it has been recognized that '*…searches for forensic pollen need not be restricted to the outdoors*' ([9]:169). This study therefore aims to investigate whether indoor settings in domestic dwellings are likely to have specific pollen assemblages contained within them that may be useful for forensic investigation. Moreover, it is important to gain a better understanding of the nature of such pollen assemblages if pollen evidence is to be interpreted meaningfully in a criminal investigation where an indoor setting is being investigated.

Cut flowers are often displayed in rooms in domestic dwellings and in a forensic context it needs to be considered whether an offender who had broken into the house could have contact with surfaces or materials within a room such that transfer of pollen grains may occur onto the clothing of the perpetrator and even secondary and tertiary transfer [16]. This is contingent upon the underlying tenet in forensic geoscience, first introduced by Locard [17], that 'every contact leaves a trace' and that contact can initiate a two-way transfer (in this case from an object in the room to the perpetrator and from the perpetrator into the room). Since there have been no experimental studies undertaken to investigate whether the very specific pollen assemblages which can be found in a room (perhaps as a result of a cut flower display), it is presently difficult to provide acceptable evidence for a court implying that pollen grains found on a suspect could indeed have come from a

* Corresponding author at: UCL JDI Centre for the Forensic Sciences, 35 Tavistock Square, London, WC1H 9EZ, United Kingdom. Tel.: +44 20 3108 3037.
E-mail address: ruth.morgan@ucl.ac.uk (R.M. Morgan).

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http://dx.doi.org/10.1016/j.scijus.2013.03.005

contact made in a particular room. This study aims to go some way to providing an insight, under controlled experimental conditions, as to the efficacy of such pollen transfers and their interpretation in a forensic context.

Preliminary experimental work has demonstrated that pollen from cut flowers is dispersed around a room onto all types of surface, with most pollen found closest to its source (in this case the vase of flowers) [1]. This is, however, one preliminary study and these patterns have not yet been established as the general rule in different domestic dwellings. We present here further and fuller studies in different settings to those reported in Morgan et al. [1] in order to establish whether it is possible to identify general trends that can be applied more universally in the field of forensic science. These experimental studies aim firstly to establish the reproducibility of pollen grain dispersal throughout a room in a domestic dwelling; and secondly the longevity/persistence of the pollen grains in a domestic setting.

2. Pollen in a room of a domestic dwelling: implications for palynological investigations in domestic crimes

2.1. Rationale

In order to address these questions, additional experiments were undertaken to develop the work presented by Morgan et al. [1]. In this original work, two vases of flowers were placed in a living room as shown in Fig. 1 (each vase contained a different type of flower and for the three experimental runs, lily, freesia, campanula and lisianthus flowers were used). The room was sampled at 23 different locations (see Fig. 1) every 24 h for 9 days during which the flowers were present in the room (after control samples were taken to establish no background pollen was present). Additional sampling was also undertaken up to 40 days after the flowers were removed. This preliminary study identified that in terms of pollen distribution there was a strong spatial pattern of distance-decay from the vases of flowers placed within the room. Further, no statistically significant difference was found between the amount of pollen collected on hard (wooden) furnishings in comparison to soft (material) furnishings and pollen was found to persist within the room up to 40 days after the flowers were removed from the room.

Further experiments were designed for this present study utilising the same methodology as the preliminary study as outlined in Table 1. The experiment was undertaken in a different house in a different location whilst keeping as many of the variables in the original experiment as similar as possible. The experiment was repeated six times with two of the same flower types (in this case lily and freesia) in vases at either end of the room as shown in Fig. 2. For the first four runs of the experiment, the 22 sampling locations (which comprised a mixture of hard and soft furnishings and aimed to cover a broad spatial area) were sampled using double sided tape on an electron microscope stub (1.27 mm diameter) every 24 h for 9 days as was carried out in the preliminary experiment (reported by Morgan et al. [1]). This was undertaken in order to establish whether or not similar trends could be identified in the different rooms. For the final two runs the sampling time frame was extended so that the 22 sites were sampled every 48 h for 17 days. The flowers were then removed (after 9 days for runs 1–4 and after 17 days for runs 5–6) and the sites within the room were

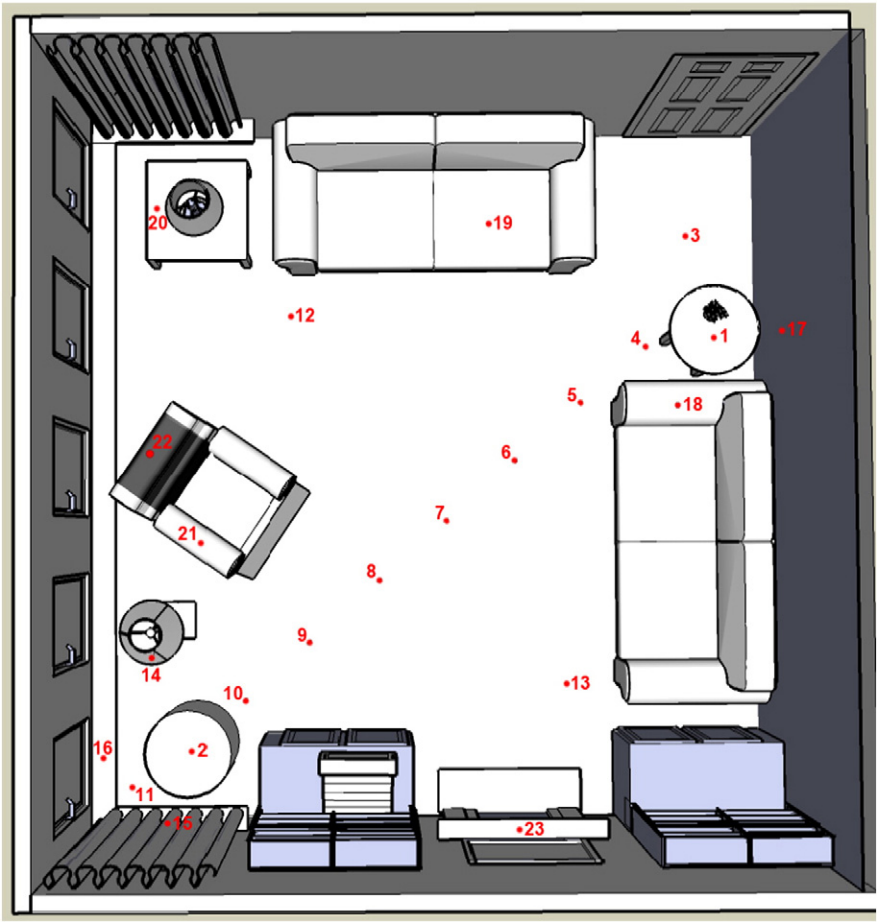


Fig. 1. Flower and sampling locations within the living room during the preliminary experiment outlined by Morgan et al. [1]. Vases of flowers were located at sampling points 1 and 2.

Table 1
An outline of experiments undertaken for this study.

Experiment	Length of time when flowers were in the room (days)	Sampling procedure	Length of time when sampling was undertaken after flowers were removed (days)
1	9	22 locations sampled every 24 h	20
2			
3			
4			
5	17	22 locations sampled every 48 h	
6			

Table 2
Mean daily lily pollen grain counts per sample site.

Distance from lilies	Site number	Mean daily lily pollen count per sample site						
		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Mean
0.41	16	62.4	160.0	193.2	25.9	16.2	11.8	78.3
0.5	13	108.3	47.7	174.9	57.2	268.1	253.2	151.6
0.55	14	164.8	111.6	141.2	73.0	430.9	582.1	250.6
0.58	22	1.7	1.7	0.4	0.0	3.3	4.4	1.9
0.8	15	139.7	76.2	17.0	63.1	340.1	206.2	140.4
1.1	12	35.0	1.7	287.8	33.2	99.0	92.1	91.5
1.53	21	0.3	0.2	0.4	0.2	0.0	0.0	0.2
1.57	17	0.7	1.6	0.0	0.9	0.6	0.3	0.7
1.65	11	1.8	0.6	0.3	2.2	5.1	5.1	2.5
1.8	18	1.3	0.3	0.2	0.7	5.0	8.6	2.7
2.34	10	0.0	0.1	0.0	0.0	0.0	0.0	0.0
2.36	19	0.4	0.1	0.9	0.3	0.2	0.0	0.3
2.89	9	0.6	0.0	0.7	0.2	1.0	0.0	0.4
3.16	20	0.4	0.4	0.4	0.3	0.0	0.0	0.3
3.5	8	0.1	0.3	0.1	0.0	1.3	0.0	0.3
3.9	6	0.0	0.0	0.0	0.0	0.2	0.0	0.0
3.93	7	0.1	0.0	0.0	0.0	0.7	0.0	0.1
3.97	4	0.4	0.1	0.7	0.2	0.1	0.1	0.3
4.04	5	0.0	0.2	0.1	0.0	0.0	0.0	0.1
4.52	2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
4.56	3	0.0	0.0	0.9	0.2	0.0	0.0	0.2
4.64	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

sampled every 5 days for the next 20 days for runs 3–6. At the end of each experimental run, the room was thoroughly cleaned and control samples were taken to establish the cleanliness of the room for subsequent runs.

2.2. Spatial trends

It was found that many of the spatial trends identified in the previous study [1] were reproduced in the new setting. Tables 2 and 3 provide the details of the mean daily pollen grain counts at each sampling location for both lily and freesia pollen. The majority of pollen grains were deposited within 1 m of the pollen source, although grains were found at the far extent of the room (up to 3.25 m for freesia and 4.56 m for lily).

Figs. 3 and 4 provide a graphical representation of the mean pollen counts for each of the six runs and clearly demonstrate a general distance decay trend for both lily and freesia pollen. It is interesting to note that there is a greater degree of variability for the lily pollen in comparison to the freesia pollen. Fig. 5 provides the mean counts for all six runs for both pollen types and illustrates the distance decay relationship for both lily and freesia pollen and also shows the mean similarity between both pollen types which indicates that they are exhibiting similar behaviour.

Fig. 6 demonstrates the spatial trend of pollen distribution in a schematic diagram. The room in which the experiment was conducted was mapped onto a grid and the sampling locations positioned within that grid to provide an indication of the variation across space. This diagram exhibits the distance decay relationship very clearly and also illustrates

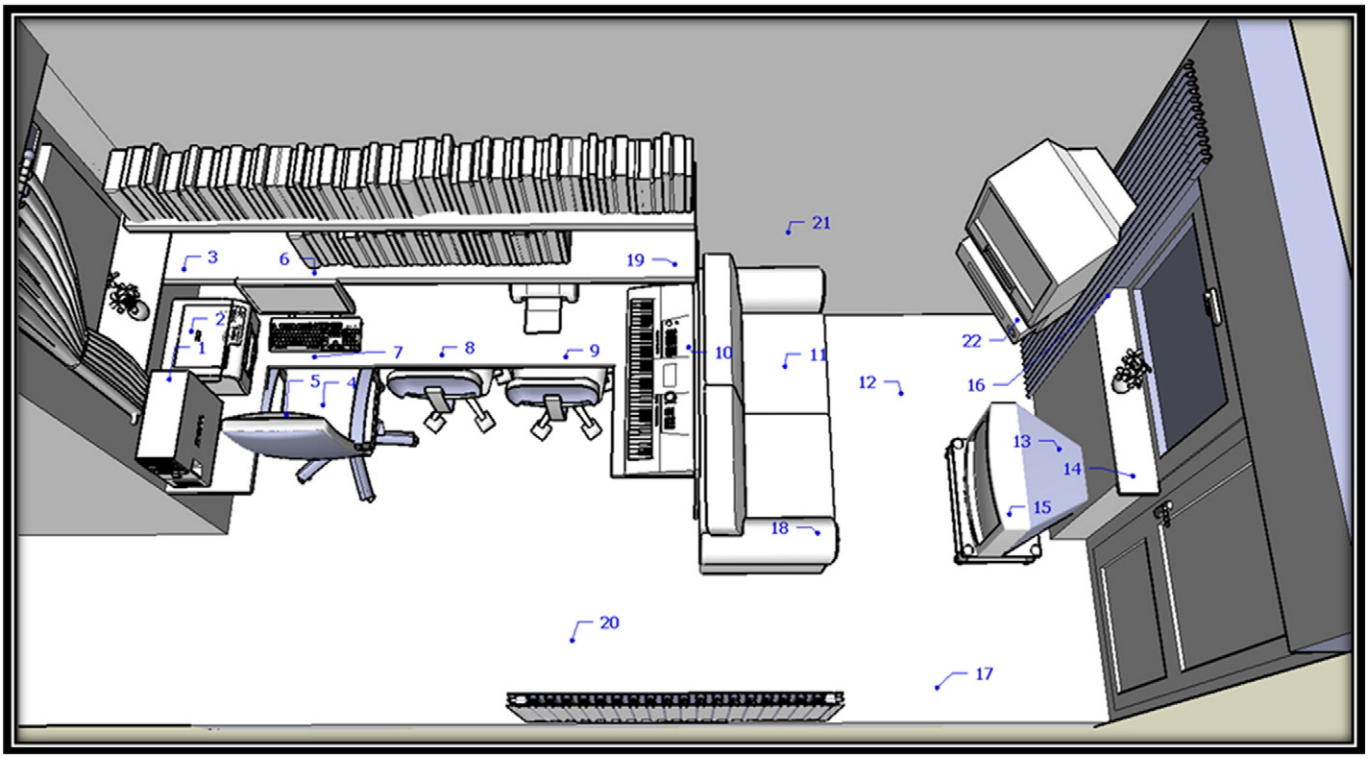


Fig. 2. Flower and sampling locations with the room for the experiments undertaken in this study.

Table 3
Mean daily freesia pollen grain counts per sample site.

Distance from freesias	Site number	Mean daily freesia pollen count per sample site						
		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Mean
0.25	1	12.7	50.1	71.4	9.8	50.3	90.2	47.4
0.32	2	11.8	43.3	50.2	9.1	36.0	76.8	37.9
0.39	3	3.2	37.9	24.9	2.7	34.1	42.1	24.1
0.83	4	1.6	4.9	1.8	1.4	2.0	15.6	4.5
0.89	7	1.2	4.0	1.0	1.2	1.7	10.4	3.3
0.9	5	1.2	1.1	0.7	1.1	0.7	2.3	1.2
0.96	6	1.2	1.1	0.4	1.0	0.3	2.1	1.0
1.29	8	0.4	0.9	0.4	0.4	0.1	0.6	0.5
1.89	9	0.2	0.7	0.3	0.2	0.0	0.0	0.2
2.23	20	0.2	0.4	0.2	0.2	0.0	0.0	0.2
2.45	10	0.1	0.2	0.1	0.1	0.0	0.0	0.1
2.51	19	0.0	0.2	0.0	0.0	0.0	0.0	0.0
3.19	11	0.0	0.1	0.0	0.0	0.0	0.0	0.0
3.25	21	0.0	0.1	0.0	0.0	0.0	0.0	0.0
3.34	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.7	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.24	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.35	17	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.38	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.51	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.67	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.78	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0

the zone of high pollen count for both lily and pollen around each vase. These findings concur with those of Morgan et al. [1] mentioned previously.

These findings indicate that the presence of cut flowers in a room will lead to the distribution of pollen grains around a room and certain areas will have high concentrations of these pollen grains that will be available for transfer should a contact be made. It also demonstrates that different monocot pollen types generally exhibit similar spatial trends in a room. This has implications for the collection phase of a forensic investigation; given the availability of pollen grains for transfer to a suspect, should a contact have been made with surfaces within the room it will usually be worthwhile to collect trace pollen evidence from a wide variety of surfaces within that room for subsequent comparison with clothing seized from a suspect.

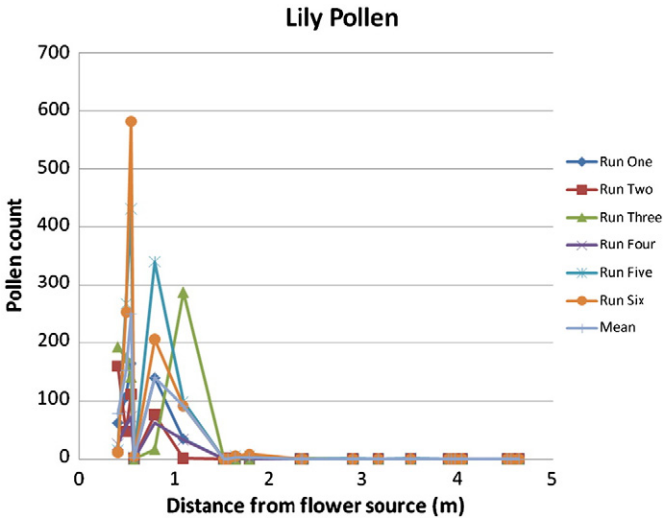


Fig. 3. Mean number of lily pollen grains collected at different sources within a room for each experimental run.

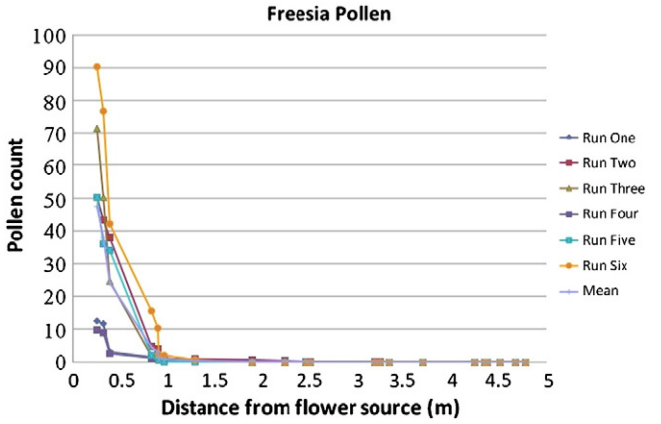


Fig. 4. Mean number of freesia pollen grains collected at different sources within a room for each experimental run.

2.3. Temporal trends

This study demonstrated that whilst the flowers were present within the room, the amount of pollen collected at each sampling location generally increased as shown in Fig. 7 (for days 1–9). For lily, the amount of pollen generally increased and reached a peak on day 9. Freesia demonstrated a similar pattern but the greatest amount of pollen was collected on day 6. Fig. 8 includes the data for runs 5 and 6 which extends the time frame to 17 days. This demonstrates that as the time frame increases there appears to be a general overall trend of increase in pollen collected. However, the amount of pollen does not continue to increase uniformly over time, there are a number of sharp increases (between days 8 and 9 for example) followed by decreases (between days 9 and 11) and so the general trend is less clear. It is possible that these trends are due to the variation in air flow within the room which may well be a function of the amount of use made of the room by the occupants of the dwelling.

Figs. 9 and 10 show the results for runs 5 and 6 over the longest time period investigated during this experiment. The mean lily pollen count for these two runs steadily increases to day 9 and then broadly decreases albeit at a slower rate. Freesia exhibits the same initial increase (days 1–7) and then undergoes a slight decrease (days 7–9) before a steep increase between days 13 and 17. This trend demonstrates the variability in the temporal distribution of the monocot pollen types which may be due to the external morphology of the grains, or, perhaps more likely, the different location of the vases within the room. Given the pollen types identified in each sample and the surrounding environment it is unlikely that an external source of freesia or lily was available.

Once the flowers were removed from the room, there was a clear steady decline in the amount of pollen collected as Fig. 11 shows. For all four runs (runs 3–6) the pollen exhibits the classic decay curve within the room (as has been demonstrated for many types of trace physical evidence [2]). It is interesting to note that 20 days after the flowers were removed (29 days after the flowers were introduced to the room for runs 3 and 4, and 37 days for runs 5 and 6) 25–32% of the original amount of pollen (when the flowers were removed) was found to still be present in the rooms and to be available for transfer. This has significant implications for the collection and interpretation stages of the forensic investigation. Pollen grains from cut flowers persist for a very long time within a room even after the flowers have been removed. It is likely therefore, that rooms in domestic dwellings are likely to have distinctive pollen assemblages indicative of the cut flowers that may have been displayed in the preceding days, weeks and even months before the forensic event. Even if cut flowers are not apparent within an indoor crime scene, these findings suggest that it will be worthwhile to collect trace evidence from the scene for subsequent comparison with garments taken from a suspect. It also provides fuller context for more accurate

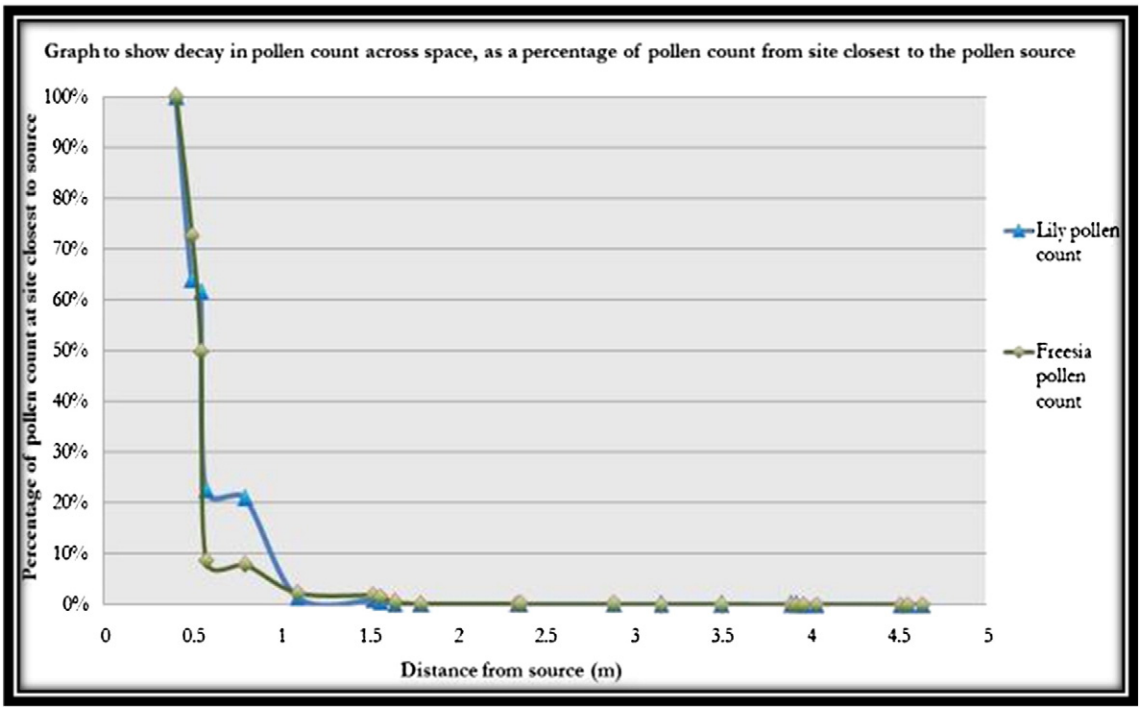


Fig. 5. Mean number of lily and freesia pollen grains collected (n = 6) with distance from the source.

interpretation of the presence of such pollen grains at a specific scene and on a suspect.

2.4. Other trends

2.4.1. Influence of monocot pollen type

Table 4 shows the total amount of each type of pollen collected in each of the 6 runs. Overall, lily produced more pollen than freesia (a ratio of 6:1), however, the patterns of pollen dispersal and persistence for both pollen types were consistent with one another. Therefore, whilst lily pollen was more abundant, both pollen types were found to disperse within a room and persist for many days. Thus, both types of pollen were available for transfer within the room setting albeit in different amounts. This finding has similar implications for a forensic investigation as outlined above in Section 2.2.

2.4.2. Different types of surface (disturbed/undisturbed)

Morgan et al. [1] commented on the lack of statistical difference between the amount of pollen recovered from different types of surfaces (flooring, hard and soft furnishings), therefore, this experiment categorised the different sampling locations according to their level of exposure/disturbance as Table 5 shows. This experiment demonstrates that in general, a far greater proportion of pollen was recovered from 'undisturbed sites' (76%) in comparison to sampling locations that were exposed to more disturbance (24%). This suggests that either disturbance inhibited pollen deposition at these sites, or that pollen was deposited but underwent transfer and was then transported out of the room.

It is interesting to note that of the 'disturbed' sites, the best retainers appear to be sampling locations 12 (carpet) and 16 (curtains); both soft furnishings. In contrast, of the 'undisturbed' sites, the greatest pollen retention was found at sites 13–15 (TV, window sill and TV respectively) followed by sites 1–3 (computer tower, printer and shelf). All of these sampling locations were hard surfaces. It is also important to note that locations 12 and 16 were both within 1 m from the freesias, locations 13–15 were between 0.5 and 0.8 m of the freesias and 1–3 were between 0.25 and 0.39 m from the lilies (as Tables 2 and 3 indicate). Therefore, all the locations which exhibited relatively high retention of pollen were located within 1 m of one of the sources of flowers. This seems to suggest that whilst disturbance has an impact on the retention of pollen, the distance decay effect appears to have a greater influence on the amount of pollen retained on a surface.

Table 5 also demonstrates that the greatest disparity in pollen count between 'disturbed' and 'undisturbed' sites occurred during runs 5 and 6 (which were carried out over a longer time frame to runs 1–4). This trend suggests that the effects of disturbance may well become more pronounced over time. It is therefore important to take into account not only the distance decay spatial pattern of pollen dispersal when taking samples, but within that context to also be aware of the relative retentive properties of different types of furniture under different degrees of usage and the likely time frame of pollen accumulation to ensure optimum sampling. These findings indicate that whilst undisturbed sites will potentially prove to be a greater source of pollen grain evidence, a more exposed/disturbed location within a room may still be worth sampling if it is of relevance to the investigation as pollen grains can persist in such locations.

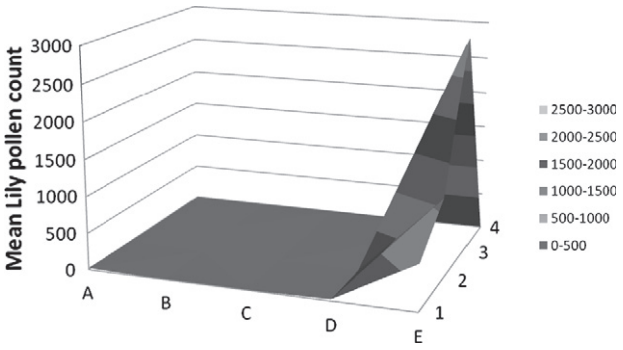
2.4.3. External sources of pollen

Table 6 shows the type and number of pollen grains (other than lily and freesia) that were found within the room for five of the experimental runs. These 'externally sourced' pollen grains were generally found at the sampling locations close to the windows, and it is interesting to note that the number of 'external' grains was generally concentrated in the later runs. This appears to reflect that the temporality of pollen production (run 1) was undertaken in early April, whilst the subsequent runs were carried out in May (runs 2 and 3), June (run 4), and July (run 5). Whilst no external pollen was identified in runs 1 and 2, grass pollen was found in reasonable numbers in runs 3–5, whilst single grains of tulip, fuchsia, and small numbers of oak and pine were also collected.

a. Sample sites in Grid Squares

	A	B	C	D	E
1	3,6	-	19	21,11	12,16
2	1,2,4,5,7	8	9,10	-	13,22
3	-	-	-	18	14,15
4	-	-	20	17	-

b. Spatial distribution of lily pollen (n=6)



c. Spatial distribution of freesia pollen in the room (n=6)

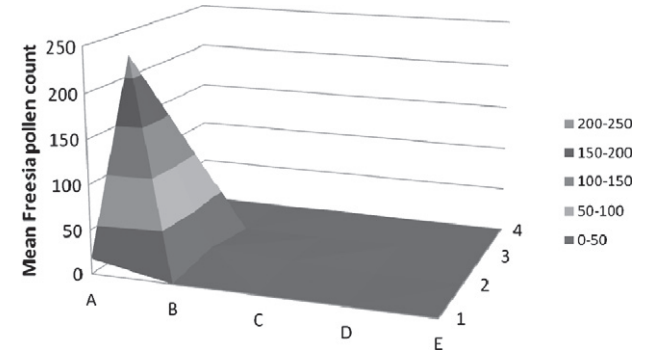


Fig. 6. The spatial trends identified for each pollen type. a. Sample sites in grid squares. b. Spatial distribution of lily pollen (n = 6). c. Spatial distribution of freesia pollen in the room (n = 6).

2.5. Summary

Overall, this study has shown that pollen grains from cut flowers disperse spatially around a room with a distinct distance decay trend. The pollen also exhibits remarkable and surprising persistence over time, often persisting in significant numbers weeks after the flowers have been removed from the room of a domestic dwelling. The greater number of runs carried out for this study has demonstrated that whilst these trends are identifiable in the different setting, they do exhibit variability. The type of pollen, whilst exhibiting different abundance, does broadly conform to the same patterns of dispersal spatially and temporally.

The relative disturbance experienced by a sampling point (in addition to its distance from the pollen source) has been shown to have a broad impact on the amount of pollen retained, but it is important to note that there are exceptions, and it is difficult to distinguish between the factors of distance to a pollen source and degree of disturbance.

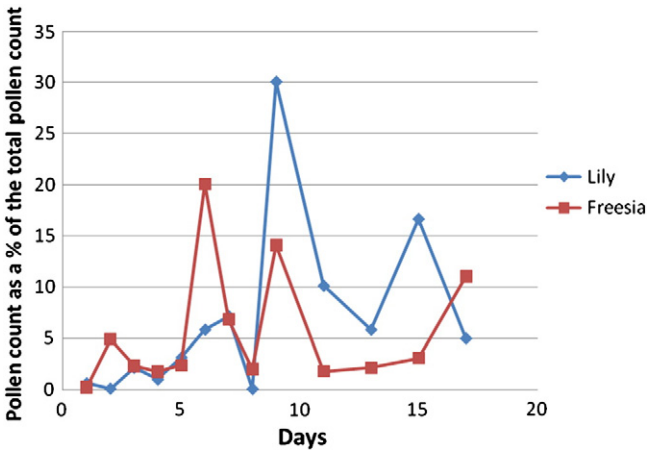


Fig. 7. Mean pollen count in the room (runs 1–4).

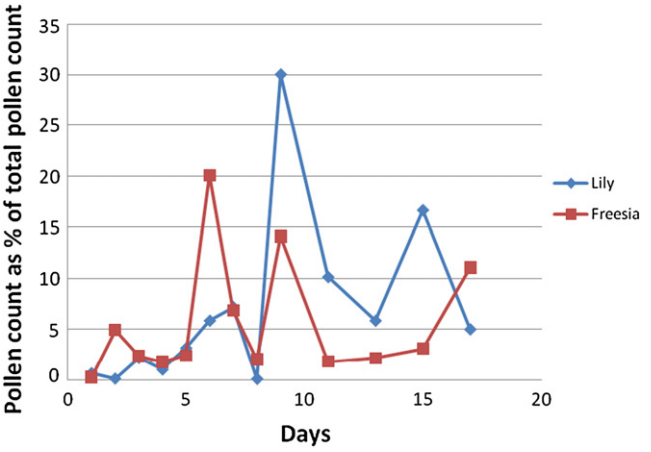


Fig. 8. Mean pollen count in the room (runs 5 and 6).

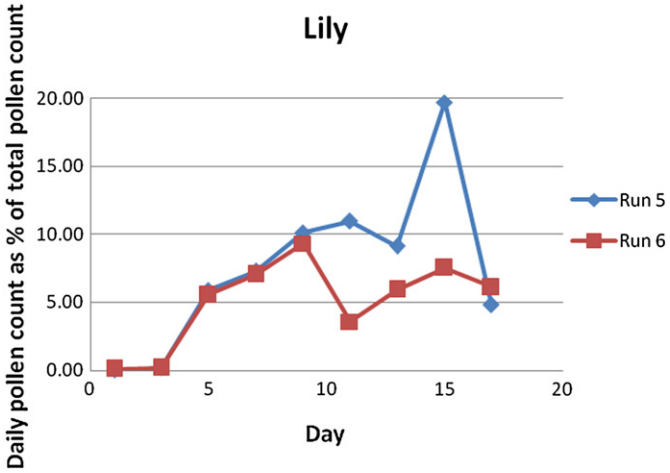


Fig. 9. Mean lily pollen count within the room (runs 5 and 6).

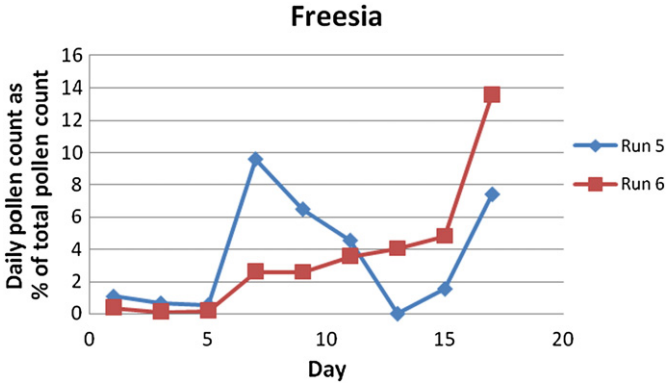


Fig. 10. Mean freesia pollen count within the room (runs 5 and 6).

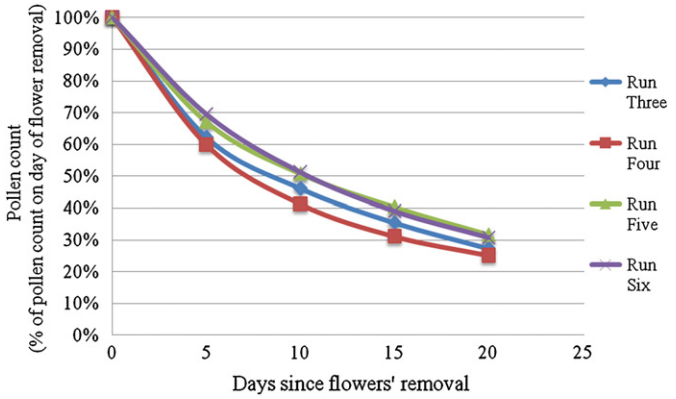


Fig. 11. Mean pollen count after the flowers were removed from the room (runs 3–6).

Table 4
The total amount of pollen grains collected in each room for all runs.

Run	Total lily pollen	Total freesia pollen
1	4664	305
2	3626	1306
3	7374	1364
4	2328	246
5	10,577	1127
6	10,476	2161
Mean total	6508	1085
Standard deviation	3527.9	720.9

This study has also demonstrated that it is highly likely that rooms in domestic dwellings do not act as hermetically sealed units; aerial transfers occur. This is likely to increase the distinctiveness of the pollen assemblage found under these circumstances which may have beneficial implications for the forensic comparison of pollen samples taken from clothing that may (or may not) have made contact with a surface in such a room.

3. Forensic implications

This study presents three main implications for forensic sampling protocols in domestic dwellings:

1. There is a potential for a person entering a room to be subject to the transfer of exotic zoophilous pollen grains onto their clothing which could serve as evidence of contact with that room; direct contact with the flowers is not required.
2. The 'zone of high pollen count' of 0.8 m radius of the pollen source is likely to yield high pollen counts. Surfaces within this zone which yield low pollen counts are likely to have experienced disturbance. Nevertheless, during a forensic investigation these findings indicate that it is worthwhile to sample any area of interest within a room as a distinctive pollen assemblage may be present and available for transfer. Such sampling may prove to be of great use for comparison studies with samples taken from the clothing of a suspect.
3. Pollen is likely to be present many days or even weeks after flowers have been removed from a room. This increases the opportunity for exotic and very location-specific pollen assemblages to accumulate in domestic dwellings which may be transferred through direct contact onto clothing. It is therefore possible for a suspect to pick up a highly distinctive pollen grain assemblage through making contact with any surface within a room in a domestic dwelling which may well provide useful intelligence or indeed evidence for a forensic investigation.

The findings of this specific study therefore highlight the potential availability of pollen grains within a domestic dwelling and the potential distinctiveness of the pollen assemblage. This has significant

Table 5
The pollen counts at disturbed and undisturbed sites in the room.

Sample site			Total amount of pollen sampled						
			Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Mean
1		Computer tower	106	341	452	88	307	691	330.8
2		Top of printer	115	452	643	82	453	812	426.2
3		Shelf	29	390	232	26	324	379	230.0
4		Chair seat	15	37	12	15	7	141	37.8
5		Chair head rest	11	12	10	10	15	5	10.5
6		Shelf	2	2	4	2	2	21	5.5
7		Desk	15	44	4	9	24	94	31.7
8		Desk	12	13	17	11	15	19	14.5
9		Desk	9	8	9	6	9	0	6.8
10		Keyboard	0	5	2	2	0	0	1.5
11		Sofa seat	16	5	3	20	47	46	22.8
12		Carpet	316	15	2591	299	891	829	823.5
13		Television	975	429	1584	515	2413	2279	1364.2
14		Window sill	1483	1004	1271	657	3878	5239	2255.3
15		Television	1257	686	453	568	3061	1856	1263.5
16		Curtains	562	1440	1739	233	146	106	704.3
17		Wall	6	14	7	8	5	3	6.0
18		Sofa arm	12	4	2	6	45	77	24.3
19		Shelf	4	1	8	3	2	0	3.0
20		Carpet	6	10	4	4	0	0	4.0
21		Wall	3	4	4	2	0	0	2.2
22		VCR	15	16	4	8	30	40	18.8
Total			4969	4932	9055	2574	11674	12637	7587.3
% yielded undisturbed sites			80%	68%	52%	76%	90%	90%	76%
% yielded disturbed sites			20%	32%	48%	24%	10%	10%	24%

Table 6
The type and number of 'external' pollen grains identified in the room (runs 1–5).

	Grass	Tulip (*Tulippa*)	Fuchsia (*Thalia*)	Oak (Quercus)	Pine (*Pinus*)
Run 1	0	0	0	0	0
Run 2	0	0	0	0	0
Run 3	196	0	0	0	0
Run 4	504	1	0	7	0
Run 5	739	0	1	1	12

implications for trace evidence collection and analysis protocols. This study also illustrates the great potential for palynological analyses of samples taken from crime scenes in domestic dwellings and may indicate the extent to which forensic palynology is at present an underutilised tool in forensic investigations in domestic settings. Further work must address palynomorph morphological variability.

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