Metadata for

"Impacts of multiple pollutants on pollinator activity in road verges"

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SUMMARY

The study was carried out in Cornwall, United Kingdom in 2019 and 2020. First, we used roadside surveys to assess the spatial distribution of pollution, flowers and pollinators in road verges. Second, we used field experiments (away from roads) to simulate each form of pollution separately and measure the impacts on pollinator densities and foraging behaviour to explain the distribution of pollinators observed across road verges.

MATERIALS AND METHODS (from manuscript supporting information)

Spatial distribution of pollution, flowers and pollinators (roadside surveys)

We surveyed nine road verges (Fig. 1) to compare the spatial distribution of pollution, flowers and pollinators within and between road verges. Sites were a minimum of 3 km apart, and were all located in landscapes dominated by agriculture, but covered a variety of road types (major roads to unclassified rural roads) and traffic densities (110-1,416 vehicles h⁻¹). Verges were all at least 9 m wide to allow measurements over a range of distances (Table 1), and were adjacent to arable or pasture fields, separated by a hedge. At each site, we set up four 50 m transects parallel to the road at distances of 1, 3, 5 and 8 m from the road edge (Fig. 2). We measured the width of each road verge at distances of 5, 15, 25, 35 and 45 m along the transect and calculated a mean. We measured traffic density by counting the number of vehicles passing by the road verge in either direction for 10 min, on three separate days, between 09:00 and 16:30.

Pollution measurements. We measured noise, turbulence, dust and metals along each transect, and measured background levels for areas away from roads where required.

Noise. We used a digital sound meter (Voltcraft SL-200), held at chest height and arm's length, and took measurements of the maximum noise level (dB(A)) when a vehicle passed. We took measurements for five vehicles on three different days along each transect. We used 40 dB(A) as the upper limit of typical outdoor background noise level in the absence of traffic (Gjestland, 2008).

Turbulence. We estimated the relative force exerted by traffic-generated turbulence with a "pollinator swingometer": recording how much the body of a dead pollinator was moved when a vehicle passed. This method was developed because an anemometer inadequately measured traffic-generated turbulence. The pollinator swingometer was a 40 cm plastic stake, with a 180° protractor

attached to the top, facing downwards, with a dead pollinator (*Platycheirus* sp. hoverfly, 20 mg) suspended from a 10 cm piece of cotton thread at the top of the stake (Fig. 3). We measured the angle that the hoverfly swung to (to the nearest 10°) when a vehicle passed by on the same side of the road. We took measurements for five vehicles along each transect, on days with little wind (< Beaufort 2).

Dust. We placed three 40 cm plastic stakes along each transect and attached transparent sticky tape to the top of each, with a 2 cm² area of the sticky side exposed, facing the road (Fig. 4). We assessed background levels by placing stakes at three locations (the control sites for the dust experiment; see below) with similar vegetation, but at least 50 m from roads. After 4 days, we collected the tape and scored it based on the amount of visible dust. Scoring was on a 5-point scale, where 0 was no visible dust and 4 was extensive visible dust (differences between each point on the scale were apparent with the naked eye; see Fig. 4).

Heavy metals. We collected a representative sample of flowers along each transect (an equal proportion of the total number of floral units that were present for each plant species). We assessed background levels by collecting vegetation from the far edge of an adjacent agricultural field (at least 50 m from roads) at three sites. In the laboratory, we freeze dried and ground the samples, then used mass spectrometry (ICP-MS) to measure the concentrations of five roadside heavy metal elements: Cd, Cu, Pb, Sb and Zn (Werkenthin et al., 2014).

Flower and pollinator surveys. We compared flower and pollinator communities along each transect to explore if they changed across expected pollution gradients. We refer to flower-visiting insects here as 'pollinators', though actual pollen transfer was not measured. Surveys took place between 29th April and 22nd May 2019. This short, intensive survey period was necessary because road verges were cut from late May onwards. This would have acted as a problematic confounding factor because (i) some verges had no flowers remaining due to being cut, and (ii) some verges had only part of the verge cut, resulting in differences in flower density and species richness with distance from the road. Furthermore, these roadside surveys aimed to supplement, at greater resolution, those carried out in the previous year across the entire season (Phillips et al., 2019), which found consistently and substantially fewer pollinators along verge edges compared to in the middle of verges, suggesting that any trends identified in pollinator densities would likely apply at other times of the year.

Surveys were carried out on days with no rain, temperature at least 12°C, and wind speed less than Beaufort scale 4. Temperature (°C) and wind speed (Beaufort scale) were recorded at the start of each survey. We recorded the identity and total number of each species of flower along transects within 1 m either side. A floral unit was defined as one or multiple flowers that can be visited by an insect without having to fly between them, following Baldock et al. (2015). We walked each transect in both directions at a steady pace over roughly 10 min and recorded all pollinators within 1 m either side of the transect and 2 m ahead. When a pollinator was observed visiting a flower, we also recorded the species of flower. Bees, hoverflies and butterflies were identified to genus or species where possible (if necessary, taking voucher specimens). To avoid excessive collecting, we often used morphotypes for certain pollinator groups that were abundant but difficult to identify, e.g. *Platycheirus* spp. and *Melanostoma* spp. hoverflies. The *Bombus terrestris/lucorum* complex were recorded together because they cannot be readily distinguished in the field. Beetles and non-Syrphid flies were recorded to order, except for common and distinctive species, e.g. *Oedemera nobilis* (thick-legged flower beetle), *Scathophaga stercoraria* (yellow dung fly), Bibionidae spp. (March flies), and Empididae spp. (dagger flies). For analyses, we grouped pollinators into flies (non-syrphid Diptera), hoverflies (Syrphidae), moths (Lepidoptera), bumblebees (*Bombus* spp.), solitary bees (non-*Bombus*, non-*Apis* Apoidea) and sawflies (Symphyta). Butterflies (Lepidoptera), beetles (Coleoptera), and honeybees (*Apis mellifera*) were observed too rarely (< 10 % of surveys) to carry out formal analyses. We surveyed each transect twice per day, on three separate days.

Sentinel plants. As few bees were observed during the roadside surveys, we conducted an additional experiment (15th-23rd July 2019) using sentinel plants to assess bee visitation at different distances from roads, in three of the nine road verges (sites 3, 4 and 7; Table 1) that had been cut (containing few other floral resources). We grew 20 plants of *Borago officinalis* (a highly attractive bee foraging plant) from seed in compost (Verve Peat Free Multipurpose), then transferred them to Ø 25 cm pots. Once flowering, we moved plants to one of the road verges. We allocated plants to one of five blocks, with four plants in each. Blocks were placed at distances of 5, 15, 25, 35 and 45 m along the transects, with plants placed in each block at distances of 1, 3, 5 and 7 m from the road (Fig. 5). We used 7 m for the furthest transect in this case (instead of 8 m) so that plants in rows were equally spaced. We left plants for 24 h, then observed plants during 5 min periods, carried out three times per plant. During observations, we recorded the number of bees visiting the plant. Once finished, we collected the plants, watered their foliage to remove possible roadside dust and then repeated the experiment at the other two road verges on different days. We rotated the position of plants within blocks, and of blocks along transects, between sites.

Effects of pollution on pollinator activity (pollution experiments)

We carried out four field experiments across three non-roadside sites to separately test the effects of 'medium' and 'high' road-realistic levels of noise, turbulence, dust and metals on pollinator densities and foraging behaviour. Whilst different forms of pollution may have interacting and synergistic effects, we chose to do separate experiments because the methodology required for exposing pollinators to the different pollutants in a realistic way differed between pollutants. Experimental exposure to noise and turbulence was done using wild plant communities, whilst exposure to simulated roadside dust required potted plans and exposure to simulated metals in nectar required feeders. The noise and turbulence experiments both used Before-After-Control-Impact (BACI) designs because treatments affect surrounding areas so couldn't be run simultaneously, whereas the dust and metals choice experiments both used Latin Square designs. Thus, comparisons between pollutants are inferred rather than direct.

Noise experiment. The noise experiment used a speaker to play sound files of traffic noise (Fig. 6). To summarise, it used a BACI design in 1 m² wildflower patches, and recorded measures of pollinator density and bumblebee foraging behaviour during 5 min observations before and after the treatment had been applied.

Traffic noise was recorded next to a busy road (Site 1; 1,416 vehicles h⁻¹) and next to a more typical road (Site 6; 348 vehicles h⁻¹). Recordings were made in the road verge, 1 m from the road edge, using a portable digital recorder (Olympus LS-100) and a microphone (Sennheiser M67/K6) equipped with a windshield, and saved as uncompressed WAV files. Sound files were edited using Audacity software to cut down to 6 min. To control for potential effects of background noise on audio recordings, we created a control audio file that consisted of the audio file for the typical road with the sections where passing vehicles could be heard edited out. On the final recordings, vehicles can be heard passing at an average of 24 vehicles min⁻¹ (busy road; File 1), 6 vehicles min⁻¹ (typical road; File 2) and 0 vehicles min⁻¹ (control; File 3) (Appendix S2). The four experimental treatments consisted of the three sound files played from a speaker (Foxpro Fury 2) and an additional control

with no playback: (i) Control 1: speaker turned off, (ii) Noise (medium): playback of typical road (6 vehicles min⁻¹), (iii) Noise (high): playback of busy road (24 vehicles min⁻¹), and (iv) Control 2: playback of typical road, with vehicle sounds edited out (0 vehicles min⁻¹).

The experiment was carried out from $17^{\text{th}}-24^{\text{th}}$ June 2019, and used a BACI design in 1 m² wildflower patches to measure the impacts of experimental treatments on pollinator activity. First, we marked out a 1 m² flower patch and recorded the flower species and number of floral units. We arranged the speaker next to the area (raised 30 cm from the ground on a table) (Fig. 6), waited 1 min for pollinators to recover from any disturbance then recorded pollinator visitation to the patch for 5 min. We also recorded the behaviour of individual bumblebees (number of flowers visited and time spent in the patch). We then applied one of the four treatments, waited 1 min, then recorded pollinator visitation again for 5 min. The volume of the speaker was set at a constant level, based on field measurements, so that the sound level reached 85 dB(A) 1 m from the speaker when vehicles passed on the Noise (high) sound file. We repeated this process for the three remaining treatments in different flower patches (with similar flower communities), together constituting a single experimental replicate, and carried out 24 replicates. To reduce possible impacts of the previous treatment, consecutive treatments were > 10 m apart, at which distance the noise level from the speaker was less than 70 dB(A). We alternated the position and direction of the speaker between treatments and alternated the treatment order between replicates.

Turbulence experiment. The turbulence experiment used blower fans to simulate an intermittent disturbance due to wind (Fig. 7). As for the noise experiment, it used a BACI design in 1 m² wildflower patches, recording measures of pollinator density and foraging behaviour during 5 min observation before and after the treatment had been applied.

Three in-line blowers (12 V, 4 A, 10 cm diameter, 6.7 m³ maximum wind capacity, 235 cfm) were mounted on a piece of wood. Blowers were connected to a 12 V battery and a timer relay (Velleman VM206), which was programmed to turn on periodically for 1 sec at a rate equivalent to vehicles passing by on one side of the road at a typical roadside (3 vehicles min⁻¹) and at a busy roadside (12 vehicles min⁻¹). Note that these rates of vehicles passing are half those in the noise experiment, because we assumed that turbulence in a road verge is exclusively from vehicles passing on the same side of the road because turbulence is primarily limited to within 3 m (see main text, Fig. 1), and roads of these traffic volumes are generally at least double this in width. The blowers produced similar "pollinator swingometer" measurements to those measured in the roadside surveys, and a wind speed of approximately 15 km h⁻¹ 1 m away, which is comparable to field measurements in other studies (Bani-Hani et al., 2018). Whilst this was not a perfect imitation of traffic turbulence, it provided a comparable form of intermittent disturbance. Blowers also generated 75 dB(A) of noise 1 m away. The four experimental treatments were: (i) Control 1: blower turned off, (ii) Turbulence (medium): 1 m from typical road (3 vehicles min⁻¹: 1 sec on, 19 sec off cycle), (iii) Turbulence (high): 1 m from busy road (12 vehicles min⁻¹: 1 sec on, 4 sec off cycle), and (iv) Control 2: blower turned on, as for Turbulence (high), but facing away from the observation area, controlling for noise and other possible effects of the blower.

The experiment was carried out from 24th-28th July 2019. As for the noise experiment, we used a BACI design in 1 m² wildflower patches, recording measures of pollinator density and foraging behaviour during 5 min observation before and after the treatment had been applied, for a total of 24 replicates. However, blowers were arranged at the height of the majority of flowers in the patch rather than at a constant height (Fig. 7). We additionally recorded the behaviour of all bees and flies because simulated noise dissipated beyond the 1 m² area, whereas simulated turbulence did not. This meant that measures of pollinator visitation to the 1 m² area in the noise experiment reflected

deterrence effects, whilst deterrence effects in the turbulence experiment were primarily limited to pollinator behaviour within the 1 m^2 patch.

Dust experiment. The dust experiment used a choice experiment with potted plants and a Latin Square design (Fig. 8). Forty-eight plants of Sinapis arvensis were grown from seed in compost (Verve Peat Free Multipurpose), then transferred to ø 14 cm pots and watered regularly. The experiment was carried out once plants were flowering, between 28th June and 4th July 2019. Plants and foliage were thoroughly watered to remove any existing dust in the evening prior to the experiment. The following morning, plants were split between three locations – two bordering the University campus study site and one bordering the University research field site (Table 2), each consisting of a road verge and a non-roadside grassland area > 50 m away from the road. Roads were two major roads (estimated vehicles $h^{-1} = 800-1000$) and a minor road (estimated vehicles $h^{-1} =$ 200-400). At each location, plants were arranged according to four experimental treatments: (i) -Control: positioned > 50 m from the road, (iii) Road 4 m: positioned 4 m from road, (ii) Road 1 m: positioned 1 m from road, and (iv) +Control: positioned > 50 m from road, but prior to data collection, dusted extensively with roadside dust (collected with a dust pan and brush from edges of the respective road, sieved to exclude particles over 1 mm, then 20 g slowly sieved over the top of the plant over approximately 10 sec; this was a somewhat arbitrary amount, but was sufficient to cover the plant thoroughly in dust, representing an extreme situation). Plants were left for 4 days, though watered at the start and after 2 days, avoiding foliage and potential removal of roadside dust. During this time there was little or no rainfall, which would otherwise have washed dust from the plants, undermining the experimental treatments. After 4 days, plants were retrieved (minimising disruption to the plants and potential loss of roadside dust), transported to the University campus study site (Table 2), and arranged in three Latin Squares (5 x 5 m, cut to remove wildflowers) with plants spaced 1 m apart and arrays at least 20 m apart (Fig. 8). Over the following two days, we carried out eight 5 min observations of each plant, observing one quarter of an array at a time (4 plants), and recorded all pollinators visiting each plant, and the number of flowers visited and visit duration to each plant for individual pollinators. On the second day, half of one array were eaten by rabbits, so measurements were curtailed for those.

Metals experiment. The metals experiment also used a choice experiment with Latin Square design, but used experimental feeders arranged in a single experimental array replicated across three days. The four experimental treatments (C, HMx1, HMx2, HMx10) were 50% (w/v) aqueous sugar solutions containing different concentrations of metals typical of those found on roads and emitted by vehicles (Cd, Cu, Pb, Sb and Zn), based on field measurements (Table 3). In the laboratory, we prepared a single base metal solution (a ten times concentrate of the HMx10 treatment) using metal nitrates (cadmium nitrate tetrahydrate $Cd(NO_3)_2.4H_2O$, copper nitrate trihydrate $Cu(NO_3)_2.3H_2O$, lead nitrate Pb(NO₃)₂, zinc nitrate hexahydrate Zn(NO₃)₂.6H₂O, and antimony(III) sulfate Sb₂(SO₄)₃) which are most appropriate because of their greater solubility in water and have been used in a similar experiment previously (Meindl and Ashman, 2013), except for Sb we used antimony(III) sulfate Sb₂(SO₄)₃ because we had difficulties obtaining antimony nitrate. We created experimental solutions by diluting the base metal solution by 10, 50 and 100 times to create 50% (w/v) aqueous sugar solutions for the HMx10, HMx2 and HMx1 treatments, respectively (Table 3). We tested the concentrations of each metal in the base solution and in one sample of each treatment using ICP-MS. Concentrations of Cu, Cd, Pb and Zn were within 5% of the intended concentration in the base solution, and within 28% of the intended concentrations in the tested experimental solutions (mean % ± SD: 21.75 ± 4.72). However, the concentration of Sb in the base solution was 55% lower than intended, and equivalently lower in the tested experimental solutions.

We carried out the experiment at the University campus study site (Table 2) between 29th-31st July 2020. The experiment used beekeeping entrance feeders (500 ml container placed upside down on a yellow, indented feeding platform with narrow opening, allowing liquid to flow in a controlled manner to the yellow feeding platform) arranged in a Latin square array (12 x 12 m, cut to remove wildflowers) with each feeder within a plastic tray to contain spillage, and with 2 m between feeders (Fig. 9). Twenty-four hours before the experiment, we placed out four training feeders containing 50% (w/v) aqueous sugar solution with a drop of anise oil (a chemical cue) – one in the middle of each of the four quadrants of the array – to attract pollinators to the feeders. After 24 h, we swapped the four training feeders for the 16 experimental feeders. On the first day, we added an Eppendorf tube containing cotton wool and a drop of anise oil to the base of each feeder to act as a chemical cue, but we found that visitation was very high, so we did not use these on subsequent days. Experimental feeders were left for at least 10 min after being placed out. We then carried out 5 min observations of feeders, observing four feeders at once (one of each treatment), so taking 20 min to observe the entire array. This was repeated for a total of five observation rounds per day, with 10 min between rounds. At the end of each day, we retrieved and washed all feeders and trays, and alternated their position and treatment between days, for a total of three days.

Statistical analyses

All statistical analyses were carried out in R 3.6.1 (R Core Team, 2019) using generalised linear mixed effects models (GLMM) ('Ime4' package; Bates et al., 2015). In all cases, models were initially fitted using Poisson error structure. Fixed effects were scaled (divided by 10 or 1000) where necessary to allow model convergence. We used the link function that provided the lowest AIC. Residuals were checked to meet model assumptions, and models were tested for dispersion, and for multicollinearity using variance inflation factors, which were < 10 in all cases. The significance of the main effects was assessed using Wald χ^2 and the significance of pairwise contrasts was assessed using least-square means ('Ismeans' package; Lenth, 2016) and Tukey's adjustment for multiple comparisons.

Spatial distribution of pollution, flowers and pollinators (roadside surveys)

For models of pollution, we statistically analysed data for noise, turbulence and dust, but not for heavy metals due to low sample size. We used a linear mixed effects model for noise because data were normally distributed. In all cases, fixed effects were distance from the road (m) and traffic density (vehicles 30 min⁻¹), and random effects were transect ID nested within site to account for the survey design.

For models of flower and pollinator densities along transects, fixed effects included distance from the road (m), survey round (1, 2 or 3), traffic density (vehicles 30 min⁻¹) and verge width (m). We did not include an interaction between distance from road and traffic density due to the small number of study sites used. Models of pollinator observations additionally included flower density, wind speed (Beaufort scale) and temperature (°C) as fixed effects. All models had a random effect of transect ID nested within site to account for the survey design, and all models of pollinator observations additionally included survey day nested within transect ID because each transect was surveyed for pollinators twice on the same day. The model for pollinator density also had an observation-level random effect to address overdispersion. For the model of flower density, residuals showed heteroscedasticity so a negative binomial error structure was used. For models of bee densities and foraging behaviour to sentinel (*B. officinalis*) plants, fixed effects were the number of flowers on the plant, distance from the road (m) and observation round (1, 2 or 3), and random effects were plant ID nested within block, nested within site.

Effects of pollution on pollinator foraging (pollution experiments)

All models of pollinator densities and foraging behaviour in the noise and turbulence experiments included fixed effects of flower density in the 1 m² observation area, the identity of the dominant flower species, and an interaction between experimental treatment and whether the observation was before or after the treatment had been initiated (accounting for the BACI design). Models for flower visits per pollinator and visit duration per pollinator additionally included a fixed effect of pollinator species in the turbulence experiment because multiple types of pollinator were observed. All models included random effects of observation ID, nested within replicate number, nested within site to account for the study design. Models of visit duration additionally included an observation-level random effect to address overdispersion.

For models of pollinator densities and foraging behaviour in the dust and metals experiments, all models included a fixed effect of treatment and a random effect of plant ID or feeder ID because repeated observations were made of the same plants and feeders. For the dust experiment, models of pollinator density and foraging behaviour additionally included a fixed effect of the number of flowers per plant, and the random model of plant ID was nested within array ID because three experimental arrays were used. For the metals experiment, we used negative binomial models in all cases due to overdispersion and used an additional random effect of array block (quadrant) nested within date (replicate number).

DATA FILE 1: "roadsidesurveys_transects_pollution.csv"

Description: Measures of different types of pollution (noise, turbulence, dust and metals) at different distances from the road edge.

- pollution = the type of pollution (noise, turbulence, dust or metals).
- pollution2 = the type of metal (Cu, Cd, Sb, Pb or Zn; n/a for other types of pollution).
- units = the unit of measurement.
- site = the ID number of the 9 study sites.
- distance_road = the distance (in meters) of the transect from the road edge.
- measure = value of the measurement.
- traffic = traffic volume (vehicle/30 min)
- traffic2 = categorisation of traffic into low (< 300 vehicle/30 min), med (300-900 vehicles/30 min) or high (900+ vehicles/30 min).
- transect_ID = the ID of the transect, in the format "site"."distance_road"

DATA FILE 2: "roadsidesurveys_transects_pollinators.csv"

Description: The flower abundance, flower species richness, pollinator abundance, and the abundances of different pollinator groups, along 50 x 2 m transects along road verges, at different distances from the road edge.

- site = the ID number of the 9 study sites.
- transect_ID = the ID of the transect, in the format "site"."distance_road"
- distance_road = the distance (in meters) of the transect from the road edge.
- survey_ID_flowers = the ID of the flower survey, in the format "site"."distance_road"."survey_round"
- survey_round = the number of the survey round (1, 2 or 3).
- survey_ID_insects = the ID of the insect survey, whereby 2 insect surveys were carried out for each flower survey (on the same day), in the format "site"."distance_road"."survey_round"."survey_number"
- survey_number = the insect survey number (1 or 2).

- flower_spp_rich = the number of different species of flowers that were observed along the transect.
- flower_abundance = the total number of floral units along the transect (defined as in Materials & Methods above).
- insect_abundance = the total number of pollinators observed along the transect (defined as in Materials & Methods above).
- insect_visits = the total number of flower visits by pollinators observed along the transect (defined as in Materials & Methods above).
- traffic = the number of vehicles observed passing on the road of each field site over a 30 minute period (recorded on 3 x 10 min periods).
- traffic2 = categorisation of traffic into low (< 300 vehicle/30 min), med (300-900 vehicles/30 min) or high (900+ vehicles/30 min).
- temperature = temperature in °C.
- cloud = cloud cover, estimated to the nearest 10%.
- wind = wind speed (Beaufort scale).
- verge_width = the width of the road verge at the study site (in meters); a mean value, calculated from measurements at distances of 5, 15, 25, 35, and 45 m along each verge centre transect.
- bumblebee_count, butterfly_count, flower_beetle_count, fly_other_count, honeybee_count, hoverfly_count, moth_count, sawfly_count, solbee_count = count of the respective pollinator group observed along the transect (defined as in Materials & Methods above).

DATA FILE 3: "borage_experiment_pollinatorsurveys.csv"

Description: The flower abundance and pollinator abundance at experimental plants of borage *Borago officinalis* located in road verges at different distances from the road edge.

- record_ID = unique identifier.
- site = the ID number of the 9 study sites.
- date = date (DD/MM/YYYY)
- survey_round = the number of the survey round (1, 2 or 3).
- plant_ID = the unique ID of the experimental plant.
- distance_road = the distance (in meters) of the transect from the road edge.
- flower_abundance = the number of flowers on the plant at the time of the survey.
- bumblebee_count, honeybee_count, bee_count = counts of the respective pollinator group observed on the experimental plant during the survey (defined as in Materials & Methods above). bee_count is the sum of bumblebee_count and honeybee_count, in addition to any other bees that were observed on the plant.
- block = the number of the experimental block.
- traffic = the number of vehicles observed passing on the road of each field site over a 30 minute period (recorded on 3 x 10 min periods).
- verge_width = the width of the road verge at the study site (in meters); a mean value, calculated from measurements at distances of 5, 15, 25, 35, and 45 m along each verge centre transect.

DATA FILE 4: "borage_experiment_pollinatorbehaviour.csv"

Description: Observations of the number of flowers visited and the time spent foraging by individual pollinators visiting experimental plants of borage *Borago officinalis* located in road verges at different distances from the road edge.

- record_ID = unique identifier.
- site = the ID number of the 9 study sites.
- date = date (DD/MM/YYYY)
- survey_round = the number of the survey round (1, 2 or 3).
- plant_ID = the unique ID of the experimental plant.
- block = the number of the experimental block.
- distance_road = the distance (in meters) of the transect from the road edge.
- flower_abundance = the number of flowers on the plant at the time of the survey.
- pollinator_ID = the type of pollinator (bumblebee or honeybee).
- flower_visits = the number of flowers visited on the plant.
- time_in_patch = the time spent visiting the plant in seconds.
- traffic = the number of vehicles observed passing on the road of each field site over a 30 minute period (recorded on 3 x 10 min periods).
- verge_width = the width of the road verge at the study site (in meters); a mean value, calculated from measurements at distances of 5, 15, 25, 35, and 45 m along each verge centre transect.

DATA FILE 5: "noise_experiment_pollinatorsurveys.csv"

Description: Observations of the number of pollinators visiting a 1 m² flower patch before and after exposure to experimental noise treatments or controls.

- record_ID = unique identifier.
- site = the name of the study site where the observation took place (research_field, bee_compound or polwheveral_meadow).
- date = date (DD/MM/YYYY)
- survey_round = the number of the survey round (1 to 24).
- survey_ID = the ID of the survey, in the format "survey_round"."treatment".
- Treatment = C1 (speaker turned off), NM (playback of typical road (6 vehicles min⁻¹)), NH (playback of busy road (24 vehicles min⁻¹)), or C2 (playback of typical road, with vehicle sounds edited out (0 vehicles min⁻¹)). See Materials & Methods above.
- plant_spp = the dominant species of flower in the 1 m² patch.
- flower_abundance = the total number of floral units in the 1 m² patch (defined as in Materials & Methods above).
- before_after = before or after the experimental treatment had been activated.
- bumblebee_count, honeybee_count, solbee_count, hoverfly_count, daggerfly_count, dungfly_count, otherfly_count, o.nobilis_count, otherbeetle_count, butterfly_count, wasp_count, sawfly_count, pollinator_count, bee_count, fly_count, beetle_count = counts of the respective pollinator group observed on the experimental plant during the survey (defined as in Materials & Methods above).

DATA FILE 6: "noise_experiment_pollinatorbehaviour.csv"

Description: Observations of the number of flowers visited and the time spent foraging by individual pollinators visiting the 1 m^2 flower patch, before and after exposure to experimental noise treatments or controls.

• record_ID = unique identifier.

- site = the name of the study site where the observation took place (research_field, bee_compound or polwheveral_meadow).
- date = date (DD/MM/YYYY)
- survey_round = the number of the survey round (1 to 24).
- survey_ID = the ID of the survey, in the format "survey_round"."treatment".
- Treatment = C1 (speaker turned off), NM (playback of typical road (6 vehicles min⁻¹)), NH (playback of busy road (24 vehicles min⁻¹)), or C2 (playback of typical road, with vehicle sounds edited out (0 vehicles min⁻¹)). See Materials & Methods above.
- plant_spp = the dominant species of flower in the 1 m² patch.
- flower_abundance = the total number of floral units in the 1 m² patch (defined as in Materials & Methods above).
- before_after = before or after the experimental treatment had been activated.
- flower_visits = the number of flowers visited in the 1 m² patch.
- time_in_patch = the time spent visiting the patch in seconds.

DATA FILE 7: "turbulence_experiment_pollinatorsurveys.csv"

Description: Observations of the number of pollinators visiting a 1 m² flower patch before and after exposure to experimental turbulence treatments or controls.

- record_ID = unique identifier.
- site = the name of the study site where the observation took place (research_field, bee_compound or polwheveral_meadow).
- date = date (DD/MM/YYYY)
- survey_round = the number of the survey round (1 to 24).
- survey_ID = the ID of the survey, in the format "survey_round"."treatment".
- Treatment = C1 (blower turned off), TM (equivalent to 1 m from typical road (3 vehicles min⁻¹: 1 sec on, 19 sec off cycle)), TM (equivalent to 1 m from busy road (12 vehicles min⁻¹: 1 sec on, 4 sec off cycle)), and C2 (blower turned on, as for Turbulence (high), but facing away from the observation area, controlling for noise and other possible effects of the blower). See Materials & Methods above.
- plant_spp = the dominant species of flower in the 1 m² patch.
- flower_abundance = the total number of floral units in the 1 m² patch (defined as in Materials & Methods above).
- before_after = before or after the experimental treatment had been activated.
- bumblebee_count, honeybee_count, solbee_count, hoverfly_count, daggerfly_count, dungfly_count, otherfly_count, o.nobilis_count, otherbeetle_count, butterfly_count, wasp_count, pollinator_count, bee_count, fly_count, beetle_count = counts of the respective pollinator group observed on the experimental plant during the survey (defined as in Materials & Methods above).

DATA FILE 8: "turbulence_experiment_pollinatorbehaviour.csv"

Description: Observations of the number of flowers visited and the time spent foraging by individual pollinators visiting a 1 m² flower patch, before and after exposure to experimental turbulence treatments or controls.

- record_ID = unique identifier.
- site = the name of the study site where the observation took place (research_field, bee_compound or polwheveral_meadow).
- date = date (DD/MM/YYYY)

- survey_round = the number of the survey round (1 to 24).
- survey_ID = the ID of the survey, in the format "survey_round"."treatment".
- Treatment = C1 (blower turned off), TM (equivalent to 1 m from typical road (3 vehicles min⁻¹: 1 sec on, 19 sec off cycle)), TM (equivalent to 1 m from busy road (12 vehicles min⁻¹: 1 sec on, 4 sec off cycle)), and C2 (blower turned on, as for Turbulence (high), but facing away from the observation area, controlling for noise and other possible effects of the blower). See Materials & Methods above.
- plant_spp = the dominant species of flower in the 1 m² patch.
- flower_abundance = the total number of floral units in the 1 m² patch (defined as in Materials & Methods above).
- before_after = before or after the experimental treatment had been activated.
- pollinator_spp = the type of pollinator.
- pollinator_spp2 = a broader categorisation of the type of pollinator (bee or fly).
- flower_visits = the number of flowers visited in the 1 m² patch.
- time_in_patch = the time spent visiting the patch in seconds.

DATA FILE 9: "dust_experiment_pollinatorsurveys.csv"

Description: Observations of the number of pollinators visiting plants (arranged in a Latin Square array) of *Sinapis arvensis* that had been exposed to experimental dust treatments of controls.

- record_ID = unique identifier.
- plant_ID = the unique ID of the experimental plant.
- treatment = relative location of the plant for four days prior to the start of the experiment.
 C- (positioned > 50 m from the road), 4m (positioned 4 m from road), 1m (positioned 1 m from road), or C+ (positioned > 50 m from road, but prior to data collection, dusted extensively with roadside dust (collected with a dust pan and brush from edges of the respective road, sieved to exclude particles over 1 mm, then 20 g slowly sieved over the top of the plant over approximately 10 sec)). See Materials & Methods above.
- location = which of the three locations that the plant was placed for the experimental treatment, for the four days prior to the experiment.
- array_ID = the number of the array (1, 2 or 3).
- array_col = the column number of the Latin Square array.
- array_row = the row number of the Latin Square array.
- block = the position in the Latin Square array. BL (bottom left), BR (bottom right), TL (top left), TR (top right).
- array_block = the ID of the array block, in the format "array_ID"."block".
- flowers_start = the number of flowers on the plant at the start of the first day of observations.
- flowers_end = the number of flowers on the plant at the end of the second (final) day of observation.
- flowers = the number of flowers on the plant during the survey.
- survey_round = the survey round (1 to 8).
- survey_ID = the ID of the survey, in the format "array_ID"."block"."survey_round".
- time = the time of the start of the survey.
- bumblebee_count, honeybee_count, solbee_count, hoverfly_count, daggerfly_count, otherfly_count, otherbeetle_count, pollenbeetle_count, bug_count, pollinator_count, bee_count, fly_count, beetle_count = counts of the respective pollinator group observed on the experimental plant during the survey (defined as in Materials & Methods above).

DATA FILE 10: "dust_experiment_pollinatorbehaviour.csv"

Description: Observations of the number of flowers visited and the time spent foraging by individual pollinators on experimental plants of *Sinapis arvensis* that had been exposed to experimental dust treatments of controls.

- record_ID = unique identifier.
- plant_ID = the unique ID of the experimental plant.
- treatment = relative location of the plant for four days prior to the start of the experiment.
 C- (positioned > 50 m from the road), 4m (positioned 4 m from road), 1m (positioned 1 m from road), or C+ (positioned > 50 m from road, but prior to data collection, dusted extensively with roadside dust (collected with a dust pan and brush from edges of the respective road, sieved to exclude particles over 1 mm, then 20 g slowly sieved over the top of the plant over approximately 10 sec)). See Materials & Methods above.
- location = which of the three locations that the plant was placed for the experimental treatment, for the four days prior to the experiment.
- array_ID = the number of the array (1, 2 or 3).
- array_col = the column number of the Latin Square array.
- array_row = the row number of the Latin Square array.
- block = the position in the Latin Square array. BL (bottom left), BR (bottom right), TL (top left), TR (top right).
- array_block = the ID of the array block, in the format "array_ID"."block".
- flowers = the number of flowers on the plant during the survey.
- survey_round = the survey round (1 to 8). Blank indicates that the pollinator was observed outside of a particular survey.
- survey_ID = the ID of the survey, in the format "array_ID"."block"."survey_round".
- time = the time of the start of the survey.
- pollinator_ID = the type of pollinator.
- no_visits = the number of flowers visited on the experimental plant.
- time_visit = the time spent visiting the experimental plant in seconds.

DATA FILE 11: "metals_experiment_pollinatorsurveys.csv"

Description: Observations of the number of pollinators visiting feeders containing sugar water (arranged in a Latin Square array) with different added concentrations of metals (treatments), or no metals added (control).

- record_ID = unique identifier.
- date = date of survey (DD/MM/YYYY).
- replicate_no = the first (1), second (2) or third (3) day of the experiment, whereby the arrangement of treatments was reset each day, providing experimental replicates.
- survey_round = the survey round (1 to 5).
- block = the position in the Latin Square array. BL (bottom left), BR (bottom right), TL (top left), TR (top right).
- survey_ID = the ID of the survey, in the format "array_ID"."block"."survey_round".
- time = the time of the start of the survey.
- feeder_ID = the ID of the feeder.
- array_col = the column number of the Latin Square array.
- array_row = the row number of the Latin Square array.

- treatment = the concentration of metals in the sugar solution in the experimental feeder. C (no heavy metals added), HM1 (0.20 ppm Cd, 17 ppm Cu, 0.46 ppm Pb, 0.15 ppm Sb, 59 ppm Zn), HM2 (2x concentrate of metals added for HM1), HM10 (10x concentrate of metals added for HM1). See Materials & Methods above.
- honeybee_count, wasp_count, bumblebee_count, solbee_count, hoverfly_count, otherfly_count, pollinator_count = counts of the respective pollinator group observed on the experimental plant during the survey (defined as in Materials & Methods above).

DATA FILE 12: "metals_experiment_pollinatorbehaviour.csv"

Description: Observations of the visit duration of individual pollinators visiting feeders containing sugar water (arranged in a Latin Square array) with different added concentrations of metals (treatments), or no metals added (control).

- record_ID = unique identifier.
- replicate_no = the first (1), second (2) or third (3) day of the experiment, whereby the arrangement of treatments was reset each day, providing experimental replicates.
- survey_round = the survey round (1 to 5).
- block = the position in the Latin Square array. BL (bottom left), BR (bottom right), TL (top left), TR (top right).
- feeder_ID = the ID of the feeder.
- array_col = the column number of the Latin Square array.
- array_row = the row number of the Latin Square array.
- treatment = the concentration of metals in the sugar solution in the experimental feeder. C (no heavy metals added), HM1 (0.20 ppm Cd, 17 ppm Cu, 0.46 ppm Pb, 0.15 ppm Sb, 59 ppm Zn), HM2 (2x concentrate of metals added for HM1), HM10 (10x concentrate of metals added for HM1). See Materials & Methods above.
- survey_ID = the ID of the survey, in the format "array_ID"."block"."survey_round".
- time = the time of the start of the observation.
- pollinator_ID = the type of pollinator.
- time_visit = the time spent visiting the feeder in seconds.