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DATA ARTICLE

A dataset of nectar sugar production for flowering plants found in urban green spaces

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Abstract

1. Nectar and pollen are floral resources that provide food for insect pollinators, so quantifying their supplies can help us to understand and mitigate pollinator declines. However, most existing datasets of floral resource measurements focus on native plants found in rural landscapes, so cannot be used effectively for estimating supplies in urban green spaces, where non-native ornamental plants often predominate.
2. We sampled floral nectar sugar in 225 plant taxa found in UK residential gardens and other urban green spaces, focussing on the most common species. The vast majority (94%) of our sampled taxa are non-native, filling an important research gap and ensuring these data are also relevant outside of the United Kingdom.
3. Our dataset includes values of daily nectar sugar production for all 225 taxa and nectar sugar concentration for around half (102) of those sampled. Nectar extraction was conducted according to published methods, ensuring our values can be combined with other datasets.
4. We anticipate that the two main uses of these data are (1) to estimate the nectar production of habitats and landscapes and (2) to identify high-nectar plants of conservation importance. To increase the utility of our data, we provide guidance for scaling nectar values up from single flowers to floral units, as is commonly done in field studies.

KEYWORDS
conservation, floral resources, flowers, gardens, nectar, pollinators, urban

1 | INTRODUCTION

In an attempt to understand and mitigate insect pollinator declines (Biesmeijer et al., 2006; Powney et al., 2019; Soroye et al., 2020), some research has focussed on measuring the supplies of the floral resources on which they feed (e.g. Baude et al., 2016; Flo et al., 2018; Timberlake et al., 2019). Quantifying nectar sugar (and occasionally also pollen) production has allowed researchers to estimate floral resources at a landscape or even national scale (Baude et al., 2016; Flo et al., 2018; Tew et al., 2021), describe temporal trends and identify

seasonal gaps in their supply (Jachuła et al., 2021; Tew et al., 2022; Timberlake et al., 2019), predict the impact of management interventions (Hicks et al., 2016; Timberlake et al., 2021), investigate factors limiting pollinator populations (Timberlake et al., 2021) and characterise the accessibility of resources to different insect groups (Tew et al., 2022). In addition, floral resource data are used by other stakeholders, including non-governmental organisations and conservation practitioners, with the aim of improving habitats for foraging pollinators. For example, Plantlife's 'Every Flower Counts' is a citizen science initiative which encourages participants to count the flowers of different species in their garden lawn, combining these values with floral resource measurements to give a 'Personal Nectar Score', along with suggestions for its improvement.

Estimating the supply of floral resources in habitat patches or across entire landscapes relies on the availability of published empirical values of nectar or pollen production at the flower level for a wide variety of species. Existing datasets are insufficient in scope to provide estimates for all habitat types, particularly urban green spaces including residential gardens. For example, Baude et al. (2016) measured floral nectar sugar production empirically for 175 species, mostly wild plants native to the United Kingdom, and Hicks et al. (2016) focused on sown urban flower meadows, collecting nectar sugar and/or pollen production data for 66 species. There is an increasing appreciation of the importance of flowering plant communities in urban green spaces for insect pollinators (Baldock, 2020; Baldock et al., 2019; Lowenstein & Minor, 2016), but we cannot quantify the supply of floral resources without empirical measurements of nectar or pollen production for the appropriate species. These flower-level assessments are also valuable in identifying particularly resource-rich plants which should be prioritised in pollinator-friendly planting schemes (Hicks et al., 2016).

Here, we present a dataset of floral nectar sugar production values for 225 plant taxa found in UK residential gardens and other urban green spaces (where a taxon is either a species, hybrid or cultivar). Many of these plants are also common in urban landscapes in other countries. We focus on nectar rather than pollen sampling because nectar is the main energy source in the diets of adult pollinators and has a less complex nutritional profile than pollen (Vaudo et al., 2015). Our methods for measuring nectar sugar production follow those of Baude et al. (2016) and Hicks et al. (2016), allowing our datasets to be combined (as in Tew et al., 2021, 2022). After describing the dataset and the sampling methods, we subsequently provide usage notes and explore some general patterns.

2 | MATERIALS AND METHODS

Nectar measurements of the 225 flowering plant taxa took place in March–October 2018 (220 taxa) or February–April 2019 (five taxa) at field sites in southern England, which included public and private gardens, allotments, garden centres and road verges (Table 1). Sites typically comprised a variety of urban land uses, including ornamental borders and shrubberies, lawns, paths and hard standing. Where possible (97 taxa), taxa were sampled at two or three locations on different days to account for variation due to site, weather and plant variety. We selected the plant taxa for sampling primarily based on a study by Baldock et al. (2019), who surveyed floral abundance from April to September in 360 sites spanning nine land use types in four UK cities. Our dataset focuses on the plants they recorded with the highest overall floral counts (with 88% of our sampled genera found in their study), supplemented with some common taxa which flower outside of their survey period.

Following Baude et al. (2016), insects were excluded from the flowers to be sampled by mesh bags (pore size 1.4 mm × 1.7 mm) for 24 ± 2 h, providing a measure of nectar accumulation over a one-day period (Figure 1). After bagging, and between the hours of 08:30 to 18:00, flowers were removed and nectar extracted by one of two methods using glass microcapillaries (0.5 to 20 μL Minicaps, Hirshmann; Figure 1). Where possible (102 taxa), we removed nectar directly from flowers until no more could be extracted. Alternatively, where the direct extraction of nectar was not possible as the quantity was too small or viscous (123 taxa), we rinsed nectaries with 0.5–10 μL of distilled water, added with a pipette. Sugar residues were left to dissolve for 1 min before all the solution was removed using microcapillaries and the process repeated one further time. The concentration of the extracted solution (C; g of sugars per 100 g solution) was measured using a handheld refractometer with a lid modified for small volumes (Eclipse, Bellingham and Stanley). Values of the sugar concentration of the nectar are only reported in our dataset for taxa whose nectar was extracted directly, as the solution obtained by rinsed extraction was diluted, so lacks ecological relevance. The total mass of sugar produced (s; μg of sugars per 24 h) was calculated for all taxa with the formula $s = 10dvC$, where v is the volume collected (μL) and d is the density of a sucrose solution at concentration C and obtained by the formula $d = 0.0037921C + 0.0000178C^2 + 0.9988603$ (Corbet et al., 2001). We sampled a mean of 18.3 (±0.6 SEM) flowers per plant taxon, with a range of 10–52. Where possible, we sampled multiple plants across each site and included a representative selection of flowers of different age, sex (if flowers were not hermaphroditic) and position on the plant or in the inflorescence.

3 | USAGE NOTES

For each of the 225 plant taxa, the dataset associated with this article includes its native status, life form, the nectar extraction method and sites where flowers were sampled, the nectar sugar mass per flower, the nectar sugar concentration (where applicable, see Section 2), the floral unit category, the number of flowers per floral unit and the nectar sugar mass per floral unit. The two main uses of these data are (1) to estimate nectar production at larger spatial scales (e.g. quadrats, habitat patches or entire landscapes), which requires multiplying by values of floral abundance (e.g. Hicks et al., 2016; Tew et al., 2021, 2022), or (2) to identify particularly nectar-rich species to include in pollinator-friendly planting schemes. In addition, researchers could

TABLE 1 The sites used for nectar sampling in the field in this study. Each taxon was sampled at either one (128), two (88) or three (9) different sites.

Site name	Site address	Sampling environment	Number of taxa
Ashley Down allotment	Ashgrove Avenue, Bristol (51.481 N, 2.578 W)	Allotment plot	2
Brackenwood Plant and Garden Centre	Pill Road, Bristol (51.467 N, 2.662 W)	Potted plants	13
Didcot town	Didcot, Oxfordshire (51.610 N, 1.239 W)	Road verges, hedges and ornamental borders	20
Royal Horticultural Society Garden Wisley	Near Woking, Surrey (51.314 N, 0.474 W)	Ornamental borders	13
Speldhurst village (a private garden)	Speldhurst, Kent (51.148 N, 0.216 E)	Ornamental borders	9
University of Bristol Botanic Garden	Stoke Park Road, Bristol (51.478 N, 2.626 W)	Ornamental borders	103
University of Bristol Halls of Residence	Parrys Lane, Bristol (51.478 N, 2.623 W)	Ornamental borders and flower meadow	47
University of Bristol Royal Fort Gardens	Tyndall Avenue, Bristol (51.458 N, 2.602 W)	Ornamental borders and flower meadow	124

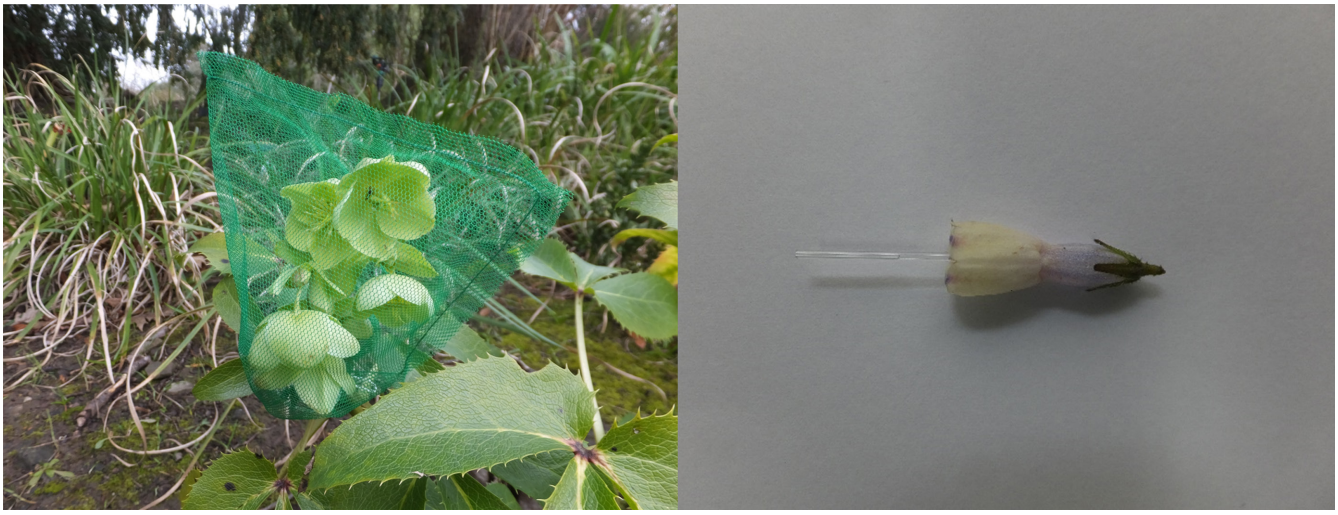

FIGURE 1 Nectar quantification methods. First, flowers were covered with a mesh bag to exclude insect visitors (left, showing *Helleborus lividus*) and 24 h later, nectar was extracted using glass microcapillaries (right, showing direct extraction in *Symphytum* × *hidcotense)*. Following this, the volume and concentration of extracted nectar were measured so that the total mass of sugars could be calculated (Photo: N. Tew).

investigate how phylogeny and floral traits predict nectar production or nectar sugar concentration using statistical models (e.g. Tew et al., 2021, 2022). Two important limitations of our presented nectar values are that (1) taxa are often represented by only one or a few different sampled varieties (see Tew et al., 2021) and (2) measures of 24-h nectar accumulation may underestimate the potential maximum secretion under repeated insect visitation (Carisio et al., 2022).

When recording floral abundance in the field, researchers often count floral units, which are commonly defined as single flowers or collections of flowers that insect pollinators can walk within but must fly between (Baldock et al., 2015; Carvalheiro et al., 2008). For example, the floral unit is often recorded as a capitulum in Asteraceae and a secondary umbel in Apiaceae, but as a single flower in most Rosaceae and Boraginaceae (Figure 2). The floral unit recorded for a plant taxon can vary between studies because it is a relatively subjective classification that depends on the pollinator group considered. However, it is crucial that researchers are meticulous in documenting how they have recorded floral abundance because confusion between flowers and floral units can lead to a large error in estimating nectar supplies. For example, we report the daily nectar sugar production of *Ceanothus thyrsiflorus* to be 21.10 μg per single flower and 3316.29 μg per single thyrse (the botanical term for the inflorescence likely to be counted as a floral unit during surveys; Figure 2). When scaling nectar production from flowers to floral units is necessary, it is important to appreciate that this adds a major source of variation (in number of flowers per floral unit as well as mass of nectar sugar per flower) and as such, researchers should count the number of flowers for many floral units where possible,

FIGURE 2 Flowers and floral units. When surveying floral abundance, single flowers are often counted, as in the case of *Chaenomeles speciosa* (left). However, a tight cluster of many flowers is sometimes recorded as the floral unit and counted instead, as in the case of *Ceanothus thyrsiflorus* (right) (Photo: N. Tew).

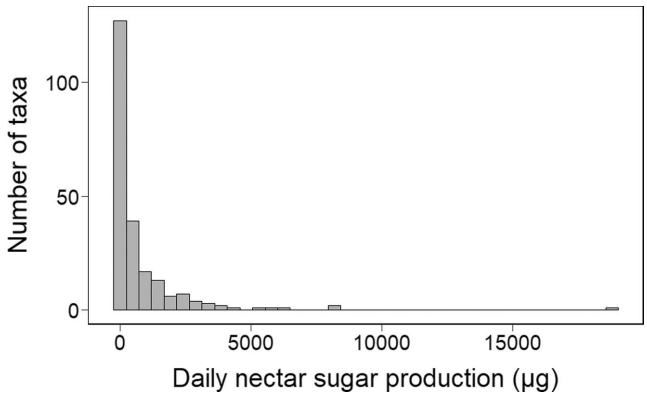

FIGURE 3 Mean daily nectar sugar production of taxa ($n = 225$) at the flower level (bin width = 500 µg).

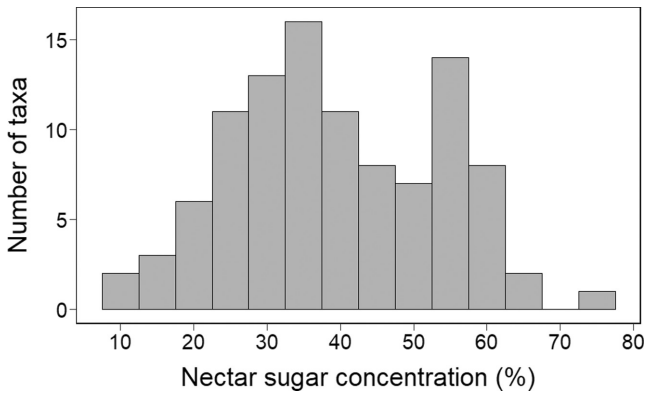

FIGURE 4 Mean nectar sugar concentration of taxa ($n = 102$) at the flower level (bin width = 5%).

before taking a mean value by which to multiply. In this dataset, we assign floral units following Baldock et al. (2015, 2019) and report the daily nectar sugar production value at both the flower and floral unit levels.

4 | GENERAL PATTERNS

Our dataset includes 225 plant taxa belonging to 158 genera in 55 families. We sampled 157 herbaceous taxa, 63 shrubs and five woody climbers (*source*: Brickell, 2016), with 14 UK native and 211 non-native taxa (*source*: Hill et al., 2004). Daily nectar sugar production of taxa at the flower level ranged from 0 µg (eight taxa) to 18,799 µg (*Iris virginica*), with a median of 163 µg (Figure 3). The highest daily nectar sugar production at the floral unit level was 22,623 µg (a single capitulum of *Echinops ritro*). For the sugar concentration of nectar, the range was 8% (*Kniphofia uvaria*) to 73% (*Rhododendron souliei*), with a median of 37% (Figure 4).

5 | RELATED WORKS

Most of the nectar sugar production values reported in this dataset were used in Tew et al. (2021) and/or Tew et al. (2022) to estimate the nectar supply of urban landscapes and land uses. These two publications show how nectar sugar values can be combined with measures of floral abundance to answer interesting ecological questions with relevance to conservation. The data associated with both Tew et al. (2021, 2022) are archived in the Dryad Digital Repository, but the dataset presented with this article includes these data as well as data for additional plant taxa, values of nectar sugar mass at both flower and floral unit levels, nectar sugar concentration and usage notes.

AUTHOR CONTRIBUTIONS

Nicholas E. Tew, Jane Memmott and Katherine C. R. Baldock conceived the ideas and designed the methodology; Nicholas E. Tew and Joanne M. Morten collected the data; Nicholas E. Tew, Jane Memmott and Katherine C. R. Baldock led the writing of the manuscript, with Joanne M. Morten, Stephanie Bird and Ian P. Vaughan

contributing critically to the drafts; Jane Memmott, Katherine C. R. Baldock, Stephanie Bird and Ian P. Vaughan acquired funding. All authors gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

The dataset associated with this publication, along with information for its use, is available from the Dryad Digital Repository https://doi.org/10.5061/dryad.0rxwdbs4x (Tew et al., 2023).

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