A mowing strategy for urban parks to support spring flowers in a Mediterranean climate city in South Africa

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Abstract

Converting road verges and Public Open Space (POS) to floral-rich resources is an important strategy for supporting populations of urban pollinators. One of the ways this can be achieved is through adjusting mowing schedules, either with a "delayed start" after the end of winter, or a reduction in mowing frequency. In Mediterranean climate ecosystems with mild, wet winters, plant growth continues through the winter season and the definition of a "delayed start" is unclear. This study sought to identify a strategic period for the suspension of mowing activities in a city in South Africa with a Mediterranean climate. It estimated the duration of the flowering to seed-broadcast season of 20 species of native geophytes. Observations were made of phenological status from bud to seed broadcast in ten city parks in Cape Town during the austral spring flowering seasons of 2019 and 2020 (August – December). The Underhill and Zucchini (1988) Moult Model was employed to estimate the duration of the flowering season. Model results showed that mowing should stop in the second week of August and should not resume until the beginning of November in the study context. The results are discussed against the relative biodiversity contribution that different parks and verges make and the potential conflicts with the utility objectives of urban society.

Introduction

Parks and road verges form an important component of natural and green infrastructure in cities. They can attract a richness of fauna, particularly insects and birds, when the quality of the landscaping provides suitable habitats (Shwartz et al. 2013; Dylewski et al. 2020; Samways et al. 2020). Community parks and greenways of all sizes

therefore present an opportunity for biodiversity "stepping stones" between larger nature parks and conserved natural areas (Goodness 2018), especially for insects and other pollinators (Threlfall et al. 2015; Hall et al. 2017; Banaszak-Cibicka et al. 2018; Davis et al. 2017).

One of the ways this potential can be managed to provide favourable landscapes for pollinators is through the provision of floral-rich lawns (Davis et al. 2017). Maintaining lawns with moderate to low frequency mowing events increases biodiversity and foraging resources for pollinators and represents a practical, timesaving intervention to support urban pollinator and plant populations (O'Sullivan et al. 2017; Lerman et al. 2018; Yang et al. 2019; Watson et al. 2020). In Europe, delaying the first post-winter mowing event from spring to summer has produced positive outcomes for local plant species richness (Humbert et al. 2012). Studies advocating for a "delayed start" to the mowing season have been predominantly carried out in European and North American cities that experience freezing temperatures and snowfall in winter (Watson et al. 2020). In contrast, cities in Mediterranean Climatic Ecosystems (MCE) experience winter rainfall, with snow limited to high-ground, and

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mowing continues throughout winter (Mooney et al. 2001). Thus, in these contexts, the notion of a "delayed start" to the grass mowing season is a misnomer. There is therefore a need to identify alternative strategies for biodiversity-considered mowing schedules. Some precedent from North America suggests that when moderate to low frequency mowing events are strategically aligned to the life-cycles of specific pollinators and plants, the population abundance of both is improved in the following year (Knight et al. 2019).

The city of Cape Town is located in an MCE in South Africa (Rundel et al. 2016). The city's municipal horticultural landscaping management minimum standards prescribes norms for municipal contractors who are employed to maintain road verges and POS. Accordingly, these areas are currently mowed at least 10 times a year, resulting in a grass-cutting schedule with intervals of four to six weeks. This schedule means that it is likely that mowing occurs at least once in spring, cutting plants before fruits have matured and seeds have been broadcast, and thereby interrupting the floral reproductive cycle for spring flowers (Manning and Goldblatt 2012). Consequently, this study aims to optimize the duration of a grass-cutting suspension during the austral spring season in Cape Town. Specifically, it provides an indication of the number of weeks for which regular grass-cutting should be suspended during spring. To date, studies in Europe and North America have taken the approach of experimental patch, followed by subsequent biodiversity measurements (Wastian et al. 2016; Sehrt et al. 2020; Watson et al. 2020). In contrast, this study adopted a phenological approach to understanding the ecological processes which support floral diversity. By quantifying the duration of the floral reproductive season, an optimal mowing suspension window is identified.

This study developed methods to generate mowing policy recommendations. The first step was to develop an inventory of the species of flowering plants in each park and classify parks according to functional richness. For each native geophyte species, the phenophases (observable stages in the annual life-cycle of a plant) from budding to seed set were investigated. The Underhill-Zucchini Moult Model (Underhill and Zucchini 1988), an algorithm which was developed to quantify the duration of bird moult, was used to quantify flower phenology (duration of flower reproduction) and based on these results, recommendations were made for a period for each park (or group of parks) during which mowing should not take place. The approach is broadly replicable and can be deployed in other MCEs.

Methods

Phenophase status as an indicator of phenology

Traditionally, phenology was tracked using records of first event dates (e.g. the date on which the first bud of the season was detected) (Miller-Rushing et al. 2008). First-event phenology datasets typically quantify the phenological status of the most extreme individuals within a population of unknown size. Using this method, variations can be erroneously reported when there are differing population sizes or less frequent monitoring and it loses the detail of information about the shifts across the population (Elmendorf et al. 2016). Capturing only the most extreme cases cannot produce recommendations for strategic management outcomes nor provide enough information to balance competing interests and park facility usage trade-offs. Status monitoring, therefore provides more detail about the progress of the life-cycle and can capture repeat events, such as a second flowering flush after a cold snap (Denny et al. 2014; Elmendorf et al. 2016). Furthermore, the adoption of phenophase status and intensity instead of traditional first-event monitoring protocols has advantages (Denny et al. 2014; Elmendorf et al. 2016; Elzinga et al. 2007) Firstly, events that sometimes occur more than once in a year can be monitored. Secondly, variations in transition dates can be measured. Thirdly, the duration of phenophase can be quantified, and fourthly, monitoring small patches and marked individuals ensures that recorded dates are decoupled from population size. This overcomes the weaknesses of first-event monitoring and when used in conjunction with regular sampling enables phenophase change estimates (Elmendorf et al. 2016). It is therefore preferable to track either peak events (Elzinga et al. 2007) or status monitoring (Denny et al. 2014). In this study, phenophase status monitoring was adopted and the peak events and duration of the season were calculated using a statistical model that was originally developed to estimate the starting date and duration of primary moult in birds (Underhill and Zucchini 1988).

The field observation terminology and protocols adopted in this study are based on the USA National Phenology Network (Table 1). This protocol describes a phenophase as "an observable stage or phase in the annual life-cycle of a plant or animal that can be defined by a start and end point". Phenophases generally have a duration of a few days or weeks. Examples include the period during which newly emerging leaves are visible, or the period in which open flowers are present on a plant" (US*A National Phenology Network, n.d*) (Table 1).

Table 1 Descriptions of the phenophases used in this study based on definitions from the USA National Phenology Network (n.d.)

Phenophase	Description
Bud appearance	Green closed flowers.
Open Flower	Open or opening flower with petals at least partially open.
Senescence	Petals have changed colour and are beginning to droop, are wilted, closing, or falling off.
Fruit formation	The appearance of a hardened nodule within the flower, or the complete loss of all petals (depending on plant species).
Seed broadcast	Fruits are cracked or open, or seeds fall out when shaken.

Observation season and frequency

Globally, no standardised frequency of phenology monitoring exists. Instead, observation frequency protocols are devised on a case-by-case basis, and depend on the species being studied, the study objectives, and budgetary and logistical constraints (Elmendorf et al. 2016). Mazer et al. (2015) studied four plant species in California across broad environmental conditions, and considered that twice-weekly sampling was sufficient to detect onset dates of vegetation growth, flowering, and fruiting. Miller-Rushing et al. (2008) recommended sampling every second day to ensure a 97% probability of detecting significant change in date of flowering; they noted however, that for many studies less frequent sampling may be adequate to determine simple trend detection. At the opposite end of the scale, sampling every two weeks was recommended to monitor tropical tree phenology (Harrison et al. 2019). Because the purpose of this study is to give an indication of the number of weeks for which regular grass-cutting should be suspended during spring, a weekly fieldwork protocol was used. The intention of this study was to make recommendations relating to park and road verge management practices in an urban context, it was consequently not concerned with the most extreme early flowering individuals but rather the peak events. Peak events are defined as the point in time when the majority of a population are in a particular phenophase (observable stage in the life-cycle of an organism). The Underhill-Zucchini Moult Model (Underhill and Zucchini 1988) which we used, can predict the start dates of the season, even if they have already started when observations begin.

Study area and site selection

The study area, Cape Town, falls within the Cape Floristic Region and contains Renosterveld, Strandveld and Fynbos vegetation types (Mucina & Rutherford 2006; Rebelo et al. 2011). Renosterveld and Fynbos are particularly rich in geophytes (Rebelo et al. 2006; Manning and Goldblatt 2012), the majority of which emerge and flower during the austral spring season (August–November) (Manning and Goldblatt 2012). Cape Town is a major metropolitan and has small (0.1 ha) to medium (10 ha) parks throughout its urban fabric (City of Cape Town 2012). Many of these retain populations of native geophytes and annuals that emerge in the lawns and flower during spring (Manning and Goldblatt 2012;).

Temperature, and to a lesser extent, rainfall, vary across the city (Cowling et al. 1996; Wilkinson 2000) and, in order to capture and control for this variability, we first consulted data from the CHIRPS satellite, and selected areas that were similar in rainfall (de Sousa et al. 2020). Mean annual summer daytime surface temperatures were extracted from the Yale Urban Heat Index (2018) and demonstrated that the temperature variations were more likely to have an impact than the rainfall variations for most parts of the city. Two groups of parks were selected from contrasting parts of the city. Park area managers were approached to identify suitable parks under their jurisdiction in which there were a known abundance of spring flowers and geophytes. The parks were then visited to establish and confirm suitability.

Neighbours and representatives from community stewardship groups were approached to obtain permission and co-operation in the project. Several of the larger park communities have formed "Friends of" groups or "Associations" which volunteer to undertake, and advocate for park upgrades, or coordinate volunteer activities. These groups were approached to notify them of the research activities and request co-operation; in total ten parks were chosen (Fig. 1). Mean summer temperatures varied by up to four degrees across the city. Four parks were identified as suitable parks in the "cool" precinct of the city and five parks were identified as suitable in the northern "warm" (<2 degrees warmer) precinct of the city.

Field observation methods

Phenological observations were made on 20 focal species in ten parks during the austral spring seasons of 2019 and 2020 (Tables 2 and 3). At two large parks with an abundant and diverse population of flowers, and already benefitting from a mowing suspension during spring, a series of transects were marked out along which flowers were counted in a 300 mm wide swathes. At each of the rest of the parks two plots of 5×5 m were staked out and "Do not mow" signs were placed in the middle of the plots. A general information sign, with contact details about the project, was placed in or near to the plots. Plots were positioned to cover stands of lawn flowers. Plots and transects were visited weekly during spring. Observations began in the second week of August 2019 and 2020, allowing for mowing to occur in the first week of August. Observations continued until more than 50% of the fruit population had cracked open. Counts

Fig. 1 Location of survey parks in Cape Town, South Africa, where experimental no-mow plots were established in the austral spring of 2019 and 2020. Observations were made of the phenophases of flower bud emergence to the onset of seed broadcasting. A = Warm precinct, B = Cool precinct

were recorded of the heads of buds, open flowers, senescent flowers, fruits and open seed capsules for each species in the plots. When they were at their most abundant, and counting individual flower-heads became challenging, 1 × 1 m quadrats were used to keep track of counts and make estimates for the study area. They were recorded on the field observation sheet (Supplementary material 1) and tabulated in a spreadsheet. At the end of the observation season, mowing resumed. The plots were re-established in August of 2020 for a second observation season.

Analysis

An adaptation of the Moult Model of Underhill and Zucchini (1988) was used to describe flowering phenology. The original model was developed to estimate the timing of primary moult in birds. In that application, birds are observed in one of three categories; each observation has a date attached to it: birds with old feathers, which will commence moult on some unknown future date; birds in which the stage of development of the feathers can be quantified through a moult index which measures the stage of progress; birds with new feathers, which completed moult at some unknown past date. The Moult Model uses the method of maximum likelihood to estimate three parameters: the average start date of moult, the variability in the average start date and the duration of moult. The statistical problem of bird moulting is unusual because no birds are observed starting to moult, and the duration is therefore not observable either. The model undertakes the statistics required to estimate these parameters which are not directly observable. Erni et al. (2013) developed software in R (R Core Team 2021) which provides an algorithm which estimates the parameters of moult, and which enables model selection to be undertaken within a standard statistical framework. Here we used the Moult Model to describe flowering phenology. The model is suitable for this task in that with weekly monitoring one does not necessarily observe the transitions between the phenophases as described in Table 1. What is observable is the phenophase of a particular flower. Thus, a sample of plants at a site on each visit can be examined and the number of flowers in each phenophase counted.

The key parameters in this case are the mean start date of budding and the variability of this start date, which measures the extent of synchronicity of the phenomenon. The flower data are analogous to moult data with the following phases: (1) observations of plants which are not yet in bud and which will start some unknown time in the future (analogous to birds that have not yet started to moult); (2) observations of plants which have completed seed set at

some unknown time in the past (analogous to birds which have completed moulting); and (3) observations of plants in the phenophases of Table 1 (analogous to actively moulting birds). In applications of the Moult Model to the primary moult of birds, the time spent in each phase has generally been regarded as equal, and this has simplified the calculation of the moult index. However, Redfern (1998) proposed a more nuanced approach for birds, in which he estimated the time in each stage of moult, and Beltran et al. (2019) pioneered a similar approach to quantifying the moult of Weddell seals *Leptonychotes weddelli*, by estimating the time spent in each moult stage. Our phenology index similarly estimated the number of days which each species spent in each phenophase and converting these to proportions (Table 2). As done for the moult indices, the phenology index for a particular stage was calculated by adding the proportions of time spent in preceding stages, and then adding half the proportion of the current stage. The value for flowers that had achieved seed broadcast was set at 1, analogous to the concept of "completed moult" in the moult model.

Twenty species of geophytes were selected for analysis based on the size of the populations (minimum 30 individual plants, and presence in more than one observation park) and an upright growth form which would be negatively impacted by grass-cutting. The R package Moult (Erni et al. 2013) was then used to compute the total flower reproductive duration from bud appearance to 50% fruit-crack/seed-broadcast. The Moult Model was run for the entire

population first, and then separately on all species individually allowing both the start date and duration of the season to vary for each species. The R-script instructed the algorithm that the data were "type = 4": A sample that identifies [flowers] which are in flowering phases and have completed broadcasting. No counts were made of numbers of plants in vegetative state prior to producing buds, thus this was the appropriate type to specify.

To determine if there was a meaningful difference between the phenophases of the warmer northern district population and the cooler south-western district, the model was run a further three more times on the total sample. It was first run holding the start date and the standard deviation of the start date constant whilst comparing the duration, then holding constant the duration and the standard deviation of the start date, and lastly, holding the duration and start date constant whilst comparing the standard deviations of the start date. A log-likelihood test was run on the results of the Moult Model to determine the model fit.

Results

Each observation patch contained between three and 12 focal species. Six species occurred at only one park. The most widespread species were *Romulea rosea*, *Moraea miniata* and *Baeometra uniflora* which each occurred at eight of the 10 observed parks. The number of observations made per species across both seasons varied between 183 for the

Table 2 Indices used in the Moult Model to estimate progress through the duration of the season of interest. In this case, the reproductive season of plants from bud to seed broadcast

Species	Family	bud	flower	senescence	fruit	seed
Babiana ambigua (Roem & Schult.) G.J. Lewis	Iridaceae	0.13	0.37	0.61	0.87	1.00
Babiana nervosa (Lam.) Goldblatt & J.C. Manning	Iridaceae	0.14	0.39	0.61	0.86	1.00
Baeometra uniflora (Jacq.) G.J. Lewis	Colchicaceae	0.12	0.35	0.54	0.82	1.00
Geissorhiza aspera Goldblatt	Iridaceae	0.11	0.33	0.58	0.85	1.00
Gladiolis alatus G.J. Lewis	Iridaceae	0.06	0.25	0.50	0.81	1.00
Gladiolis carinatus Aiton	Iridaceae	0.14	0.36	0.59	0.86	1.00
Moraea flaccida (Sweet) Steud.	Iridaceae	0.10	0.28	0.51	0.83	1.00
Moraea miniata Andrews	Iridaceae	0.13	0.40	0.69	0.92	1.00
Moraea neglecta G.J. Lewis	Iridaceae	0.12	0.33	0.53	0.82	1.00
Moraea tripitala (L.f.) Ker Gawl.	Iridaceae	0.11	0.32	0.54	0.82	1.00
Moraea vegeta L.	Iridaceae	0.09	0.29	0.52	0.82	1.00
Pauridia capensis (L.) Snijman & Kocyan	Hypoxidaceae	0.15	0.45	0.70	0.90	1.00
Pauridia serrata (Thunb.) Snijman & Kocyan	Hypoxidaceae	0.12	0.38	0.67	0.90	1.00
Pterygodium catholicum (L.) Sw.	Orchidaceae	0.23	0.60	0.87	1.00	1.00
Romulea cruciata (Jacq.) Beg.	Iridaceae	0.09	0.30	0.57	0.87	1.00
Romulea obscura Klatt	Iridaceae	0.09	0.29	0.53	0.83	1.00
Romulea rosea (L.) Eckl.	Iridaceae	0.11	0.43	0.72	0.91	1.00
Sparaxis bulbifera (L.) Ker Gawl	Iridaceae	0.10	0.32	0.56	0.84	1.00
Sparaxis villosa (Burm.f.) Goldblatt	Iridaceae	0.11	0.36	0.61	0.86	1.00
Orthogalum thyrsoides Jacq.	Hyacinthaceae	0.09	0.31	0.56	0.84	1.00
Wachendorfia multiflora (Klatt) J.C. Manning & Goldblatt	Haemodoraceae	0.10	0.30	0.51	0.80	1.00

elusive *Moraea tripetala* which had a small population that was difficult to track in Keurboom Park, to 12,005 observations for *Sparaxis bulbifera* which had strong populations at five of the parks.

Using the adapted Moult Model, the earliest estimated mean start date was 31 July for *Wachendorfia multiflora* (SE 1.4) and the latest mean start date was 22 September for *Ornithogalum thyrsoides* (SE 1.1) (Table 3). Half of the focal species (10), started budding in the fourth week of August. The standard deviation of the start dates was smallest for populations of *Gladiolus carinatus* (7), *Ornithogalum thyrsoides* (9) and *Pterygodium catholicum* (8). In contrast, the greatest standard deviation of the start date was recorded for *Pauridia capensis* (34), followed by 19 days for each *Wachendorfia multiflora*, *Pauridia serrata* and *Moraea neglecta*. The latest estimated mean seed broadcast date (more than 50% of fruiting bodies releasing seeds) was 22 November for *Pauridia capensis*.

The mean duration of the total measured phenophases from bud emergence to seed broadcast, "mean season duration",across all species occurred between 14 August and 30 October with a standard deviation of 19 days. *Gladiolus carinatus* had the shortest mean season duration (28 days) and *Pauridia capensis*, *Moraea tripetala*, *Wachendorfia multiflora* and *Moraea neglecta* had the longest seasons at 85–98 days. With the exception of *Wachendorfia multiflora*, this group was relatively uncommon in city parks and tended to occur in sites with biodiversity stewardship plans in place, or low-intensity management practices (e.g. in vacant lots and undeveloped land). Parks with biodiversity stewardship plans in place had engagement from civil society for the protection of designated biodiversity areas during the flowering season. Of the common species (occurring at three or more parks), *B. uniflora* had the longest seasonal duration at 84 days and was trailed by a cluster of seven species with durations of 60–70 days. Although the mean duration of the flowering season was 77 days across all species, more than half of the species had durations between 50 and 70 days.

Observations of the impact of grass-cutting in late August and September on the remainder of the park (outside the no-mow plots) demonstrated that 30% of growing tips of *Sparaxis bulbifera*, *B. uniflora* and *Moraea vegeta* were lost in August and a further 30% of the tops of plants were cut without removing the growing tip, the remainder were undamaged. In contrast, 100% of flowering heads were lost by the September cut and did not regrow new buds, consequently losing the seed set for the reproductive season.

By the beginning of November, most species had begun broadcasting seeds and had some opportunity for dispersion (See mean end date in Table 3). Those species which had not started broadcasting by the second week of November

occurred at sites of greater diversity with existing mowing suspensions in place (three of the ten parks, and where more than 10 species of angiosperm were present) and may be indicators for special management intervention.

The difference between the timing of the season duration (measured phenophases) in the warm district and the cooler areas was less than a week. This was not deemed to be biologically meaningful for the purposes of informing city wide strategic mowing practices.

Discussion

The purpose of city parks is to provide a leisure resource for the relaxation and recreation of citizens, but for many urban-dwellers, parks are the most accessible opportunity for experiencing and connecting to nature (Hand et al. 2017). A sense of connection to nature fosters cues to care and fuels a biophilic value set which can lead to pro-environmental behavioural outcomes (Martin and Czellar 2017). Time spent connecting with nature has psychological and physiological benefits. It decreases hypertension, increases cognitive function, and can mitigate obesity in communities with good access to recreational activities in natural settings (Hartig et al. 2014; Restall and Conrad 2015). What constitutes "good access" is not limited to proximity and convenience but also a function of the quality of the park. Aesthetic quality and biodiversity both contribute to positive nature experiences (Taylor and Hochuli 2015), providing reasons for implementing strategies aimed at improving biodiversity in urban and community parks, but safety is also of importance to determining use and access.

Safety within an urban setting is strongly related to crime prevention which is predicated on the opportunity for legitimate passive surveillance from individuals who feel a sense of ownership and territoriality about the park: neighbours, parents, child-minders and concerned citizens. Passive surveillance is achieved by maintaining sightlines and ensuring optimum usage (Zavadskas et al. 2019). Sightlines can become obscured by long grass (and overgrown shrubs) and hence, regular mowing is required. In addition to obscuring sightlines (thereby obstructing passive surveillance), long grass fuels the perception of degradation and lack of care (Türkseven Doğrusoy and Zengel 2017; Zavadskas et al. 2019). Parks should therefore aspire to a balance between utility, aesthetics, conservation and cues to care to ensure desired usage volumes (enough for passive surveillance, but not crowding), quality and accessibility (Li and Nassauer 2020; van den Berg and van Winsum-Westra 2010; Marshall et al. 2020).

Venn and Kotze (2014), in considering no-mow areas as a biodiversity-supporting solution, acknowledged the

Table 3 Estimates (and standard errors) of the parameters of phenology (mean start date, standard deviation of start date and duration of the period: bud to the onset of seed-broadcast) for 20 species of geophytes growing in the community parks of Cape Town. In addition, the individual datasets were pooled, and estimates were derived from the overall dataset. Parameters were defined by the adaptation of the Underhill-Zucchini Moult Model described in the text and estimated using the R-package: Moult (Erni et al. 2013)

| Species | Model Parameters | | | | | | | |
	Mean start date (SE)		Standard deviation of start date (SE)		Duration (days) (SE)		Mean end date	Sample Size	
Babiana ambigua	14 Aug	(1.8)	13	(3.4)	57	(3.7)	11 Oct	403	
Babiana nervosa	02 Sep	(1.2)	11	(2.1)	57	(1.8)	30 Oct	704	
Baeometra uniflora	12 Aug	(0.6)	17	(1.9)	84	(0.9)	05 Nov	9878	*
Geissorhiza aspera	27 Aug	(1.1)	17	(2.6)	60	(1.5)	27 Oct	2878	
Gladiolus alatus	25 Aug	(2.1)	14	(3.2)	62	(3.1)	26 Oct	0	
Gladiolus carinatus	29 Aug	(1.9)	7	(1.9)	28	(2.2)	05 Sep	0	
Moraea flaccida	20 Aug	(1.3)	15	(2.6)	57	(1.7)	16 Oct	2121	
Moraea miniata	26 Aug	(1.0)	13	(2.1)	46	(1.3)	11 Oct	1740	
Moraea neglecta	25 Aug	(2.5)	19	(4.0)	85	(3.5)	18 Nov	886	**
Moraea tripetala	08 Aug	(7.8)	18	(6.5)	91	(10)	07 Nov	0	
Moraea vegeta	09 Aug	(0.9)	14	(2.1)	69	(1.3)	16 Oct	2302	
Ornithogalum thyrsoides	22 Sep	(1.1)	9	(1.8)	52	(1.6)	14 Nov	609	**
Pauridia capensis	16 Aug	(7.7)	34	(11.4)	98	(11.8)	22 Nov	470	**
Pauridia serrata	26 Aug	(4.4)	19	(6.4)	47	(7.0)	12 Oct	259	
Pterygodium catholicum	23 Aug	(0.7)	8	(1.3)	57	(1.1)	19 Oct	829	***
Romulea cruciata	19 Aug	(1.4)	12	(2.5)	61	(2.1)	19 Oct	591	
Romulea obscura	23 Aug	(1.5)	14	(2.6)	62	(2.1)	24 Oct	932	
Sparaxis bulbifera	27 Aug	(0.4)	15	(1.5)	62	(0.6)	28 Oct	12005	
Sparaxis villosa	06 Aug	(1.4)	10	(1.9)	65	(1.7)	09 Oct	754	
Wachendorfia multiflora	31 Jul	(1.4)	19	(3.1)	88	(1.9)	28 Oct	2395	
All Species	**14 Aug**	**(0.3)**	**19**	**(1.5)**	**77**	**(0.5)**	**30 Oct**	**41607**	

* Charismatic indicator species for the spring season

** Late spring flowers

*** No fruit phase detected

potential loss of utility to parks and proposed a strategic mowing schedule which first involved identifying lawns required for sitting or play and distinguishing them from lawns which can be landscaped as biodiversity meadows. The latter group can then be maintained with "benign neglect" to encourage biodiversity (Venn and Kotze 2014; Wastian et al. 2016). They proposed a two-tier strategy where leisure lawns are intensively mowed (7–10 times per year) and biodiversity lawns are extensively mowed (bi-annually) (Venn and Kotze 2014).

The proposed strategic halt for the duration of the flower to seed broadcast cycle, would be in-line with a "delayed start" mowing philosophy (Humbert et al. 2012). There-fore, this study set out to establish the length of time it takes for seed broadcast to begin in spring geophytes in order to inform better mowing practices for supporting urban popu-lations of spring-flowering geophytes and their pollinators. The study adopted a model originally designed to estimate the duration of primary moult season in birds (Underhill and Zucchini 1988). Unlike passerine birds, the growth period for each phenophase of feather growth is non-linear. Therefore, the Moult Model introduces an index of assumed

proportion of time that each phase of feather growth occu-pies within the greater progress of moult (Underhill and Zucchini 1988). This offers a level of flexibility for calcu-lating phenological duration which, through the use of the estimated index, is adapted to different species. Instead of stages in feather development, stages in seed development were identified making it possible to transfer the algorithm and apply it to plants. This was a novel approach to the study of plant phenology and provides a valuable backbone for being able to estimate seasonal duration (van der Valk 2011).

Developing a strategic approach

This study proposes that an assessment of the relative qual-ity and usage of each park is carried out beginning with a survey of the presence of spring-flowering geophytes and annuals. Citizen science can be mobilized as a powerful resource for determining the floral richness of each park and developing an inventory of native bulbs and annuals. The availability of crowd-sourced, geo-spatially available data makes the logistics of urban plant inventories accessible for

this kind of biodiversity classification (Barve et al. 2020). Data were collected on floral richness in 142 randomly selected parks in 2017 and 2018 (Brom 2022). From those data, parks can be classified into four categories: Type (1) Parks which contained three or fewer species of flowers from the most common group of exotic weeds and annuals; Type (2) Parks which contained between three and 10 species of native angiosperms, the majority of which are geophytes; Type (3) Parks which contained more than 10 species of native flowers; and Type (4) Parks which contained summer species and/or perennials. In this study, most of the observation parks were type 2. Keurboom Park, was a type 3 park, and Jack Muller and St John's POS were type 4 parks.

Type 1 parks require no grass-cutting suspension unless undergoing specific landscaping or rehabilitation treatments. This is because the common plants in this group have recovery strategies which make them well adapted to surviving frequent disturbance, over-grazing, and mowing events (Brom 2022). Type 2 parks benefit from the grass-cutting suspension window identified within the results of this study, namely August to mid-November. Type 3 parks would benefit from conservation or management interventions, rehabilitation, and invasive species management. Type 4 parks require further research and assessment for either a second mowing suspension window or alternative management strategies.

Four species within the study broadcast seed in late spring and were outliers to the median season of the focal species. Most notable was *Moraea neglecta*, a charismatic species which was enthusiastically pointed out by citizens at the parks where it occurred. The species is both relatively uncommon in the city and tends to occur on Type 3 parks justifying citizen stewardship. A charismatic species, it can

be managed with engagement from the local community and volunteer stewards with ease; however, seed broadcast had already begun by the end of the recommended mowing suspension window and so even without special management, populations would benefit from the proposed suspension.

For less charismatic species, a more creative intervention may be required. Visibility of plants from the tractor seat is a likely impediment to the success of a limited area mowing suspension and a clear landscape architectural language needs to be developed to signal different mowing responses. For example, the early onset of the *Dimorphotheca pluvialis* (Fig. 2) season at one park provided a visible marker for communicating to the contractor the area where the community regularly encountered a flush of spring flowers. Boosting lawns with bold floral markers, easily recognizable in the field could provide an affordable and simple way of signalling no-mow areas if patches were systematically sewn with species that flowered for the full duration of the season. Unfortunately, no single flower is in bloom for the entire season and so using floral markers would require a mix of species flowering at different times in order to support seed set success. *Ursinia nana* follows *Dimorphotheca pluvialis* and the parasol seeds have a structure which resembles flowers. A mix of these two abundant, rapid-reseeders, may provide the markers needed to protect geopyte-rich lawns through the spring season in Cape Town. Further research is needed to establish appropriate native seed mixes in other regions.

A common charismatic indicator species

The combination of *Baeometra uniflora*'s commonality, charismatic growth form (Fig. 2B) and long fruiting phase (mean end date 5 November), make this a suitable plant to

Fig. 2 A. *A field of the annual* Dimorphotheca pluvialis *was used by community members in some parks to communicate to the tractor driver where the boundaries of a spring no-mow test site should start.* **B**. *The geophyte,* Baeometra uniflora *in bud, flower and fruit pheno-* phases which has the longest fruiting phase of the observed flowers and, when the fruiting bodies crack, can be used as an indicator for the end of the spring flower season

use as an indicator species for capturing the local variation in phenological occurrences. The thick fruiting bodies are easy to identify and take longer to mature than most of the other focal species. These qualities mean that attentive contractors can wait for *B. uniflora* to open as an indicator for when the common bulbs and annuals have already begun seed broadcasting.

Conclusions and recommendations

Maintaining lawns in public space and road verges for their biodiversity and pollinator habitats as floral-rich resources, is an affordable and accessible way of boosting urban insect and angiosperm biomass. Other studies have found that improved pollinator and insect populations can be achieved through benign neglect, and low-intensity mowing schedules (Davis et al. 2017; O'Sullivan 2017; Venn and Kotze 2014), but a total moratorium on grass-cutting in road verges and public space is undesirable due to safety and weed-control requirements (Türkseven Doğrusoy and Zengel 2017; Zavadskas et al. 2019). In parts of the world that experience frost or snow in winter, which prevents mowing, a delayed start to spring mowing has demonstrated biodiversity benefits in the following year (Humbert et al. 2012), however this is not practical in regions that do not experience winter freezing.

In this study, we observed the phenology of flower phases and employed the Moult Model of Underhill and Zucchini (1988) to establish the duration of the period from bud to seed broadcast of austral spring flowers in a city in a Mediterranean Climate Ecosystem. In the case of the commonly-occurring native spring-flowering species (in this case austral), the flowering season lasted from August to the second week of November. A classification system is proposed based on structural diversity. We propose that in the study city, for parks containing three to ten species of spring-blooming flowers, mowing is suspended from the second week of August to the beginning of November. *Beaometra uniflora* emerged as a good indicator species for when the season is over. It is easily identifiable, relatively common, and has the longest fruiting period of the spring-flowering geophytes. For parks containing more than ten species of indigenous plants, the feasibility of setting aside permanent no-mow biodiversity areas within the park should be explored.

Implementing these strategies, would require minor revisions to the city's minimum standards to accommodate mowing suspensions without increasing frequency of mowing at other times of the year. Instead, resources should be deployed to managing invasive weeds during the spring season. Engagement with community organisations such as park associations can boost a city's capacity for fine-tuning mowing and maintenance practices to balance potentially conflicting community needs for utility and environmental stewardship. Lastly, it is recommended that a system of landscape markers be developed to aid tractor-drivers in recognizing areas which have been earmarked for a mowing suspension.

The methods recorded in this study for using phenology to define a strategic mowing suspension are applicable to Mediterranean Climatic Ecosystems that experience winter rainfall and a distinct spring flowering season.

Data Availability Data is available on request from the corresponding author.

Code Availability Code was constructed in RStudio and is available on request from the corresponding author.

Declarations

Conflicts of interest/Competing interests None.

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