Assessment of Field Fleawort (*Tephroseris integrifolia*) flowering, seed-set and grazing in Bedfordshire, UK

FIELD PROJECT REPORT

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ABSTRACT

Field Fleawort (*Tephroseris integrifolia* subsp. *integrifolia*) is a yellow chalk grassland perennial that is declining across its range. In the UK, populations have been designated as vulnerable to extinction and yet very few studies have been carried out to understand the factors affecting its survival. This current study asks whether insufficient flowering and seed-set, or interruption of these processes through grazing, is contributing to Field Fleawort's decline. A demographic study of 147 plants across two national nature reserves (Barton Hills and Knocking Hoe, Bedfordshire, UK) was carried out to monitor flowering, pappus production and signs of grazing between April and June 2024. Over half of the plants flowered at each site but differences in grazing pressure led to significant variation in the number of plants producing pappus. Analysis of grazed stems suggests that despite the presence of managed conservation livestock such as Herdwick sheep and Exmoor ponies, it is most likely rabbits that cause the primary interruption to the early phases of Field Fleawort's reproductive cycle.

CHAPTER 1 – INTRODUCTION

1.1 – Introduction

Chalk grassland is an internationally rare habitat that supports a diverse range of flora and fauna. It is characterised by shallow, nutrient-poor, lime-rich soil with a sward traditionally maintained by livestock grazing (Jefferson et al., 2019). An estimated 97% of all forms of semi-natural grassland have been lost in the UK since World War II (Fuller, 1987) due to a combination of conversion to arable land, nutrient-enrichment and over-grazing (Jefferson et al., 2019). These intensification processes favour the establishment of hardy grasses such as perennial ryegrass (*Lolium perenne*) and cocksfoot (*Dactylis glomerata*) and the nitrogen-fixing species white clover (*Trifolium repens*) at the expense of specialist forbs (Fuller, 1987). The threat to remaining lowland chalk grassland continues to this day via an opposite albeit no less damaging route: under-management. Under-grazing and neglect of calcareous grassland enables more vigorous species to take hold and shade out many of the plants that make chalk grassland unique (Stroh et al., 2017). The question of how best to manage land to protect surviving chalk grassland habitat and species is therefore increasingly pressing.

Field Fleawort (*Tephroseris integrifolia* subsp. *integrifolia*) is one such vulnerable chalk specialist. It is a densely hairy perennial with a basal rosette, single flowering stem and yellow flowers held on a terminal corymb (Stroh, 2016) (Figure 1). Flowers produce pappus and seeds are wind-dispersed an estimated 1-2m from the parent plant (Smith, 1979).

Figure 1 – Four key stages in the life cycle of Tephroseris integrifolia subsp. *integrifolia:*
1) Rosette with cottony hairs. 2) Emerging flowering stem with buds.
3) Corymb with multiple capitula. 4) Pappus formation.

The UK's Field Fleawort populations have been shrinking since the 1950s (Stroh et al., 2020) along with closely related sub-species across its range (Kadereit et al., 2021). While efforts are being made to protect wider chalk grassland habitats through scrub-clearing, seeding and conservation grazing (Ashwood, 2014), it is not known how UK populations of *T. integrifolia* are responding to these general management practices. Key to this lack of understanding is a complete absence of basic measures of population health, such as the ability of these plants to flower and set seed. There is a single 59-year-old demographic study of *T. integrifolia* subsp. *integrifolia* (then known as *Senecio integrifolius*) in Barham, Kent (Morgan, 1965) but there have been no such investigations since.

In order to understand the likelihood of *T. integrifolia* surviving into the future, it is crucial to know as a minimum whether existing conservation practices are supporting successful flowering and seed-set and how these outcomes differ under varying management strategies. It is not enough to put conservation measures in place without having evidence of outcomes (Sutherland, 2006) or to assume that what works for one species works for all. This study therefore aims to start filling this basic yet crucial evidence gap by assessing the early reproductive success of *T. integrifolia* populations across two Bedfordshire nature reserves.

1.2 – Literature Review

Tephroseris integrifolia subsp. *integrifolia* is part of a large and taxonomically complex genus of closely-related species and subspecies found across temperate and arctic regions of the northern hemisphere (Kadereit et al., 2021) (Figure 2). Most *Tephroseris* species across Europe are recorded as vulnerable, threatened or endangered (Kadereit et al., 2021), which implies a series of common threats across its range. In England, *T. integrifolia* subsp. *integrifolia* is classed as vulnerable (Stroh et al., 2014).

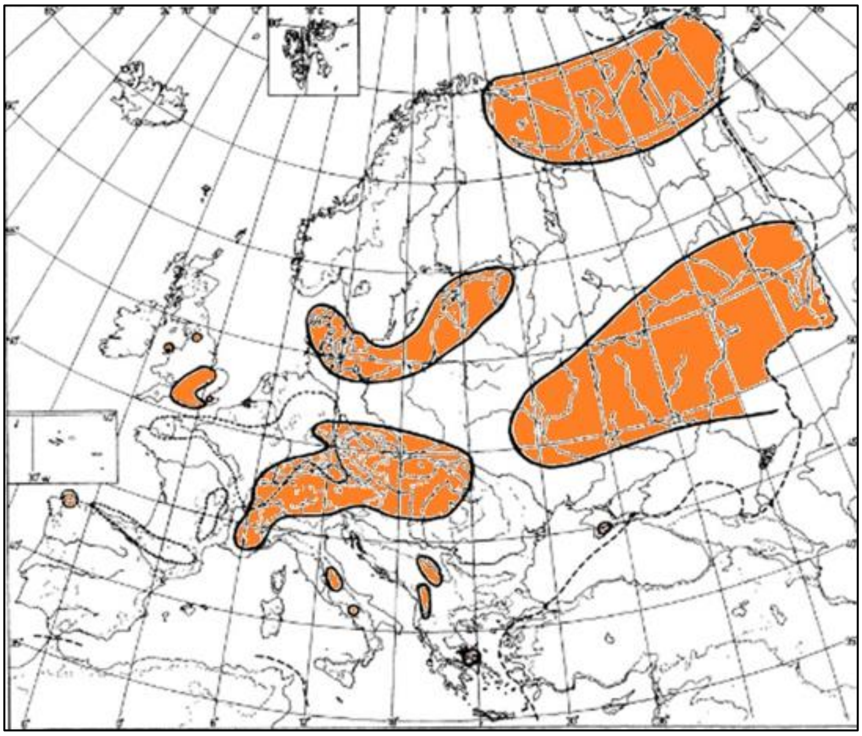

Figure 2 - Map showing European distribution of T.integrifolia. Adapted from Smith (1979).

Demographic studies of *T. integrifolia* in the UK (Morgan, 1965), southern Sweden (Widén, 1987) and Germany (Miendl, 2011) have all found that flowering varies widely from year to year. Widén (1987) and Meindl (2011) both suggest that this is primarily a result of weather conditions, with wet summers (Widén, 1987) and cold winters (Meindl, 2011) being beneficial to flower production. A more recent study of climatic effects points to increasingly warm temperatures in March and April for the long-term decline of *T. helenitis* in Germany, which the authors surmise is preventing the vernalisation needed for abundant flowering (Griebeler & Kadereit, 2023).

However, Morgan (1965) observed that even in a 'good' flowering year, less than half of his study population produced flowering stems, suggesting that even apparently ideal weather conditions are not sufficient to trigger flowering in all individuals. He also noted that 'good' years seemed to appear every other year, a pattern also observed by Smith (1979). Morgan (1965) asserts that this is unlikely to be the result of an environmental cause and instead proposes an intrinsic biennial habit, with the differing age structure of the cohort determining 'on' and 'off' years. This biennial pattern was not replicated in southern Sweden though (Widén, 1987), where over 50% of the plants in the study population flowered only once during five years of observation. These contradictory findings present an opportunity to contribute new evidence of flowering proportions to compare with existing European datasets and investigate factors that may influence flowering potential.

One such factor is the size of the plant. Morgan (1965) found that plants with five or more leaves in one year had a higher probability of flowering in the next, although this relationship was not predictive. Meindl (2011) discovered a similar relationship, showing that rosettes with a larger diameter in year *t* were more likely to flower in year *t+1* than rosettes that remained vegetative. As plant growth is affected by competition with its neighbours, these findings suggest a possible role for poor land management in suppressing plant growth and consequently reducing the proportion of individuals able to flower. With the mean lifespan of *T. integrifolia* estimated to be as short as 3.7 to 3.9 years (Meindl, 2011) and seeds that do not form a seed bank (Widén, 1987), it would not take many years of neglect and reduced flowering for a population to die out by chance without the opportunity to flower, seed and replace itself.

Stroh et al. (2017) also points to the role of current and historic land management practices in the decline of *T. integrifolia*. After resurveying twenty-two UK sites that supported *T. integrifolia* in the 1960s, they found that nine out of the ten sites where it had disappeared had been subjected to extended periods of neglect or under-grazing. These sites now supported a coarser sward with significantly increased coverage of *Bromopsis erecta*, *Dactylis glomerata* and *Poterium sanguisorba,* which have the potential to outcompete rosette-forming calcareous species such as *T. integrifolia* (Stroh et al., 2017). Once lost, calcareous grassland plants are less likely to recolonise even if favourable environmental conditions and grazing levels are reinstated (Bennie, 2006).

Under-grazing is widely judged to be more harmful to *Tephroseris spp*. than over-grazing not only thanks to competition, but also by reducing the availability and creation of bare patches for germination (Widén, 1987; Meindl, 2011; Stroh et al., 2017). Moderate livestock grazing is recommended to land managers as a means of providing both a short sward and a patchwork of bare ground (Stroh et al., 2017). However, the definition of 'moderate' is unclear. A quantitative study of the effect of grazers on *T. integrifolia* surviving to set seed is therefore long overdue.

1.3 – Objectives and questions

Three previously unstudied populations of *Tephroseris integrifolia* exist across two National Nature Reserves (NNRs) at Barton Hills and Knocking Hoe in Bedfordshire, UK. Both are actively managed by Natural England for the benefit of chalk grassland conservation, but reserve managers lack specific data on *T. integrifolia.* A demographic study will therefore be conducted across a three-month period to monitor flowering, seed-set and response to current conservation grazing.

My research questions are therefore:

- What proportion of the Field Fleawort populations flower across the two reserves?
- What proportion of the populations set seed across the two reserves?
- Is there a relationship between successful flowering and/or setting seed and: a) plant size or b) grazing?

The aim is not only to provide baseline knowledge in the present, but to design a repeatable protocol that offers potential for longer-term monitoring of the health of the UK's Field Fleawort populations.

CHAPTER 2 – METHODOLOGY

2.1 – Survey sites

Tephroseris integrifolia subsp. *integrifolia* is confined to southern regions of England on nutrient-poor chalk downland (Stroh, 2016). Hectads where the species has found over the past century are shown in Figure 3, along with the locations of our two reserves of interest, Barton Hills (Grid ref: TL089297) and Knocking Hoe (Grid ref: TL131307).

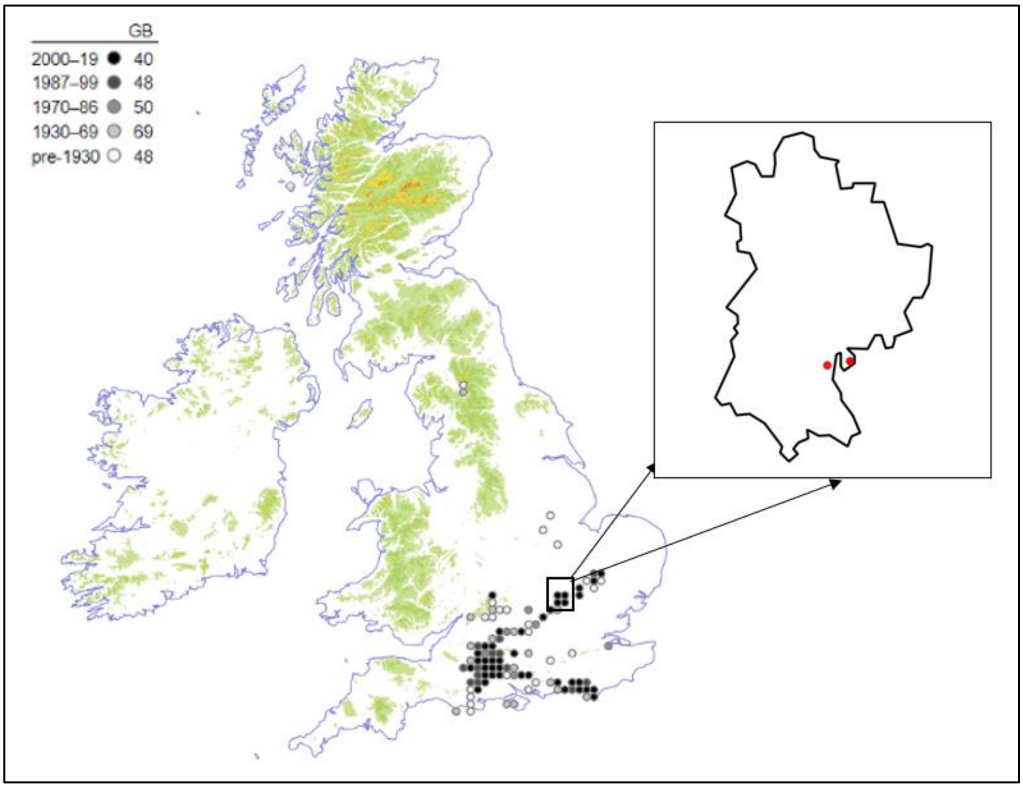

Figure 3 - Map showing number of hectads with presence of T. integrifolia subsp. *integrifolia since pre-1930. Adapted from Plant Atlas 2020 (Stroh et al., 2020). Insert shows the county of Bedfordshire and red dots the location of Barton Hills NNR and Knocking Hoe NNR (L-R).*

Knocking Hoe (8ha) and Barton Hills (48ha) are sited at the north end of the Chilterns near to the villages of Barton-le-Clay and Hexton (Figure 4).

Figure 4 - Location of Barton Hills NNR and Knocking Hoe NNR in Bedfordshire, UK.

Both NNRs have SSSI designations for the presence of unimproved lowland calcareous grassland as well as a number of nationally and locally rare species (Natural England, 2022a; 2022b). Knocking Hoe is home to a particularly high number of rarities including Burnt Tip Orchid (*Neotinia ustulata*), Moon Carrot (*Seseli libanotis*), Pasqueflower (*Pulsatilla vulgaris*), Spotted Catsear (*Hypochaeris maculata*) and our species of interest, Field Fleawort (*Tephroseris integrifolia*). The SSSIs in both cases were classified as 'Favourable' at the most recent inspection, with 8% of Barton Hills judged as 'Unfavourable – Recovering' (Natural England, 2022a; 2022b).

There are three main *T. integrifolia* populations across the two sites, with one being newly discovered by former reserve manager Graham Bellamy ahead of this study. All are found on southerly- and westerly-facing slopes on unimproved land. An initial visual survey in early April 2023 showed that populations formed broad, discrete clusters (a distribution pattern also found by Smith (1979)) with individuals in some cases numbering in the many hundreds. Each population - two at Knocking Hoe and one at Barton Hills - was designated as an individual sampling site for the purposes of this survey (Figure 5).

Figure 5 - Location of survey sites within: (A) Knocking Hoe NNR (yellow outline) and (B) Barton Hills NNR (orange outline).

Isaksson (2009) determined that *T. integrifolia* has a maximum pollination distance of 10 metres. As Knocking Hoe sites 1 and 2 are over 50 metres apart, we can reasonably assume that they are functionally separate and independent populations even if they are in fact fragments of an older, continuous patch.

Each survey site is summarised as follows:

Knocking Hoe site 1 - "KH1" - UNFENCED

- *T. integrifolia* population located on the steep sides of a remnant strip lynchet system.
- Sward is short and herb-rich, although less so than Knocking Hoe site 2. Some low shrubs emerging, mostly hawthorn (*C. monogyna*).
- Grazed all year round by a flock of between 46 and 57 Herdwick sheep (Figure 6) in 2023/34 (G. Bellamy, personal communication, July 2024).

Figure 6 - Herdwick sheep graze Knocking Hoe.

Knocking Hoe site 2 - "KH2" – FENCED

- *T. integrifolia* population found across the hill section of the hoe.
- It is the most botanically diverse of the sites and is surveyed annually for its large population of *Pulsatilla vulgaris.*
- Winter grazing by Herdwick sheep begins in late September after *Spiranthes spiralis* has finished seeding and ends in mid-March when *Pulsatilla vulgaris* begins to flower.
- Sheep are excluded at all other times by an electric fence.

Barton Hills site - "BH" - FENCED

- *T. integrifolia* located on top of 'Plum Pudding', a steep-sided, exposed hill in the heart of the reserve (Figure 7).
- Short sward at the top, increasing in height and scrubbier further downhill. Plants present include: Yellow-wort (*Blackstonia perfoliata*), Pasqueflower (*Pulsatilla vulgaris*), Harebell (*Campanula rotundifolia*) and Dwarf Thistle (*Cirsium acaule*).
- Grazed by a small herd of Exmoor ponies for most of the year but excluded by orange plastic fencing while *P. vulgaris* is flowering and seeding (March to June).
- Rabbit grazing has been reported at the site (Natural England, 2022b), which may not be prevented by the fence.

Figure 7 - Plum Pudding hill features prominently in the landscape at Barton Hills NNR.

This design enables comparisons between sites and in fenced and unfenced conditions.

2.2 – Sample selection and identification

Conducting a demographic study of *T. integrifolia* involves repeated relocation of plants that may remain vegetative throughout the season (Meindl, 2011) and may not be immediately obvious in the sward. The paper mapping method used in the only other UK-based demographic study was imprecise and many individuals were lost amid long grass (Morgan, 1965). Permanent tagging provides an alternative but is not feasible as all three sites are accessible to the public and tags may be taken or damaged. Markers can also draw unwanted attention to the location of rare plants (Vitt and Havens, 2016).

A more subtle yet reliable plotless method has been used at Knocking Hoe in a long-term study of Autumn Lady's Tresses (*Spiranthes spiralis*) (Wells, 1967). It involves a series of permanent posts from which co-ordinates are measured for individual plants and has enabled effective re-identification of plants over a 60-year period. This method was deemed equally suitable for the study of *T. integrifolia*.

At each site, two 60cm wooden posts were hammered into the ground within the *T. integrifolia* population, leaving approximately 15cm above the surface. The exact location was deemed unimportant as they are simply permanent reference points; the only arbitrary proviso being that they should mark the upper extent of the survey site and therefore not be placed at the lower extent of the *T. integrifolia* patch. Fifty individual plants were then randomly selected downhill from the two posts. This was achieved by a 30-minute search effort by three people, marking rosettes with flags as they were discovered (Figure 8a). A random number generator was then used to select fifty study plants per site, as recommended in Vitt and Havens (2016) to provide a random sample of the population. This initial selection process was carried out on April 18th 2024 once the rosettes had emerged but before flowering had commenced, in order to avoid biasing plant selection.

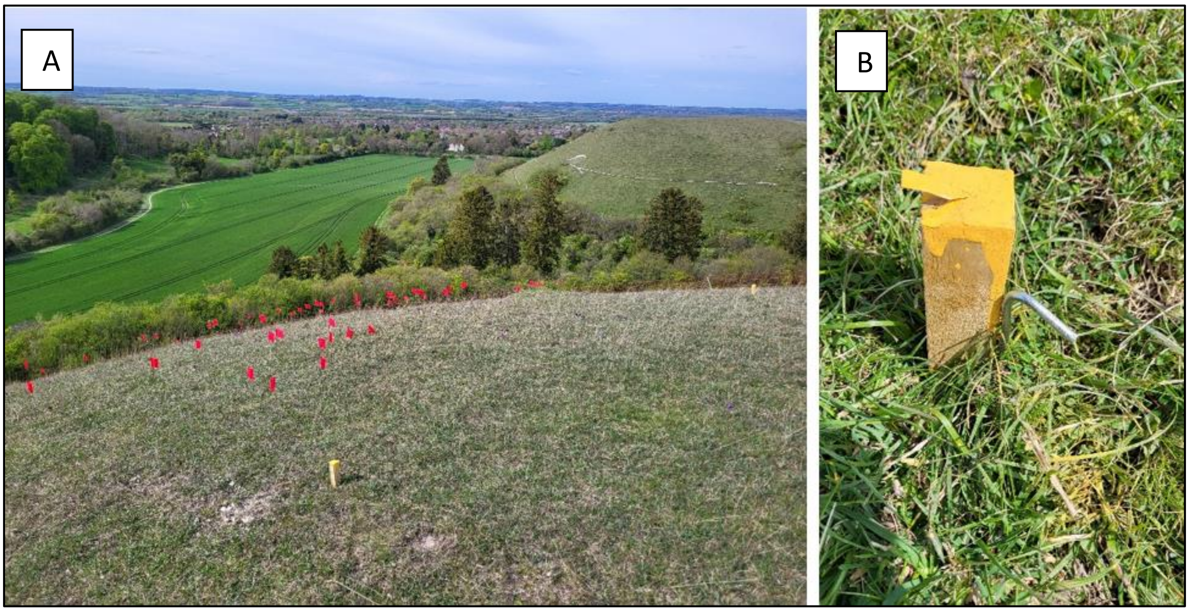

Figure 8 - A) Flags marking T.integrifolia rosettes during 30-minute search in area below two permanent posts. B) Permanent post with metal peg on inside corner, used to attach tape measures.

Following the protocol devised by Wells (1967), a metal peg was placed on the lower inner corner of each wooden post (Figure 8b). A 30m tape measure was then attached to each peg and distances recorded from post 1 and post 2 to each of the selected plants. These triangulation co-ordinates were then used to locate individuals on return visits. Triangulation from two posts has been found to be more accurate and reliable for long-term re-identification than a single post distance with a bearing (Vitt and Havens, 2016).

2.3 – Data recording

Each site was re-visited five times (May 17th, 24th, 30th and June 14th, 20th 2024), which covered the period of peak flowering through to pappus formation and seed set. The following data were recorded:

FLOWERING - To understand how flowering varies across the three sites, each individual was monitored for the presence of a flowering stem and the number of capitula produced.

SIZE – During the initial sample selection process, the diameter of individual rosettes was measured and the number of leaves counted. This is to understand if there is any relationship between plant size and its ability to flower. The height of each flowering stem (from ground to the base of the corymb) was also measured and repeated on subsequent visits in order to determine maximum height. This measurement was made in response to the observation by Widén and Andersson (1993) that flowering stems are taller in more shaded environments. In the present study, this could be related to taller swards caused by lower grazing pressure.

SEED-SET – The length of this study precludes monitoring successful germination. However, by recording the number of plants in the sample that successfully reach the pappus stage, we will have an indication of the proportion of plants that survive to potentially produce the next generation. Previous studies have shown that at least some level of seed set occurs as long as plants are not more than 10 metres from each other (Isaksson, 2009) and that a high proportion of viable seeds are produced per capitula (Meindl, 2011). This suggests that the presence of pappus is a reasonable proxy for successful seed set. Whether the seeds germinate and produce seedlings is not within the scope of this study.

GRAZING – To understand how current grazing protocols affect flowering and seeding, the presence of grazed stems was recorded. Remaining grazed stems were measured to see if it was possible to identify the herbivore responsible, as different grazers are known to reduce the sward to differing minimum heights (Thompson et al., 2004).

The datasheet used for the study can be found in Appendix 1.

2.4 – Statistical analyses

Chi-squared analysis was used to compare proportions of flowering, seed-set and grazing between sites. Where data conformed to necessary assumptions, ANOVA and Student's t-test were used. Where data could not be successfully transformed, Mann-Whitney U and Kruskal-Wallis tests were conducted. All statistical analyses were performed using RStudio version 23.09.1.

CHAPTER 3 - RESULTS

A summary of the data is in Table 1. Note that plants counted as having flowered include those that had already been grazed by the first return visit on May 17th, as only plants that have attempted to flower will produce a flowering stem. Plants counted as unknown could either no longer be found or were still in flower by the time of the final survey visit.

Table 1 - Summary of data collected across the three survey sites. Numbers are count data.

Site	No. of plants	Flowered	Grazed	Pappus stage	Unknown
KH1	47	25	24	1	0
KH2	50	31	4	25	2
BH	50	29	17	9	3
TOTAL	**147**	**85**	**45**	**35**	**5**

3.1 - Flowering

The fenced site at Knocking Hoe (KH2) had the highest proportion of flowering individuals at 62%. 58% flowered at the fenced site at Barton Hills (BH) and 53% at the unfenced Knocking Hoe site (KH1) (Figure 9). The difference in proportion of flowering plants between sites was not significant (χ^2 = 0.7052, df=2, p=0.7029), suggesting that any factors that affect flowering are similar across all sites.

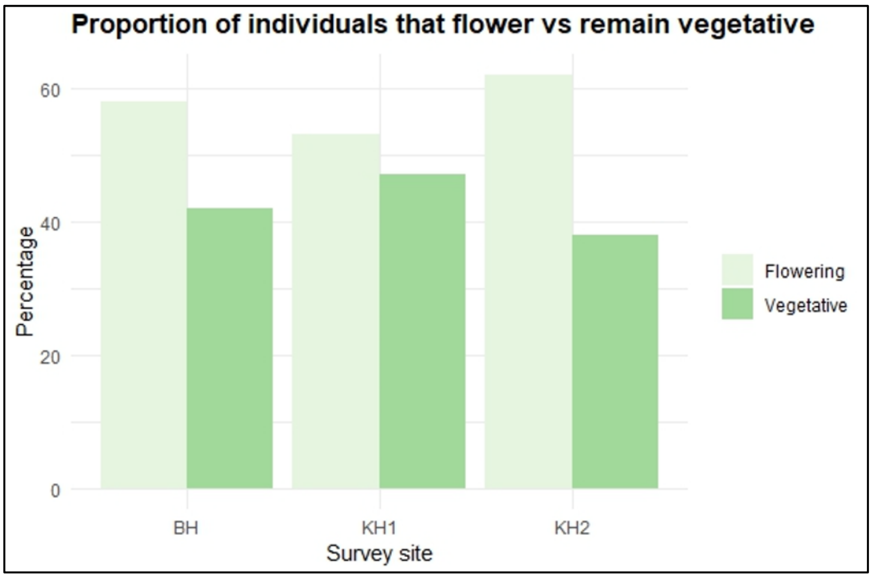

Figure 9 - Bar plot showing the proportion of surveyed plants that flowered versus remained vegetative across three sites in Bedfordshire.

The number of capitula per plant ranged from 1 to 6, with a mean of 1.92 for KH1, 2.4 for KH2 and 2.05 for BH. Again, the difference is not significant (Kruskal-Wallis = 3.3373, df = 2, p = 0.1885).

3.2 – Size

To analyse the effect of plant size on flowering, data were pooled across the three sites. As there is no difference in the proportion that flower between the three populations, an assumption was made that there are no mixed effects and that the data can be reasonably pooled.

NUMBER OF ROSETTE LEAVES - The mean number of leaves was 6.6±1.8 in those that flowered and 5.3±1.3 in those that remained vegetative. The distribution is shown in the boxplot in Figure 10. As the data cannot be normalised, a Mann-Whitney U test was conducted and showed a highly significant difference between flowering and vegetative individuals (Mann-Whitney U, $W=3747.5$, $p<0.0001$). Individuals with 6 or more leaves are more likely to flower than those with 5 or fewer.

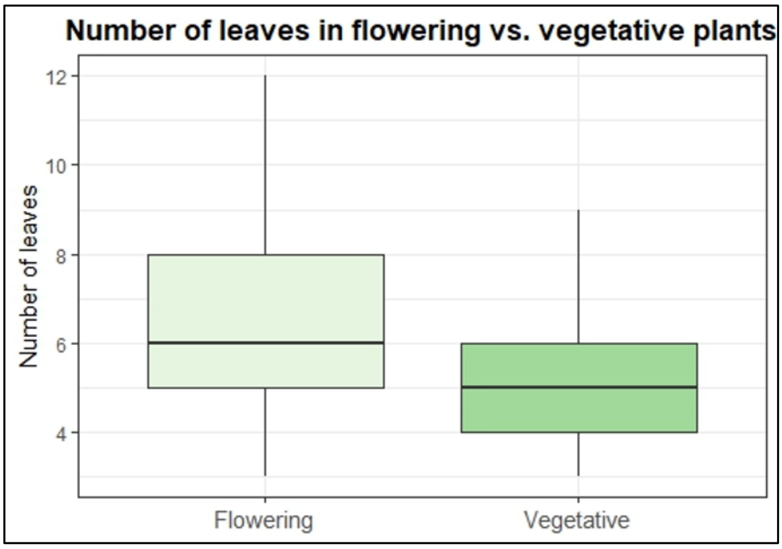

Figure 10 - Box plot showing how number of rosette leaves in April differs between flowering and vegetative plants.

ROSETTE DIAMETER – Data for flowering and vegetative rosettes were found to be normally distributed and have equal variances. A t-test showed no significant difference between the rosette diameters between those that flowered and those that remained vegetative (Student's t-test = 1.4268, df = 126.32, p-value = 0.1561).

STEM HEIGHT – The mean flowering stem heights at each site were: KH1=59.5mm, KH2=160.2mm and BH=115.7mm. Data was normally distributed with equal variance, and an ANOVA showed that the difference in height was highly significant (ANOVA, $F(2,56)=26.77$, $p<0.0001$). Post-hoc testing showed that these differences were highly significant between all three sites ($P<0.001$) (Figure 11).

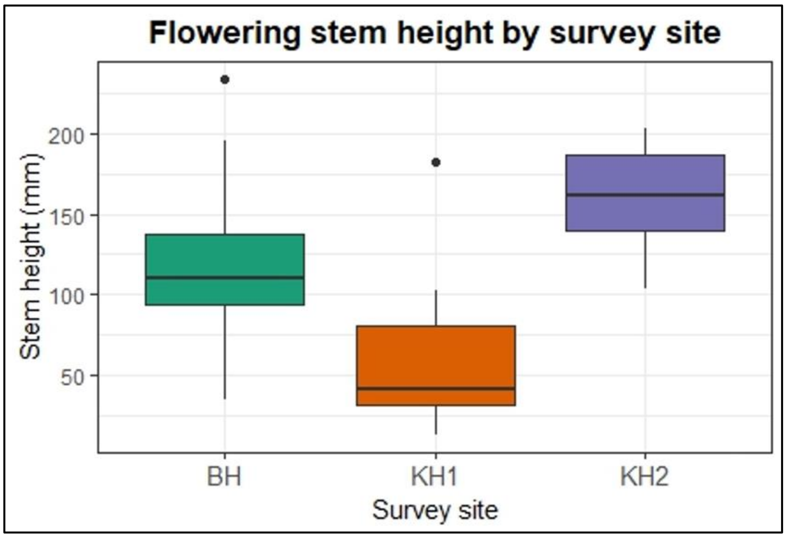

Figure 11 - Box plot showing how stem height (mm) varies between the three survey sites.

3.3 – Seed-set

Of the plants that flowered, 4% survived to the pappus stage at KH1, 80.6% at KH2, and 31% at BH (Figure 12). The difference is highly significant (χ^2 = 78.345, df = 2, p <0.0001). Where the proportion of plants producing pappus was high, signs of grazed stems were low and vice versa (Table 1).

Grazing was highest at KH1 and lowest at KH2, and the difference in grazing between sites was highly significant (χ^2=61.25, df=2, p<0.0001).

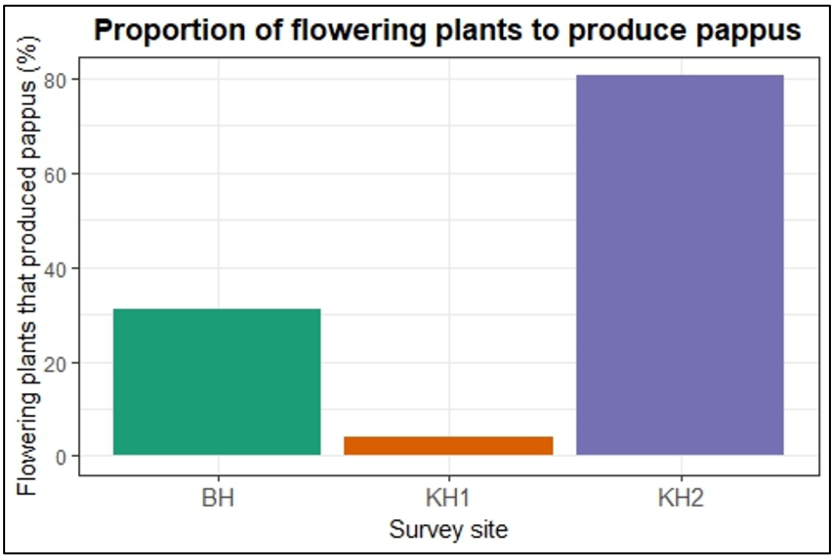

Figure 12 - Proportion of flowering plants that produced pappus per site.

3.4 - Grazing

Data of flowering stem heights after grazing could not be normalised. A Kruskal-Wallis test was therefore conducted and showed that the remnant stems did not significantly differ in height between sites (Kruskal-Wallis = 1.0916, df = 2, p = 0.5794).

The heights of the remnant stems were plotted to see if distinct patterns emerged to indicate the type of herbivore responsible (Figure 13).

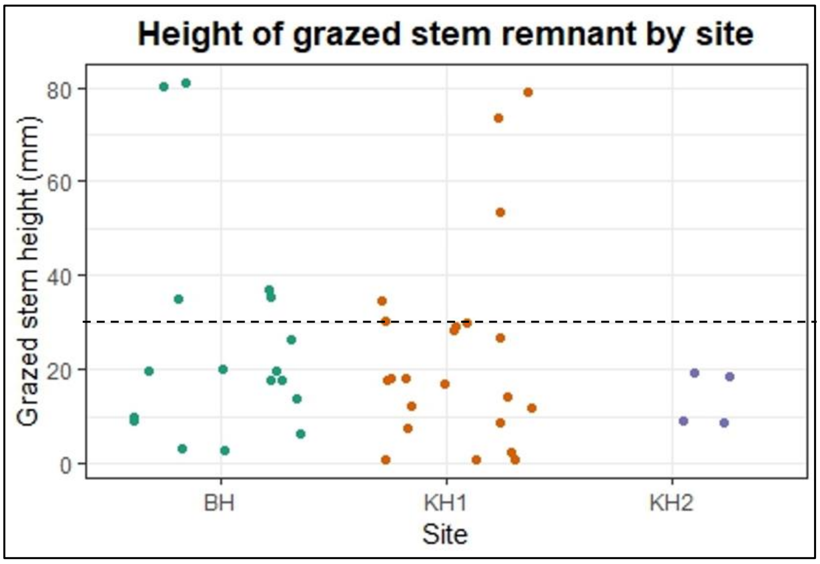

Figure 13 - Scatterplot showing the height of the remnant stem after grazing, by site. Dashed line indicates lower bound of expected height from sheep grazing.

Sheep are reported to graze swards to 30-40mm (Thompson et al., 2004; Chapman, 2017), the lower bound of which is indicated in Figure 13 by the dashed line. Rabbits are reported to graze to 25mm or less (Tansley & Adamson, 1925; Thompson et al., 2004). While it is not possible to be certain about the grazer responsible for any particular stem, the abundance of data points below 30mm indicates that a herbivore other than sheep is likely the primary grazer of *T. integrifolia* at both Knocking Hoe and Barton Hills.

CHAPTER 4 - DISCUSSION

4.1 – Flowering

The *T. integrifolia* populations at Knocking Hoe and Barton Hills all showed abundant flowering during the survey season, ranging from 53% to 62%. Anecdotally, 2024 has been described as a good year for flowering (G. Bellamy, personal communication, July 2024) and is in line with previous 'good year' results found across Europe: with 57% flowering recorded in the 1990s in Swedish populations (Widén and Andersson, 1993) and 38-67% flowering in 2006 in the related *T. integrifolia* subsp. *vindelicorum* (Meindl, 2011). From a conservation perspective, we can conclude that the current survey populations are flowering at expected levels and that this phase of reproduction is not a cause for concern. Furthermore, as there is no statistical difference in flowering proportions between the three sites, we can assume that the underlying environmental conditions that affect flowering are consistent where *T. integrifolia* is present.

The high proportion of flowering may be a response to above average spring rainfall (Met Office, 2024a), which has previously been associated with good flowering years (Widén, 1987). Flower production has also been linked to cold winters (Meindl, 2011) and cool spring temperatures (Griebeler & Kadereit, 2023) but this was not observed in the present study. The UK Met Office (2024b) reported the second warmest winter on record for England and Wales in 2023/24, with Bedfordshire experiencing just a single 5-day period of sub-zero temperatures in mid-January. As *T. integrifolia* is known to be particularly sensitive to drought (Smith, 1979), it may be the case that the benefits of a wet spring outweighed the detrimental effects of a warm winter. Alternatively, the short cold spell in January may have provided sufficient vernalisation to stimulate flowering. Further study is needed to see how the populations fare in future. However, with the prospect of the climate warming into the future it is encouraging to see that there is potential for high levels of *T. integrifolia* flowering during warmer, wetter years.

As with previous studies, flowering was found to be influenced by the size of the plant as measured by the number of leaves (Morgan, 1965). The mean number of leaves across the three sites was 6.6±1.8 in flowering individuals and 5.3±1.3 in those that remained vegetative. Morgan (1965) obtained markedly similar results, with plants found to have 5 or more leaves in the previous year being more likely to flower the following spring than those with 4 leaves or fewer. As a hemicryptophyte, the rosette leaves of *T. integrifolia* die back in the autumn and produce small overwintering buds that form new leaves in the spring (Stroh, 2016). This suggests that conditions in the current year may affect the number of leaves – and thus the likelihood of flowering – the following year. An interesting line of future enquiry would be to see if flowering plants produce fewer leaf buds in subsequent years until they have sufficient energy to flower again. If such a relationship exists, it would prove useful to ecologists as a means of predicting the likelihood of flowering in any particular year.

4.2 – Flowering and grazing

Chalk grassland species are sensitive to competition from neighbouring vegetation (Bennie, 2006), which is why conservation grazing is used to maintain a short sward. A mixture of fenced / unfenced areas and different livestock densities resulted in differing sward in the three sites by late-May 2024. The sward at KH1 was short; KH2 was tall and so luxuriant it became difficult to locate the permanent posts; and BH was generally short but with more flowering stems that at KH1. This variation in sward height – and by extension grazing intensity – is reflected in the significant differences observed in mean flowering stem height between the sites (Figure 12). Previous studies have found that *T. integrifolia* grows taller stems in luxuriant vegetation (Smith, 1979) and in ungrazed areas near to shrubs (Widén, 1987). However, as the proportion of flowering plants does not differ between the sites, we can conclude that flowering is not negatively affected by the current grazing regime.

4.3 – Seed-set and grazing

The proportion of flowering plants that formed pappus and assumed seed-set was high at KH2 (80.6%) but low at BH (31%) and KH1 (4%). This was undoubtedly the result of grazing, with many of the flowering stems at KH1 having been grazed before the first data collection in May. This could be a cause for concern. Over-grazing is well-known to prevent successful flowering (Widén, 1987) and *T. integrifolia* does not produce a seed bank (Smith, 1979) meaning that continued over-grazing risks the eventual depletion and loss of the population.

However, a low number of pappus-producing plants is not necessarily a hindrance. Meindl (2011) found that in the related *T. integrifolia* subsp. *vindelicorum*, recruitment was high despite years of low-level flowering. The population included many young plants and showed stable or positive growth in the presence of a suitable grazing regime (Meindl, 2011). This was attributed to high seed production per plant (>200) and grazing providing open vegetation and safe sites for germination.

These findings are of potential significance for the management of *T. integrifolia* subsp. *integrifolia* in Bedfordshire. Crucially, it suggests that the number of flowers that produce seed is less important than having a place for the seeds to successfully establish. In the present study, site KH1 had a single pappus-producing plant with two capitula (Appendix 2). Smith (1979) reports an average of 72 ± 1.9 seeds per capitulum with a 75-80% rate of germination in the first 15 days. Using these figures, KH1 may have produced a potential 144 seeds to contribute to the next generation and only one needs to establish to replace the parent plant. Seedling establishment was beyond the scope of this survey and is known to be a particularly vulnerable phase of the life cycle (Smith, 1979; Meindl, 2011), but further study would confirm whether or not the seeds produced at Knocking Hoe and Barton Hills have sufficient places in which to develop.

4.4 – Types of grazers

Sites KH2 and BH are fenced in order to exclude grazing livestock at certain times of year. However, the data show that almost as many individuals were grazed from BH (17/50 plants) as in the unfenced KH1 (24/47 plants). Wild grazers must therefore be breaching the fence.

This study has made the first-known attempt to use the height of grazed stems to understand which animals are grazing *T. integrifolia* (Figure 13). While the results are not conclusive and need further verification, it is proposed that the likely primary grazer at all sites is the rabbit (*Oryctolagus cuniculus*). For Barton Hills, this will be of no surprise to reserve managers as rabbits have previously been noted as a problem (Rolls, 2022b). Rabbit droppings were also spotted during data collection. Figure 13 reveals that most stems at BH were grazed to 20mm or less, which is within the precise range expected for rabbits (Tansley & Adamson, 1925). The four instances of grazing at the fenced KH2 also fall in the <20mm range.

Of greater interest is the pattern that emerges at KH1. Figure 13 shows that just over half the grazed stems are <20mm, which we can assume is the result of rabbit grazing as before. Stems 30mm and over are in the expected range for sheep (Thompson et al, 2004), which are present year-round at KH1. However, the overall pattern is very similar to that seen at BH where sheep are absent. This raises the prospect that rabbits are grazing most if not all stems at KH1 as well, with some by chance being grazed longer than others. Further study, perhaps involving the introduction of a series of rabbit-proof fences, would allow a better understanding of their role.

As 2024 experienced above-average rainfall, it is worth noting that Smith (1979) proposes slugs and snails as the main 'animal feeders' of *T. integrifolia*. She also states that 'the plant…does not appear to be eaten by grazing mammals…This might be because of the poisonous nature of the alkaloidal substances which it contains.' While this study cannot comment on the role of slugs and snails, the evidence suggests that the absence of mammalian feeding is unlikely.

CHAPTER 5 - CONCLUSION

In this first UK study of *T. integrifolia* subsp. *integrifolia* for 59 years, three Bedfordshire populations have been shown to successfully flower and set seed. As the original Burham Down population studied by Morgan has since been lost (Kitchener, 2012), this dataset now provides an important new baseline for further study.

Reserve managers should be reassured that *T. integrifolia* can survive under varied conservation grazing regimes. However, it is recommended that specific focus is paid to rabbit populations as they are proposed to be the main grazers at these sites. This does not imply rabbits are the enemy - indeed the loss of rabbits from myxomatosis has been directly attributed to the *T. integrifolia* extinction at Burham Down. In 2024, Rabbit Haemorrhagic Disease is similarly threatening wild rabbits and the grasslands they engineer (APHA, 2020). This study therefore recommends adjusting livestock grazing to incorporate moderate rabbit populations where possible. Rabbit control should only be considered when numbers suggest possible irreversible damage to the grassland.

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APPENDIX 1

FIELD FLEAWORT DATASHEET			NAME OF SURVEYOR						DATE
SITE			WEATHER						TIME START
SITE DESCRIPTION									
PLANT NUMBER	CO-ORDINATES (POST 1 / POST 2) (cm)	ROSETTE DIAMETER (mm)	NO. OF LEAVES	FLOWERING (Y/N)	NO. OF FLOWERS	STEM HEIGHT (mm)	GRAZED (Y/N)	PAPPUS (Y/N)	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									

APPENDIX 2 – summary data for sites KH1, KH2 and BH

Site code	Plant #	Rosette diameter (mm)	No. of rosette leaves	Flowered (Y/N)	Grazed (Y/N)	No. of flowers	Pappus (Y/N)	Flowering stem height (mm)	Grazed stem height (mm)
KH1	1	59	4	Y	N	2	Y	182	
KH1	2	67	6	Y	Y		N		14
KH1	3	45	7	N	N		N		
KH1	4	62	6	Y	Y		N		9
KH1	5	44	8	N	N		N		
KH1	6	38	7	Y	Y		N		35
KH1	7	48	8	Y	Y		N		18
KH1	8	60	8	Y	Y	4	N	40	12
KH1	9	41	8	Y	N	1	N	13	
KH1	10	42	4	N	N		N		
KH1	11	61	8	Y	Y		N		
KH1	12	40	7	N	N		N		
KH1	13	51	9	N	N		N		
KH1	14	44	7	Y	Y	2	N	31	30
KH1	15	67	8	Y	Y		N		18
KH1	16	39	4	Y	Y	1	N	81	79
KH1	17	60	11	Y	Y		N		1
KH1	18	48	7	Y	Y		N		8
KH1	19	38	6	N	N		N		
KH1	20	33	5	N	N		N		
KH1	24	36	6	N	N		N		
KH1	25	60	8	Y	Y	2	N	40	27
KH1	26	43	8	Y	Y	2	N	17	2
KH1	27	61	5	N	N		N		
KH1	28	48	7	Y	Y		N		1
KH1	29	67	7	Y	Y	2	N	103	53
KH1	30	70	9	Y	Y		N		17
KH1	31	59	7	N	N		N		
KH1	32	45	7	Y	Y	3	N	85	74
KH1	33	61	5	N	N		N		
KH1	34	38	6	Y	Y	1	N	25	29
KH1	35	55	7	Y	Y		N		28
KH1	36	32	4	N	N		N		
KH1	37	57	6	N	N		N		
KH1	38	59	6	N	N		N		
KH1	39	50	9	Y	Y		N		1
KH1	40	50	3	N	N		N		
KH1	41	62	4	N	N		N		
KH1	42	54	10	Y	Y	1	N	65	12
KH1	43	46	3	N	N		N		
KH1	44	32	4	Y	N	2	N	41	
KH1	45	55	5	N	N		N		
KH1	46	43	4	N	N		N		
KH1	47	42	7	Y	Y		N		18
KH1	48	58	8	N	N		N		
KH1	49	63	4	N	N		N		
KH1	50	42	7	Y	Y	2	N	50	30

Site code	Plant #	Rosette diameter (mm)	No. of rosette leaves	Flowered (Y/N)	Grazed (Y/N)	No. of flowers	Pappus (Y/N)	Flowering stem height (mm)	Grazed stem height (mm)
KH2	1	64	7	N	N		N		
KH2	2	60	6	Y	N	3	Y	162	
KH2	3	55	5	Y	N	3	Y	149	
KH2	4	61	4	Y	N	3	Y	145	
KH2	5	56	6	Y	N	3	Y	203	
KH2	6	65	6	Y	N	3	Y	175	
KH2	7	62	5	N	N		N		
KH2	8	46	6	N	N		N		
KH2	9	54	6	N	N		N		
KH2	10	48	6	Y	N	1	Y	141	
KH2	11	63	5	Y	N	2	Y	165	
KH2	12	62	4	Y	N	2	Y	190	
KH2	13	57	5	Y	N	3	Y	160	
KH2	14	49	5	N	N		N		
KH2	15	75	11	Y	N	1	Y	115	
KH2	16	50	12	Y	N	2	Y	193	
KH2	17	48	6	N	N		N		
KH2	18	58	6	Y	Y		N		9
KH2	19	65	6	Y	N	2	Y	127	
KH2	20	60	8	Y	N	2	Y	169	
KH2	21	65	7	Y	Y		N		18
KH2	22	73	6	Y	N	6	Y	202	
KH2	23	63	6	N	N		N		
KH2	24	72	8	Y	N	3	Y	189	
KH2	25	40	7	Y	N	3	Y	164	
KH2	26	45	5	N	N		N		
KH2	27	75	6	Y	N	3	Y	146	
KH2	28	51	6	N	N		N		
KH2	29	68	4	N	N		N		
KH2	30	56	6	Y	N	2	Y	185	
KH2	31	69	4	Y	Y		N		19
KH2	32	41	4	N	N		N		
KH2	33	69	4	N	N		N		
KH2	34	54	7	Y	N	2	N	112	
KH2	35	58	8	N	N		N		
KH2	36	44	7	N	N		N		
KH2	37	50	8	Y	N	1	Y	162	
KH2	38	49	4	N	N		N		
KH2	39	64	6	Y	Y		N		9
KH2	40	40	5	N	N		N		
KH2	41	59	8	Y	N	2	Y	123	
KH2	42	43	5	Y	N	1	Y	138	
KH2	43	60	5	Y	N	1	N	104	
KH2	44	49	6	N	N		N		
KH2	45	61	5	Y	N	4	Y	202	
KH2	46	55	9	Y	N	2	Y	129	
KH2	47	59	6	N	N		N		
KH2	48	56	5	Y	N	2	Y	190	
KH2	49	50	5	N	N		N		
KH2	50	57	7	Y	N	4	Y	185	

Site code	Plant #	Rosette diameter (mm)	No. of rosette leaves	Flowered (Y/N)	Grazed (Y/N)	No. of flowers	Pappus (Y/N)	Flowering stem height (mm)	Grazed stem height (mm)
BH	1	53	5	Y	N	2	Y	111	
BH	2	51	6	Y	N	2	Y	125	
BH	3	34	6	Y	N	2	Y	47	
BH	4	57	9	Y	N	4	Y	35	
BH	5	59	9	Y	Y		N		6
BH	6	43	5	N	N		N		
BH	7	60	10	Y	Y		N		9
BH	8	61	5	N	N		N		
BH	9	65	5	N	N		N		
BH	10	60	6	N	N		N		
BH	11	54	6	Y	N	2	Y	110	
BH	12	59	6	N	N		N		
BH	13	51	8	Y	N	2	Y	54	
BH	14	61	6	Y	N	2	Y	94	
BH	15	69	4	Y	N	3	N	171	
BH	16	61	6	Y	N	2	Y	145	
BH	17	80	4	Y	N	2	Y	195	
BH	18	37	4	Y	Y		N		18
BH	19	49	8	Y	Y		N		10
BH	20	53	6	N	N		N		
BH	21	60	5	Y	Y	1	N	94	81
BH	22	51	5	N	N		N		
BH	23	59	5	Y	N	2	N	65	
BH	24	68	4	N	N		N		
BH	25	57	7	Y	Y	2	N	171	80
BH	26	52	5	N	N		N		
BH	27	44	6	Y	Y	3	N	110	18
BH	28	47	6	Y	Y	2	N	98	14
BH	29	61	4	N	N		N		
BH	30	34	6	N	N		N		
BH	31	55	3	N	N		N		
BH	32	50	5	Y	Y		N		35
BH	33	53	7	Y	Y	2	N	99	20
BH	34	49	5	N	N		N		
BH	35	43	6	Y	Y	1	N	110	20
BH	36	48	7	Y	N	2	N	130	
BH	37	63	4	N	N		N		
BH	38	65	5	N	N		N		
BH	39	52	4	N	N		N		
BH	40	45	3	Y	Y	1	N	234	26
BH	41	48	3	N	N		N		
BH	42	83	5	N	N		N		
BH	43	68	5	Y	Y		N		20
BH	44	60	5	Y	Y		N		3
BH	45	55	6	Y	Y		N		3
BH	46	60	7	Y	Y		N		37
BH	47	73	6	N	N		N		
BH	48	48	5	N	N		N		
BH	49	60	6	Y	Y		N		35
BH	50	46	5	N	N		N		