Field Wormwood

Its ecology and conservation

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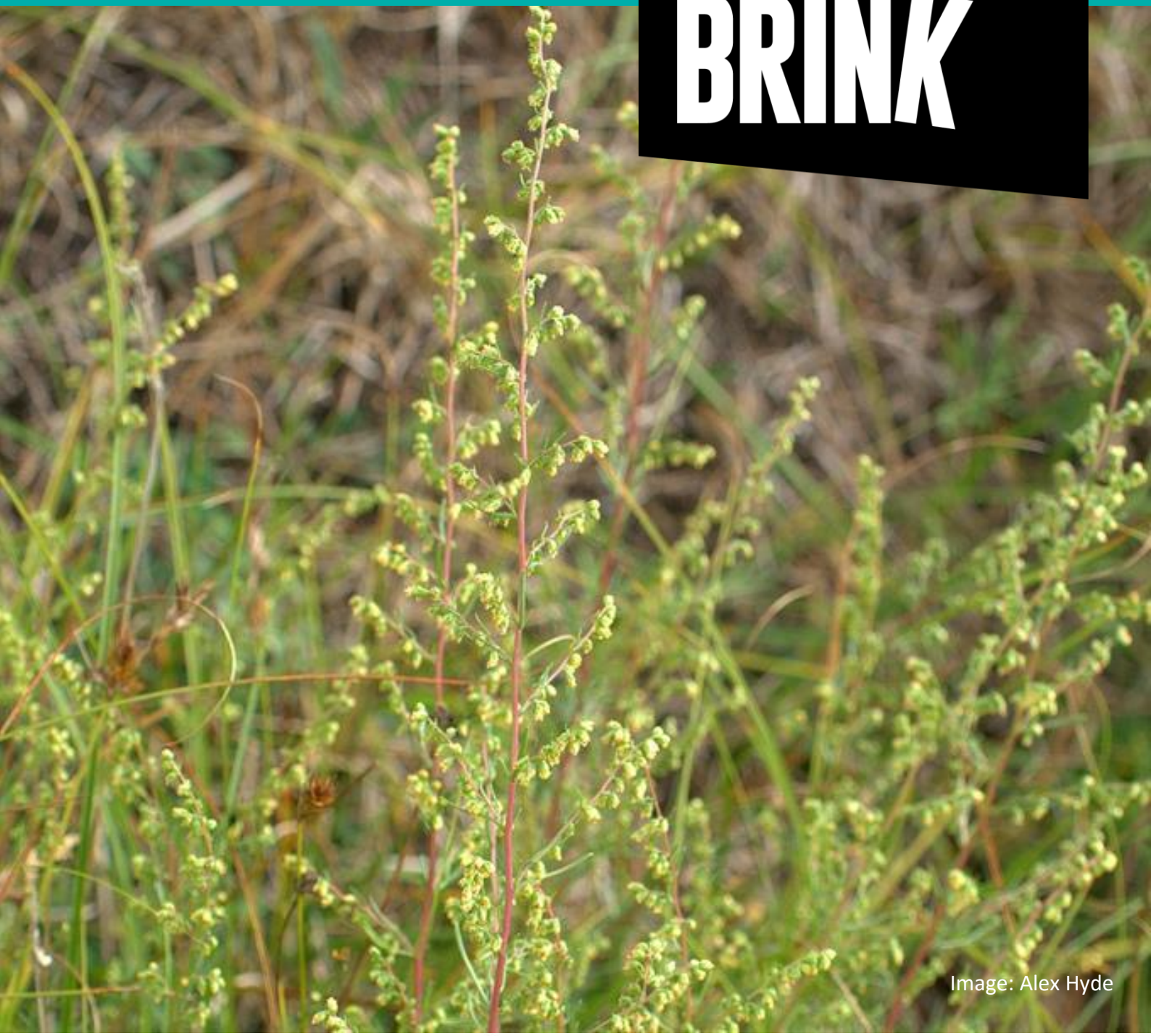
BACK FROM THE BRINK



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1. Morphology, Identification, Taxonomy & Genetics

1.1. Morphology & Identification

Field wormwood (also known as field southernwood, Breckland wormwood and Breckland mugwort) is a deep-rooted perennial herb with a branched, creeping, woody stock, producing tufts of short, non-flowering shoots and decumbent to ascending flowering stems to 75 cm. The stems are annual, dying back each year and being replaced with new ones from the base. The leaves are deeply divided, grey-green and pubescent when young, glabrous when mature. Unusually for this genus, they are *not* aromatic, or almost so (Thorogood 2016). The compound flowers lack nectaries and are produced from August into September in the UK. The numerous capitula are borne on loose racemose panicles.

1.2. Taxonomic considerations

Field wormwood is closely related to dune wormwood *Artemisia crithmifolia* and until recently, the two were considered conspecific, field wormwood being regarded as *A. campestris* subsp. *campestris* and dune wormwood as *A. campestris.* subsp. *maritima.* Stace (2010) marks this and it is retained in Stace (2019); however, dune wormwood is now widely elevated to species level as *Artemisia crithmifolia.* This has implications for assessment of distribution; all existing UK *Artemisia campestris* is now considered to be in Breckland (see 2.3.2.2.2. [below]). It is not possible to assign species names to old records of *A. campestris* from outside Breckland for which there are no voucher specimens in herbaria. The relationship with other subspecies is also of note as there are many known from other parts of the world (see 2.1. [below]); so, for the purposes of this document, what follows refers only to that entity known formerly as *Artemisia campestris* subsp. *campestris.*

2. Distribution and Current Status

2.1. World

Field wormwood has a circum-boreal, temperate distribution which, in this instance, includes the Mediterranean regions of Tunisia and Algeria. It is listed as of Least Concern at a global level by the IUCN, although widespread declines are noted.

2.2. Europe

The species has a Euro-Siberian distribution in the Palaearctic and is known as a native from all European countries except Eire, Malta, Iceland, Monaco and San Marino. Widespread and, in places, abundant, it is also listed as of Least Concern.

2.3. United Kingdom

Field wormwood has been recorded from East Anglia, south Wales, the Crosby dunes, the Humber estuary and around Edinburgh. However, it is only considered native in East Anglia. The species was considered vulnerable at the Great Britain level (Cheffings *et al* 2005) but has been recently re-assessed as Endangered (Leach 2019).

2.3.1. Wales and Scotland

All records for the species from Wales and Scotland used to be considered as aliens. However, the determination of plants at Crymlyn Burrows, in Wales, as *A. crithmifolia* has led to a re-assessment and these plants are now considered native. This is only significant for this document if one does not accept the elevation of the subspecies to species.

2.3.2. England

The same (as in 2.3.1. [above]) applies for plants at Crosby which are now considered native *A. crithmifolia.* However, all other records from England outside East Anglia are still considered non-native.

Field wormwood is considered Endangered in England (Stroh *et al* 2014).

2.3.2.1. East Anglia - outside the Brecks

In East Anglia, field wormwood has been recorded outside the Brecks at seven locations:

Five in Norfolk: at Blickling in 1866, on Mousehold Heath at Sprowston near Norwich in 1887, near Holt in 1934, at Cley-next-the-Sea in 1954 and on a road verge at East Tuddenham in 1992. All of these can be considered casuals, as they did not persist.

Two in Suffolk, at Bury St Edmunds in 1954.

The origin of the East Tuddenham plant is unknown but its occurrence on a roadside verge is consistent with the most recent finding within the Brecks, in an informal car park – tyre tread or botanist's boot must be the most likely transport modes.

2.3.2.2. Breckland

2.3.2.2.1. Known sites

(Also see Appendix I - Register of sites)

Breckland has always been the stronghold of field wormwood in the UK. Data collated for the 2010 Breckland Biodiversity Audit enables us to claim with some certainty that the plant has only ever been known from 36 native sites. This is not however a precise number. Some of the early records refer to broad areas within which some of the more specific locations may lie – so it would be more accurate to say that the plant has been known from no more than 36 native sites. In addition, in the years to 2019, the plant has been introduced to six further sites from where it has never been

known, making a total of 42 sites. Other re-introductions have been made where plants had seemingly disappeared, but more on this in 7.1 [below].

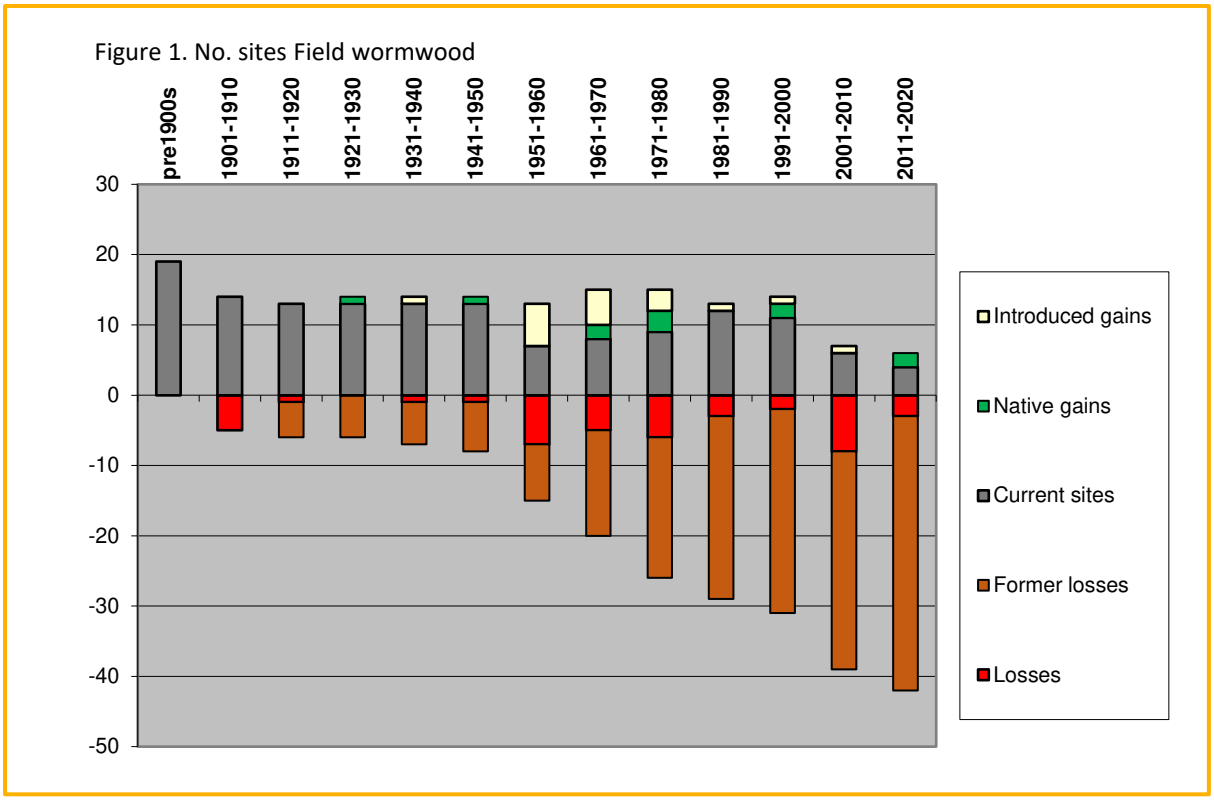
Table 1. Sites for field wormwood in Breckland as of summer 2019, last records for these sites are included up to September 2021. The table is dated to summer 2019 because conservation translocations were undertaken in the winter of 2019/20 which change and complicate the situation. Again, more on this in 7.1 [below]. Introduction/reintroduction sites are shaded orange (see Appendix 1 for register of sites), sites where is extant is highlighted in green. NK indicates unknown.

Site	First record	Last record	Peak count	Extant?
Elveden	1670	1962	NK	N
Barnhamcross Common	1695	1976	15	N
Thetford, Norwich Road	1724	1805	NK	N
Worlington Freckenham	1773	1909	NK	N
Icklingham Plains	1796	1880	NK	N
Cranwich, Devils Dyke	1840	1934	41	N
Barnham, Little Heath	1841	1923	NK	N
Brandon, Mile End – Town St.	1845	2003	2-3,000	N
Wangford Warren Airfield Lights	1860	2005	30	N
Risby	1876	1876	NK	N
Thetford, London Road	1876	1950	NK	N
Culford Heath	1878	1879	NK	N
Brandon, Ling Heath	1881	1960	NK	N
Lakenheath, A1065	1889	2008	200	N
Ickburgh Fields	1890	1988	200-300	N
Cranwich Heath	1900	1924	NK	N
Thetford Heath	1926	1960	NK	N
Icklingham, Pilgrim's Path	1939	1950	NK	N
Old Thetford Golf Course	1948	1949	NK	N
Icklingham	1948	1958	NK	N
Lakenheath Warren	1955	2021	94	Y
Weeting Heath/Arable Weed Reserve	1957	1992	36	N
Barnhamcross Common	1959	1979	NK	N
East Wretham Heath	1962	1976	4	N
Thetford, Howards Belt	1963	1964	NK	N
Thetford, nr. Weyroc factory	1964	1964	NK	N
Santon, St Helen's Well area	1977	1977	NK	N
Brandon depot, Forestry Commission	1980	1980	NK	N
Santon Street	1980	1988	1	N
Thetford Heath	1983	2000	NK	N
Mildenhall, High Lodge	1988	2020	653	Y
Brandon Artemisia Reserve	1988	2021	1722	Y
Mildenhall Woods	1993	1994	NK	N
Thetford, Elm Road	1994	1999	NK	N
Brandon, London Road Industrial Estate	1998	2021	NK	Y
Elveden, Center Parcs	1999	1999	1	N
Ickburgh Fields	2006	2021	27	Y
College Heath Rd	2018	2021	41	Y

Site	First record	Last record	Peak count	Extant?
Icklingham informal car park	2019	2021	1	Y

Introduced sites = shaded orange – see Appendix I for register of sites.

Figure 1. Graph showing number of known sites for field wormwood across decades



The table suggests a pattern of continual decline but this is not so. Figure 1 [above] shows the number of sites known in different decades and reveals a different story.

Although sites have been lost in most decades, generally they have been replaced by a combination of new native finds and (re-)introductions; this has been sufficient to maintain the number of sites at around 11-14 for a century or so. It is not until the 2000s that we see the number of sites halve, although a further loss of three sites after 2010 has been mitigated in part by two new native finds. It is also important to remember that this is set against a background of dwindling population size more or less across the board.

The locations listed tend to fall into 12 (arguably 10) areas of occupation, about eight of which, prior to industrial and residential development and the advent of extensive afforestation, are likely to have formed multi-centred, dynamic meta-populations.

i. Worlington/Freckenham Area – seen in 1773 and then in 1909 in this area, but that was it.
ii. Thetford – it was known from the Norwich road on the north-east side of town but there are few records and no accurate locations. More significantly, there was an extensive population that formed a broad swathe from the old golf course (southwest of the town centre) south across the current industrial estate, over Barnhamcross Common to Thetford Heath and south of the Barnham crossroads. This population probably extended as far as Elveden.

iii. Elveden – known from the north-west side of the village from the 17th Century but last seen in 1962.
iv. Lakenheath – the plant has never been recorded as a native on the current Warren but native stands were known from the A1065 road verges, both alongside the warren and further north-east by the airfield lights field (to the west of the road). Both of these locations were, before the construction of the air base and by-pass road (both of which, according to aerial photos, were in existence in 1945 but are not on any earlier maps), part of the same extensive grass heath as Lakenheath Warren. The north-eastern most records are less than 2km away (up the A1065) from Brandon.
v. Brandon – a large and extensive population occurred to the south-west of Brandon and there are also records from Ling Heath to its south-east, almost certainly part of the same population as, prior to the setting out of Brandon Park, they would have been part of the same continuous grass heath landscape. There is a record from just north of Brandon, on the Norfolk side of the river, arguably part of the population along Stanton Street
vi. Santon Street – aside from the record by Brandon, there are two areas with records, both to the east of Santon on the north side of the river.
vii. Mildenhall – the plant was more widely recorded to the north-east of Mildenhall than at present but persists.
viii. Icklingham – the plant was recorded on Icklingham Plains up to 1876 but not subsequently. Oddly, it was then recorded on the Pilgrim's Path on the other side of the village in 1939 but has not been seen there since c. 1950 (the Pilgrims Path is a former footpath, now defunct, that ran just east of north from Icklingham church, to the west of the King's Forest and between Berner's and Weatherhill Heaths.
ix. Ickburgh Fields – a large population existed here, with hundreds of plants known from the forest rides. Records do however go back to well before afforestation so the latter records might be considered a relict population. Faden's 1797 map of Norfolk shows the area was occupied by Ickburgh Heath.
x. Cranwich - the plant was known from the Devil's Dike in Cranwich from the early 19th Century but was last recorded in 1934.
xi. Risby – an isolated record from 1876.
xii. Culford – isolated records from 1878 and 1879.

2.3.2.2.2. Current sites

As of summer 2021 there were seven sites at which field wormwood may still be seen: 3 are native and 4 introductions (but see 7.1. [below]). The three native sites that remain are:

- Brandon Industrial Estate
- College Heath Road
- Icklingham informal car park

The industrial estate at Brandon has been, since 2008, the only known native site until the discovery of the 40 odd plants in 2018 at College Heath, Mildenhall. A single plant was then located in an informal car park in Icklingham in 2019.

Brandon Industrial Estate
(See also Appendix I – Site register)

The core of this site is the fenced area known as the Brandon Artemisia Reserve or London Road Industrial Estate SSSI. This area was set aside as a nature reserve when the heath around it was developed as a light industrial estate, destroying the last bit of relict habitat remaining of what was perhaps the 2nd largest population in the UK. The population had risen to over 1700 plants in the 2008 but subsequent failure to manage the site led to a substantial decline with only 74 plants recorded in 2019. In 2018-19, management has again been applied and initial results are positive, and it is hoped the resurgence will continue.

It has long been known that plants have 'escaped' from the reserve into the surrounding area, 'seedlings' seemingly popping up in verges and cracks in paving slabs nearby; however it was not until 2017 that the population outside the reserve was properly surveyed and mapped. The population was found to be substantial and widespread across the Industrial estate; plants were found to be surviving, as at Lakenheath Warren, as small tufts of perennial vegetation arising from extensive sub-surface root mats, perhaps of some age. The designation of this area as a County Wildlife Site in 2019 enhances the protection of this population, particularly as it has facilitated changes to the Local Authority's management plan such that mowing does not take place routinely but only after plants have been allowed to flower and set seed – this makes the plants available in the right condition for its dependent insect, the wormwood moonshiner beetle *Amara fusca.* Initial results to management regime changes have been positive, with increased abundance of the plant and beetle recorded on verges.

College Heath Road

Plants of this species were first found here in 2018 by a worker for West Suffolk Council and a Breckland Flora Group member. John recognised them when he came to mow the area. 41 mature plants were counted. Later that year 869 seedlings were also seen. However, in 2019, the same 41 mature plants were counted alongside 30 seedlings, suggesting very poor recruitment from seed and high winter mortality to unknown causes. At the time of discovery, this was the only second known native site for the plant in the UK.

Icklingham Informal Car Park

A single mature plant was found in 2019 by Tim Pankhurst in the informal car park used for access to the Icklingham Triangle. At the time of discovery, this was only the third known native site in the country. It must be a distinct possibility that the plant has been transported there by a botanist, either in the cleats of their boots or tyre tread, from one of the other Breckland sites. The plant was mature and had set seed the previous season, so there is potential at least for the population to expand. However, no seedlings have been found at the site, despite habitat that looks eminently suitable, with much bare loose sandy ground.

3. Genetics

There have been a variety of genetic studies undertaken on field wormwood but all the references refer to the production, naturally and commercially, of artemisinin (e.g. Ranjbar 2015) and other therapeutic chemicals, usually between different species in the genus. No studies that we have found refer to genetic diversity or health of field wormwood.

In 2018, however, in partnership with Plantlife, University of East Anglia and Natural England, a preliminary examination of genetic diversity in the UK population was undertaken by John Innes Centre, Norwich. That work has yet to be published, but a brief summary is presented here.

The study aimed to assess the genetic variation of the Brecks population and compare it to that of a thriving population in France, to determine whether the UK population has a healthy amount of genetic diversity. The variation was measured by amplifying and sequencing the ITS region and matK gene - frequently used DNA bar-coding regions - in 22 leaf tissue samples, and calculating the percentage DNA nucleotide base variation in these regions for each population.

The 22 leaf samples were collected, as per Table 2, in 2018; the table also shows the identity of the variable bases on the ITS region – the matK region was found to be unrepresentative of genetic diversity.

Table 2. Identities of variable bases – T=Thymine, C=Cytosine, A=Adenine, G=Guanine, Y = C or T, R = A or G, W = A or T, M = C or A, K = T or G, S = G or C.

Base No.		20	52	57	59	75	88	111	222	355	408	410	433	461	607	623
Consensus		T	C	C	A	C	C	C	A	G	A	A	T	T	C	A
1	Brandon Artemisia Reserve, Highbury Rd															
2	Brandon Artemisia Reserve, Highbury Rd															
3	Brandon Industrial Estate					Y										
18	Edge of car park, Brandon Artemisia Reserve															C
19	Edge of car park, Brandon Artemisia Reserve															
4	Mildenhall High Lodge Pit1							Y								
5	Mildenhall High Lodge Pit2															
6	College Heath Rd															C
7	Icklingham Car Park															
20	Lakenheath Warren			T												
8	Oytier-Saint-Oblas (Isere, France)										C	M				
9	Oytier-Saint-Oblas (Isere, France)			Y												
10	Oytier-Saint-Oblas (Isere, France)	C								R			K		S	
11	Oytier-Saint-Oblas (Isere, France)						Y							G		
12	Oytier-Saint-Oblas (Isere, France)	C														C
13	Oytier-Saint-Oblas (Isere, France)						Y									C
14	Oytier-Saint-Oblas (Isere, France)															
22	Sefton Coast, Crosby		Y	T	R		Y		W							
15	Not valid for use															

16	Not valid for use
17	Not valid for use
21	Not valid for use

It is of note that where a base is recorded as being 'x ***or*** y', it means that both options are found in the sample, not that their identity is unknown.

There are many observations to be made from this study:

- Sample 22 stands out because it belongs to the subspecies *A.c.maritima* or, as mentioned above in 'Taxonomy', *A. crithmifolia.*
- The French material is generally much more genetically diverse than the Brecks material.
- There were five strains identified in the Brecks, only one of which was found in the French population.
- Samples 1, 2, 5, 7 & 19 from the Brecks, and 14 from Isere in France all belong to the same strain.
- Two strains from the Brecks, sample 3 with S75Y and sample 4 with 111Y, contain base combinations not seen in the French material.

Although the study is small, it signals the way ahead by raising some other points and some questions:

i. The core of the Brecks population would appear to be Brandon Industrial Estate, including the Reserve, the road verge and Edge of Car park samples. The study has taken, in effect, five samples from that one population.
ii. Between them, those 5 samples show 3 strains of *Artemisia*, including one with the anomalous base 75.
iii. The Icklingham Car Park population (sample 7) is only one plant of the same strain as that seen in Brandon Artemisia reserve. We might infer that it has possibly colonised from there.
iv. The College Heath population (sample 6) contains many plants but it's one sample is of the same strain as one of the Brandon samples – this too might indicate that this population (which was only recently found) is a colonist from Brandon.
v. The Mildenhall High Lodge Pit 1 (sample 4) has the anomalous base 111 but is from an introduced population made with, as far as we know, material from Brandon.
vi. Sample 5 was also introduced (we believe as seed) but we don't know the provenance, although it is of the same strain as seen at Brandon Artemisia Reserve.
vii. The Lakenheath Warren sample is different from all the other Brecks ones, although this too is an introduction; the provenance of the material is uncertain but is probably Brandon again. It might not be possible to verify this.
viii. The low level of diversity in the Brecks population as a whole is potentially of concern – the conservation strategy may need to address this by targeting introduction of differing genetic stock into existing populations, be they native or introduced.
ix. Samples 3 and 4 may be significant for conservation purposes as they contain genes not observed in the French material.

The study also concluded that the Brecks population of field wormwood may be hexaploid. This makes them more stable than diploid plants and less prone to mutations. Further investigation of ploidy levels in *Artemisia* would be useful.

4. Ecology and Life cycle

4.1. Germination

There is little information available about the germination requirements of field wormwood in the wild, but the following account about *in vitro* germination is provided by the millennium Seed Bank…

"Regarding germination requirements for Artemisia campestris: We have found that seeds of this species are straightforward to germinate in the laboratory on agar and we have high (>90% germination) at constant temperatures ranging between 20C & 25C (light regime 12/12hours). Tests are usually complete within 7 weeks, although most seeds germinated within 28 days. We don't have information about their persistence in the soil seed bank, but seeds are maintaining their viability in conventional storage (dried and stored at -20C) at the MSB. Our oldest collection was made in 1975 and is still showing >90% viability".

"Seeds are tiny and should be firm and probably tawny brown when mature – they may remain embedded in the infructescence for some time (into) October/November".

Field wormwood is strongly associated with bare, open habitats with a substrate surface that is friable and mobile. It seems likely that it would require cool(-ish) and damp weather events for germination but there is no evidence for this. Such open, permeable substrates are highly aerated and seeds within them are accordingly vulnerable to predation from invertebrates and from attack by fungi, unlike wetted soils. It may be therefore that there is little seed bank potential, not because of any incapacity in the seed but because of natural degradation. It may also be however that the natural aridity of such soils reduces this threat.

4.2. Development

Field wormwood requires open, skeletal vegetations within which to develop. Plants are intolerant of competition and evidence from College Heath Rd, Mildenhall, suggests that seedling mortality can be very high (i.e. up to 100%) in any one year. Dominance of open habitats and the absence of grazing will be influential on the survival of young plants; such dominance may be achieved by suppression of other vegetation through allelopathy (Yun 1997).

Maturity may be considered to be achieved at first flowering, but we have no data on how long that takes. It is probably related to prevailing conditions. In damp, warm conditions development may be fast, but the plant lives in places which can be very arid and, in winter, very cold. It may be some years before flowering is achieved.

Plants in favourable, open conditions develop a woody stock that produces herbaceous annual stems up to 1m, which die back each winter. When grazed or mown, the stock can expand underground to form an extensive woody mat just below the surface which produces numerous small herbaceous stems with a few leaves. In such circumstances, the plant can be difficult to locate, and it may be that plants in this condition yet persist at sites where it is thought extinct. Indeed, this may be more common than not, for although the capacity to adopt this growth form is in the literature (Clapham *et al* 1987), the plant's tendency to do so in response to grazing has gone un-noticed. The plant has been held to be 'sensitive' to grazing (Leonard 1999), a perception propagated from Watt (1971) who alluded to its sensitivity to grazing by rabbits (*Oryctolagus cuniculus).* The plant is certainly palatable, but the effects of rabbit grazing are different from those of other grazers and the Brecks has seen a decline in rabbits and their replacement as a grazing force, mainly by sheep but also in some part by cattle. It does not follow that a high level of sensitivity to rabbit grazing is indicative of the same level sensitivity to other grazers. Indeed, Figure 2 [right] shows how, in 2011, 96 field wormwood plants were recorded at Watt's plot, with 41 plants inside the grazing exclosure all recorded as mature and all 56 outside recorded as seedlings; we can be confident that these 'seedlings' were in fact vegetative shoots from a subterranean woody stock. Such observations are of great importance because they indicate that, despite there being 'mature' plants inside the exclosure, the fact that they flowered *does not* imply that there was recruitment from seed, an observation consistent with the belief that the vegetation is not in a condition suitable for germination and subsequent early development.

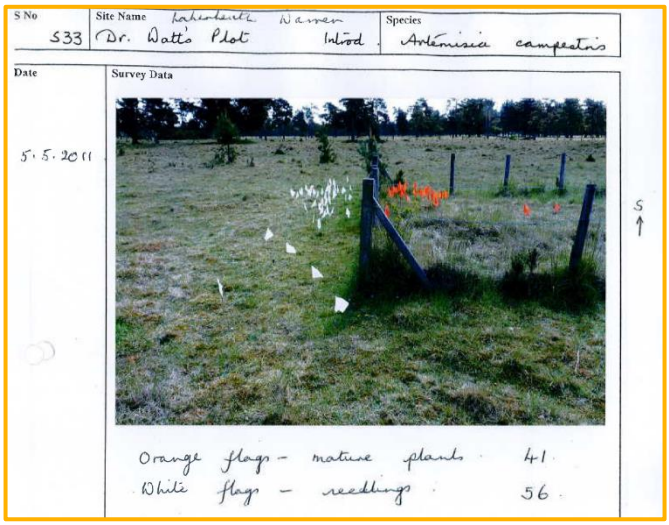


Figure 2. Part of 2011 survey form showing field wormwood plants recorded at Watt's Plot, Lakenheath Warren

From this perspective, while potentially vulnerable to grazing, field wormwood may be considered as being at least partly adapted for it, in that when grazed it adopts a different growth form that enables it not only to survive but also to multiply vegetatively so that, in naturalistic periods of grazing relaxation, it can produce numerous flowering shoots rapidly and thereby enhance the probability of sexual recruitment.

4.3. Flowering and Fruiting

The plant produces short rosette leaves on an increasingly woody stock; if un-grazed, it will then go on to produce sinuous, decumbent to ascending flowering shoots, bearing numerous flowers in a racemose panicle from as early as May (Preston *et al* 2002) but most commonly from August to September (Clapham *et al*, 1987). The flowers bear c. 10 - 14 florets, the outer 5 - 6 female, the central 5 - 6 hermaphrodite or male but usually infertile (Clapham *et al* 1987, Tison *et al* 2014). Each female floret generates one achene. The flowers are believed to be wind-pollinated.

4.4. Habitat preferences

4.4.1. Communities and vegetation

Field wormwood is a plant of skeletal vegetation on friable, sandy but calcareous substrates. The plant is a long-lived perennial but the mobility of such soils, and the consequent suppression of other plants, is important in providing the open conditions required for germination and subsequent early development. Such mobility can be transient however as, once established, the plant can persist for many decades in closed vegetations, as long as surrounding vegetation does not shade it out.

Within the NVC, such vegetations generally fall somewhere on the range between the CG7b: *Festuca* ovina-Hieracium pilosella-Thymus praecox/pulegioides grassland: Cladonia spp. sub-community and the U1: Festuca ovina-Agrostis capillaris-Rumex acetosella grassland, tending more towards the CG7 on account its calcareous nature. Both these grassland types can be highly skeletal, either because they have developed on former inland sand dunes, with commensurate mobility in the upper horizons, or because they support significant rabbit populations. Where soil mobility or rabbit disturbance has diminished, the vegetation becomes increasingly closed and less suitable for field wormwood. As mentioned above, however, large plants can persist for many years where they overtop the surrounding vegetation; alternatively, they may survive as small, low-growing vegetative shoots from a persistent subterranean stock where grazing suppresses the competitiveness of other plants. In such circumstances, there is negligible recruitment from seed.

4.4.2. The landscape perspective

The association with mobile, sandy soils has a landscape aspect. The Brecks is known for the widespread occurrence of former sand dunes but the decline in activity is a relatively recent phenomenon; the last mobile dune, at Wangford, stopped moving in the 1980s. The mobility of dune systems creates the open conditions necessary for germination while, more static phases allow for early establishment. Subsequent moderate mobility may be countered by mature plants being anchored by their tough root stock and such plants are also able to survive prolonged stability (grey dune phase).

There also appears, from the distribution of old records, to be an association of the plant with commons, old droving routes and trackways; it has been suggested that the plant may have benefited from rabbits tending to keep away from places with a heavy human presence; there may also have been dispersal benefits (see below).

4.5. Dispersal

Field wormwood has no known specialised dispersal adaptations. Unlike many members of the Asteraceae, its seeds do not have a pappus or hooked appendage to aid wind or animal dispersal. The seeds are however small and, when desiccated, light. In the mobile former sand dunes of the Brecks, it seems probable that they would blow around in the sand column like a grain of sand. It is

also likely that seeds disperse, or at least have done historically, on wild and domesticated animals; mugwort *Artemisia vulgaris* seeds, which are anatomically very similar to field wormwood seeds, are known in Europe to disperse by epizoochory on wild boar *Sus scrofa* (Schmidt *et* al 2004). These days, the 'botanist's boot' and the treads of tyres are more likely candidates as dispersal vehicles for field wormwood; the records from Tuddenham and the recent find at Icklingham fit this model.

4.6. Summary ecological description

Field wormwood is a long-lived, perennial herb with a hard, woody stock; it can form a large (to 1m) flowering shrub but in the presence of grazing may form an expanding sub-terranean woody mat with occasional short leaves. It is associated with very open, skeletal vegetation on mobile calcareous sands and is tolerant of hot summers, cold winters and parched conditions all year. That said, it may require intermittent periods of high rainfall for germination. Over-stability in its substrates probably results in a decline in germination and recruitment from seed, although mature plants can persist for many years in more closed succeeding vegetation; they do however eventually succumb to excessive competition. The plant has some tolerance of grazing, other than by rabbits which graze too close. However, it seems to do well where human activity suppresses grazing activity. Natural dispersal is probably by wind (like grains of sand) and externally on animals (epizoochory); the plant is probably also dispersed by people, in the cleats of their boots, by pets and vehicles.

5. Implications for management

The dynamic systems for which field wormwood appears to be adapted are difficult to simulate through management. The Breck tradition of very long fallow periods would have favoured the plant, as that practice mimics the highly-natural, intermittent instability of long-phase dune systems. The plant has never been associated with the warrening history of the Brecks but, with a shift from rabbits to mainly sheep grazing, perhaps there is potential for the plant to become established in such places.

At sites which are grazed or mown, intermittent withdrawal of management will allow low-growing plants to flower and set seed. One would want however to monitor the condition of plants upon the renewal of grazing, to ensure that such a renewal did not kill off established specimens.

At un-grazed or mown sites, there is likely to be a management requirement to suppress other competitive vegetation, unless the soils are so impoverished or worn that there is no threat in this regard. In the latter circumstance, no management is required.

6. Threats and factors leading to loss and decline, or limiting recovery

Without doubt the loss of dynamic dune geomorphology has underpinned the decline in field wormwood. This loss has occurred because of agricultural 'improvement' and the afforestation of large areas of the Brecks. Coupled with the accelerated vegetational succession, due to atmospheric nutrient deposition and a trend of increased rainfall, these factors have effectively removed the characteristic Brecks features that made it suitable for field wormwood. Plants survive now at a few places that, by chance, retain the harsh conditions for which it is adapted. The potential for recovery is severely limited by the difficulty of restoring such conditions to former sites and likely shortage of suitable new sites.

7. Conservation

7.1. *In-situ* measures

Early-successional habitat creation, such as cultivation, turf-paring and rotovation have been tried in attempts to suppress growth of competitive vegetation but has had only limited success around established flowering plants.

Grazing has never been used a tool to manage field wormwood but at Lakenheath Warren, plants have survived for over 40 years under a light grazing regime, mainly of sheep but also occasionally cattle. The number of beasts sustainable on the warren has increased with the decline and now virtual absence of rabbits.

There have been three attempts to reintroduce field wormwood to former sites. Only one of these are known to survive, at Ickburgh Fields (Stanford Training Area). It is unfortunate that the likely reasons for the failure are the same as the original reasons for disappearance: site succession and grazing. Having said that, new insights into the survivability of small plants where they are difficult to detect, raises the possibility that they may yet survive but have gone undetected. A programme of revisiting former sites is underway at the time of writing to see if any of these populations are extant.

This also applies to the five sites at which introductions have taken place; only two of these survive, at Mildenhall High Lodge Pit 1 and 2, where the gradient of the side of the pit significantly reduces grazing pressure and also provides a suitable substrate for the plant to seed into and at Ickburgh Fields, Stanta where recently the surviving plants, which were straggly, have been fenced. While this is a short-term, gardening, measure, the plants have shown that without grazing pressure they quickly grow strongly forming bushy structures. At High Lodge, in Pit 2, vegetation is rapidly invading, swamping plants and inhibiting growth.

In recent years, under the National Lottery Heritage Funded *Shifting Sands* project (part of the *Back from the Brink* programme), attempts have been made to re-introduce (and introduce) field

wormwood to further sites; Cranwich Camp Extension, Three Hills Mildenhall, Harling Drove, Weeting Heath Nature Reserve and Weeting Heath Car Park. Sites have been chosen because local topography or human use means that plants should be less subject to grazing. Two of these efforts have failed (Cranwich Camp and Three Hills), others are surviving to date (Weeting Heath Compartment Two Pit, and Visitor Car park and Harling Drove) but have been in place too short a time for their success to be evaluated.

The presence of field wormwood on industrial estate verges indicates that human disturbance through regular use could maintain suitable conditions without the need for grazing, with its negative impact on this species' growth, to retain open ground. This was the rationale behind the Weeting Heath Car Park and Harling Drove introduction and could represent a shift in how translocation locations are targeted; if successful, more opportunities could arise in non-grazed human disturbed areas. While plants may survive grazing in a low growth form, that they produce flower spikes is particularly relevant for Wormwood moonshiners that feed on this species' seeds.

7.2. *Ex-situ* measures

Plants have been grown at Cambridge University Botanic Gardens and at the authors' homes to supply re-stocking events.

7.3. Data resources

The history of field wormwood occurrence across the Brecks (and the nation) is well charted. The Brecklands Rare Plant Database, held by Plantlife, contains a comprehensive record of field wormwood sightings going back centuries. A detailed list of references is given at the end of this dossier.

7.4. Monitoring

All field wormwood sites in the Brecks are monitored annually by the Breckland Flora Group, using a standardised method. The data is collated each year into an annual register which informs the conservation strategy for the plant.

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Tim Pankhurst
Johanna Jones

September 2021

Appendix 1

Register of sites in Breckland for field wormwood

(Sites where field wormwood *has been recorded for a period of more than 20 years, or where counts of 100+ plants have been recorded)*

1. **Elveden**

   Field wormwood was recorded here up to 1907 and then again in 1961-62 but was not found in 1974.

2. **Barnhamcross Common**

   Records from 1695-1944 come from Barnhamcross West, after which they are from Barnhamcross East or Site 1 or Site 2. In 1949 field wormwood was found on the steep slopes of old earthworks. In 1959 about 20 plants were transplanted from the 'Thetford site' to the east of the common, as the former site was levelled for a recreation ground. In 1961 a few plants are recorded, however an area on the common had been covered by dumping from the New Town site and of the two fields west of the common, where there were numerous plants, little remains due to the building of houses. In 1962 about 14 plants were removed from Thetford site of compacted arable land, ± in shade of pine trees, and planted at the original transplant site where several of the earlier transplants were growing vigorously and producing numerous inflorescences. In 1964 clumps were still present, with evidence of nibbling by rabbits. A few plants were recorded through the 1970s, with last records of two plants in 1987, and a record in 1992 from the NW part of the common, in a maze of trackways.

3. **Worlington Freckenham**

   Field wormwood was found here in 1773 by Sir John Cullum, again in 1909 but was not found in 1975.

4. **Cranwich Devils Dyke**

   Field wormwood was recorded here in a chalkpit in 1840. In 1851 and 1883 it was recorded on the southern end of the Dyke. In 1910 41 tufts were found, in a 200 yard stretch, the majority on the west side of the Dyke. In 1914 and 1922 it was found in Northwold by a chalkpit, with 5 plants counted on the latter date. The last record was 1934, it was not found here in 1976.

5. **Little Heath**

   There are recordings of field wormwood here at least every 15 years between 1841 and 1923.

6. **Brandon Mile End – Town St (later part to become Brandon Artemisia Reserve, see site 15)**
First recorded in 1845, field wormwood has been regularly recorded here up to 2019. In 1946 there was concern that this species had been lost from the site. However, in 1950, and 1952 it was found on the grassy verge of field and roadside. In 1953, 300 large plants were counted, along with thousands of seedlings, on waste ground, which has 'since been used largely for building'. In 1959 'large quantities' of plants were again found at the caravan site amongst shacks and bungalows and Dick Pawsey dug up plants and transported them to Thetford and Weeting. In 1961 it was thought plants were disappearing because of building, however in 1962 established colonies were found and in 1970 the species still survived here despite the site being bull-dozed. In 1974 300+ plants were counted, however many sub-sites had been destroyed by building. In 1974, 2-3,000 plants were counted at the caravan site on the NW side of the A1065. In 1979 the same recorder found 300 plants, and 54 plants in the area of the bank that had been levelled off and recolonised. He noted there was a possibility a car showroom was going to be built on the site.

   Populations of the plant have been known to have survived in the road verges around the reserve since its creation but were not properly surveyed until 2017. These road verges were, in 2019, designated a County Wildlife Site on account of both the presence of *Artemisia campestris* and its dependant beetle *Amara fusca* but also the assemblage of skeletal Breck grassland plants.

7. **Wangford Warren Airfield Lights**

   First recorded here in 1860-78, field wormwood was not recorded again here until 1960. In 1974, 20 plants were found, but it was noted that the verge had been mown very short and the base of the fence sprayed and in 1975, it was noted that there was too much traffic on the verge. In 1985, one large clump with over 100 flowering stems was found, and despite the site being 'destroyed' in 1987, in 1991, 276 flowering stems were counted here. In 1996, tips of branches were collected and seeds grown and two plants were planted out in 1997 but were grazed by rabbits within a week. In 1998 and 1999, 3 plants were counted but no records were found in 2003. In 2005, 35 seedlings were present, probably seedlings introduced from the box at West Stow Country Park. In 2006, none of these introduced seedlings were found.

8. **Thetford, London Road**
Field wormwood was regularly recorded here by the roadside between 1840 and 1950. A. Bennett, who had found the plant here in 1876 and 1907, thought the species was less plentiful than it had been, 'yet there is no apparent reason why. The road is perhaps better kept perhaps [and the] grass seems coarser and thicker than it used to be'. In 1950 the record came from the roadside bank, near the cemetery on the road to Elveden, however the recorder noted that there were only a few plants.

9. **Brandon, Ling Heath**
There are five records of field wormwood at this site between 1881 and 1960, but with no counts of plants, or additional notes from recorders.

10. Lakenheath, A1065

First recorded here in 1889, then not again until 1969 when 6 plants were found. In 1974 a count of 16 plants was made, however the plants were described as 'flattened'. In 1980, 3 plants were found but were 'badly damaged'. There is not suggestion of what caused the damage. However, in 1983 at Lakenheath Warren A1065 East, large clumps of 150 plants and seedlings were found, in 1991 this reached a peak of 200 plants, which had reduced to 42 by 1999, 17 in 2006 and just 1 plant in 2008.

11. Ickburgh Fields

Field wormwood was first found here in 1890, then Mrs Baxter, of Ickburgh Field Cottages records in 1930 that it has been found here for the last 40 years by herself and her mother, 'on a wide fire-break, which used to sometimes be ploughed.' In 1971, c50 plants were found on a broad grassy firebreak in the pine forest, growing on chalky breck sand. In 1973 it was found growing on thin grassland along a front of 100 yards, with many seedlings. Most of the mature plants had had their main stem bitten off by a herbivore. Eric Swann is reported as saying that grazing damage occurs every year. In 1974, 94 clumps were found on a Forestry Commission (FC)on ride E of A1065 to Hilborough around clear-felled & replanted area. Poles of pine were being dumped on each side of the ride. In 1975 the poles were removed and 20 clumps found on the south side of the ride. In 1977, 97 clumps were found on a formerly ploughed firebreak. Seed was collected in 1975. In 1979 it had 'declined', but in 1980, 2-300 plants were found, but were lost when the FC piled logs on the colony. In 1984 a few plants were found surviving. The last record is of one plant found in 1988 along this forest ride in STANTA and rotovating of the sides of the ride were carried out to encourage establishment of plants as the grassy edges were becoming very overgrown. However, the species was not found here in 1992 and there are no subsequent records.

12. Thetford Heath

Field wormwood was first found here in 1926 and then introduced in 1959 to the chalkpit in the north-west of the Heath, but then was found by the Barnham/Elveden roadside edge of the heath in 1960-62. There was a further introduction in 1963 (**Error! Reference source not found.**). This species' presence was recorded at this second introduction site in small numbers in the 1970 and 1980s. In 1991, 11 plants were counted, several with their heads bitten off. In 2000 the enclosure fence was down and rabbits and sheep inside, and the wire enclosures were overgrown and needed clearing out. No visit was allowed in 2003, (presumably because of the presence of breeding Stone Curlew, although this is not noted).

13. Weeting Heath

Field wormwood was introduced here in 1957, 1958, 1959 and 1970 (**Error! Reference source not found.**). Plants were transplanted from the Brandon site to this site in these years, In 1959 just one surviving plant from over 75 transplants was found. However, 6 large plants were present in and around the pits. In 1962, 5 plants were counted, but no regeneration by seed of

the transplanted stock, although in 1963 foliage of 3 plants were found. In 1970, a further clump was transplanted from Brandon and in 1977 36 clumps were recorded, mostly on the edge of arable land. In 1992, 6 plants remained. There are no further records of visits to this site.

14. Mildenhall High Lodge

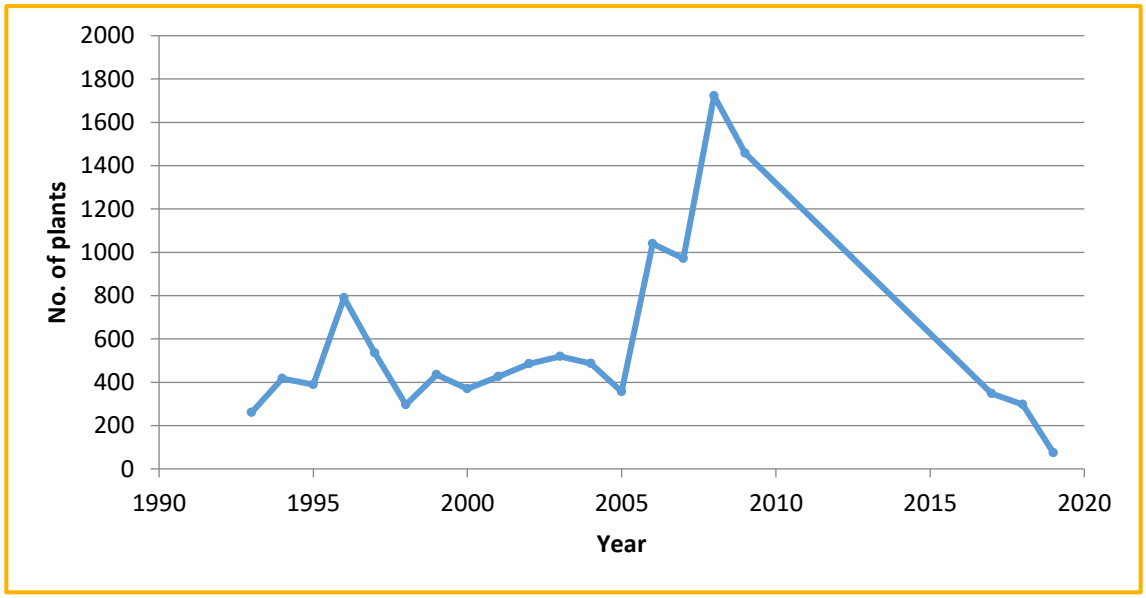
16 plants of field wormwood were introduced here in 1988 at the Suffolk Wildlife Trust reserve, from the Cambridge Botanical Gardens. In 1989, there were doing well and 2 had flowering stems. In 1991, 14 plants were counted, but several plants had been run over and there were motorcycle tracks in the area. In 1994, 55+ plants were counted, with seedlings and plants on the bank. In 1996-8, c. 40 plants were counted each year. The bracken was sprayed in 1999, and in 2000, 46+ plants were counted. This increased to 153, 464+ and 653 plants in 2003, 2006 and 2008 respectively. During this period recorders noted presence of motorbikes, mountain bikes, scrub encroachment, increased bracken and Calamagrostis invading, with Yvonne Leonard, the 2008 recorder stating that 'small oaks, broom and bracken need removing from the bank.' In 2018, numbers were again low, with only 253 plants counted; plentiful muntjac *Muntiacus reevesi* activity was observed then, suggesting that the population was being reduced by grazing. In 2019, however, the population had almost doubled to 433 plants, indicating that the plant can hold its own and recover quickly from over-grazing events.

15. Brandon Artemisia Reserve

For earlier history of records of field wormwood at this site, see history of site 6. Brandon Mile End – Town Street. Field wormwood continues to flourish at this site which is managed specifically for this species and at which there has usually been an annual plant count (see **Error! Reference source not found.**). By 1998, eleven plots had been dug or rotovated since 1993, and 3 plots turf stripped. Further management that has been undertaken includes pulling of Evening Primrose, and spraying of Bramble, Bracken, Broom, Nettle and Sycamore with glyphosate, and smashing of field wormwood seed heads to disperse seeds, the construction of new banks and cutting of grass in the winter and removal of arisings.

Since 2009, counting seems not have occurred until 2017, with numbers right down into double figures in 2019. In that year however, management interventions have been made which will hopefully result in a resurgence of the plant on this important site; management includes removal of bramble and bracken and scraping off sand sedge mats.

Number of plants of field wormwood recorded at Brandon Artemisia Reserve, 1993-2019.



In 2019, the verges alongside the roads nearby within the Industrial Estate were recognised as a County Wildlife Site, as many plants have been found to grow there too (See Brandon Mile End [above]).

16. Lakenheath Warren

Field wormwood was introduced here in 1955 (three plants) but then again in 1961 when numerous seed were sewn into a grazing exclosure by Dr A S Watt (1971). The greatest subsequent count was of 97 plants in 2011, both within and outside the exclosure, and the plant is still recorded there (as of 2019). It is at this site that small plants were observed perennating from tough, long-lived root mats. Clapham *et al* (1987) allude to the plant's ability to adopt this growth form but its tendency to do so in response to grazing seems to have gone un-noticed; previously, small plants at this site (and others e.g., Brandon Artemisia Reserve (Jo Jones *pers comm*)) have been described as seedlings and subsequently found to not be.

17. College Heath Rd, Mildenhall

First found in 2018 by John Smithson, 41 mature plants have been recorded here. The site is mown annually in February, the timing designed to allow access to seeds by the dependent beetle *Amara fusca.* At the time of discovery, this was the only second known native site for the plant in the UK.

18. Icklingham informal Car Park

A single mature plant was found in 2019 by Tim Pankhurst in the informal car park used for access to the Icklingham Triangle. At the time of discovery, this was only the third known native site in the country. A close search of the site was made at the time and no further specimens were found, although the plant was mature and had flowered and produced fruit the previous year.