EFFECTS OF MECHANISED CUTTING ON THE SHORT TERM REGROWTH OF HAWTHORN HEDGEROWS

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ABSTRACT

This paper reports on an investigation into the short term effects of mechanical cutting on hedgerows. The subsequent regrowth of hawthorn was used as an indicator of the effect of alternative cutting methods.

The investigation was carried out over three years on farm hedgerows in mid-Bedfordshire. The hedgerows were predominantly comprised of Hawthorn and the study was confined to this species. The treatments were; three types of flail, a finger bar cutter, a circular saw, and an uncut control. A damage rating system was developed and used, together with other recorded data, to describe the type of severance and the effect on regrowth.

This study demonstrates that in general flails leave a more ragged cut than the other methods, and that as this apparent damage increases there are beneficial effects to regrowth in terms of position and number of new shoots.

INTRODUCTION

The traditional method of hedge management in this country has been 'hedge laying', however, as labour costs have increased the majority of managed hedges are now maintained using some form of mechanical cutter, often a version of the flail mower. Many observers have voiced opposition to the flail as a maintenance tool, because of perceived detrimental effects to the hedge due to the distressing appearance of a mature hedge that has been cut back in this way. Conversely, some users of flail trimmers have noted a beneficial effect on hedge growth.

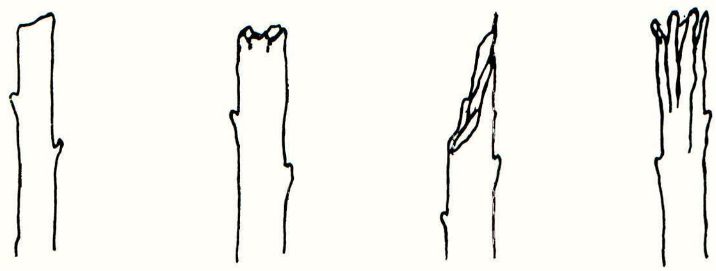
METHODOLOGY

This investigation took place over three years with different hedges being cut each year. The hedges were cut during their dormant period, and the majority of the branches cut were less than three years old. The regrowth of the hedge was recorded during the subsequent growing season. The position of each treatment along the hedgerow was randomised. Each treatment was twenty metres long and three replicates of ten branches were taken. The hedges were all cut to a topped A shape, and the results of each treatment measured on the same side of the hedge.

Branches were tagged, and photographs taken at regular intervals during the growing season, as a permanent reference. The main assessment of the treatments was made after the initial regrowth of the hedge. A damage rating system was developed to record the type and amount of damage to the branch. The length and thickness of the branch, the number of new shoots and their position relative to the cut end were also recorded.

In order to give a repeatable assessment of the damage incurred by the branch the rating system was defined by the type of damage inflicted on the end of the branch and the length to which the damage extended. The main categories of damage are shown in Figure 1.

FIGURE 1. Types of damage inflicted by cutting the branches.



Clean cut   Ragged cut   Tear/split   Shattered

The damage scores awarded for different types of cut are shown in Table 1.

TABLE 1. Damage score awarded to types of cut

Type of cut	Damage score
Clean	0
Ragged	1
Tear < 5 x branch diameter in length	2
Shatter < 5 x branch diameter in length	3
Tear > 5 x branch diameter in length	4
Shatter > 5 x branch diameter in length	5

TREATMENTS

The cutting treatments were the heavy duty, standard and competition flails produced by Bomford Turner Ltd with the cutter rotation in both forward (rotating in the same direction as the tractor wheels) and reverse mode (rotating in the opposite direction as the tractor wheels), a finger bar cutter, a circular saw (0.75 m in diameter) and a control of no cut.

The heavy duty flail is recommended by the manufacturer for cutting thick material up to 100 mm in diameter or restoring an overgrown hedge.

The standard flail is recommended for cutting material up to 38 mm in diameter, typically one to four year old wood and is the flail normally supplied with this type of machine.

The competition flail is normally used for wood up to one year old and is designed to give a more even finish than the other flail types when used for annual trimming.

The finger bar cutter is normally used for wood up to two years old and cuts the branches by a shearing action, leaving full length trimmings.

The circular saw also leaves the trimming full length, but it can cut very thick wood in one pass.

RESULTS AND DISCUSSION

For the purpose of this paper the data collected from the three years of field trials has been amalgamated and the main results are shown in Figures 2 to 5. Not all of the treatments were used each year, so the number sets for each treatment vary. However, the overall trends shown in the graphs remain the same for the individual years as for the amalgamated data set.

Figure 2 shows the average damage score achieved by each cutting treatment. As can be seen from the graph, all of the flail treatments cause a similar level of branch damage. The saw has a lower average score than all the flails and the finger bar is very much lower than the flails.

These results may be explained by the type of cutting action employed by the four cutter groups.The flail has a relatively blunt cutting edge rotating at a high velocity and cuts by utilising the branch stiffness and inertia to generate a reaction force. Each branch is struck a number of times as the cutter head moves over it and this tends to leave a ragged severance, especially on thicker branches. The finger bar cutter, if properly maintained, has a sharp cutting edge and shears the branch cleanly between a pair of reciprocating blades. The circular saw has a sharp cutting edge and saws through the branch utilising the branch stiffness to react to the sawing action.

In Figure 3 the effect of damage to the branch at the time of cutting is demonstrated by the influence it has on the position of the new shoots relative to the cut end. As can be seen from the figure the shape of the cumulative percentage lines for each damage level remains fairly constant, but as the damage increases the position of the new shoots is displaced further away from the cut end. As most hedges are trimmed to the same size and shape in subsequent years, the implication is that by inflicting more damage to the branches the regrowth will be 'pushed' further into the hedge. Less regrowth will be removed in subsequent trimming, leaving a greater amount of new wood to promote the development of a thick hedge.

Figure 4 shows the effect of increasing cut damage on the number of shoots. There is an upward trend in the average number of shoot with damage score suggesting that increasing damage may have a beneficial effect on shoot numbers.

Figure 5 shows an upward trend between the diameter of the branch and the damage sustained by it when cut. This suggests, as would be expected, that the older and thicker the wood the more likely it is to be damaged when cut.

Due to the considerable variation in the data a much larger data set would be required to statistically prove the relationships shown in Figures 4 and 5.

CONCLUSIONS

Flail cutters inflict more damage on Hawthorn branches than the other mechanical cutting methods tested.

There is little difference in damage rating between flail types when cutting wood up to three years old.

Increasing the cut damage inflicted on a branch 'pushes' the position of new shoots further from the cut end.

Increasing the cut damage inflicted on a branch may slightly increase the number of new shoots.

Thicker branches appear to sustain higher levels of damage when cut by flails.

This study was confined to the short term effects on Hawthorn branches less than three years old. Further work will be required to determine the effect of the repeated mechanical cutting of hedgerows and the effects on older and thicker wood.

ACKNOWLEDGEMENTS

The authors thank Bomford Turner Ltd for providing equipment and technical support. D.A. Semple was funded by a MAFF CASE award and a DAFS studentship.

FIGURE 2. The effect of cutter type on damage score

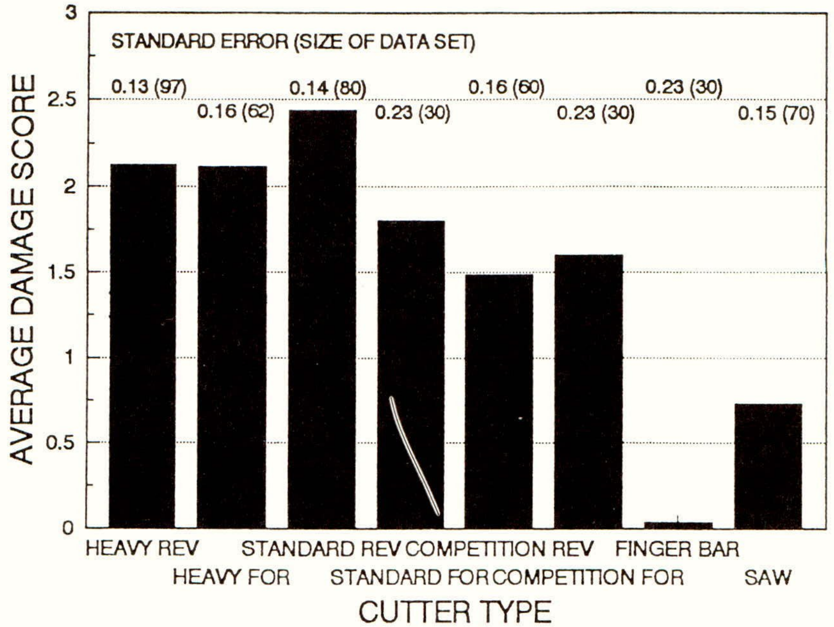


FIGURE 3. The effect of damage type on shoot position

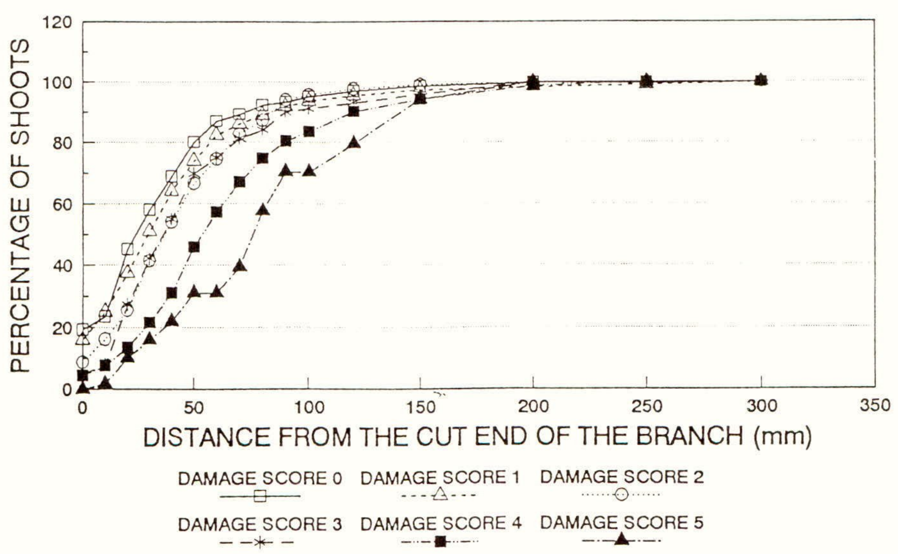


FIGURE 4. The effect of damage on shoot numbers

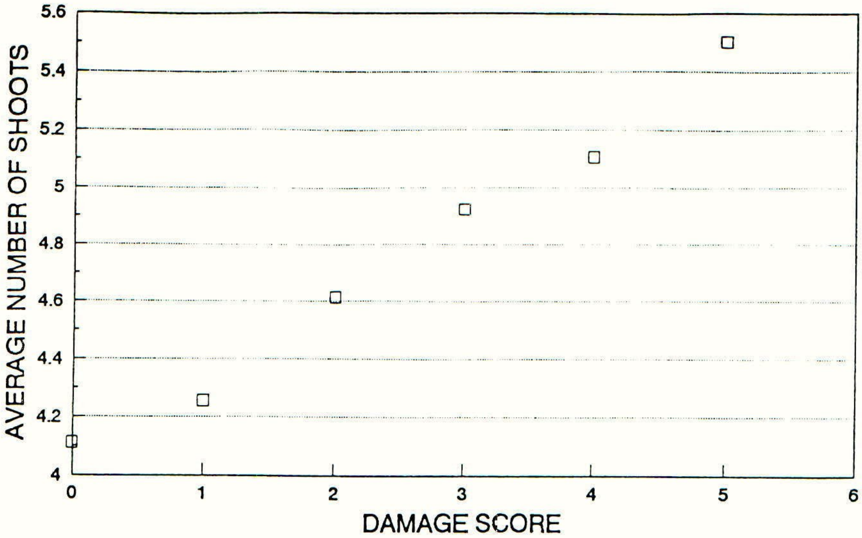
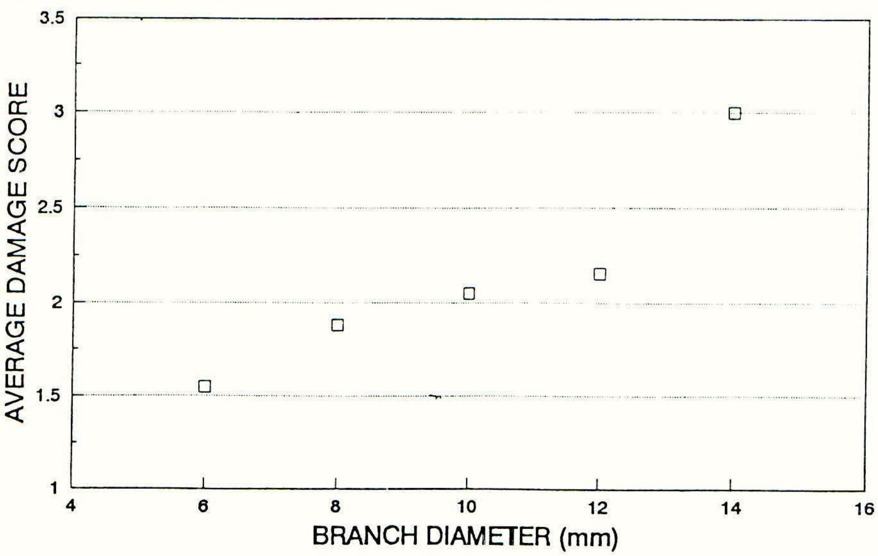


FIGURE 5. The effect of branch diameter on damage score



CLEMATIS VITALBA (OLD MAN'S BEARD) AS A COMPETITIVE "WEED" IN HEDGEROWS AND THE EFFECTS OF HEDGE CUTTING REGIMES ON ITS DEVELOPMENT

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ABSTRACT

Clematis vitalba is a woody, climbing plant commonly found on calcareous soils in the Midlands and south of England. Unless it is controlled by management practices, it is capable of smothering hedges. An experiment at Stratford-upon-Avon, Warwickshire examined the effects of four hedge management techniques on a *Clematis*-covered Hawthorn hedge. Cutting *C. vitalba* stems at their base and treating the stumps with glyphosate gave effective control of this species, with a consequent improvement in Hawthorn vigour. The method of mechanical hedge trimming had no clear short-term effect on *C. vitalba* abundance.

INTRODUCTION

Various national surveys have shown a continuing decline in the length of hedgerows in the UK over the past 20 years. Recent losses have been primarily due to general neglect, with many former hedges being reclassified as lines of trees or shrubs (Barr *et al*, 1991). Traditional hedge management techniques, involving regular laying of hedges, provided opportunities to cut out any species considered to be competitive "weeds". Several practical handbooks on hedges recommend removal of climbers before they damage the shrub species (eg Brooks, 1975). Modern farm management, however, often gives scant regard to hedges; hedge-laying, and consequently "weed" removal, are declining practices.

Clematis vitalba (Old Man's Beard) is one of a number of woody shrubs and climbers potentially damaging to hedgerows (Brooks, 1975). Found in several parts of the world, it is recognised as a problem species in the UK (Brooks, 1975), other parts of western Europe and in New Zealand (Popay, 1986 and Ryan, 1985). In the UK *C. vitalba* occurs in hedgerows and woodland-margins, chiefly on calcareous soils southwards from Denbigh, Stafford and South Yorkshire (Clapham *et al* 1962; Stace, 1991), although there is documented evidence of a northerly spread (Sinker *et al*, 1985). *C. vitalba* is often the dominant climbing species and many authors have referred to its smothering effect on hedge plants and trees up to 30 m in height (eg Brooks, 1975 and Ryan, 1985). Plants and seeds are long-lived (Salisbury, 1961 and Popay, 1986).

Clay (pers. comm.) reported that an extensive search had revealed no major study of the biology of this species. He stated that further research was required, studying the effect of different hedge management practices on the development and spread of climbers. This was the principal aim of the experiment described here.

MATERIALS AND METHODS

A hedge predominantly of *Crataegus monogyna* (Hawthorn) , with a uniform and fairly dense cover of *C. vitalba*, was selected for the experiment. The hedge, growing on heavy, calcareous, clay soil at ADAS Drayton, Stratford-upon-Avon, Warwickshire ran in a straight line, down a gentle slope, from west to east. It was situated between a Perennial Ryegrass ley, on the southern side, and a grassy road verge. Previous hedge management had been consistent, with annual mechanical cuts on both sides and the top, to produce a rectangular hedge, around 1.4 m high.

The hedge was subdivided into 16 plots, each 17 m long; of uniform height and density, and with similar species composition. These were used to study the effects of four experimental treatments (see Table 1) in a randomised complete block design.

On 20 December 1990 each plot was mechanically cut (flail cutter) according to the requirements of the experimental treatments. All *C. vitalba* and *Rubus fruticosus* agg. (Bramble) stems in treatment 4 plots were cut just above ground level using hand-held loppers, and the stumps painted with undiluted glyphosate herbicide (360 g l^{-1} , SL) on 14 May 1991. The hedge trimming treatments were repeated on 29 January 1992, 30 December 1992 and 20 October 1993. Hand cutting and glyphosate painting of *C. vitalba* and *R. fruticosus* stems, where required, were repeated on 10 June 1992 and 29 June 1993.

TABLE 1. Treatment list

Treatment	Frequency of Trimming	Shape	Cut	Target Height	Additional Treatments
1	Annual	Rectangular	Both sides/top	1.4 m	None
2	Annual	Rectangular	Alternate sides*/top	1.4 m	None
3	Annual	A-shape	Both sides	1.8 m	None
4	Annual	Rectangular	Both sides/top	1.4 m	Hand cut *Clematis* stems

* south side of hedge cut in 1990.

Three similar 50 m sections of *Clematis*-infested Hawthorn hedge, in an adjacent field, were used for related observations in 1993. *Clematis* and *Rubus* in one section were hand-cut, as described previously, on 15 March. The number of stems cut of both species, and the length of time taken, were noted. This exercise was repeated for the second 50 m section on 29 June. No stems were cut in the third section.

Assessments

The percentage *C. vitalba* cover was estimated using ten 0.1 m^2 quadrats per plot, held at 1.2 m height on the south side of the hedge. The number of *C. vitalba* stems per plot was counted. Hedge heights were measured at 13 regularly spaced points in each plot before and after trimming. 'Density', or more accurately a combination of density and thickness, was measured using 50 black diamond shapes arranged in 10 rows on a white board, 1.6 m tall and 0.45 m wide. Each diamond was 13 cm tall and 9 cm wide. This board was held vertically 2 m from, and perpendicular to, the mid-line of the hedge. An observer, positioned an equal distance on the opposite side of the hedge recorded the number of diamonds of which more than 50% of the total area was visible. Six counts were made per plot. Numbers of fruits were counted, using 0.1 m^2 quadrats, as for the *C. vitalba* cover assessments.

On the 21 September 1993 an assessment of percentage cover and relative abundance of *Clematis* and *Rubus* was made on the three separate observation plots.

All data were subjected to analysis of variance, using Genstat 5. Where necessary, data were transformed and re-analysed, and the back-transformed means and 95% confidence limits are shown in the results tables.

RESULTS AND DISCUSSION

TABLE 2 . Estimated % *C. vitalba* cover, at approximately 1.2 to 1.5 m height

Treatment	October 1991	September 1992	August 1993
1. Rectangular	30.5	31.3	28.9
2. Rectangular/alternate	36.3	33.9	34.7
3. A-shape	9.7	34.7	30.3
4. Rectangular + hand cut	10.7	5.0	0.0
SED	10.83	16.06	12.23
SE per plot	±15.32	±22.71	±17.29
df	9	9	9
CV%	70.2	86.6	73.6

Excellent control of *C. vitalba* was achieved by hand cutting stems (Table 2), with very few additional shoots being produced in 1992 and 1993. Differences between treatments were not, however, statistically significant at the 5% level of probability ($P = 0.08$, 0.26 and 0.07 for 1991, 1992 and 1993 data respectively).

There were significant treatment differences in mean numbers of *C. vitalba* stems in two shoot diameter groups when these were counted in March 1993 ($P < 0.001$) (Table 3). Hand-weeded plots had fewest *Clematis* stems; plots cut to an A-shape had most.

TABLE 3. Mean number of *C. vitalba* stems per plot in 5-20 mm (real values) and > 20 mm (back-transformed values) categories - 23 March 1993

Treatment	Shoot base diameter 5 - 20 mm	> 20 mm	L_l	L_u
1. Rectangular (control)	27.5	1.9	0.67	7.05
2. Rectangular/alternate	29.5	3.5	1.14	19.79
3. A-shape	37.8	6.2	1.75	86.85
4. Rectangular + hand cut	2.2	0.0	0.00	0.28
SED	5.35			
SE per plot	±7.57			
df	9			
CV%	31.2			

L_l = lower 95% confidence limit; L_u = upper 95% confidence limit

TABLE 4. Mean hedge heights (cm)

Treatment	Nov 91	Mar 92	Sept 92	Feb 93	Sept 93
1. Rectangular (control)	188.1	138.0	194.7	137.6	201.0
2. Rectangular/alternate	186.5	142.1	202.9	140.6	199.3
3. A-shape	202.2	179.5	223.2	174.9	212.3
4. Rectangular + hand cut	208.3	142.3	205.8	142.6	220.0
SED	6.15	4.52	10.49	3.57	8.13
SE per plot	±8.70	±6.39	±14.84	±5.05	±11.49
df	9	9	9	9	9
CV%	4.4	4.2	7.2	3.4	5.5

Table 4 shows mean hedge heights measured at five dates. There were significant differences between treatments after hedge trimming (February/March assessments), as the A-shape treatment was deliberately left taller ($P<0.001$).

Although cut to a similar height to treatments 1 and 2 in December 1990, hand-weeded plots in treatment 4 were significantly taller by November 1991 ($P<0.05$). Height differences between treatments in September 1992 and September 1993 were not significant at the 5% level ($P = 0.116$ and 0.094 respectively). The greatest height increase, in each year, was shown by the hand-weeded treatment.

TABLE 5 . Hedge density scores (number of diamonds with ≥ 50% visibility)

Treatment	Feb 92	Feb 93
1. Rectangular	14.6	23.1
2. Rectangular/alternate	9.8	15.7
3. A-shape	8.4	18.5
4. Rectangular + hand cut	13.6	27.9
SED	1.57	3.33
SE per plot	±2.21	±4.70
df	9	9
CV%	19.1	22.1

* 0 = very thick or dense hedge; 50 = very thin or sparse hedge

Table 5 shows the mean scores of hedge density measured in winter, after trimming. All plots were fairly dense, without gaps. In both years, density scores were higher in treatments that had been trimmed to a rectangular shape (ie treatments 1 and 4) ($P<0.05$). This is probably simply because of the greater width of hedge sections receiving the rectangular/alternate and A-shape treatments, rather than any real differences in density.

Numbers of fruits were generally low in all three years (data not shown). The highest counts were recorded in October 1991, on plots trimmed to an A-shape.

TABLE 6. *C. vitalba* and *R. fruticosus* abundance scores and % cover - 21 September 1993

	Date of hand-weeding		
	Not Cut	15 March	29 June
C. vitalba			
Abundance score (0-5)*	3.0	0.0	0.6
% cover	36.4	0.0	2.0
R. fruticosus			
Abundance score (0-5)	0.7	0.1	0.0
% cover	8.6	0.7	0.0

* 0 = absent, 1 = rare, 2 = occasional, 3 = frequent, 4 = abundant, 5 = dominant

Table 6 presents the results of an assessment of *C. vitalba* and *R. fruticosus* in the hedge in the adjacent field, used for the supplementary hand-weeding observations. These results suggest that cutting *Clematis* and Brambles in March or June is effective.

Observations made on rates of hand-cutting showed them to be higher in March (217 *C. vitalba* stems cut in just 39 minutes) than in June, when tall nettles had to be strimmed before cutting was possible (total time taken was 60 minutes to cut 118 stems).

Annual botanical assessments along the southern (field) side of the main experiment hedge showed no discernible treatment effects (data not shown). Major short-term treatment effects on the flora were not expected. The mean number of plant species per plot (hedge and hedge-bottom) in 1993 was 20.1 (4.4 woody/climbing species, 5.2 grasses and 10.5 dicotyledonous herbs). In all, 51 species were recorded in 1993.

CONCLUSIONS

Cutting *C. vitalba* stems near the base, and treating the stump with glyphosate appears to be an effective method of control of this species. Preliminary observations suggest that winter treatment is as effective as summer cutting, and may in certain circumstances be easier and faster to perform. Hand-weeding by this method can improve hedge vigour and should be seriously considered where *C. vitalba* threatens to smother a hedge.

The method of hedge trimming had no clear short-term effect on *C. vitalba* abundance. A longer-term study might reveal changes in climbing weed frequency, and other gradual changes in the hedge and ground flora not observable within just three years.

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REFERENCES

Barr, C.; Howard, D.; Bunce, R.; Gillespie, M.; Hallam, C. (1991). Changes in hedgerows in Britain between 1984 and 1990. NERC Contract Report to Department of Environment. Institute of Terrestrial Ecology. 13 pp.

Brooks, A. (1975). Hedging : A Practical Conservation Handbook. British Trust for Conservation Volunteers. 117 pp.

Clapham, A. R.; Tutin, T. G.; Warburg, E. F. (1962). Flora of the British Isles (2nd edition). Cambridge University Press. 1269 pp.

Popay, A. I. (1986). Old Man's Beard, *Clematis vitalba*, control measures. *Farm Production and Practice* 858, New Zealand MAF. 2 pp.

Ryan, C. (1985). Pests and problems - Old Man's Beard. *Soil and Water* 3. pp 13-17.

Salisbury, E. J. (1961). Weeds and Aliens. Collins. 384 pp.

Sinker, C. A.; Packham, J. R.; Trueman, I. C.; Oswald, P. H.; Perring, F. H.; Prestwood, W. V. (1985). Ecological Flora of the Shropshire Region. Shropshire Trust for Nature Conservation. pp 179-180.

Stace, C. (1991). New Flora of the British Isles. Cambridge University Press. 1226 pp.

MANAGEMENT OF DITCHES IN ARABLE FENLAND: MOWING REGIMES FOR DRAINAGE AND CONSERVATION

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ABSTRACT

In the peat Fens of Cambridgeshire, arable land is intensively managed for crop production. Field margins are potentially very important as wildlife refuges or corridors, and ditches are of particular interest for their relict aquatic flora and fauna. However, ditches in arable fenland are managed primarily for drainage and this requirement can conflict with those of wildlife management. The effects of altering bank mowing regimes on drainage and the emergent aquatic flora of ditches were investigated in a small replicated trial. Four mowing frequencies were chosen, from twice yearly to no cut over four years.

Two major gradients were identified in the species composition of the emergent aquatic plant associations in the ditches: the first reflected the transition from swamp to herbaceous fen; the second contrasted associations which were dominated by *Phragmites australis* and *Sparganium erectum* with associations which lacked those species. The species richness of all associations decreased during the course of the experiment, but the net loss of species was inversely correlated with mowing frequency. However, the effects of mowing on species composition differed between plant associations. Frequent winter mowing promoted the growth of *Phragmites* and adversely affected drainage efficiency.

INTRODUCTION

The peat Fens of Cambridgeshire contain some of the most intensively farmed arable land in western Europe. Consequently, field margins in this area have particular importance as wildlife refuges or corridors. Drainage ditches are the most widespread type of field boundary and, as the peat Fens were formerly a major wetland prior to drainage for agriculture, ditches are important as wildlife refuges because of their relict wetland plant and animal communities. However, the conservation management of ditches in arable fenland presents many problems (Milsom *et al.*, 1994).

Ditches in the peat Fens are managed primarily to maximise their drainage efficiency. This is done by periodic removal of accumulated plant debris and silt (slubbing), and by frequent cutting of vegetation on ditch banks and in the water (Newbold *et al.*, 1989). Some of these operations are thought to have an adverse effect on the flora and fauna of ditches but there are no empirical data from the peat Fens to determine whether current management regimes could be adjusted for the benefit of conservation without conflicting with drainage needs. Management for drainage is applied rigorously in the larger arterial drains by Internal Drainage Boards, but the regimes on smaller private ditches are more flexible and offer scope for adjustment.

This paper describes the emergent aquatic flora (as defined by Alcock and Palmer, 1985) of private ditches, about which little is known, and reports the effects of manipulating bank mowing regimes on the flora and on drainage efficiency. Further details of the experiment are given in Sherwood and Harris (1991) and in Milsom *et al* (1994).

METHODS

The experiment was carried out on two adjacent ditches at ADAS Arthur Rickwood Research Centre, in Mepal Fen, Cambridgeshire. Further details of the site are given in Sherwood and Harris (1991).

Three mowing treatments were compared against a control where vegetation on the ditch banks remained unmown for the duration of the experiment, which was four years. The treatments comprised: (i) a cut made twice a year in March and, again, in October; (ii) an annual cut in October and (iii) a cut made once every two years in October. October and March were chosen to avoid damage to crops during the main growing season and to minimise risk of destroying birds and their nests. Mowing was carried out using a Bomford 457 flail, following local practice. The flail was passed repeatedly over both ditch banks down to water level to create a low uniform sward. Each ditch was sectioned into 25m plots, with eight in one ditch and four in the other. Two replicates of treatments were assigned to the former ditch and one to the latter. Within ditches, the layout of the treatments was randomised.

Floristic assessments were made at six-week intervals, from April to September of each year. The middle 20 metres of each plot was split into 10 contiguous two metre sections and plant species lists were compiled for each section. These presence/absence data were used to calculate an abundance score on a ten point scale for each species in each plot.

The patterns of variation between plots in the species composition of the emergent aquatic vegetation were examined by using Detrended Correspondence Analysis (Hill, 1979). Detrended Correspondence Analysis (DECORANA) was used to ordinate plots in multi-dimensional space bounded by four axes, each of which represents a gradient in species composition. Data from separate years were entered individually so that changes in species composition over the course of the experiment could be evaluated using vector analysis (Hill *et al.*, 1993). Only the first two axes were considered because the proportion of the variation in the dataset that was explained by the remaining axes was very low, as indicated by the decrease of the eigenvalues from the first to the fourth axes: 0.1869, 0.0973, 0.0402, 0.0206. The DECORANA co-ordinates for each plot in 1989 were compared with their equivalents in 1992 and resultants were calculated trigonometrically from the differences between years on the first and second DCA axes. The angle between the resultant and Axis 2 was used as the measure of the direction of floristic change. Non-parametric analyses of variance (Siegel and Castellan, 1984) were used to test for differences between treatments in the resultants and angles of movement respectively.

RESULTS

An ordination of plots in the first and last years of the experiment is shown in Fig. 1. Axis 1 represents a gradient from swamp to herbaceous fen, which are denoted by low and high DECORANA scores respectively. Common Reed (*Phragmites australis*) was a characteristic species of the swamp associations but it was replaced by Reed Canary-grass (*Phalaris arundinacea*), Purple Loosetrife (*Lythrum salicaria*) and Hemp Agrimony (*Eupatorium cannabinum*) in the fen. The second axis contrasts associations, where either *Phragmites* or Branched Bur-reed (*Sparganium erectum*) were dominant (low scores), with those where *Phragmites* and *Sparganium* were absent and the Jointed Rush (*Juncus articulatus*) was locally abundant (high scores). A full species list given in Milsom *et al* (1994).

The effects of the mowing treatments were assessed against two criteria: (i) rates of change in species richness, and (ii) changes to the species composition of the emergent aquatic flora. Turnover of species occurred in all plots although losses tended to outnumber the gains. The loss of species was least in the plots that were mown twice yearly and greatest in those that were left unmown for four years. There was also a suggestion that number of gains per plot and mowing interval were inversely correlated but the test statistic was not quite significant. Overall, however, the net loss of species was significantly correlated with mowing interval (Fig. 2). These trends were investigated further using DECORANA (Fig. 1). The extent and direction of change in species composition between 1989 and 1992 varied considerably between plots, though in some, such as 5,6, 7 and 10, there was almost no change at all. Neither the extent of change nor its direction, as measured by the resultants and angle respectively, differed significantly between treatments (Kruskal-Wallis ANOVA: Chi-square 1.26, n=12, NS for resultants; Chi-square 1.67, n=12, NS for angle).

DISCUSSION

This experiment was the first attempt to describe the aquatic flora of arable fenland ditches in detail. Its main finding was that the emergent aquatic plant associations both within and between ditches were diverse which was unexpected. The floristic gradient, over 200 m, from swamp to herbaceous fen plant associations in one ditch (Plots 1-8), and the difference in swamp associations between adjacent ditches (Plots 1-8 vs 9-12), have implications for management prescriptions because of the variable effects of mowing.

Manipulation of the mowing frequency had an effect that was common to all emergent aquatic plant associations in the ditches. The reasons for this relationship are not clear from the results of the experiment. However, it is known that the species richness of fen plant communities is inversely correlated with their above-ground biomass (Wheeler and Giller, 1982), and mowing may well have affected the quantity of the vegetation in the ditches.

The effects of mowing on species composition were less uniform, however. There was some evidence from the plots dominated by *Phragmites* (Plots 1,2 & 3) that the lack of mowing resulted in build up of litter and loss of species richness, whereas this process was slowed when cutting was done at least every two years. These differences between mowing treatments are reflected in Fig. 1. There was also some suggestion that the degree of change in the *Juncus* swamp association (Plots 9-12) may also have been inversely related to mowing frequency. However, in the herbaceous fen (Plots 4-8), there was no evidence of a simple correlation between mowing frequency and either the extent, or the direction, of change in species composition. These effects are being explored further in a follow-up experiment which has greater replication.

Ditch banks in the Fens are mown to minimise their resistance to water flow (hydraulic roughness) which may be critical during periods of high flow. This management is aimed particularly at *Phragmites* because of the significant contribution that the species makes to the hydraulic roughness of the banks and the water course itself. However, the evidence from this experiment was that frequent winter mowing promoted the growth of *Phragmites* on the banks, a finding which is in agreement with other studies (Haslam, 1968, Cowie *et al.*, 1992). Reed growth also became more luxuriant in the water course itself, possibly due to lateral spread, where it impeded water flow and resulted in water backing up one of the ditches (Rose and Harris, 1993).

Apart from the hydraulic implications, pure stands of reed are undesirable from the conservation point of view. Though stands of reed are often the only nesting habitat for birds in ditches, they shade the water course and, thereby, reduce the species diversity of floating and submerged aquatic plant associations. Moreover, evidence from this experiment (Milsom *et al*, unpublished) suggests that swamp communities dominated by reeds support the least diverse species assemblages of dragonflies and butterflies. Summer cutting is a possible remedy to these problems because it is known to inhibit *Phragmites* growth (Haslam 1968) and to increase the diversity of herbaceous fen plant communities (Rowell *et al.*, 1985). However, the practicality of summer cutting needs to be evaluated because maturing agricultural crops often hinder access to ditches and there are also implications for nesting birds.

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REFERENCES

Alcock, M.R.; Palmer, M.A. (1985). A Standard Method for the Survey of Ditch Vegetation. Nature Conservancy Chief Scientist Team Notes, **37**. Peterborough, J.N.C.C.

Cowie, N.R.; Sutherland, W.J.; Ditlhogo, K.M.; James, R. (1992). 'The effects of conservation management of reed beds. II. The flora and litter disappearance', Journal of Applied Ecology, **29**, 277-284.

Haslam, S.M. (1968). The biology of Reed *Phragmites communis* in relation to its control. Proceedings of 9th British Weed Control Conference, pp. 392-397.

Hill, D.; Rushton, S.P.; Clark, N.; Green, P.; Prys-Jones, R. (1993). Shorebird communities on British estuaries: factors affecting community composition. Journal of Applied Ecology, **30**, 220-234.

Hill, M.O. (1979). DECORANA - a FORTRAN program for Detrended Correspondence Analysis and Reciprocal Averaging. Section of Ecology and Systematics, Ithaca, Cornell University.

Milsom, T.P.; Runham, S.R.; Sherwood, A.J.M.; Rose, S.C.; Town, S.J. (1994). Management of fenland ditches for farming and wildlife: an experimental approach. Proceedings of Symposium on Nature Conservation and the Management of Drainage System Habitat. Loughborough, ICOLE, *in press*.

Newbold, C.; Honnor, J.; Buckley, K. (1989). Nature Conservation and Management of Drainage Channels. Peterborough, Nature Conservancy Council and Association of Drainage Authorities.

Rose, S.C.; Harris, G.L. (1993). The management of ditches in arable fenland for drainage and wildlife - Phase 1 hydrology report. Cambridge, ADAS Soil and Water Research Centre.

Rowell, T.A.; Guarino, L.; Harvey, H.J. (1985). The experimental management of vegetation at

Wicken Fen, Cambridgeshire. Journal of Applied Ecology, **22**, 217-227.

Sherwood, A.; Harris, G.L. (1991). The management of ditches in arable fenland for drainage and wildlife. Cambridge, ADAS Land and Environment.

Siegel, S.; Castellan, N.J. (1984). Nonparametric statistics for the behavioral sciences, New York, McGraw-Hill.

Wheeler,B.D.; Giller, K.E. (1982). Species richness of herbaceous fen vegetation in Broadland, Norfolk in relation to the quantity of above-ground plant material. Journal of Ecology, **70**, 179-200.

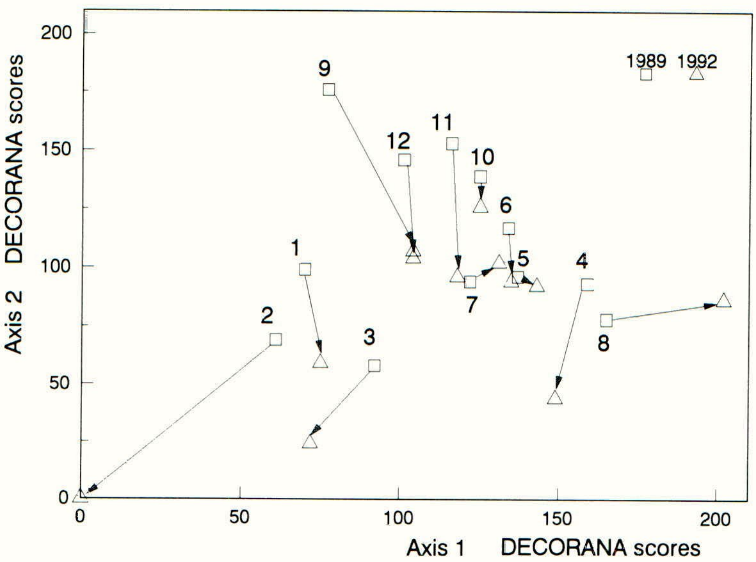

FIGURE 1. Ordination of plots with respect to first two axes from Detrended Correspondance Analysis showing DECORANA scores and changes within plots between 1989 and 1992. Plot numbers refer to those in the text. Plots 1,4 & 10 were mown twice a year; Plots 5, 8 and 11 were mown annually; Plots 3,6 and 12 were mown once every two years and Plots 2, 7 and 9 remained uncut over 4 years.

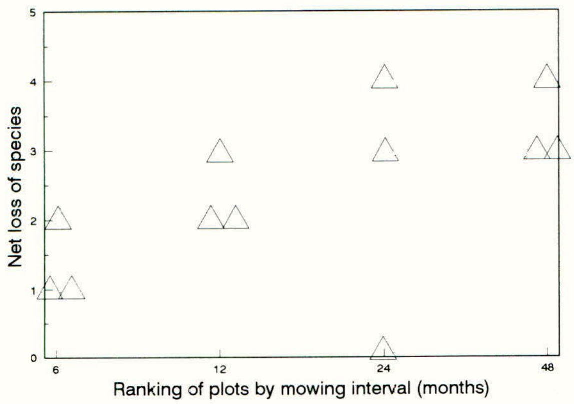

FIGURE 2. Correlation between net loss of species per plot and mowing interval. Kendall Rank Correlation coefficient: 0.495, P=0.024.