The distribution, population size and growth of the rare English endemic *Sorbus bristoliensis* A. J. Wilmott, Bristol Whitebeam (Rosaceae)

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ABSTRACT

The distribution, population sizes and growth of the rare endemic *Sorbus bristoliensis* A. J. Wilmott (Rosaceae) are summarised, based on literature and herbarium studies, and field surveys in 2004 and 2005 using GPS to localise trees. It is endemic to the Avon Gorge, where 262 trees are currently known in woodland, on woodland edges, on open rocks and in disused quarries. It occurs on a range of soils derived from carboniferous limestone, plateau clays and more acidic sandstone rocks. Data on height and girth show a continuous range of age classes indicating regular regeneration. Tree ring data suggest that the oldest tree is at least 227 years old, and many trees are more than 100 years old. Comparison against 1970s survey data from Leigh Woods shows the population is increasing at c. 10% per decade. Under the 2001 IUCN Threat Criteria it is categorised as "Vulnerable".

KEYWORDS: Gloucestershire, Somerset, conservation.

INTRODUCTION

Sorbus bristoliensis A. J. Wilmott, Bristol Whitebeam, is a rare English endemic tree confined to the Avon Gorge, Bristol (Wigginton 1999). Flanagan (1998) listed it as declining and in need of recovery, with most of the plants in the Avon Gorge being mature trees with little natural regeneration, and it was regarded as one of the four species of *Sorbus* with the highest priority for conservation in Britain.

A full history of the discovery of *S. bristoliensis* is in given by Lovatt (2007); here only a summary related to the increase in the number of trees known with time is given. The first record and earliest herbarium specimens of *S. bristoliensis* are those of Miss M. M. Atwood on 10 June 1852 from the summit of Nightingale Valley, Somerset, in herb. Watson at **K** (Lovatt 1982; Swete 1854, as *Pyrus aria* Sm. γ *intermedia* Ehrh.). This tree has been widely suggested (e.g. by Green *et al*. 2000) to be the multi-coppiced tree by the Stokeleigh Camp viewpoint, Leigh Woods, on the north side of Nightingale Valley (grid reference ST56107328), but a large multi-coppice tree hanging over the edge of the cliffs on the south side of Nightingale Valley below North Road (ST56217305) fits the description of the location, and White (1912, as *Pyrus latifolia* Syme) noted that only the tree on the southern edge of the valley was known to the early botanists. White (1912) reported that only two or three trees were known until 1901, when five more were found to the north by A. Ley ("Nightingale Valley, south side, at the edge of the rocks nearly opposite the first cross roads. Also on the north side"; **BRISTM**), and subsequently more were found by J. W. White in 1902 (**BRISTM**, **NMW**, **UPS**; White 1912), but other herbarium specimens suggest it was also found elsewhere despite T. B. Flower's insistence to White (1912) that there was only one tree. It was reported as first found on the Gloucestershire side in 1909 by White (1912)

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who noted that "a very old tree with several boles overhangs some steep rocks on a thickly wooded slope of Clifton Downs" (a large old tree in a similar location was still present in 2006 but in poor condition). However, there is an earlier specimen in **GLR** which can be traced to a field trip by W. H. Purchas, T. B. Flower and G. A. St Brody to the Gully in 1869 (Lovatt 2007). When Wilmott (1934) described *S. bristoliensis* as a distinct species, he noted that there were "many trees, occurring on both sides of the gorge" but he only noted one tree from the Gloucestershire side in Riddelsdell *et al*. (1948). His type specimen was collected from this tree on Clifton Down in 1933 (**BM**), and not the tree on the summit of Nightingale Valley as often reported (e.g. Hendry & Pearson 1973). Bailey *et al*. (1972) and Hendry & Pearson (1973) noted it was present in substantial quantities in Leigh Woods, both within the National Nature Reserve (N.N.R.) and above Quarries 1, 2 and 3, with smaller numbers between. Russell (1979, Appendix 3) listed 146 trees (80 mature, 66 regeneration) in the Leigh Woods NNR. Nethercott (1998) suggested that there were probably about 100 trees, mainly on the Leigh Woods side. It is difficult to be certain of population trends given the extent of quarrying and destruction of the original woodland vegetation in the gorge, but given how rare White (1912) regarded *S. bristoliensis* as and the frequency with which it has now colonised secondary habitats, it has either increased markedly over the last 100 years or its true extent had simply never been established.

As part of work on the rare *Sorbus* species of the Avon Gorge, we have compiled records of *S. bristoliensis* from herbaria and carried out field work between 1996 and 2005, and here report the first detailed estimate of the distribution and population size. We have also collected some of the data on its growth and performance to assess the population trends. Full details of the records have been lodged with the National Trust, Natural England, Bristol Environmental Records Centre, the Threatened Plants Database and the National Biological Records Centre, Monks Wood.

Sorbus bristoliensis is a relatively distinct member of the *S. latifolia* group, characterised by the obovate, shallowly but sharply lobed leaves with a cuneate base, and the orange ripe fruits (Sell 1989). We have not observed yellow ripe fruits as reported by Sell (1989) and, in exposed sunlit sites, some ripe fruits can be distinctly reddish on one side at least. *Sorbus bristoliensis* occurs with three other members of the *S. latifolia* group in the Avon Gorge, *S. latifolia* (Lam.) Pers. sensu stricto (occasional), *S. croceocarpa* P. D. Sell (locally frequent), and *S. decipiens* (Bechst.) Irmisch (rare), as well as other *Sorbus* species; they may be identified using the leaf silhouettes in the *Plant Crib* (Rich & Jermy 1998), and T. Rich will be happy to determine specimens, which should preferably consist of leaves from the short lateral rosettes, and fruit if present.

METHODS

Historical records were compiled from herbaria (**BIRA**, **BIRM**, **BM**, **BRISTM**, **CGE**, **E**, **GLR**, **LIV**, **LTR**, **MBH**, **NMW**, **OXF**, **RNG** and **UPS**), published and unpublished literature and reports (e.g. Bailey *et al*. 1972, Hendry & Pearson 1973, Russell 1979, Rich & Houston 1996), and from correspondence with botanists. These records were used to direct field surveys, though most, with the notable exception of Russell (1979), lacked sufficient detail to be any use in the field.

RELIABILITY OF GPS READINGS AND GROWTH MEASUREMENTS

Small, hand-held, cheap GPS units are being widely used to collect botanical survey data, but there are few published estimates of their reliability for repeating survey work. The reliability of the GPS readings was tested by repeat measurements at the same point by the same and different units, and for some individual trees. The repeatability of height and girth measurements was also assessed for some trees.

DISTRIBUTION AND POPULATION SIZE FROM FIELD SURVEY

A detailed survey was carried out between August 2004 and October 2005 by the authors, and on 2 October 2004 with help of 13 volunteers from the Somerset Rare Plants Group and the B. S. B. I. The best time to search for trees was found to be late September and early October, when some leaves have blown to the ground, which can then be traced back to the tree. Towards the end of October, too many leaves of all species cover the ground, making the fallen *S. bristoliensis* leaves less conspicuous and consequently the trees are harder to trace. Fallen fruits, which tend to fall directly under the trees, were also a useful aid to finding the trees quickly. Efforts were made to avoid recording the same trees twice by temporarily marking the trunks with chalk. Trees and saplings were searched for and their locations pinpointed using five Garmin Etrex units as well one other hand-held GPS.

In general it was straightforward to define an individual. We have only observed *S. Bristoliensis* suckering once from exposed roots c. 1 m from the main trunk on the edge of the Gully, and have generally treated separate maiden trunks as separate plants even if very close together. On two occasions, two trees have been observed growing together at the base but with no sign of having been coppiced, so they were treated as maidens.

No seedlings or young *S. bristoliensis* plants less than 0·75 m high were recorded, either because they were difficult to see amongst undergrowth or were difficult to identify, though in general there is good regeneration of most *Sorbus* species in the Avon Gorge, especially in the open areas. Young saplings were difficult to identify as the characteristic short lateral shoot leaves were not developed, and leaves of young, shaded *S. bristoliensis* plants are difficult to tell apart with confidence from leaves of young, shaded *S. latifolia* and *S. croceocarpa*, both of which are also regenerating in the gorge.

GROWTH AND PERFORMANCE

The height of the tree was estimated by eye, the girth of the largest trunk measured with a tape-measure at 1·3 m above the ground, and notes were made on the growth form (maiden or coppiced) and the presence or absence of fruit. Where ivy could not be removed or prised away from the trunk, a visual allowance was made to correct for the increased girth. Coppiced trees may have originated from deliberate coppicing as part of woodland management, or may be naturally coppiced following loss of a trunk in a storm, etc. (*S. bristoliensis*, like many *Sorbus* species, appears to coppice readily from the base of the trunk following damage). Where trees occurred on cliffs or in inaccessible situations, it was not possible to collect some data. Four trees for which girths were measured in 1996 (Rich & Houston 1996) were re-measured in 2004.

AGE OF TREES

Tree ring data were collected to help assess tree ages and trends in the population. One core was taken from each of 26 trees (22 maidens, 4 coppice) at, with a few exceptions, 1·3 m above the ground using a Haglof 5·15 mm increment borer on 17 March 2005. Trees were selected from a range of growth conditions, from shaded woodland on plateau clays to dry, open rocks, and their girth was noted at the height of coring. Where trees were on slopes or adjacent to wood edges, cores were taken from the side of the trunk parallel to the slope to avoid reaction wood and minimise asymmetrical growth. In total 17 cores reached the middle of the trunk, and nine cores either missed the centre or did not reach it. No core holes were plugged as this is regarded as unnecessary (Grissino-Mayer 2003). In the lab, the annual growth rings were marked with pencil under a microscope and their widths measured with a graduated lens to the nearest 0·1 mm. The rings do not always stand out clearly in this species, and checks showed that rings had occasionally been missed. The most recent rings were the hardest to measure, partly due to their small size in recent years, and partly due to distortion caused by the increment borer. To estimate at what age a sapling would reach 1·3 m tall, six saplings were aged from the annual bud scars.

The girth data were also analysed for maiden trees in eight areas (two woodland, two scrub, two natural cliff and two quarry sites) with reasonable populations of trees. The girths were converted to estimated age from the tree ring data and summarised into age class by decade.

COMPARISON OF 2004–2005 SURVEY DATA WITH RUSSELL (1979) DATA

Russell (1979) mapped 80 mature and 66 regenerating trees in grid squares within Leigh Woods N.N.R. between 1976 and 1978. The 2004–2005 field data for mature and/or fruiting trees were compared with his data to assess loss and gain of mature trees.

RESULTS

RELIABILITY OF GPS READINGS AND GROWTH MEASUREMENTS

For the location and growth data to be useful for monitoring in the future, it is important to have some estimate of their reliability. The 10-figure (i.e. to the nearest metre on the ground) grid references from the Garmin Etrex GPS units were tested for repeatability by recording the coordinates for the gated entrance to Leigh

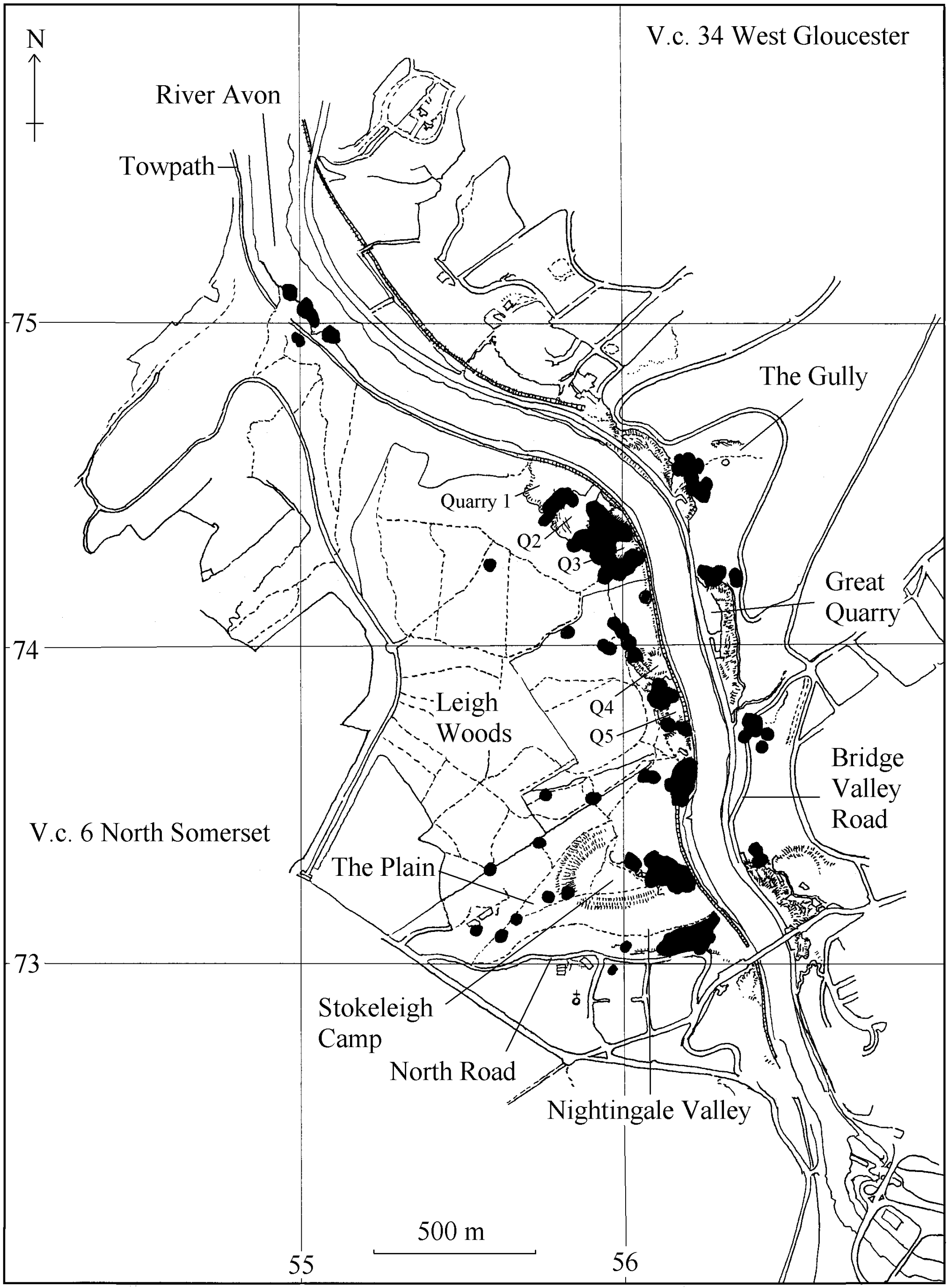

FIGURE 1. Detailed distribution of *Sorbus bristoliensis* in the Avon Gorge, Bristol, 2004–2005.

Woods on North Road at the start and end of the survey on 2 October 2004. The units reported their accuracy as an average of ±8·6 m (range ±6–12 m). Relative to the overall average reading at the start of the day, five units varied by an average of 4·25 m east–west (range 2–10 m) and 8·25 m north–south (range 1–18 m). At the end of the day, three of the units retested varied by an average of 4·33 m east-west (range 0–8 m) and 13 m north–south (range 5–24 m) from their individual readings at the beginning of the day. Readings for the same trees, made on different days by different Garmin units (n = 12, mean reported accuracy ±15·4 m, range ±6–47 m), varied by an average of 20 m east-west (range 2–74 m) and 17 m north–south (range 2–47 m).

The accuracy of the GPS unit readings varied depending on the location and canopy cover. Where there was a clear view of the sky and no tree canopy, the accuracy was usually reported on the units as ±6–7 m, but under closed canopy in tall woodland, it was much more variable (and often over ±20 m), and readings for the individual trees varied markedly. Nonetheless, the use of these simple, cheap GPS units provided significantly more accurate locations than could be obtained from traditional maps, and considerably speeded up localising individual trees. Basic GPS readings of this level of accuracy are unlikely to be of significant use for monitoring individual trees in clustered populations, where other means of localising and identification may also be needed. More expensive GPS units with differential correction could be used to give greater repeatability, but are unlikely to be affordable to many amateur botanists.

Repeated height measurements for three trees on different days varied by an average of 0·67 m (range 0–1 m); tree heights are notoriously difficult to estimate reliably by eye. Repeated girth measurements on the three trees varied by an average of 3 cm (range 1–4 cm); the variation may be due to a combination of different people measuring at slightly different heights on the tree and the difficulty of keeping the tape level and tight round large trees.

DISTRIBUTION AND POPULATION SIZE FROM FIELD SURVEY

The distribution of plants is shown in Figure 1 and the number of plants in each area summarised in Table 1. A total of 262 *S. bristoliensis* trees are currently known, but there is little doubt that there are more on the less accessible parts of cliffs and disused quarries, and in dense woodland. The map shows that most trees occur on the Leigh Woods side of the Avon Gorge in v.c. 6 North Somerset (234 trees), with the highest densities associated with the natural rock outcrops, the quarry tops and edges, and the change of slope from the valley sides to the plateau. On the Leigh Woods plateau there are scattered trees, the lower density in the northern Forestry Commission area reflecting the woodland clearance and replanting undertaken in that area. A total of 28 trees occur on the east side in v.c. 34 West Gloucester, mainly associated with young woodland.

PLANTED TREES

There is one planted tree on The Plain, Leigh Woods, and one outside the former Bristol University Botanic Garden in Church Road on the Somerset side (v.c. 6). There is one planted tree on the Promenade near Merchant's Hall and three trees grafted onto *S. aucuparia* L. rootstock on Durdham Down on the Gloucestershire side (v.c. 34).

OTHER RECORDS

Specimens collected by D. Fry, 1886, Oakleigh, near Keynsham, which had part of a label missing, led Salmon (1899) mistakenly to publish a new locality; it subsequently turned out that the specimens were from a tree in a shrubbery which had been planted by a member of the Fox family (Fry 1899; White 1912).

GROWTH AND PERFORMANCE

Height and girth are highly correlated measurements of growth and performance and, as might be expected, the taller the tree the larger the girth (Figure 2; for maidens alone $r = 0{\cdot}808$, $n = 170$, $p<0{\cdot}001$; for all trees $r = 0{\cdot}806$, $n = 190$, $p<0{\cdot}001$). There is a weak but not significant trend for stems of coppiced trees to have smaller girths than maiden trees of the same height. For trees where measurements were available, height (n = 241) and girth (n = 200) were analysed separately for the maiden and coppiced trees.

The mean height of maidens was 7·7 m ± 0·32 m s.e. (n = 226), and of coppiced trees 5·9 m ± 0·54 m s.e. (n = 35); these were significantly different ($p = 0{\cdot}046$, 2-tailed t-test with sample variances assumed to equal). The mean girth of maidens was 40·6 cm ± 2·5 cm s.e. (n = 180),

TABLE 1. NUMBER OF *SORBUS BRISTOLIENSIS* TREES AND SAPLINGS OVER 0·75 M HIGH IN EACH AREA, EXCLUDING PLANTED TREES

V.C.	Locality	No. plants
6	North Road, gardens	2
6	Nightingale Valley, rocks on south side	19
6	Leigh Woods National Trust southern area (including The Plain)	11
6	Stokeleigh Camp	6
6	Stokeleigh Camp, cliffs below viewpoint	48
6	Stokeleigh Camp, valley NE of	1
6	Leigh Woods NT, northern plateau	5
6	Leigh Woods, Donkey Slide/Goat Path south to railway tunnel	17
6	Leigh Woods, Forestry Commission area	1
6	Leigh Woods, towpath north of Quarry 1	9
6	Leigh Woods, north end west of railway	3
6	Leigh Woods, Quarry 2 and top edges	23
6	Leigh Woods, Quarry 3 (Police Quarry) and top edges	42
6	Leigh Woods, ridge between Quarries 1 and 2	10
6	Leigh Woods, towpath near Quarry 3	2
6	Leigh Woods, Quarry 4 and top edges	4
6	Leigh Woods, Quarry 5 and top edges	13
6	Leigh Woods, between Quarries 2 and 3	13
6	Leigh Woods, between Quarries 3 and 4	5
34	Bridge Valley Buttress (Jack's Hole, Great Fault)	3
34	Bridge Valley Road, above	5
34	Bridge Valley Road, below	3
34	Clifton Down, wooded slopes north of Great Quarry	9
34	The Gully/Walcombe Slade, south side	3
34	The Gully/Walcombe Slade, north side	5
	Total	262

and of coppiced tree stems 31·8 cm ± 4·8 cm s.e. (n = 23); these were not significantly different (p = 0·114). Similar proportions of the maidens (50%) and coppiced (47%) trees were fruiting.

Figure 3 shows the variation in the estimated heights of the maiden trees, with the proportion of trees in each size class with fruit. The graph shows a skewed distribution with most trees in the 2·1–8 m height categories, and progressively fewer larger trees. There are relatively few saplings in the smallest size category up to 2 m tall, either because they were small and overlooked or not identifiable with certainty, or because they may be genuinely rarer. In forest, the tree height tends to match the general height of the canopy, which at the changes of slopes preferred by *S. bristoliensis* is about 10 m high, and in the taller woodland on the plateau about 15 m high. The proportion of trees with fruit increases as the trees get taller, as might be expected. The smallest tree with fruit was 3 m tall with a girth of 12·5 cm. The largest tree without fruit was 18 m tall with a girth of 78 cm; it was growing in a tall area of dense woodland on the plateau and had no leaves in the canopy.

Figure 4 shows the frequency of the different girth sizes (2005 data corrected to 2004). The girth size classes are again strongly skewed towards the smaller size classes (the smallest size class again being under-represented due to the practicalities of survey) but a large range of girth sizes is present, with a few large trees. The proportion of trees with fruit increases as the girth sizes increase, again as expected.

AGE OF TREES

The tree ring growth data for the 26 trees (c. 10% of the population) are summarised in Table 2. The oldest cores were from tree 23 (107 rings) and tree 26 (103 rings). Individual rings varied in width from 0·1 mm to 5·0 mm, with an overall mean of 1·31 mm ± 0·018 mm s.e. The mean ring width for each tree ranged from 0·75 mm (tree 8) to 3·05 mm (tree 25), with an overall average of 1·53 mm ± 0·092 mm s.e. a year, suggesting an average increase in girth of 9·6 mm per year. The data for coppiced and maiden trees were lumped together as a t-test indicated no significant differences (p = 0·46) between them, though this is partly as only four coppiced trees were cored.

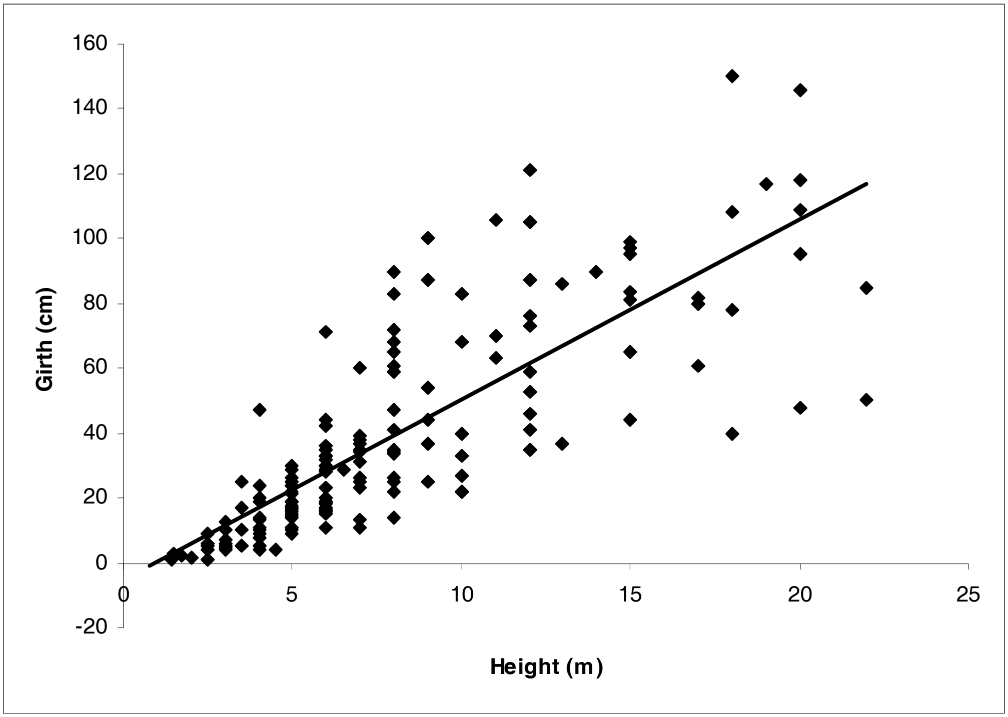

FIGURE 2. Relationship between height and girth of maiden *Sorbus bristoliensis* trees (n = 170). A best fit line is also shown.

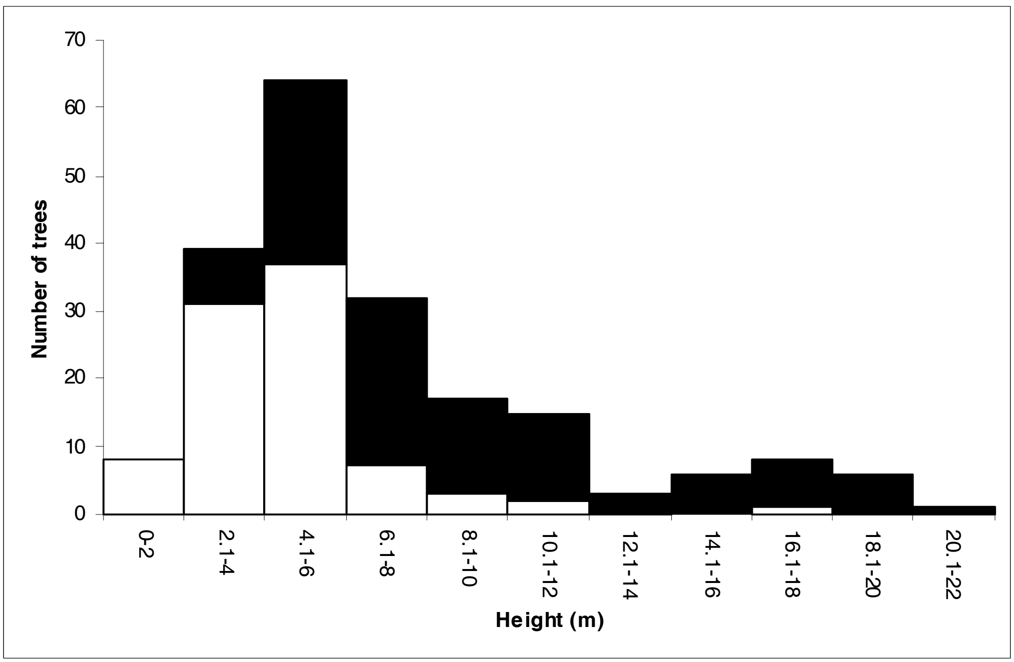

FIGURE 3. Variation in height of maiden *Sorbus bristoliensis* trees. ■ proportion with fruit. □ proportion without fruit.

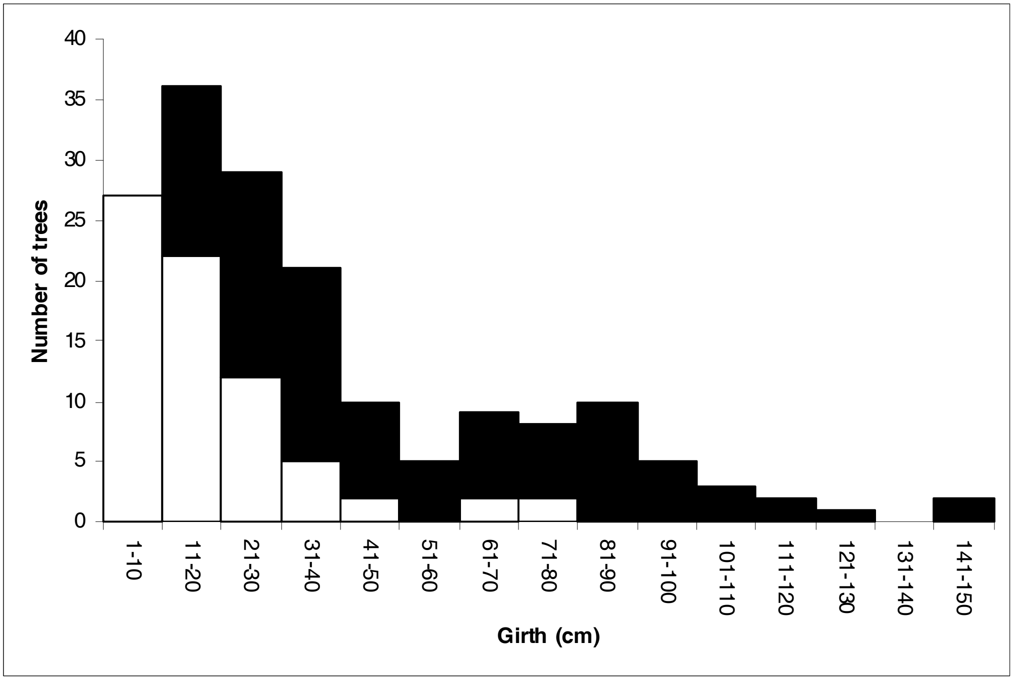

FIGURE 4. Variation in girth of maiden *Sorbus bristoliensis* trees at 1·3 m (data for 2005 corrected to 2004). ■ Proportion with fruit. □ Proportion without fruit.

The age of the individual trees can be estimated from the girth data as the girth and core age data are highly correlated ($r = 0{\cdot}825$, $p<0{\cdot}001$). On average, the bud scars showed that saplings took 14·8 ± 1·6 s.e. years to reach 1·3 m tall (the height at which cores were taken), so 15 years can be added to each age estimated from the cores. Treating the trunks as cylinders, the oldest trees cored, both on the Somerset side, are estimated to be 159+15 = 174 years (tree 26) and 141+15 = 156 years (tree 23). The first tree found on the Gloucestershire side (cf. White 1912) has the one remaining trunk estimated to be potentially 227 years old (currently girth of 93 cm and mean annual ring width of 0·66 mm/year) but the large coppiced base suggests it may be much older. Two trees at the bottom of the woodland slope north of the Great Quarry were estimated to be 160–170 years old. Observations in the field show that the assumption the trunks are cylinders may overestimate the age of some trees, as, for the 17 cores which reached the centre, the actual core length to the centre was 87% of the calculated core length (assuming a cylindrical trunk). This is due to the asymmetrical trunk growth in natural conditions and the cores being taken from the side of the tree parallel to the slope.

The mean ring growth of trees in woodland was 1·44 mm in width per year, and for trees in the open 1·62 mm per year, but these are not statistically different ($p = 0{\cdot}38$), suggesting that other unmeasured factors such as climate, soil depth and soil nutrient status may also be important for growth. The ring data for some woodland trees (e.g. tree 2 from the edge of the ramparts of Stokeleigh Camp) also showed that there could be sudden changes from periods of slow growth to fast growth and vice versa, perhaps related to woodland management, loss of adjacent trees or closure of the canopy.

The age distributions of individual trees for four different habitats in eight areas of the gorge are shown in Figure 5. Whilst the age estimates are fairly crude, there are some interesting differences between the habitats. The densely wooded slopes north of the Great Quarry (Figure 5a) have only mature, old trees present (estimated ages 80–170 years) with no regeneration. In contrast, the wooded area of the Leigh Woods plateau (Figure 5b), once pasture woodland, have a broader range of

TABLE 2. TREE-RING DATA FOR 26 CORED *SORBUS BRISTOLIENSIS* TREES

Tree	Maiden or coppice	Girth (mm) at 1·3 m	Habitat	Core length analysed (mm)	No. rings measured	Mean ring width (mm)	Estimated age of tree (years)*
1	Coppice	240	wood	37	35	1·30	44
2	Coppice	390	wood	52	60	0·95	80
3	Coppice	410	open	53	42	1·47	59
4	Coppice	1010	open	112	62	1·72	108
5	Maiden	170	open	42	40	1·51	33
6	Maiden	230	open	29	18	1·87	35
7	Maiden	240	wood	31	52	0·77	65
8	Maiden	340	wood	38	68	0·75	87
9	Maiden	340	open	43	49	1·27	58
10	Maiden	350	open	44	51	1·25	49
11	Maiden	360	open	53	48	1·58	51
12	Maiden	540	wood	79	75	1·46	74
13	Maiden	630	wood	106	58	2·15	62
14	Maiden	770	wood	79	58	1·17	120
15	Maiden	780	wood	117	73	1·71	88
16	Maiden	795	wood	92	68	1·07	133
17	Maiden	810	open	94	59	1·91	83
18	Maiden	870	open	100	75	1·55	104
19	Maiden	920	wood	123	101	1·35	124
20	Maiden	980	clearing	119	93	1·34	131
21	Maiden	1020	open	136	76	2·05	94
22	Maiden	1080	wood	96	75	1·57	124
23	Maiden	1175	wood	121	107	1·33	156
24	Maiden	1190	clearing	154	76	2·11	105
25	Maiden	1380	wood	110	45	3·05	87
26	Maiden	1500	wood	157	103	1·50	174
Mean		707		85	64	1·53	89

*Age includes 15 years for the trees to reach 1·3 m, and assumes trunks are cylinders; the age is then calculated from the radius and mean ring width.

trees, including some young regeneration, especially along the edges of woodland rides and in some of the slightly more open areas. The open woodland-scrub-grassland areas around the Goat Path and The Gully (Figures 5c, d) both show a range of age classes, with some older trees up to 120 years old. The largely natural cliffs at Stokeleigh Camp and on the south side of Nightingale Valley (Figures 5e, f) show a strongly skewed distribution towards younger plants, with few trees up to 100(–120) years old. This young age distribution may be partly a result of trees on the cliffs often being naturally small and frequently damaged through exposure. The age distribution for Quarries 1 and 2 (Figure 5g) is strongly skewed towards young trees to 60(–80) years old, and indicates colonisation since 1935 following cessation of quarrying. The age distribution for Quarry 3 (Figure 5h) is bimodal but again skewed towards younger trees which are colonising the gentler northern slopes of the quarry.

COMPARISON OF 2004–2005 SURVEY DATA WITH RUSSELL (1979) DATA

Of the 82 mature trees in total mapped by Russell (1979), it is probable that 61 were refound in 2004–2005. The comparison is difficult because it is not always clear that a mature tree mapped by Russell (1979) is exactly the same as the one refound in the same grid square in 2004–2005, or how Russell defined a mature or a regenerating tree; data for his grid squares OF and NE are not specified, and some trees may have been overlooked. Some 23 trees appear to have been lost

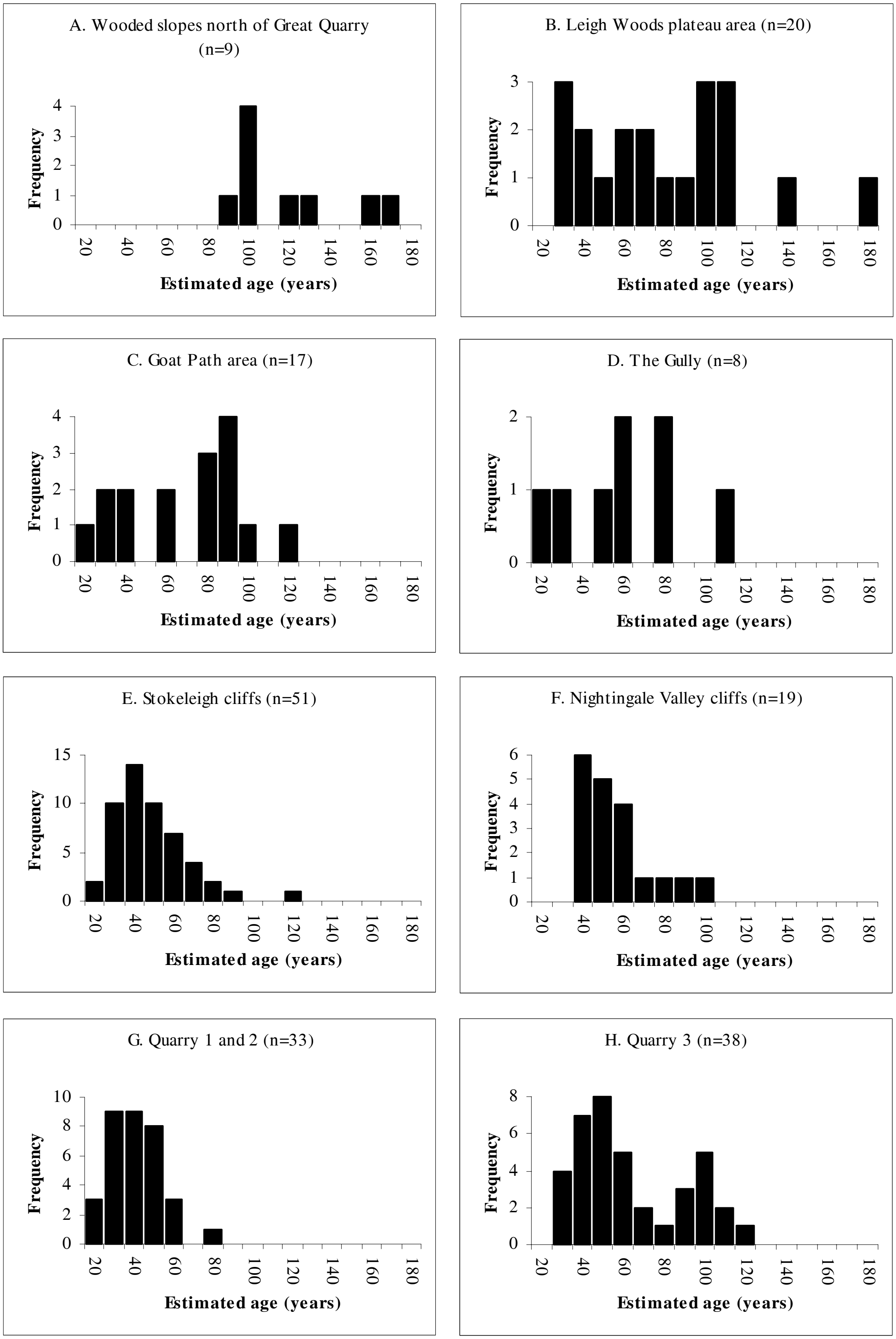

FIGURE 5. Age distribution of maiden *Sorbus bristoliensis trees* in eight different areas of the Avon Gorge

between 1976–78 and 2004–2005. We have observed a few trees with heart-rot during our surveys, but have not seen any dead trees for certain.

In 2004–2005, we found 118 mature trees in the same area covered by Russell (1979). Allowing for growth of trees since 1976–1978 (i.e. excluding trees with a girth of less than 40 cm, our estimate for 28 years old), we found 53 trees which had matured since that time. Some trees apparently additional to Russell's survey partly resulted from more detailed survey of the hazardous cliffs below Stokeleigh Camp and on the south side of Nightingale Valley. The net population increase of 30 trees between 1976–78 and 2004–2005 suggests an increase of c. 10% per decade.

DISCUSSION

The data in this paper are the first detailed population census of *S. bristoliensis*. The census indicates there are at least 262 plants, and their height and girth data, coupled with the population increase observed in Leigh Woods N.N.R. since 1976–1978, suggest that the population is currently healthy and regenerating. We attribute the absence of the smallest size class of plants to their being largely overlooked during our surveys rather than a sudden and recent lack of regeneration; Russell (1979) found frequent regeneration in *S. bristoliensis* and there is no reason for this situation to have changed. These new data allow Flanagan's (1998) assessment of *S. bristoliensis* as 'declining and in need of recovery' to be updated to 'increasing and not in need of recovery'. Similarly, the IUCN Threat Category (I.U.C.N. 2001) of *S. bristoliensis* can now be revised to "Vulnerable" as the population size exceeds 250 plants, updating the "Endangered" assessment in the recent Red Data List by Cheffings & Farrell (2005) which was based on our unattributed, incomplete 2004 survey data and which also lacked our caveats about the data.

The age distribution of the trees estimated from the girth measurements indicates that at least four trees from different areas of the gorge are likely to have been present at the time of Miss Atwood's first record in 1852, suggesting that *S. bristoliensis* had been present for some time prior to the first record and that her tree was not the first to originate; we cannot however say when it did originate. The number of trees known has increased due to a combination of recruitment and increasing knowledge of its distribution, and it is clear that it has been widely overlooked in the past.

Observations in autumn 2005 and autumn 2006 of the holes created by coring in spring 2005 showed that there were often splits in the trunks up to 20 cm long, and once up to 1 m long associated with the holes (this splitting was not apparent at the time of coring). Few holes had healed fully and a few were still weeping sap by autumn 2006. Observations show that the trees have healed from other wounds and that they survive coppicing, but given this unexpected damage we do not advise coring other rare *Sorbus* unless it is imperative to obtain such data for their conservation.

Sorbus bristoliensis is relatively widespread in the Avon Gorge, where it is probably the second commonest *Sorbus* after *S. aria* (L.) Crantz. It is especially characteristic of Leigh Woods on the upper edges of the open, natural rocks and disused quarries and of the broad ledges and screes in the gorge, where it occurs with many woody species including *Tilia cordata* Miller, *Taxus baccata* L. and other *Sorbus* species over a field layer dominated by *Brachypodium sylvaticum* (Hudson) Beauv. It also occurs on the woodland plateau soils in Leigh Woods where it can occur as a tall tree in ancient woodland with *Fraxinus excelsior* L., *Acer pseudoplatanus* L. and *Quercus* spp. over *Rubus fruticosus* s.l. and *Hedera helix* L. On the Clifton side of the gorge *S. bristoliensis* mainly occurs as scattered trees in secondary woodland and scrub with *Quercus ilex* L., as much of the original vegetation has been destroyed. At the northern end of the gorge some saplings occur on the acidic sandstone slopes with *Quercus spp., Betula spp.* and *Luzula sylvatica* (Hudson) Gaudin (soil pH 4·9).

Relatively little detail is known about the ecology of *S. bristoliensis*. Russell (1979) recorded it on shallow to medium depth soils (2–19 cm deep) with a pH range of (5·3–)6·0–7·2. One sapling was seen as an "epiphyte" on a pollarded oak. He noted that, although *S. bristoliensis* occurred on deeper soils than *S. aria*, it seemed less competitive in most situations. Squirrels, blackbirds, thrushes, crows, magpies, tits and finches were seen to take the fruits and, compared to *S. aria, S. anglica* Hedl. and *S. wilmottiana* Warb., *S. bristoliensis* had the highest number of viable seeds per fruit in 1976, with a range of (0–)74–182 seeds per hundred fruits (n = 10, mean

1·22 seeds/fruit). Seeds had a high mean germination rate of 59%, and germination was higher in sheltered growth conditions than in open growth conditions. Russell found that drought was the biggest cause of mortality in young plants, followed by invertebrate feeding and vertebrate grazing.

Given that virtually all of the trees except those in gardens occur within the statutorily protected areas of the Avon Gorge SSSI and SAC, there are few obvious threats to its long term survival other than mismanagement. Occasional plants have been cleared for public safety or access: Hendry & Pearson (1973) noted that 15 small trees or tall saplings present in May 1969 on the towpath below Stokeleigh Camp had been felled in 1972. Based on past experience with *S. wilmottiana* (Rich & Houston 2004), loss of some trees during conservation work might also be expected but so far this has not been noted and, once cut down, the trees usually respond by coppicing from the base. The development of closed, tall woodland dominated by shade-tolerant species such as *Tilia cordata* and *Fagus sylvatica* could limit *S. bristoliensis* to the shorter, more open areas of woodland at the changes of slope and on open outcrops (cf. Figure 5a). An increase in browsing from deer populations could limit regeneration (we have observed deer several times in Leigh Woods, but not on the Clifton side of the gorge).

Live trees, possibly mostly or all originating from the well known tree at the Stokeleigh Camp viewpoint, are held in cultivation at Bristol University Botanic Garden, Cambridge University Botanic Garden, Ness Botanic Garden, Westonbirt Arboretum, the National Botanic Garden of Wales, and elsewhere. Some seed has been deposited in the Millennium Seed Bank, Wakehurst Place. *Sorbus bristoliensis* and other rare Avon Gorge *Sorbus* species were distributed by N. J. Wray as part of the Bristol University Botanic Garden Millennium Tree Project in 1999–2000 to the Forest of Avon Project, Bristol Zoological Gardens, Avon & Somerset Police Head Quarters at Portishead, Bristol University Gardens Department, and elsewhere in the UK to members of Bristol University Alumni and a few private collectors; records were kept of where each species of tree was sent (pers. comm. N. Wray 2006).

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