Juniper regeneration in the Porton Ranges

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Summary

The fates of 542 marked juniper seedlings were monitored over 3 years. Annual disappearance rates decreased from >60% in the smallest seedlings (<3 cm high) to 10% in the largest seedlings (20 cm and over). The proportion of survivors with an annual increase in height declined with seedling size, whereas the proportion of survivors having an annual decrease in height increased to >50% in seedlings 10 cm and taller at the start of the year. Most of the smallest seedlings were found in rabbit scrapes, but most of the large seedlings were found in long grass. Disappearance of seedlings was disproportionately great from scrapes, particularly for seedlings 3-4.5cm high; this size group survived disproportionately better in long grass. Whereas clusters of many small seedlings were found around a minority of adult female bushes, very few of these survived; larger seedlings were found mainly away from adult bushes, frequently in long grass. Herbivory, primarily by rabbits but possibly including deer browsing of large seedlings, is considered the major mortality factor and responsible for restricted growth. Caged seedlings did not disappear. Protection of seedlings from herbivory and the formation of bare ground are essential for natural regeneration of juniper to be successful at this site. The extreme difficulty of finding small junipers is discussed.

Introduction

Although widespread in Europe, juniper (*Juniperus communis*) has declined, especially across the chalk lands of southern England (Ward 1973, Ward & King 2006, Ward & Shellswell 2017), where the remaining populations are mainly composed of older bushes, with no regeneration apparent. Many aspects of juniper biology and ecology have been researched (reviewed in Thomas et al 2007, Ward & Shellswell 2017), with various reasons for the decline and lack of regeneration put forward, from habitat loss to herbivory and loss of seed viability. "Plantlife" initiated conservation action, recommending methods of seed preparation to aid germination and establishing herbivore-proof cages with scarified soil for germination. These were placed both under female bushes to catch falling ripe cones (juniper 'berries') and in the open into

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which locally collected and processed seeds were sown (Wilkins & Duckworth 2011). Some of the sites at which these actions were taken were on the Porton Ranges, where there is the largest population of adult juniper bushes in southern England. This population has been studied by L. Ward since the 1960s, when it was surveyed as part of the Ward (1973) research. The adult bushes were censused again in 2010-2014 (A. Appleyard, S. Fitzpatrick, A. McKee, A. Mundell, P. Woodruffe, unpublished data), but no bushes small enough to be younger than at least 30 years old were found. The lack of regeneration noted previously therefore seemed to have continued. However, many of the authors have found and studied juniper seedlings at Dean Hill Park, less than 10km south of the Porton Ranges, and in September 2014 AA noticed some seedlings at Porton while involved in some ongoing research by L. Ward. We therefore initiated a wider search for seedlings, which we studied as described here. Some preliminary descriptions and photographs are included in Ward & Shellswell (2017).

The Porton Ranges have the highest conservation status; SSSI, SPA and SAC. They were requisitioned for MOD use from 1916, and MOD holdings now cover 2752 ha, being used for a variety of classified purposes. There is no access for the general public. All participants in this study are security vetted members of the Porton Conservation Group, but they are permitted access only at weekends, bank holidays and summer evenings when work related activity has ceased. Even at these times, the Range areas and times where access is permitted are usually further restricted. The habitats on the ranges are varied, comprising several types of calcareous grassland, areas of woodland and scrub, and, of course, abundant juniper. Detailed vegetation descriptions were given by Wells et al (1976).

Methods

All fieldwork was conducted between September and April (2014-17) during the winter when our previous work showed that the evergreen juniper seedlings are most easily found as the other vegetation dies back. During the 2014/15 season, searches for juniper seedlings were concentrated on the ground under female bushes, as this was the situation in which the first seedlings were found. Subsequently, seedlings were also found away from bushes in one area (site 4) where research effort was then concentrated.

When seedlings were found, use of a hand-held GPS (Geographical Positioning System) provided ten-figure grid references (NGR) for parent bushes (taken at the trunk) and the bushes were tagged with high visibility tape for ease of re-finding. When seedlings had been found under bushes in close proximity, the bushes were also given a numbered aluminium label.

Site descriptions of the location in which each seedling was found included details such as bare ground in a rabbit scrape, short turf (<5 cm height) and longer sward (>5 cm height and occasionally to 30 cm). The height of each seedling was recorded to the nearest 0.5 cm, using a ruler, and its condition described. Its position in relation to features such as anthills was noted. Small seedlings were marked with coloured golf tees to facilitate re-finding and to simplify counts where larger numbers of seedlings were located. Golf tees were used because, although vulnerable to being dislodged by rabbit activity, markers that penetrated the ground more deeply were not permitted by the range authorities. Larger seedlings were marked by white-tipped sticks inserted horizontally into the neighbouring vegetation, and for many a numbered label was tied loosely at the base of the seedling (if large enough) or on the stick.

An abundance of very small seedlings, each marked with a coloured golf tee. They are growing in close proximity to a female bush both in bare ground, disturbed by rabbits, and also in closely cropped turf with quantities of moss.

Photograph: P Woodruffe

Grid references of seedlings distant from parent bushes were recorded. Where many quite small seedlings were found within a few square metres of a parent bush and it was necessary to identify them individually on subsequent visits a year later, plans of the seedlings in relation to the bush were drawn. This was done using graph paper, plotting the parent bush according to its NGR reading, and measuring the distance and direction of individuals from the bush using a measuring tape and hand held compass. Distances between seedlings were also measured, and by triangulation a plot of the relative positions of the plants was made. Approximate NGRs could be estimated to twelve figures, equivalent to location within a 10 cm square (within the limits of GPS accuracy). The plants themselves were marked as above.

Searches for seedlings were restricted to limited areas because of the scale of the population and time and manpower limitations. All the nine sites where seedlings were found were

monitored at least annually, the presence or disappearance of individually identifiable seedlings noted, and the heights and widths of survivors measured. Under a few prolific female bushes, seedlings were too numerous for unambiguous individual identification, and only the number of seedlings found was recorded on each occasion.

For analysis, each individual was recorded on a spreadsheet by NGR and label number, with its presence, height and location description entered. Eastings and northings from the NGR were used to create scattergraph maps of the seedling locations. Seedlings were categorised by initial height for survival and growth analyses after one year: small seedlings 0.5-2.5 cm, medium seedlings 3.0-9.5 cm, large seedlings 10.0-19.5 cm, and extra-large seedlings 20 cm and over. (See Fig. 8). Growth of survivors was categorised according to whether the measured height had increased, decreased, or stayed the same at the subsequent measurement. Seedlings which survived more than one year were reclassified for height at the start of the second year and the subsequent changes in height in that year recorded.

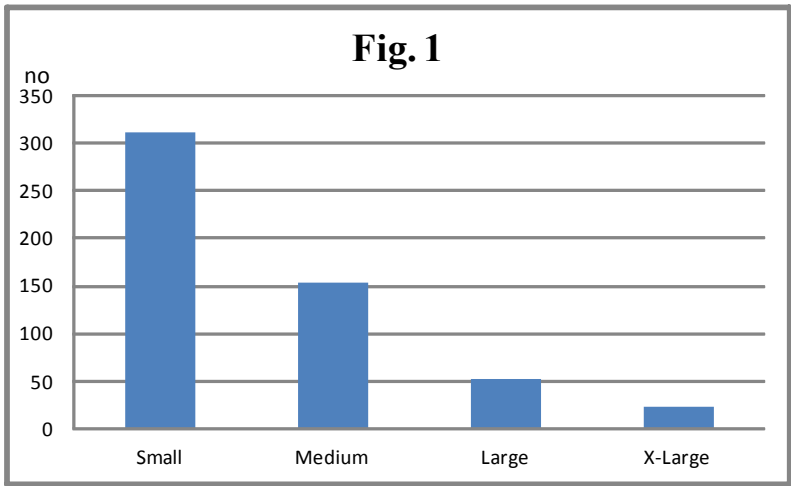
Statistical analysis used χ^2 tests of contingency tables of numbers in the height categories.

Results

Numbers, survival and growth

Young junipers were discovered and 542 marked in the autumn/winters of 2014/5, 2015/6 and 2016/7. More than half of these were in the 0.5-3cm height category 'small' (Fig.1), and progressively fewer in each of the larger size categories.

Fig.1. Total number of juniper seedlings found in each size class: small 0.5-3cm; medium 3.5-9.5cm; large 10-19.5cm; extra-large 20cm and over.



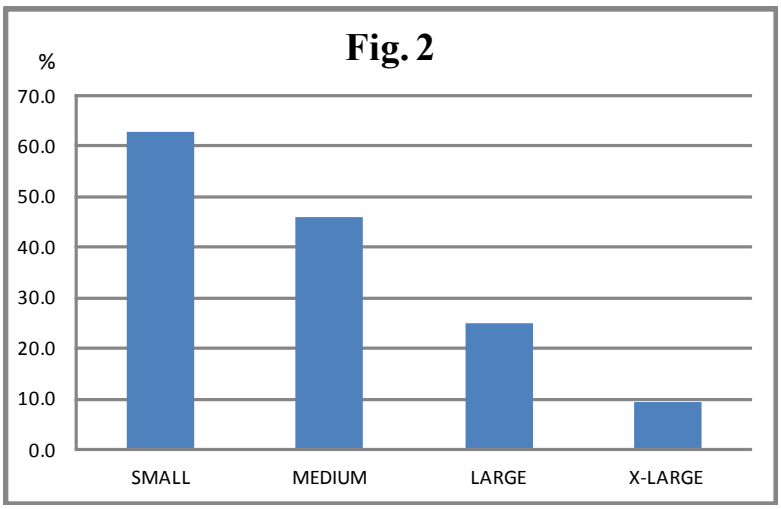
Nine sites within the Porton Ranges where seedlings were found are shown in Table 1. Eight of these sites had small seedlings, but most sites had very few or none of the larger seedlings.

Table 1. Number and sizes of juniper seedlings found at nine sites in the Porton Ranges

Site	Grid Ref	Small	Medium	Large	Extra-large	Total
1	SU227362	24	1			25
2	SU250381	18				18
3	SU245375	55	6	1		62
4	SU245376	85	128	48	18	279
5	SU248366	25	1			26
6	SU247385	59	6	1		66
7	SU225358	18	11			29
8	SU242363	28	1			29
9	SU245394			2	6	8
Total		312	154	52	24	542

Many of these seedlings could not be found on subsequent visits. The proportion of previously identified and measured seedlings 'not found' the subsequent year is shown in Fig. 2. This annual disappearance rate is greatest for the smaller size classes, with 60% of the small seedlings not being found again.

Fig.2. Proportion of seedlings not found in the subsequent year.
Size categories are as in Fig.1.



Changes in height of the seedlings re-found a year later are shown in Fig. 3. The majority of small seedlings increased in height, but the proportion of junipers showing a positive height increment declined with the original size of the plant. Moreover, the proportion of junipers subsequently reduced in height increased with original size especially in the larger size classes in which more than half the plants were shorter in the following year (Fig. 3). This pattern of changing growth increment with size is highly significantly different from what would be expected by chance ($\chi^2 = 33.3$, d.f. 6, $p << 0.001$).

Fig. 3. Annual height increment of surviving plants. Size classes as in Fig. 1.

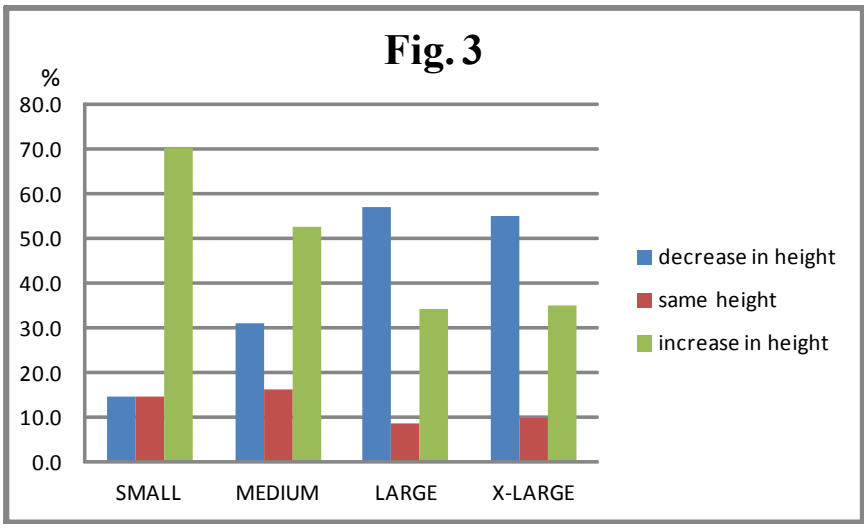
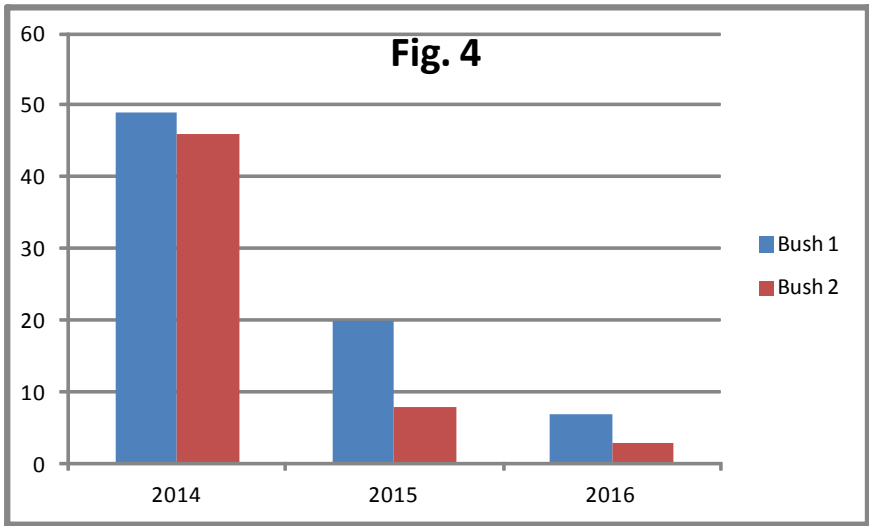


Fig. 4. Number of seedlings found under two bushes in 2014, 2015 and 2016



At each of two sites (3 and 8), a female bush with a prolific number of very small (1-2cm) seedlings around it was discovered in 2014. The fates of these cohorts were followed in subsequent years, using total numbers of seedlings found. From initial counts of 49 and 46 small seedlings, the number found dropped markedly at both bushes (Fig.4); only 7 and 3 seedlings were present in 2016. The initial numbers were such that individual recognition of plants was not possible, and these seedlings are additional to the 542 described above. The numbers in subsequent years are therefore of net change, new germination possibly having occurred, and the data thus represent minimal disappearance rates.

Caged seedlings

In 2010 "Plantlife" initiated an experimental caging of sown juniper seeds in order to exclude herbivores. Six cages placed on the Porton Ranges were monitored intermittently during our study (Table 2). Cages 1-3 were at our Site 9 close to where we found large (but not small) seedlings; the other three cages were in an area where we did not discover any naturally germinated seedlings. The heights of these caged seedlings were in our 'small' and 'medium' categories when first monitored, some plants increased to 'large' by 2016/17, but the cages prevented accurate measurements, and also made accurate counting difficult when numbers were high. The numbers are therefore somewhat approximate.

Table 2. Numbers of junipers found in "Plantlife" cages on Porton Ranges

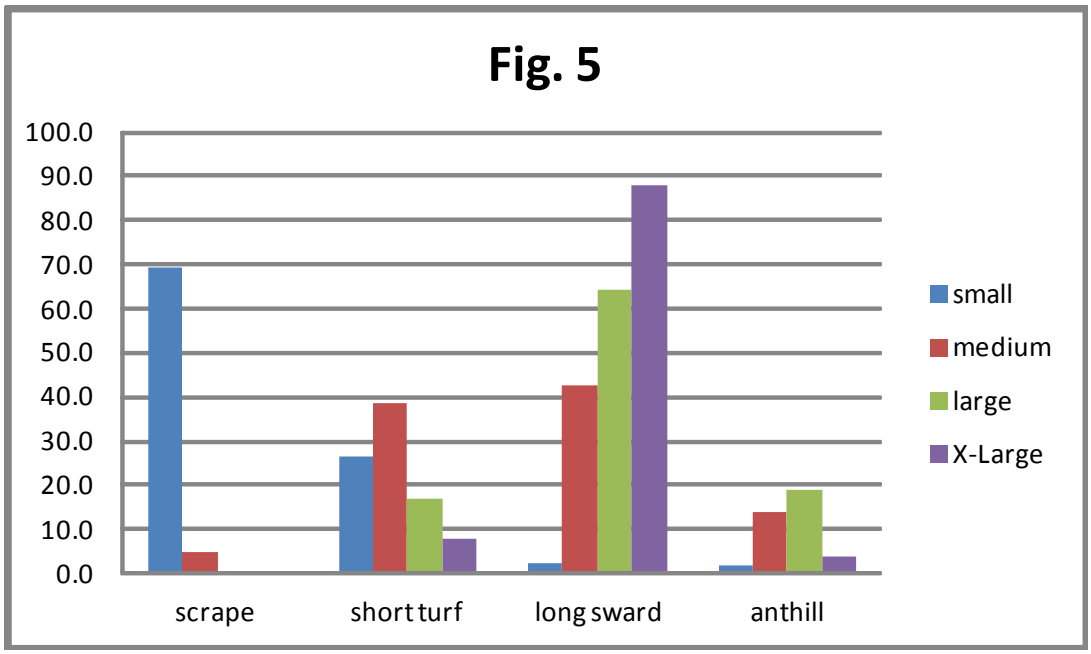
Date	Cage 1	Cage 2	Cage 3	Cage 4	Cage 5	Cage 6
2013/14	-	-	-	19	18	2
2014/15	14	12	0	-	-	-
2015/16	14	15	0	-	-	-
2016/17	15	20	-	37	20	3

Numbers estimated to be inside the cages did not decline, but rather increased, in strong contrast to the high annual disappearance rate of uncaged small and medium height seedlings.

Habitats of seedlings

Most of the small seedlings were found in ground which had previously been dug in by rabbits (scrapes) and in short turf with sward height <5cm. (Fig. 5).

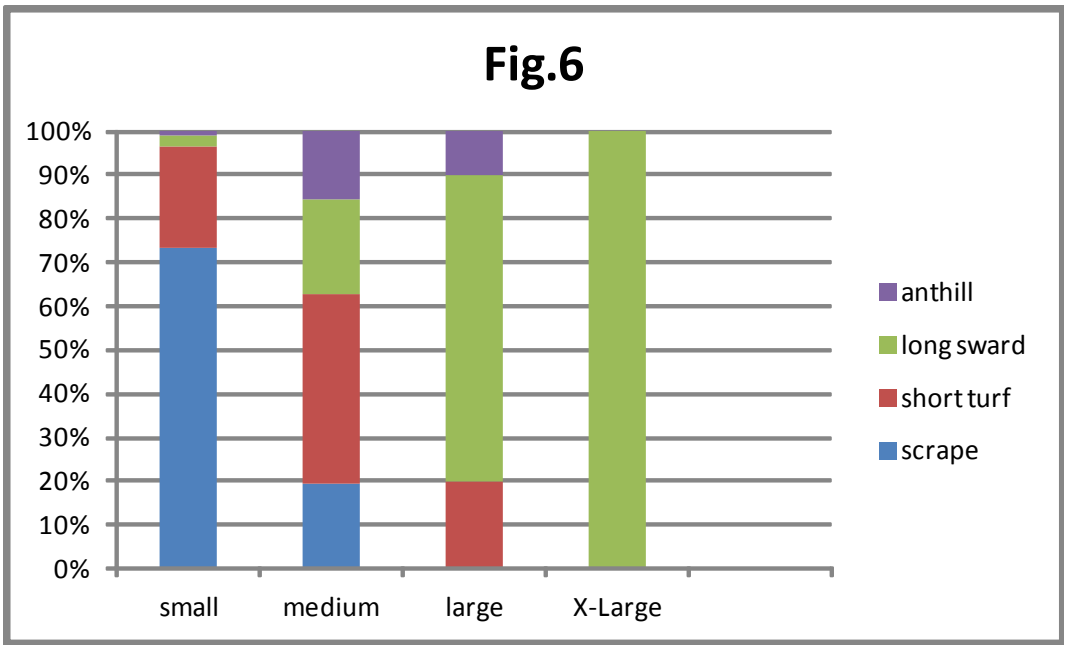
Fig. 5. Percentage of each size class found in scrapes, short turf, longer swards, and on anthills.



In contrast, large and extra-large seedlings were found mainly in long grass swards. The medium sized seedlings were rarely found in scrapes, most being found in short and long swards (Fig. 5). All seedling sizes occurred on or adjacent to anthills, which were abundant at the sites, but the proportions were highest for medium and large seedlings. These results are highly significantly different from what would be expected by chance ($\chi^2 = 359.5$, d.f. 9, $p << 0.001$). The critical value of χ^2 for $p = 0.001$ is 27.88, and this is exceeded by the constituent contributions to χ^2 in six of the cells of the contingency table, there being more-than-expected small seedlings in scrapes and fewer in long sward; too few medium seedlings were found in scrapes and too many in long sward; and many more large and extra-large seedlings were found in long sward than expected by chance. A further five cells in the contingency table contributed more than 10.12 to the total χ^2, and thus each alone would make the result significant at $p = 0.05$: too few large and extra-large seedlings were found in scrapes, and there were too few small and too many medium and large seedlings on anthills.

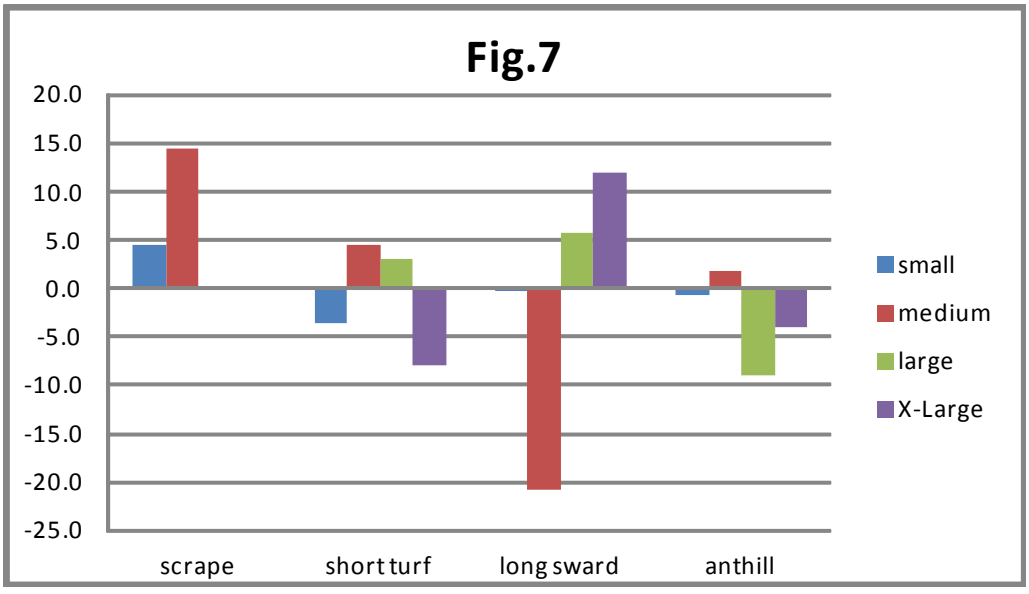
The habitats of seedlings not subsequently found are shown in Fig. 6 for each size class. All the extra-large seedlings which disappeared were in long grass, but this was only two individuals. Other size classes disappeared from three or four of the habitats. A comparison of the % occurrence of each size class in the 4 habitats and the % 'not found' is shown in Fig. 7. For small seedlings, there was a somewhat greater disappearance rate from scrapes, and a smaller one from short turf, than expected from their occurrence.

Fig. 6. Habitats of each size class of 'not found' seedlings as a percentage



During our survey, we made several observations of uprooted small seedlings lying on the soil surface in recent rabbit scrapes, and also refound some seedlings buried beneath the spoil heaps of rabbit excavations. For medium sized seedlings, there was marked disparity between occurrence and disappearance (Fig. 7): a greater proportion disappeared from scrapes and to some extent short turf, than expected from their occurrence, whereas the proportion disappearing from long grass sward was 20% less than their occurrence in this habitat.

Fig. 7. Difference between the percentage occurrence and percentage disappearance of each size class of seedling in each habitat. Positive values show when disappearance was greater than occurrence; negative values indicate occurrence was greater than disappearance.

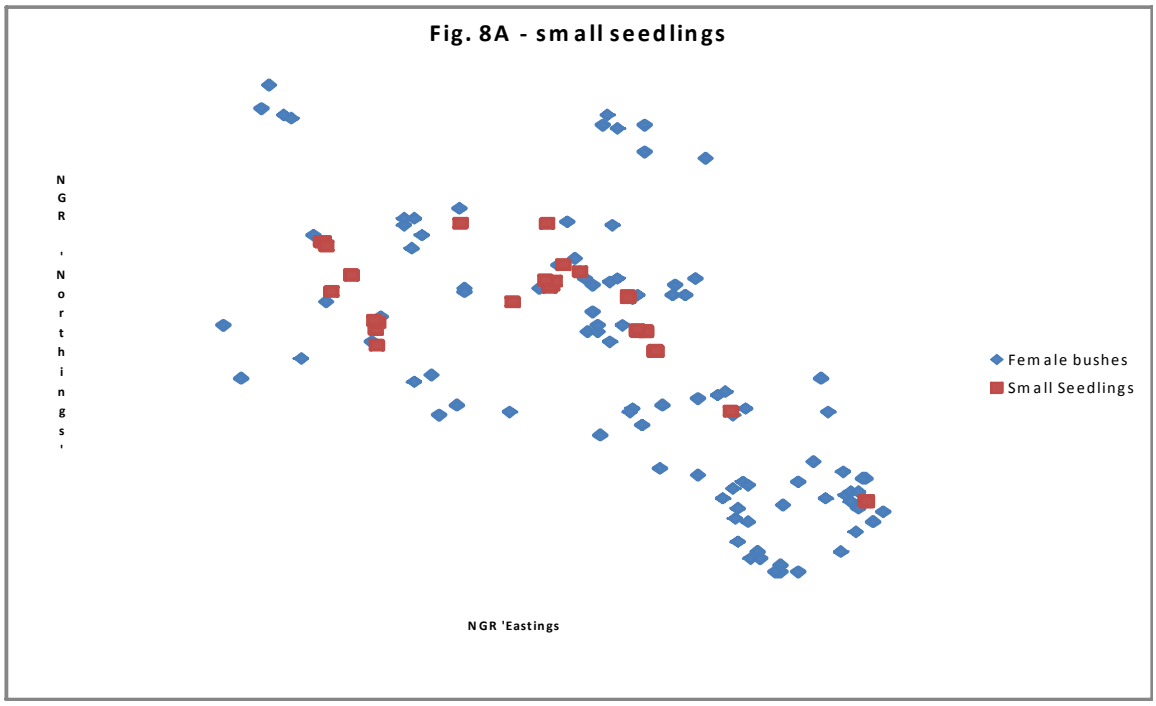


In contrast, large and extra-large seedling disappeared proportionately more from long swards than their occurrence would indicate. Less disappearance from than occurrence on anthills was found for large and, to a lesser extent, extra-large seedlings, and the latter size category also disappeared less from short turf although the sample size was very small in this case.

Seedlings in relation to adult juniper bushes

At Site 4, where most of the larger seedlings were found, a detailed survey examined the distribution of seedlings in relation to the adult bushes at the site. Small seedlings were found near a minority of female bushes (Fig. 8A), in most cases close to the bush, presumed to be the parent as many juniper 'berries' were observed on the ground under female bushes. Medium sized seedlings were more frequently located at greater distances from female bushes (Fig. 8B), and in places where no small seedlings were found. These medium seedlings were all in the central region of the site; small seedlings under female bushes in the SE quadrant were not accompanied by medium sized seedlings. Large seedlings (Fig. 8C) had a similar distribution to medium seedlings in the centre of the site, and were similarly frequently some distance from female bushes. This tendency to be found spatially separated from adult female bushes is even greater in the extra-large seedlings (Fig. 8D), where nearly all of them occupy open ground. We interpret these different distributions as reflecting survival, as discussed later.

Fig. 8. Location of seedlings at Site 4 in relation to adult female juniper bushes: A small, B medium, C large, D extra-large seedlings. Adult female bushes are shown by blue diamonds in all graphs. Axes use the northings and eastings of the national grid in square SU, area covered is approximately 300m by 150m.



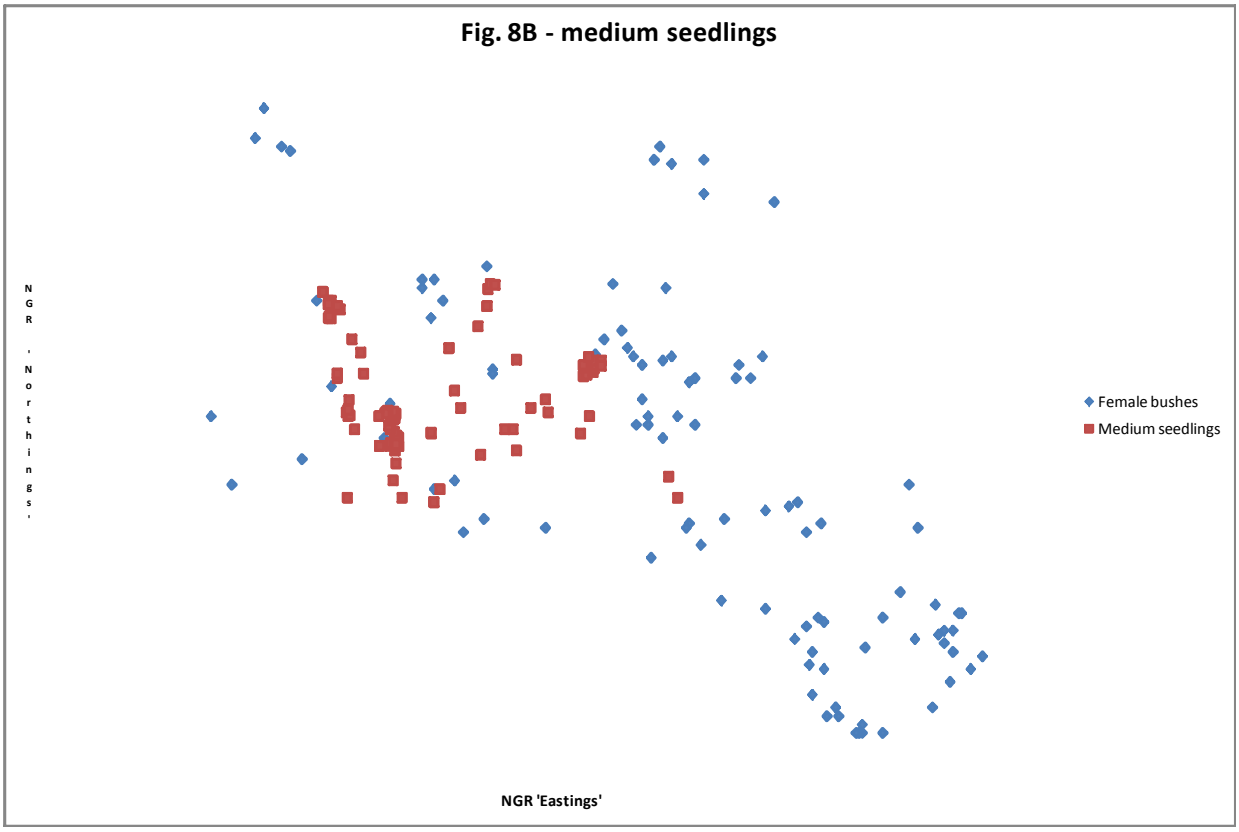


Fig. 8B - medium seedlings
NGR 'Northings'
NGR 'Eastings'
Female bushes
Medium seedlings

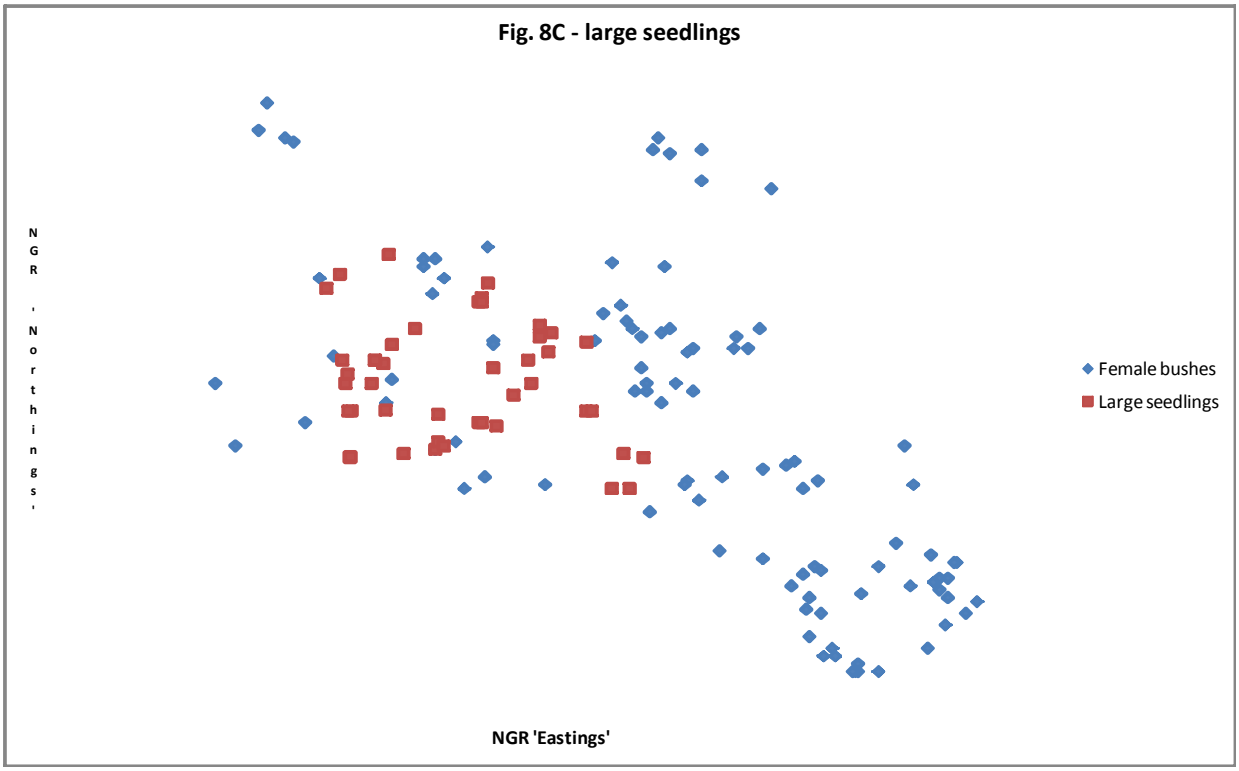
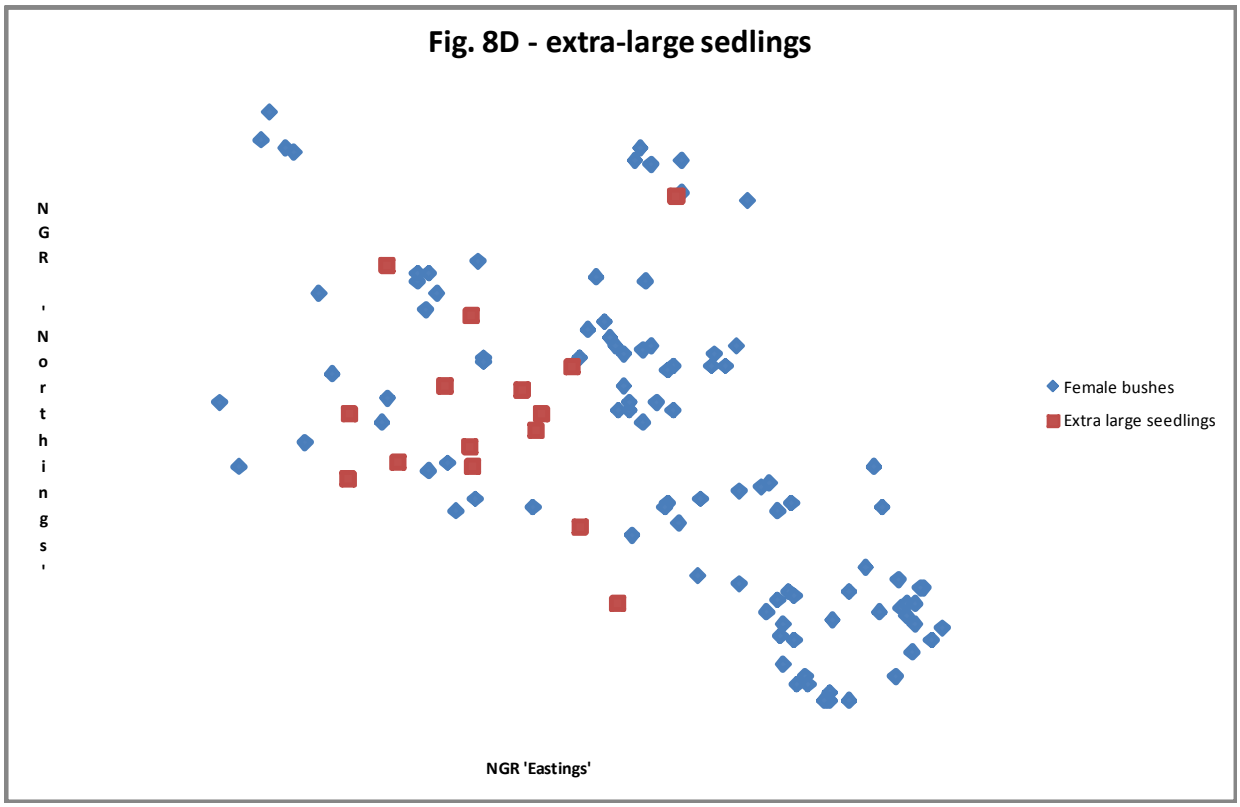


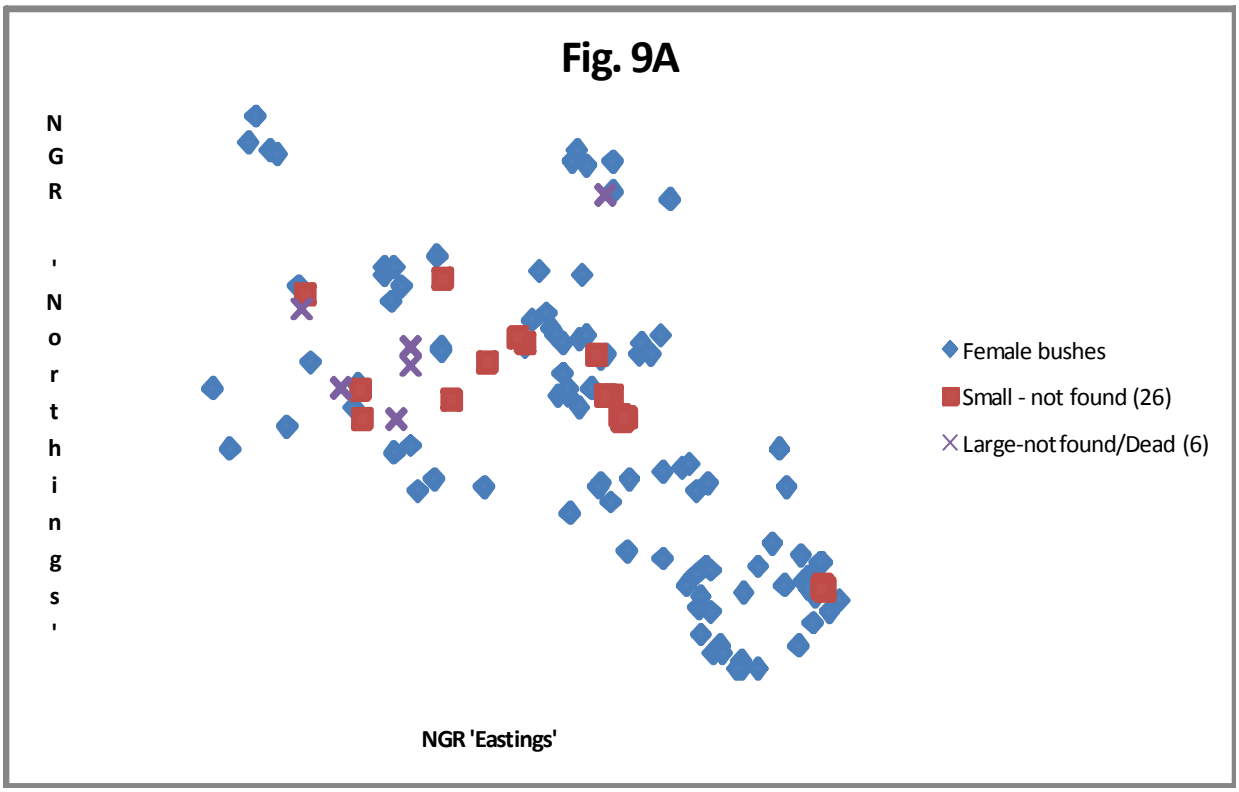
Fig. 8C - large seedlings
NGR 'Northings'
NGR 'Eastings'
Female bushes
Large seedlings

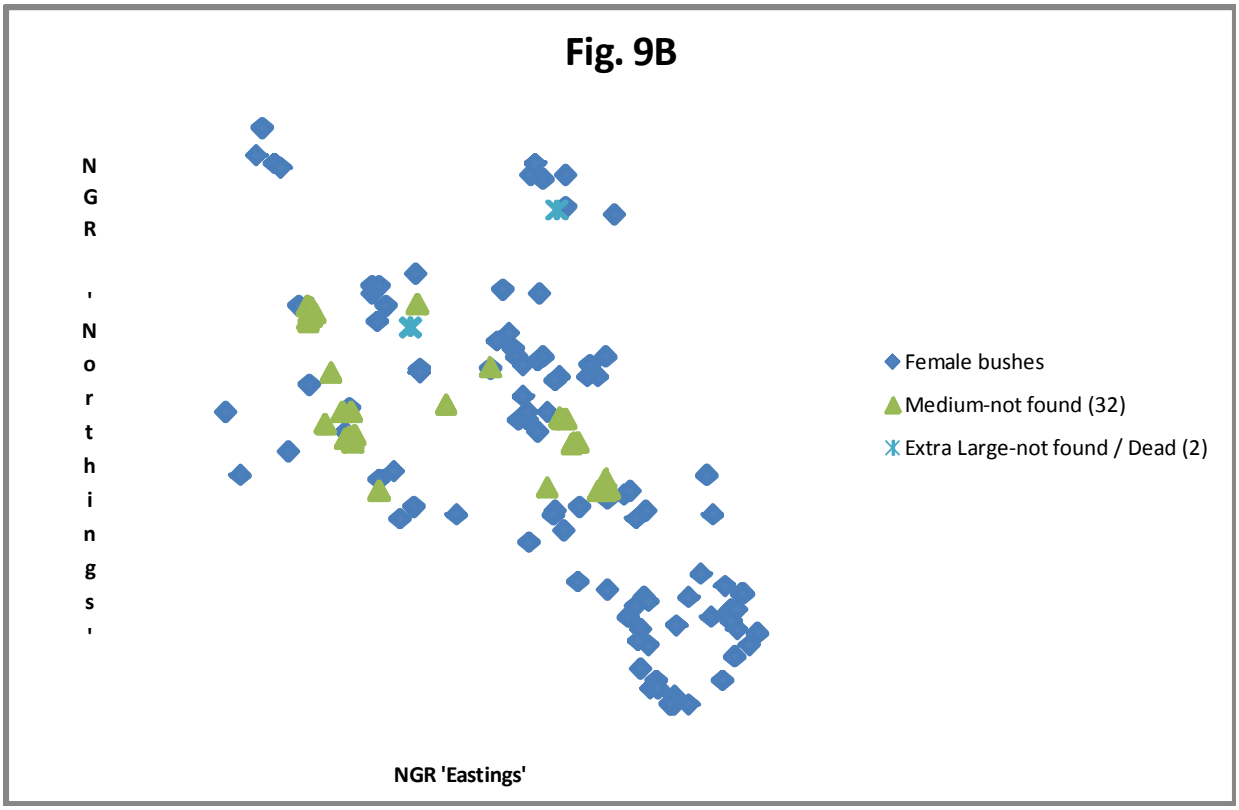


The positions of seedlings not subsequently found are shown in Fig. 9. Losses of small and especially medium seedlings were mainly from the vicinity of female bushes, whereas there was a central area, away from female bushes, from which large and extra-large seedlings disappeared. Some small and medium-sized seedlings also disappeared from this area.

Two small seedlings, approx 1cm height, growing in relatively bare ground. Photograph: A McKee

Fig. 9. Distribution of seedlings at Site 4 not subsequently found, in relation to adult female bushes. Blue diamonds, female bushes; red squares, small seedlings; green triangles, medium seedlings; purple X, large seedlings; cyan star, extra-large seedlings. Axes use the northings and eastings of the national grid in square SU. Area covered is approximately 300m by 150m. Numbers in brackets are actual number of seedlings not found in each class. Two diagrams are generated to minimise overlapping of symbols but adjacent seedlings do often overlap.





Discussion

The aging and mortality in the juniper populations of southern England has been of concern for decades (Ward 1973, Ward & King 2006, Wilkins & Duckworth 2011, Ward & Shellswell 2017). These populations apparently have a complete lack of regeneration and no young bushes. Browsing of juniper seedlings, by both domestic stock and rabbits (*Oryctolagus cuniculus*), has long been recognised as a problem (Fitter & Jennings 1975, Mátrai et al 1998, Ward & King 2006 reviewed in Ward & Shellswell 2017). In addition, fewer good quality seeds are produced by old juniper (Ward 1982) and both poor seed viability and high seed abortion rates are found across Europe (Garcia et al 2000), due to both a variety of seed-eating arthropods and pollination failure (reviewed in Thomas et al 2007 and Ward & Shellswell 2017). Juniper seeds take several winters to germinate, requiring alternating periods of warmth and cold stratification (reviewed in Thomas et al. 2007), although pre-treatment of seeds can speed the process somewhat (Wilkins & Duckworth 2011).

Our finding of abundant germination of young junipers on the Porton ranges thus seems exceptional and potentially useful in the conservation of juniper in Southern England. The greatest proportion of small seedlings that we found were in scrapes i.e. soil denuded of vegetation by rabbits. This is as expected from recommendations of sowing juniper seeds into bare ground (Wilkins & Duckworth 2011), but as we also found small seedlings in short and occasionally long turf, and on anthills; there seems to be greater flexibility than generally expected in juniper germination sites. Conditions may, of course, have been different when large seedlings germinated perhaps a decade ago. We have no direct records on this, but the characteristics of the area where we found many junipers in long grass were described in Wells et al. (1976) as *Festuca rubra /Avenula pratense /A. pubescens* tussock grassland, suggesting a tall sward. It now has a high proportion of *Bromopsis erecta* in some places, although it is still tussocky. Our observations over three winters indicate that scrapes can at least partially revegetate with short turf within that time period, and that such revegetation, while perhaps indicative of reduced rabbit activity, also may provide a degree of

A medium sized seedling growing in tussocky grassland where it is protected but difficult to see. Photograph: A Appleyard

protection to the seedlings. Seedlings that had germinated in deep scrapes, in particular, could become almost completely hidden by grass overgrowing the top of the scrape. The small seedlings, apparently 1-2 years old, found growing in short turf and moss might have germinated in a shallow scraped area which revegetated before we found the seedlings. As well as rabbits, other sources of bare ground in the area include badger activity and molehills.

Small seedlings found in deep scrapes in closely grazed turf.
Photograph: P Woodruffe

Unfortunately, the small seedlings we found disappeared at very high annual rates, especially from scrapes. Although the difficulty of finding small seedlings means we cannot completely equate 'not found' with mortality, very few of our disappeared small seedlings have been subsequently rediscovered so far, and we are confident that most have indeed died, eaten or been uprooted. Medium-sized seedlings also disappeared relatively more frequently from scrapes than from other habitats, and seedlings of all sizes are much easier to find in scrapes and short turf. Rabbits seem to be the cause of disappearance, from digging up and/or burying seedlings as we have seen, but mainly from eating seedlings as they nibble the turf, maintaining a short sward. The absence of such disappearance from the "Plantlife" caged seedlings supports this interpretation, although other herbivores such as slugs and voles may also eat young junipers (reviewed in Thomas et al 2007, Ward & Shellswell 2017). However Wilkins & Duckworth (2011) found rodent grazing to be unimportant. High annual rates of seedling disappearance have been recorded elsewhere (reviewed in Ward & Shellswell 2017). In Hungary, rabbits browsed on juniper mainly in the winter (Mátrai et al 1998), but our data do not permit analysis of the timing of the losses. We did note, however, that a number of small seedlings discovered in September had disappeared within a month, and hence not all browsing occurred in midwinter.

The surviving small seedlings had mostly increased in height by the next year, but they take several years' growth to reach medium size. Small proportions of surviving small seedlings remained the same size or decreased in height, presumably because of sub-lethal rabbit browsing. Medium-sized seedlings were more frequently found to have decreased in height,

and the evidence of nibbling was stronger; several were found reduced to a stump, and truncated terminal shoots were commonly observed. These nibbled junipers responded by producing side shoots and becoming bushier plants. It seems that once a seedling has become established for several years and reached a height of more than 3cm, it can withstand a moderate degree of rabbit browsing.

Rabbit numbers and behaviour thus seem key factors in both the survival and growth of recently-germinated junipers. Rabbits eat a higher proportion of grasses than forbs (Bhadresa 1977, 1987; Mátrai et al 1998), varying seasonally (Mátrai et al 1998), and selectively feed on grasses with higher nutritional values (Somers et al 2008). Rabbits also respond to predation risk when selecting foraging sites (Moreno et al 1996; Bakker et al 2005). Rabbits preferentially graze in short turf, avoid eating long grass, and maintain 'lawns' by their grazing (Iason et al 2002, Bakker et al 2005, Dekker 2007). Their favoured sites offer both food and a degree of protection from predators – close to the burrows and overhead cover (Moreno et al 1996, Dekker 2007). At Porton, we frequently observed foxes (*Vulpes vulpes*) and buzzards (*Buteo buteo*, and there are also polecats (*Mustela putorius*) and badgers (*Meles meles*), so predation risk is high for the rabbits (Harris et al 2017). Much of the rabbit activity of scraping and grazing, keeping turf short, was under and in the immediate vicinity of juniper bushes, potentially explaining the higher disappearance rate of seedlings in these sites. Rabbit numbers have fluctuated, with intermittent outbreaks of myxomatosis, and this may have contributed to the successful establishment of seedlings in some years.

Two larger juniper seedlings. Left: one that has had its leader removed and is beginning to show signs of lateral growth. Right: a plant that was damaged several years ago and is now developing into a healthy, bushy specimen. Photographs: A McKee.

Our observations of disappearance of seedlings in longer turf not considered to be favoured by rabbits, and size-reduction evidence of browsing, raise the possibility that another species, presumably deer as stock have been excluded from the Porton ranges since 1916 (Wells et al 1976), is also impacting juniper regeneration in the area. It may be significant that deer antler damage was observed on an adult juniper just to the west of the area from which the large juniper seedlings had disappeared (Fig 8 C & D). Deer are known to browse on juniper (Thomas et al 2007; Muñoz-Reinoso 2016, Ward & Shellswell 2017), although their digestion is affected by the terpenoids present (Schwartz et al 1980).

The distribution of small seedlings was very patchy – abundant under some female bushes but completely absent under the majority of adult females. This is obvious in Fig 8A, where out of 101 female bushes, we found seedlings under only 10. Of course, seedlings may have been present more widely, but eaten before the bush was surveyed. Even with this caveat, however, it is clear that the productivity of female bushes varied. As the seeds take at least two years to germinate, this variation could have led to our initial discovery of large numbers of seedlings in 2014 under prolific bushes. Seed viability, and its variation, may thus interact with rabbit browsing pressure to produce juniper regeneration varying in both space and time.

The origin of seedlings under female bushes is presumed to be mainly from the seeds in cones falling from that bush, but may also originate from droppings of birds perching in the bush. Seeds are primarily dispersed by birds, particularly members of the thrush family (reviewed in Thomas et al 2007, Ward & Shellswell 2017). We frequently observed flocks of fieldfares (*Turdus pilaris*) on the juniper bushes as we conducted our winter surveys, and the depletion of ripe cones was very evident by midwinter. Seeds from bird droppings or perhaps pellets from perched birds could explain the seedlings we occasionally found under male bushes and also under hawthorns (*Crataegus monogyna*) and pines (*Pinus sylvestris*). The dispersal agent of seedlings found in the open, metres from the nearest bush, and usually in long grass, is also likely to be from overflying birds. Other possibilities exist, however, as mice and other small rodents and even rabbits may eat and disperse juniper seeds (Otto et al 2010, Wilkins & Duck-worth 2011, reviewed in Thomas et al 2007). Omnivorous badgers are another possibility, as their tracks are prominent on this site. We are confident that these seedlings have germinated and grown in the open; there are no traces of dead adult junipers there, and elsewhere on the ranges we have found dead wood from junipers recorded by Ward (1973, 1982) as senescent. The seedlings found on and at the edge of anthills also pose questions. Anthills are sites of ground disturbed by the ant activity, are topped by short, sparse vegetation, and used by rabbits as latrines. Most of the anthills were not under female junipers, and the germinating seeds were

therefore dispersed. Overflying birds are again a possibility, as are the ants themselves, and seeds from rabbit droppings which may roll down to the edge of the anthill. Examination of rabbit droppings for juniper seeds would be potentially illuminating. However they arrived, junipers germinating at the edges of anthills were often protected by taller vegetation growing in this presumably nutrient-enriched environment, and as shown in Fig. 7, survived relatively well.

In summary, our work suggests that juniper germination success in several areas of the Porton ranges, while patchy, provides candidate seedlings potentially adequate for population regeneration, and that in some areas the larger seedlings are evidence that such germination has occurred during a decade or more. The reason why we have found no small bushes 0.5-1m in height on the Porton Ranges seems to be the cumulative effects of grazing by herbivores, which cause very great mortality of the smallest seedlings and intermittent reduction in height of the survivors. We infer that rabbits are the cause of the problems to small junipers, and to further our work we have set up an ongoing experiment with mesh cages aimed at protecting junipers from rabbits but not the smaller herbivores. It seems that juniper has fallen into an 'ecological trap': rabbits scrape ground bare suitable for juniper seed germination around the bushes where there is an annual fall of ripe cones, but in the very place where rabbits prefer to forage and hence end up eating nearly all the seedlings. The Porton Ranges are not unique in the occurrence of many small seedlings under female bushes – we have found hundreds of small seedlings at other nearby sites such as Dean Hill Park and Pepperbox A36 verge. Recently-germinated seedlings are exceedingly difficult to find; it requires a hands-and-knees fingertip search of the vegetation and is only feasible when the vegetation has died down in autumn and winter. We suspect that previous fieldwork with normally summer visits has failed to find them, and they have been eaten before they grow large enough to be noticed. Our findings have implications for the management of juniper on all Southern England sites; the level of detail and timing of searches for seedlings are critical, and protection of seedlings from herbivores as well as management of scrub incursion may be necessary to ensure successful long-term survival of juniper populations.

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