RESULTS OF SPRING 2017

SQUIRREL SURVEYS

Mahboobeh Shirkhorshidi & Mel Tonkin

Scottish Wildlife Trust
Harbourside House
110 Commercial Street
Edinburgh EH6 6NF

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1. SUMMARY

We present the results of Saving Scotland's Red Squirrels' (SSRS) Spring 2017 surveys of red and grey squirrels and compare them with the Spring 2011 and 2012 surveys for the north of Scotland and Spring 2013 for the south of Scotland. We also present the results of additional intensive grey squirrel detection surveys in North East Scotland.

Overall, we see a picture of red squirrels maintaining or increasing their occurrence since the beginning of the surveys, but a mixed picture for the occurrence of grey squirrels: a positive change towards decreased grey squirrel range for the northern half of Scotland contrasts with expanding grey squirrel distribution in South Scotland.

Taking the regions in turn, the evidence supports a statistically significant increase in red squirrel distribution and a significant decline in grey squirrels in the North East, particularly in areas close to the City of Aberdeen. Across the Highland Line the trend shows a stabilisation of red squirrel occurrence in survey areas, and grey squirrel occurrence limited to the significantly reduced range when compared with the tetrads in 2011 and 2012 Thus we have been successful in preventing incursion of grey squirrels into Scotland's core red squirrel populations to the north of the Highland Line and protecting.

In the south of Scotland, overall, grey squirrel occupancy is shown to have increased since 2014, especially in Berwickshire, where red squirrels are now seldom seen, and, more worryingly, in Dumfriesshire between Thornhill and New Galloway. We believe this to be associated with an exceptional masting year in the autumn of 2014, when there was a superabundance of beech nuts. This led to increased over-winter survival and a peak in production of grey squirrels in 2015, which was evident in our 2015 trapping figures as a surge in grey squirrel numbers right across the country.

Despite this, red squirrels appear to have maintained their range and even slightly expanded their occupancy in South Scotland, although the change is not statistically significant.

2. AIM OF THIS REPORT

Saving Scotland's Red Squirrels (SSRS) is a project to stop the decline of Scotland's core red squirrel populations. North of the Central Belt we aim to prevent the further replacement of red squirrels by grey squirrels by working to progressively reduce the geographic range and abundance of grey squirrels in and around Aberdeen, aiming ultimately at complete eradication, and by preventing their spread northwards from the Central Lowlands. This is achieved through a co-ordinated network of grey squirrel control at the interface between the red and grey squirrel distributions. Grey squirrel control began in Aberdeenshire in 2007, and in the Central Lowlands in 2010.

South of the Central Belt, the aim of the project is to protect red squirrels in priority areas for red squirrel conservation (PARCs) in southern Scotland that are under threat from replacement by grey squirrels.

Monitoring in the North East and the Central Lowlands was set up in 2011 to provide evidence on which to assess the effects of grey squirrel control on both red and grey squirrel populations. Here

we report the results of the Spring 2017 surveys and compare them to results obtained in 2011 and 2012. We provide estimates of the level of change and assess whether the results suggest that our Red Squirrel Protection Network is achieving benefits for red squirrels.

In South Scotland, distribution monitoring was carried out for the first time in Spring 2013, with a view to detecting the relative distributions of red and grey squirrels, and repeated in 2014, 2015 and 2016. The Spring 2017 surveys continue the series of snapshots so that the short-term trends can now be seen.

3. METHODOLOGY

To determine red and grey squirrel presence in a particular area, monitoring tetrads (2km x 2km squares) were set up in 2011 for North East Scotland and the Central Lowlands (Argyll & Trossachs and Tayside), and in Spring 2013 for the Scottish Borders and Dumfries & Galloway. Each tetrad is identified by the grid reference of the south-western 1km square. In each tetrad, four feeder-boxes were positioned to sample right across the square, each with a sticky pad to collect hair-samples from visiting animals. Each feeder-box was checked by volunteers a total of three times over a period of six weeks and thus three hair samples were collected from each box. Hairs were identified under a microscope and each tetrad was consequently allocated to one of the following four categories: “red squirrels only”, “grey squirrels only”, “both species” or “neither” species.

Tetrads were considered to be complete (and therefore included in the analysis) if three samples were collected from each of the four feeder boxes – thus 12 hair samples per tetrad. Tetrads for which fewer than 12 hair samples were collected were also included in the analyses where both species of squirrel were detected.

Comparisons were made between survey results from 2017 with those from 2016 using Replacement Indices (see below). We also compared the results of 2017 with 2012 in order to have an understanding of the change over a longer period of time.

For all analyses, the results from the North of Scotland (the North East, Argyll & Trossachs and Tayside) were treated separately from those from the South of Scotland (the Scottish Borders and Dumfries & Galloway and parts of Ayrshire and South Lanarkshire).

Replacement Index

In order to compare the results of pairs of tetrad surveys, we calculated a Replacement Index (RI) using a matrix showing the changes that occurred in each tetrad between two surveys.

Following Usher *et al.* (1992) and Bryce (1997), the survey results from consecutive years were each plotted in a matrix such as those shown in Table 2 & Table 4 below. The survey results were also compared between the start and end year of the survey to capture the change in occupancy over a longer period of time. The matrices for this comparison are shown in Table 3 and Table 5. Only results from tetrads for which surveys had been completed in both years (“paired tetrads”) were used in these analyses. The matrix shows all possible changes in which species occupied the tetrads between two surveys by summarising results for each year in the categories: “red squirrels only”, “both red

and grey squirrels", "neither species", "grey squirrels only". The rows show the number of tetrads of each category detected in the earlier survey and the columns show the number of tetrads for each category during the later survey. The shaded diagonal represents no change in the occupancy category of the tetrad. Figures above the shaded diagonal boxes represent changes in favour of grey squirrels and those below represent changes in favour of red squirrels. Using these values, a Replacement Index was calculated as follows:

$$RI = \frac{\text{(sum of values above the diagonal) - (sum of values below the diagonal)}}{\text{(the sum of all values in matrix except the "neither-neither" value)}}$$

A positive index represents a change in tetrad occupancy in favour of grey squirrels – either due to the loss of red squirrels from the area or grey squirrels moving into the area. Conversely, a negative index represents a change in favour of red squirrels (Usher *et al.* 1992) through the loss of grey squirrels or the new occurrence of red squirrels. Note that this index can range from +1 to -1, where +1 would represent a complete shift to occupancy of all tetrads by greys (or neither) and -1 a complete shift to reds (or neither) occupying all tetrads (Bryce 1997).

4. RESULTS

Table 1 shows the number of tetrads detecting red squirrel, grey squirrel, both species or neither species in each year. The results for individual tetrads are presented as mapping in Appendix 1 and as Tables in Appendix 2.

Table 1: Results summary

Project Area	Survey season	Red squirrels only	Grey squirrels only	Both Species	Neither species	Total no. of tetrads completed	(Total including incomplete tetrads)
North	Spring 2011	18	4	19	7	48	48
	Spring 2012	55	8	26	4	93	112
	Spring 2013	67	7	12	12	98	120
	Spring 2014	73	7	12	20	112	124
	Spring 2015	59	11	15	24	108	120
	Spring 2016	78	9	17	15	118	127
	Spring 2017	67	5	15	14	100	125
South	Spring 2013	40	15	7	25	87	102
	Spring 2014	44	16	8	18	86	99
	Spring 2015	31	18	13	23	85	102
	Spring 2016	41	27	11	14	93	96
	Spring 2017	42	26	8	4	80	98

Replacement index

Replacement Index matrix table for 2016/17 giving the number of tetrads in each change category for the North of Scotland (Table 2) shows that the numbers of changes in favour of red squirrels between 2016 and 2017 (below the shaded diagonal) is very similar to the number of changes in favour of greys for the same two years (above the shaded diagonal). The Replacement Index (RI) calculated from the table is very close to zero change (-0.011).

Table 2: Matrix of changes in tetrad occupancy between 2016 and 2017 for the North of Scotland

North Scotland 2016/2017		**Spring 2017**				
		Red	Both	Neither	Grey	**Total**
2Spring 2016	Red	49	3	9	0	**61**
	Both	6	8	0	0	**14**
	Neither	5	1	5	1	**12**
	Grey	0	3	0	3	**6**
	Total	**60**	**15**	**14**	**4**	**92**

Replacement Index = -0.011 *Not significantly different from "No change"*

Replacement Index matrix for 2012/17 was also calculated from the change since the early survey years. (2011 data was not used because we only had a small number of paired tetrads (n=38)).The result in Table 3 shows a change in favour of red squirrels, largely through loss of grey squirrels (RI=-0.1667). Statistical testing (binomial analysis, not shown in this report) showed that this decrease in grey squirrel occupancy is statistically significant

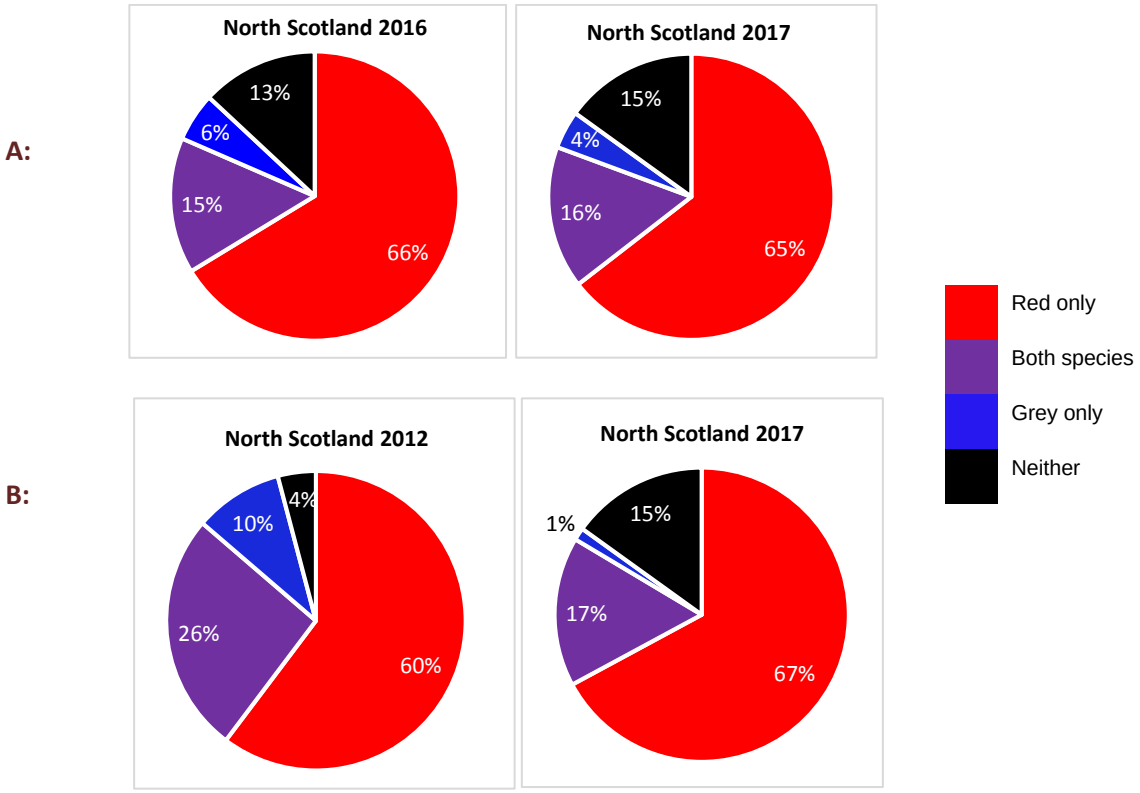
Table 3: Matrix of changes in tetrad occupancy between 2012 and 2017 for the North of Scotland

North Scotland 2012/2017		**Spring 2017**				
		Red	Both	Neither	Grey	**Total**
2Spring 2012	Red	33	4	7	0	**44**
	Both	14	2	2	1	**19**
	Neither	1	1	1	0	**3**
	Grey	1	5	1	0	**7**
	Total	**49**	**12**	**11**	**1**	**73**

Replacement Index = -0.1667 Significant decrease in grey squirrel occupancy.

The same results are shown visually in Figure 1 as pie-charts.

Figure 1: Proportion of paired tetrads in which red squirrels, grey squirrels, both species or neither for the North of Scotland A: 2016/2017 (n=92) and B: 2013/2017 (n=73)



For the South of Scotland, the negative Replacement Index figure from the matrix for 2016/17 (Table 4) shows a slight improvement for red squirrels in 2017 compared with 2016 (Replacement Index is very close to zero change at -0.01).

The earlier comparison with 2013 (Table 5, RI=0.19) shows a shift in favour greys in 2017, while mapping confirms they were expanding their range to the places where neither species was detected in 2013. (The binomial test – not presented here - indicated that the increase in grey occupancy of greys observed between 2013 and 2017 is not statistically significant.) On the positive side, the proportion of tetrads occupied by red squirrels between 2013 and 2017 has remained stable despite the expansion of grey range.

Table 4: Matrix of changes in tetrad occupancy between 2016 and 2017 for the South of Scotland

South Scotland 2016/2017		**Spring 2017**				
		Red	Both	Neither	Grey	**Total**
Spring 2016	Red	29	3	0	0	**32**
	Both	3	4	1	2	**10**
	Neither	4	0	2	1	**7**
	Grey	0	1	0	19	**20**
	Total	**36**	**8**	**3**	**22**	**69**

Replacement Index = -0.01 *Not significantly different from "No change"*

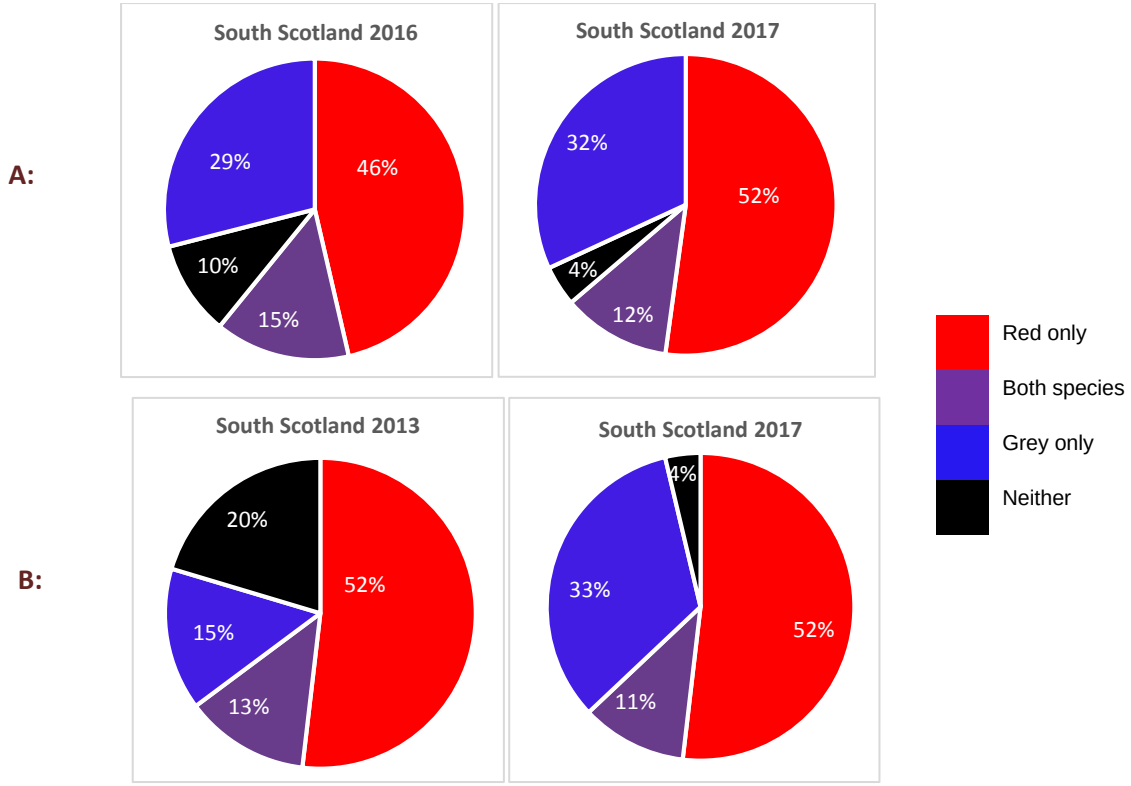
Table 5: Matrix of changes in tetrad occupancy between 2013 and 2017 for the South of Scotland

South Scotland 2013/2017		**Spring 2017**				
		Red	Both	Neither	Grey	**Total**
Spring 2013	Red	23	4	0	1	**28**
	Both	3	2	0	2	**7**
	Neither	1	0	2	8	**11**
	Grey	1	0	0	7	**8**
	Total	**28**	**6**	**2**	**18**	**54**

Replacement Index = 0.19

The same results are shown visually in Figure 2 as pie-charts.

Figure 2: Proportion of paired tetrads with both species, either species or none detected for South Scotland A: 2016/2017 (n=69) and B: 2013/2017 (n=54)



5. DISCUSSION

North Scotland

The results show that although the detected occurrence of red squirrels across the northern half of the SSRS project has fluctuated year to year, there has been little change since 2016. However, a greater favourable change emerges when 2017 is compared with the start of the project. Overall it is fair to say that red squirrel distribution over the area has been at least stabilised.

Although fortunes have fluctuated for reds across all areas, the mapping for the North East shows the expected result of progressively removing grey squirrels from an isolated grey squirrel enclave. This is explored in more detail in the account in Appendix 4 of additional intensive grey squirrel detection surveys carries out in the North East, in which statistically significant change in favour of red squirrels is detected.

In Argyll & Trossachs and Tayside, less change is detectable, since both areas would be expected to be subject to continuous replacement of removed grey squirrels coming from the high density grey populations to the south

The large upward fluctuation in grey squirrel proportion which occurred between 2014 and 2015 (see our Survey report s for 2015 and 2016) coinciding with an exceptional breeding year for grey squirrels in 2015 has not been sustained into 2017. This peak followed an enormous beech crop the previous autumn, a textbook illustration of the cyclic nature of squirrel populations in relation to cycles of food availability. Although this upturn for grey squirrels was noticeable in trapping results and in grey squirrel weights, it appears that red squirrels remained widely distributed during this year and recovered any lost ground quickly once grey squirrel numbers were reduced again.

South Scotland

Overall the results for red squirrels from the South of Scotland (Tables 4 & 5, Figure 2 and the mapping in Appendix 1), are encouraging in that red squirrels appear to have maintained the greater proportion of their earlier range over the years of survey, apart from in Berwickshire. The negative replacement index (favourable to reds) for the comparison of 2016 and 2017 is particularly encouraging following the 2013/2014 and 2014/2015 comparisons, both of which returned positive replacement indices (unfavourable to reds).

The pie charts in Figure 2 clearly show the large increase in detection of grey squirrels between the start of the surveys in 2013 and the surveys of 2017. The mapping in Appendix 1 shows a clear drift of grey squirrels towards tetrads between Thornhill and New Galloway, which now show as registering both squirrel species. This accords with our sightings data and observations from local trappers. From previous reports, it appears that this drift coincided with 2015, the year of exceptional breeding in grey squirrels. It is suggestive of populations of greys building up and overspilling from

established areas, causing them to populate areas in which they had not been seen before in any numbers. Unfortunately in the south of Scotland the previous less extensive grey squirrel distribution has not yet been restored despite continuing efforts by landowners to the east and volunteer groups to the west. With new resources being deployed by the SSRS project to Dumfries & Galloway to increase the conservation work here, we hope to be able to reverse this worrying trend.

With each passing year we learn more about squirrel population interactions and the effect on species range – thanks to the systematic data collected over the SSRS project period. This is essential in helping us to assess the effects of grey squirrel control on both red and grey squirrel populations, and to determine just how much effort will be necessary over the years to maintain red squirrel populations in the priority landscapes.

For this reason Saving Scotland's Red Squirrels wishes to thank all the volunteers who gave up their time to help us collect this data, and all those landowners who co-operated by allowing us access to their land, without which this research would not be possible.

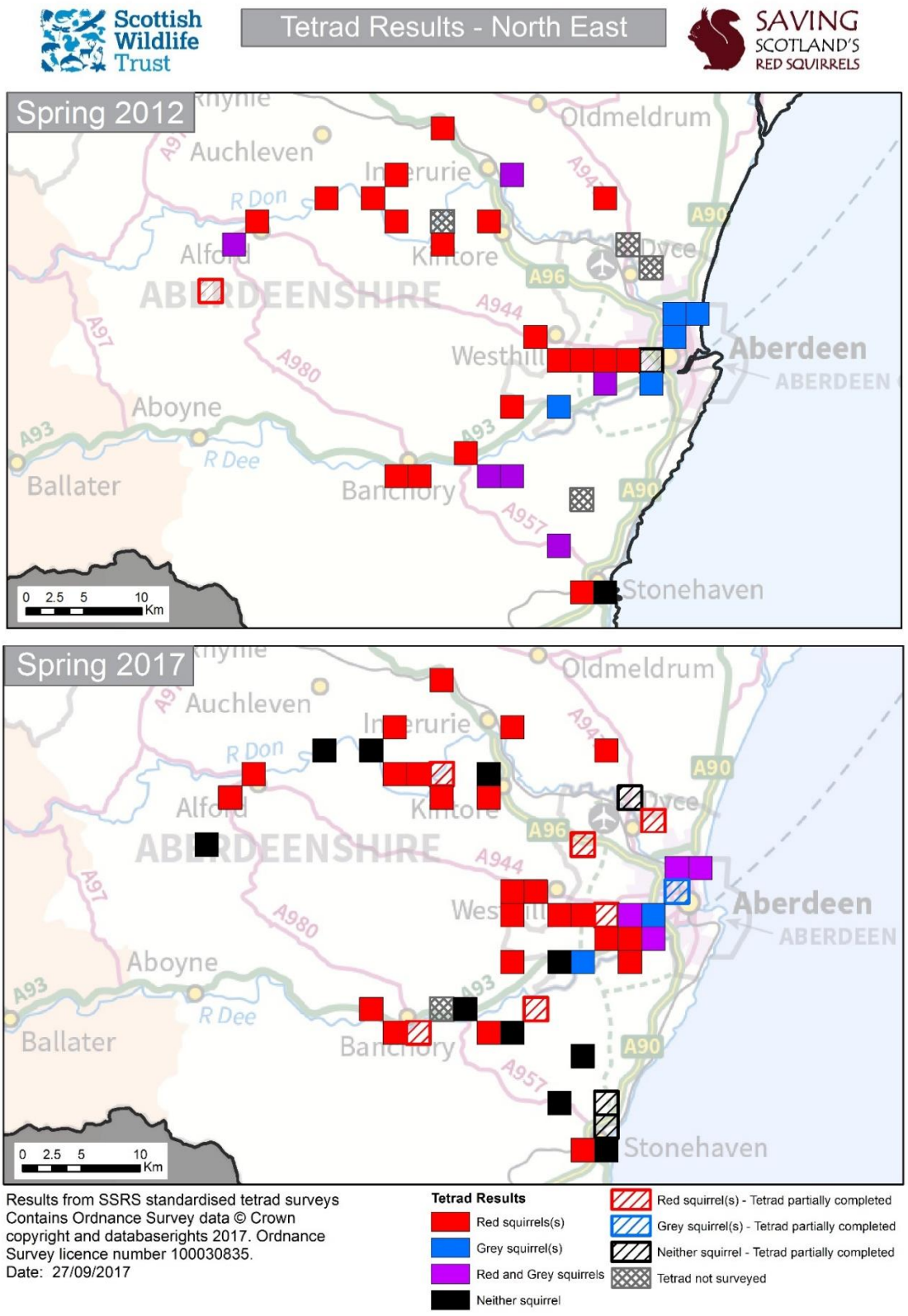
6. REFERENCES

Bryce, J. (1997) Changes in the distributions of Red and Grey Squirrels in Scotland. *Mammal Review.* **27**, 171-176.

Usher, M.B., Crawford, T.J. & Banwell, J.L. (1992) An American invasion of Great Britain: The case of the native and alien squirrel (*Sciurus*) species. *Conservation Biology,* **6**, 108-115.

7. APPENDIX 1: TETRAD SURVEY MAPPING

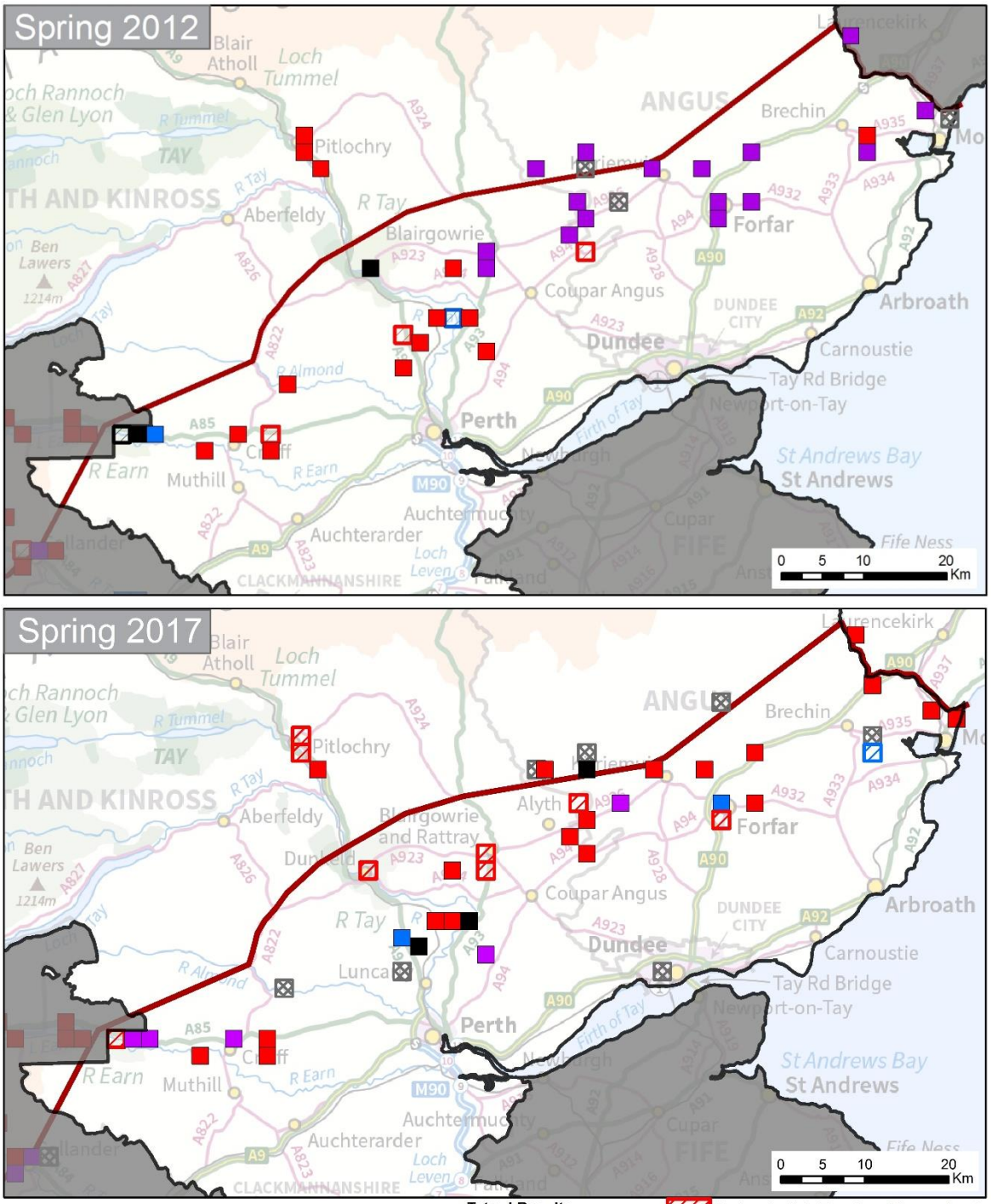
The 2017 results for project areas in the North are compared with 2012, the first year with a comparable number of complete tetrads. For the South 2017 is compared with 2013 (the first year of survey).



Scottish Wildlife Trust

Tetrad Results - Tayside

SAVING SCOTLAND'S RED SQUIRRELS



Results from SSRS standardised tetrad surveys
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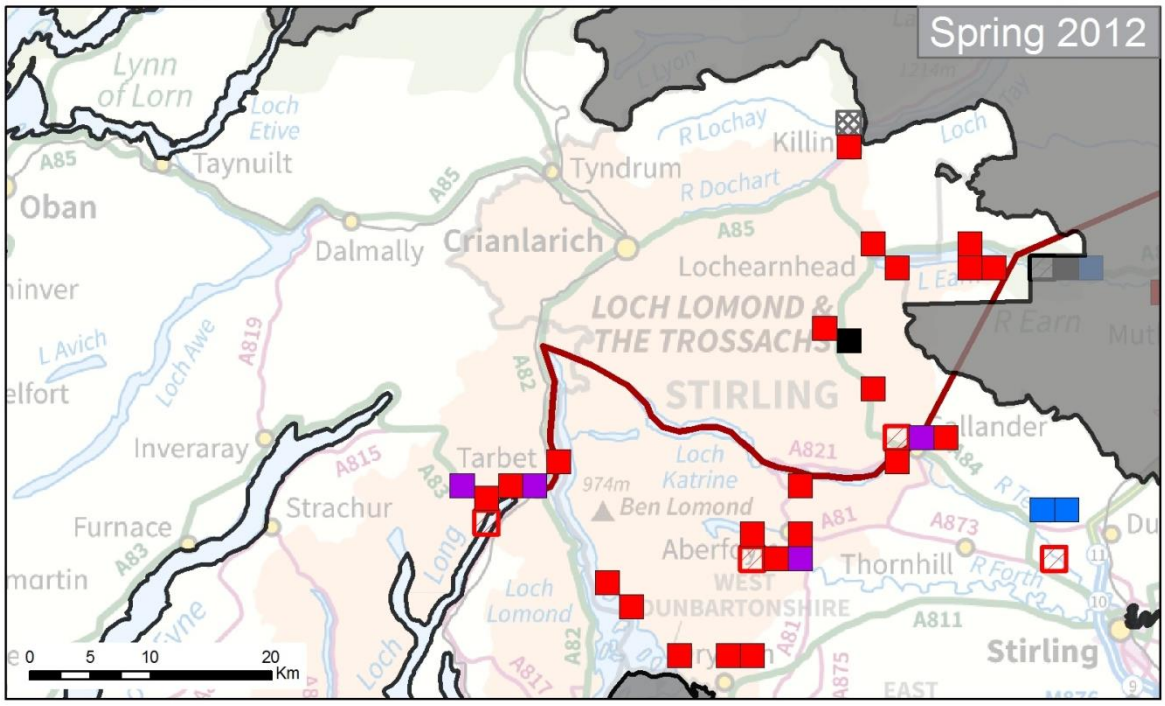
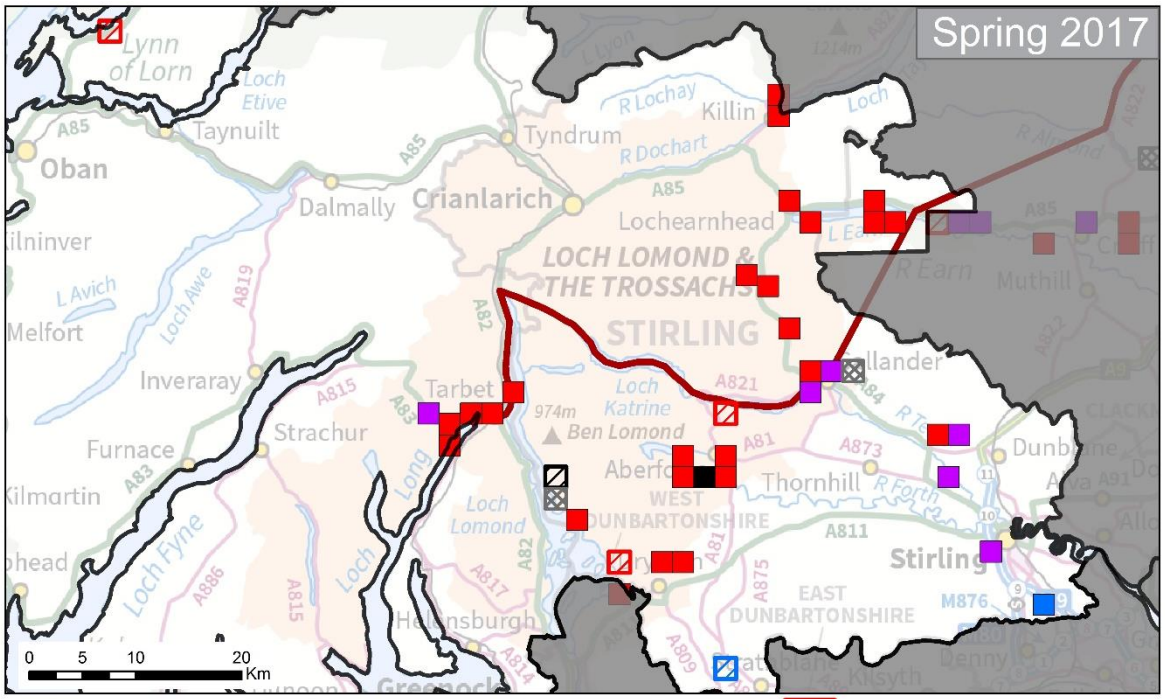
Date: 27/09/2017

Tetrad Results

- Red squirrels(s)
- Grey squirrel(s)
- Red and Grey squirrels
- Neither squirrel
- Red squirrel(s) - Tetrad partially completed
- Grey squirrel(s) - Tetrad partially completed
- Neither squirrel - Tetrad partially completed
- Tetrad not surveyed
- Red squirrel protection line

Tetrad Results - Argyll & Trossachs





Results from SSRS standardised tetrad surveys

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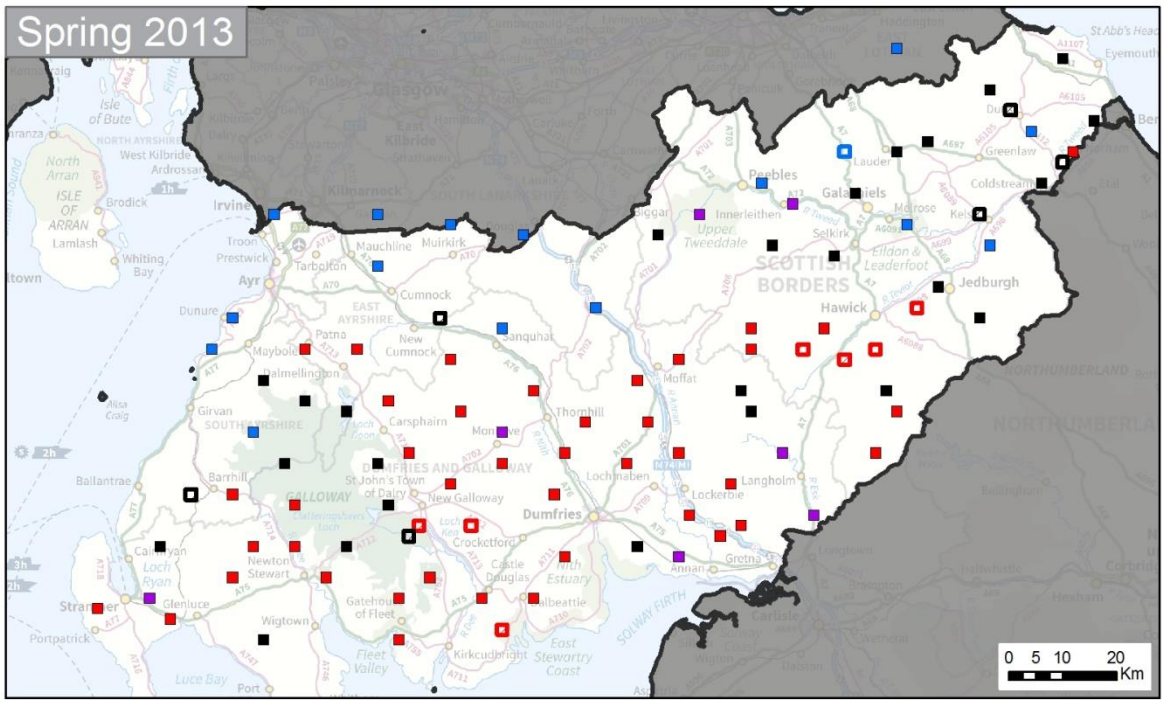
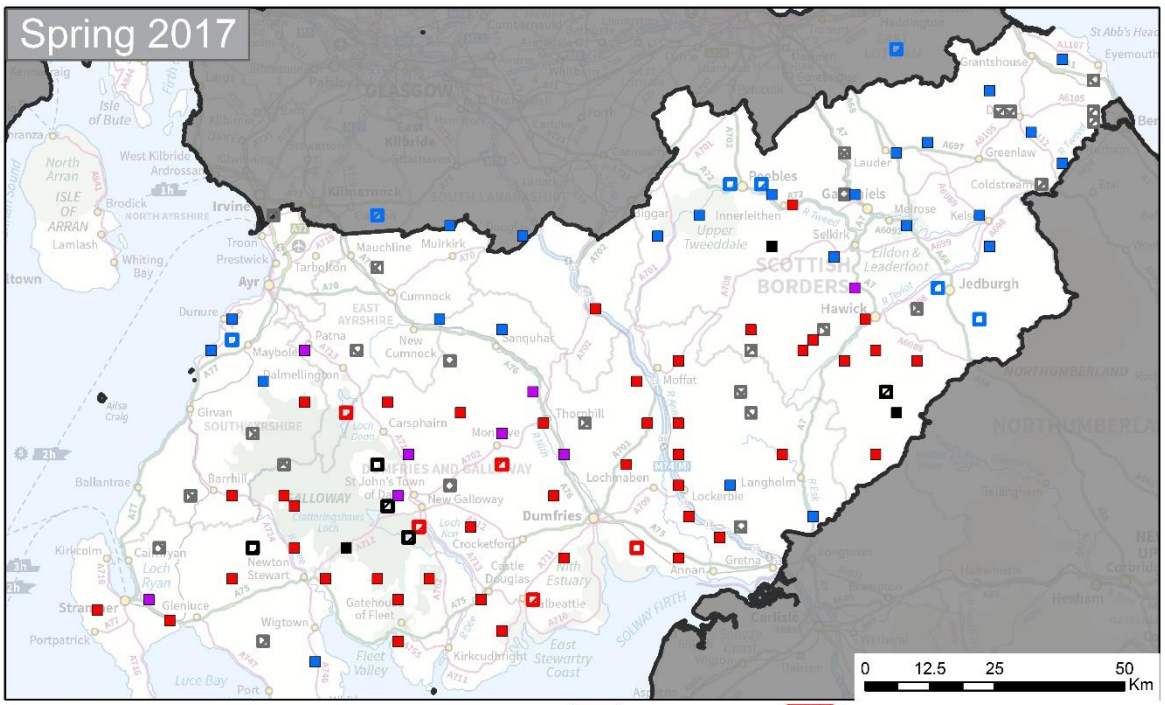
Date: 27/09/2017

Tetrad Results

- Red squirrels(s)
- Grey squirrel(s)
- Red and Grey squirrels
- Neither squirrel
- Red squirrel(s) - Tetrad partially completed
- Grey squirrel(s) - Tetrad partially completed
- Neither squirrel - Tetrad partially completed
- Tetrad not surveyed
- Red squirrel protection line

Tetrad Results - South Scotland





Results from SSRS standardised tetrad surveys
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Date: 27/09/2017

- Red squirrel(s)
- Grey squirrel(s)
- Red_Grey squirrel(s)
- Neither squirrel
- Red squirrel(s) - Tetrad partially completed
- Grey squirrel(s) - Tetrad partially completed
- Neither squirrel - Tetrad partially completed
- Tetrad not surveyed

8. APPENDIX 2

Individual tetrad results tables

(Green denotes a positive change for red squirrels over time; Orange denotes a negative change for red squirrels over time)

North Scotland								
Tetrad	**Region**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
NM9440	Argyll & Trossachs	n/a	n/a	Red only	Red only	Red only	Red only	n/a
NN2404	Argyll & Trossachs	Red only	Both species	Red only	n/a	Red only	Both species	Both species
NN2601	Argyll & Trossachs	Red only	n/a	n/a	n/a	Red only	Red only	Red only
NN2603	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	Red only	Red only
NN2804	Argyll & Trossachs	n/a	Red only	Neither species	Red only	n/a	Red only	Red only
NN3004	Argyll & Trossachs	Both species	Both species	Both species	Red only	n/a	Red only	Red only
NN3206	Argyll & Trossachs	Both species	Red only	Red only	Red only	Red only	Neither species	Red only
NN4800	Argyll & Trossachs	Red only	Red only	Red only	n/a	Red only	Red only	Red only
NN5200	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	n/a	Red only
NN5204	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	Neither species	n/a
NN5417	Argyll & Trossachs	Red only	Red only	Red only	n/a	n/a	Red only	Red only
NN5616	Argyll & Trossachs	Neither species	Neither species	Red only	n/a	n/a	Red only	Red only
NN5632	Argyll & Trossachs	n/a	Red only	n/a	n/a	n/a	n/a	n/a
NN5634	Argyll & Trossachs	n/a	n/a	n/a	n/a	n/a	n/a	n/a
NN5732	Argyll & Trossachs	n/a	n/a	Red only	Red only	Red only	Red only	Red only
NN5734	Argyll & Trossachs	n/a	n/a	Red only	Red only	n/a	Red only	Red only
NN5812	Argyll & Trossachs	Red only	Red only	Red only	n/a	Neither species	Red only	Red only
NN5824	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	Red only	Red only
NN6006	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	Red only	Both species
NN6008	Argyll & Trossachs	Red only	n/a	Red only	Red only	Red only	Red only	Red only
NN6022	Argyll & Trossachs	n/a	Red only	Red only	Neither species	n/a	Neither species	Red only
NN6208	Argyll & Trossachs	Both species	Both species	Both species	Both species	n/a	Both species	Both species
NN6408	Argyll & Trossachs	Both species	Red only	Both species	n/a	n/a	n/a	n/a
NN6622	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	Red only	Red only
NN6624	Argyll & Trossachs	Both species	Red only	Red only	Red only	Red only	Red only	Red only
NN6822	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	Red only	Red only
NN7202	Argyll & Trossachs	n/a	Grey only	Grey only	Both species	Both species	Both species	Red only
NN7402	Argyll & Trossachs	Grey only	Grey only	Both species	Neither species	Grey only	Both species	Both species
NN7690	Argyll & Trossachs	n/a	n/a	n/a	n/a	Grey only	Grey only	n/a
NS3696	Argyll & Trossachs	Red only	Red only	Red only	n/a	n/a	n/a	n/a
NS3698	Argyll & Trossachs	n/a	n/a	Neither species	Red only	Neither species	Red only	n/a
NS3894	Argyll & Trossachs	Both species	Red only	Neither species	Neither species	Neither species	n/a	Red only
NS4287	Argyll & Trossachs	n/a	n/a	n/a	n/a	n/a	Neither species	Red only
NS4290	Argyll & Trossachs	Neither species	Red only	Red only	Red only	n/a	Red only	n/a
NS4690	Argyll & Trossachs	Neither species	Red only	Red only	Red only	Red only	n/a	Red only
NS4890	Argyll & Trossachs	Neither species	Red only	Red only	Red only	Red only	Red only	Red only
NS4898	Argyll & Trossachs	n/a	n/a	Red only	Red only	Red only	Red only	Red only
NS5098	Argyll & Trossachs	Red only	Red only	Red only	Red only	Red only	Red only	Neither species
NS5280	Argyll & Trossachs	n/a	n/a	n/a	n/a	Grey only	Grey only	n/a
NS5298	Argyll & Trossachs	Both species	Both species	Red only	Red only	Red only	Red only	Red only
NS7398	Argyll & Trossachs	Grey only	n/a	n/a	Grey only	Both species	Both species	Both species
NS8286	Argyll & Trossachs	n/a	n/a	n/a	n/a	Grey only	Grey only	Grey only
NJ5210	North East	n/a	n/a	Red only	Neither species	Neither species	Red only	Neither species
NJ5414	North East	n/a	Both species	n/a	Red only	Red only	Red only	Red only
NJ5616	North East	n/a	Red only	Red only	Red only	Red only	Red only	Red only
NJ6218	North East	n/a	Red only	Red only	Red only	Neither species	Red only	Neither species

NJ6618	North East	n/a	Red only	Red only	Neither species	Neither species	Red only	Neither species
NJ6816	North East	n/a	Red only	Neither species	Neither species	Neither species	Red only	Red only
NJ6820	North East	n/a	Red only	Red only	Red only	Red only	Red only	Red only
NJ7016	North East	n/a	n/a	Red only	n/a	Neither species	Red only	Red only
NJ7214	North East	n/a	Red only	Red only	Red only	Red only	Red only	Red only
NJ7216	North East	n/a	n/a	Red only	Red only	Both species	Red only	n/a
NJ7224	North East	n/a	Red only	Red only	Red only	Red only	Red only	Red only
NJ7614	North East	n/a	n/a	n/a	Red only	Red only	Red only	Red only
NJ7616	North East	Both species	Red only	n/a	Red only	Red only	Red only	Neither species
NJ7800	North East	Both species	Red only	Neither species	Neither species	Neither species	Red only	Red only
NJ7804	North East	n/a	n/a	n/a	Red only	Red only	Red only	Red only
NJ7806	North East	n/a	n/a	n/a	Red only	Red only	Red only	Red only
NJ7820	North East	n/a	Both species	Red only	Red only	Red only	Red only	Red only
NJ8006	North East	Red only	Red only	Red only	Both species	Both species	Both species	Red only
NJ8200	North East	Grey only	Grey only	Neither species	Red only	Red only	Red only	Neither species
NJ8204	North East	Neither species	Red only	Both species	Red only	Red only	Red only	Red only
NJ8400	North East	n/a	n/a	Grey only	Neither species	Neither species	Grey only	Grey only
NJ8404	North East	Red only	Red only	Red only	Red only	Red only	Red only	Red only
NJ8410	North East	n/a	n/a	n/a	Red only	n/a	Red only	n/a
NJ8602	North East	Both species	Both species	Red only	Neither species	Red only	Red only	Red only
NJ8604	North East	Both species	Red only	Red only	Red only	Red only	Red only	n/a
NJ8618	North East	Neither species	Red only	Neither species	Neither species	Neither species	Red only	Red only
NJ8800	North East	n/a	n/a	n/a	n/a	Grey only	Neither species	Red only
NJ8802	North East	n/a	n/a	n/a	Grey only	Neither species	Both species	Red only
NJ8804	North East	Grey only	Red only	Neither species	Both species	Both species	Both species	Both species
NJ8814	North East	n/a	n/a	Red only	Red only	Both species	Both species	n/a
NJ9002	North East	n/a	Grey only	Grey only	Grey only	Grey only	Grey only	Both species
NJ9004	North East	Neither species	n/a	Neither species	Grey only	Both species	Grey only	Grey only
NJ9012	North East	Both species	n/a	Both species	Red only	Red only	Red only	n/a
NJ9206	North East	n/a	Grey only	Grey only	Grey only	Grey only	Grey only	n/a
NJ9208	North East	n/a	Grey only	Grey only	n/a	Grey only	Grey only	Both species
NJ9408	North East	n/a	Grey only	Grey only	Grey only	Grey only	Neither species	Both species
NO6696	North East	n/a	n/a	n/a	Neither species	Neither species	Neither species	Red only
NO6894	North East	n/a	Red only	Red only	Red only	Red only	Red only	Red only
NO7094	North East	Both species	Red only	n/a	Red only	Red only	Red only	n/a
NO7296	North East	n/a	n/a	n/a	Red only	Red only	Red only	n/a
NO7496	North East	Both species	Red only	Red only	Neither species	Neither species	Neither species	Neither species
NO7694	North East	n/a	Both species	n/a	Red only	Red only	Red only	Red only
NO7894	North East	n/a	Both species	Neither species	Neither species	Neither species	Red only	Neither species
NO8096	North East	n/a	n/a	Red only	Red only	Neither species	Red only	n/a
NO8288	North East	n/a	Both species	Red only	Red only	Red only	Red only	Neither species
NO8484	North East	Red only	Red only	Red only	Red only	Red only	Red only	Red only
NO8492	North East	n/a	n/a	n/a	n/a	n/a	Neither species	Neither species
NO8684	North East	n/a	Neither species	Neither species	Neither species	Neither species	Neither species	Neither species
NO8686	North East	n/a	n/a	n/a	Neither species	Neither species	Neither species	n/a
NO8688	North East	n/a	n/a	n/a	Neither species	Neither species	Neither species	n/a
NN7222	Tayside	n/a	n/a	Red only	Red only	Both species	Red only	n/a
NN7422	Tayside	n/a	Neither species	Red only	Red only	Red only	Red only	Both species
NN7622	Tayside	n/a	Grey only	Red only	Both species	n/a	Both species	Both species
NN8220	Tayside	n/a	Red only	Red only	Red only	Red only	Red only	Red only

NN8622	Tayside	n/a	Red only	Both species	Both species	Both species	Both species	Both species
NN9020	Tayside	n/a	Red only	Red only	Red only	Red only	Red only	Red only
NN9022	Tayside	n/a	n/a	Both species	Both species	Both species	Both species	Red only
NN9228	Tayside	Both species	Red only	Red only	n/a	n/a	n/a	n/a
NN9456	Tayside	n/a	Red only	Red only	Red only	Red only	n/a	n/a
NN9458	Tayside	n/a	Red only	n/a	Red only	Red only	n/a	n/a
NN9654	Tayside	n/a	Red only	n/a	Neither species	Red only	n/a	Red only
NO0242	Tayside	n/a	Neither species	n/a	Both species	n/a	Both species	n/a
NO0630	Tayside	n/a	Red only	Red only	Red only	n/a	Red only	n/a
NO0634	Tayside	n/a	n/a	Grey only	Grey only	Grey only	n/a	Grey only
NO0833	Tayside	n/a	Red only	n/a	Red only	Red only	Neither species	Neither species
NO1036	Tayside	n/a	Red only	Red only	Red only	n/a	n/a	Red only
NO1236	Tayside	Both species	n/a	Red only	Red only	n/a	Red only	Red only
NO1242	Tayside	n/a	Red only	n/a	Red only	n/a	Red only	Red only
NO1436	Tayside	n/a	Red only	Both species	Neither species	Neither species	Red only	Neither species
NO1632	Tayside	n/a	Red only	Both species	Both species	Both species	Both species	Both species
NO1642	Tayside	Both species	Both species	n/a	Both species	Both species	Red only	n/a
NO1644	Tayside	n/a	Both species	n/a	n/a	Red only	Red only	n/a
NO2254	Tayside	n/a	Both species	n/a	n/a	n/a	n/a	n/a
NO2354	Tayside	n/a	n/a	n/a	Red only	n/a	Red only	Red only
NO2646	Tayside	n/a	Both species	Both species	Red only	Red only	Red only	Red only
NO2750	Tayside	n/a	Both species	Red only	Red only	n/a	Red only	n/a
NO2844	Tayside	n/a	n/a	Both species	Both species	Both species	Both species	Red only
NO2848	Tayside	n/a	Both species	n/a	Red only	Red only	Red only	Red only
NO2854	Tayside	n/a	n/a	Red only	Red only	Neither species	Neither species	Neither species
NO2856	Tayside	n/a	Both species	Red only	Red only	n/a	n/a	n/a
NO3250	Tayside	n/a	n/a	Red only	Red only	Red only	Red only	Both species
NO3654	Tayside	n/a	Both species	Red only	Red only	Red only	Red only	Red only
NO3730	Tayside	n/a	n/a	n/a	Both species	n/a	n/a	n/a
NO4254	Tayside	n/a	Both species	Neither species	Neither species	Neither species	n/a	Red only
NO4448	Tayside	n/a	Both species	n/a	Red only	n/a	Red only	n/a
NO4450	Tayside	n/a	Both species	n/a	Neither species	Neither species	Neither species	Grey only
NO4462	Tayside	n/a	n/a	n/a	n/a	n/a	n/a	n/a
NO4850	Tayside	n/a	Both species	Red only	Red only	Red only	Red only	Red only
NO4856	Tayside	Both species	Both species	Red only	Red only	Red only	Red only	Red only
NO6070	Tayside	n/a	Both species	Red only	Red only	Red only	Red only	Red only
NO6256	Tayside	Both species	Both species	n/a	Red only	Both species	Red only	n/a
NO6258	Tayside	n/a	Red only	Red only	Red only	Both species	Both species	n/a
NO6264	Tayside	n/a	n/a	n/a	n/a	Neither species	n/a	Red only
NO6961	Tayside	n/a	Both species	Red only	n/a	Red only	Red only	Red only
NO7260	Tayside	n/a	n/a	Red only	n/a	Red only	Both species	Red only

Note – The results are only listed for the completed tetrads (3 visits per box and 12 samples per tetrad – or fewer samples but both species are detected, therefore considered complete) that were used for data analyses. “n/a” refers to the tetrads which were not surveyed or not completed.

(Green denotes a positive change for red squirrels over time; Orange denotes a negative change for red squirrels over time)

South Scotland					
Tetrad	**2013**	**2014**	**2015**	**2016**	**2017**
NS2208	Grey only	Grey only	Grey only	Grey only	Grey only
NS2610	n/a	n/a	Grey only	Grey only	n/a
NS2614	Grey only	Grey only	n/a	Grey only	Grey only
NS3202	Neither species	n/a	n/a	Grey only	Grey only
NS3335	n/a	n/a	Grey only	n/a	Grey only
NS3434	Grey only	n/a	n/a	n/a	n/a
NS4008	Red only	Both species	Grey only	Both species	Both species
NS5008	Red only	Red only	n/a	n/a	n/a
NS5206	n/a	n/a	Neither species	Neither species	Neither species
NS5424	Grey only	n/a	n/a	n/a	n/a
NS5426	n/a	n/a	Grey only	Grey only	n/a
NS5434	Grey only	Grey only	Grey only	Grey only	n/a
NS6614	n/a	Grey only	Grey only	n/a	Grey only
NS6806	Red only	Red only	n/a	n/a	n/a
NS6832	Grey only	Grey only	Grey only	Grey only	Grey only
NS7812	Grey only	Neither species	Neither species	Grey only	Grey only
NS8230	Grey only	n/a	Grey only	Grey only	Grey only
NS8400	Red only	Red only	Both species	Grey only	Both species
NS9616	Grey only	Red only	Red only	Red only	Red only
NT0402	Red only	Red only	Neither species	Red only	Red only
NT0830	Neither species	Neither species	Neither species	Grey only	Grey only
NT1206	Red only	Red only	Red only	Red only	Red only
NT1634	Both species	Grey only	Grey only	Grey only	Grey only
NT2240	n/a	n/a	Grey only	Grey only	n/a
NT2400	Neither species	Red only	Neither species	Red only	n/a
NT2608	Red only	Red only	Red only	Red only	n/a
NT2612	Red only	Red only	Red only	Red only	Red only
NT2840	Grey only	Grey only	Grey only	Grey only	n/a
NT3028	Neither species	Red only	Neither species	Neither species	Neither species
NT3038	n/a	n/a	n/a	Grey only	Grey only
NT3436	Both species	n/a	Red only	Red only	Red only
NT3608	n/a	Red only	Red only	Neither species	Red only
NT3810	n/a	Red only	Red only	n/a	Red only
NT4012	Red only	n/a	n/a	n/a	n/a
NT4226	Neither species	Grey only	Both species	Grey only	Grey only
NT4406	n/a	n/a	n/a	Red only	Red only
NT4438	n/a	n/a	n/a	n/a	n/a
NT4446	n/a	n/a	n/a	n/a	n/a
NT4620	n/a	n/a	n/a	Both species	Both species
NT4638	Neither species	Grey only	Grey only	Grey only	Grey only
NT4814	n/a	n/a	n/a	Both species	Red only
NT5008	n/a	Grey only	n/a	Neither species	Red only
NT5200	Neither species	Red only	Neither species	n/a	n/a
NT5446	Neither species	Neither species	n/a	Grey only	Grey only
NT5466	Grey only	n/a	Grey only	n/a	n/a
NT5632	Grey only	Grey only	n/a	n/a	Grey only
NT5806	n/a	n/a	Red only	n/a	Red only
NT5816	n/a	Both species	n/a	Both species	n/a
NT6048	Neither species	Neither species	Both species	Grey only	Grey only
NT6220	Neither species	Grey only	Both species	Grey only	n/a
NT6410 or NT6408	n/a	n/a	n/a	n/a	n/a
NT7014	Neither species	Neither species	n/a	Neither species	n/a
NT7034	n/a	Grey only	Neither species	Both species	Grey only
NT7228	Grey only	Grey only	Grey only	Grey only	Grey only
NT7258	Neither species	Neither species	Neither species	Neither species	Grey only
NT7454	n/a	n/a	n/a	n/a	n/a
NT7654	n/a	n/a	n/a	n/a	n/a
NT7854	n/a	n/a	Both species	Grey only	Grey only
NT8050	Grey only	Grey only	Both species	Grey only	Grey only
NT8240	Neither species	Neither species	n/a	n/a	n/a
NT8644	n/a	Neither species	n/a	n/a	Grey only
NT8664	Neither species	n/a	n/a	Grey only	Grey only

NT8846	Red only	Neither species	n/a	n/a	n/a
NT9252	Neither species	Grey only	n/a	n/a	n/a
NT9254	n/a	n/a	Neither species	Neither species	n/a
NT9260	n/a	n/a	Neither species	Neither species	n/a
NX0058	Red only	Red only	Red only	Red only	Red only
NX1060	Both species	Both species	Both species	Red only	Both species
NX1270	Neither species	Neither species	Neither species	Neither species	n/a
NX1456	Red only	Red only	Red only	Red only	Red only
NX1880	n/a	n/a	n/a	n/a	n/a
NX2664	Red only	Neither species	Red only	n/a	Red only
NX2680	Red only	Red only	Neither species	Red only	Red only
NX3070	Red only	Both species	Red only	n/a	n/a
NX3092	Grey only	Red only	n/a	n/a	n/a
NX3252	Neither species	n/a	n/a	n/a	n/a
NX3680	n/a	n/a	n/a	Red only	Red only
NX3686	Neither species	Neither species	Neither species	n/a	n/a
NX3870	n/a	Red only	Red only	Red only	Red only
NX3878	Red only	Red only	n/a	n/a	Red only
NX4098	Neither species	Neither species	Neither species	Neither species	Red only
NX4248	n/a	Neither species	Neither species	Both species	Grey only
NX4464	Red only	n/a	Red only	Red only	Red only
NX4870	Neither species	n/a	Neither species	n/a	Neither species
NX4896	Neither species	Neither species	Neither species	Red only	n/a
NX5464	n/a	n/a	Neither species	Neither species	Red only
NX5486	Neither species	Neither species	Red only	Red only	n/a
NX5678	Neither species	Neither species	Neither species	n/a	n/a
NX5698	Red only	n/a	n/a	Red only	Red only
NX5852	Red only	Red only	Red only	Red only	Red only
NX5860	Red only	Red only	n/a	Red only	Red only
NX5880	n/a	n/a	Grey only	Both species	Both species
NX6072	n/a	n/a	n/a	Neither species	n/a
NX6088	Red only	Red only	Red only	Red only	Both species
NX6274	n/a	Red only	n/a	Neither species	n/a
NX6464	Red only	Red only	Red only	n/a	Red only
NX6882	Red only	Red only	Red only	n/a	n/a
NX7096	Red only	Red only	Red only	Red only	Red only
NX7274	n/a	Red only	Both species	Red only	Red only
NX7460	Red only	n/a	Red only	Red only	Red only
NX7854	n/a	Red only	Red only	Red only	Red only
NX7886	Red only	Red only	Neither species	Red only	n/a
NX7892	Both species	Both species	Red only	Both species	Both species
NX8460	Red only	Red only	Red only	Red only	n/a
NX8694	n/a	n/a	Both species	Both species	Red only
NX8880	Red only	Red only	Both species	Red only	Red only
NX9068	Red only	Red only	Red only	Red only	Red only
NX9088	Red only	Red only	n/a	Red only	Both species
NX9494	Red only	Red only	n/a	Red only	n/a
NY0286	Red only	Red only	Both species	Both species	Red only
NY0470	Neither species	Red only	Red only	Red only	n/a
NY0694	Red only	Red only	Both species	Red only	Red only
NY1268	Both species	Both species	Both species	Red only	Red only
NY1282	n/a	n/a	Red only	Red only	Red only
NY1288	Red only	Red only	Grey only	Red only	Red only
NY1294	n/a	n/a	n/a	Red only	Red only
NY1476	Red only	Red only	Red only	Red only	Red only
NY2072	Red only	Red only	Red only	Red only	Red only
NY2282	Red only	Red only	Neither species	Grey only	Grey only
NY2474	Red only	Both species	Red only	Red only	n/a
NY2696	Neither species	Neither species	Neither species	Neither species	n/a
NY3288	Both species	Red only	n/a	n/a	Red only
NY3876	Both species	Both species	Grey only	Grey only	Grey only
NY5088	Red only	Red only	n/a	Red only	Red only
NY5496	Red only	Red only	Red only	Both species	Neither species

Note – The results are only listed for the completed tetrads (3 visits per box and 12 samples per tetrad – or fewer samples but both species are detected, therefore considered complete) that were used for data analyses. “n/a” refers to the tetrads which were not surveyed or not completed.

9. APPENDIX 4

Intensive Grey Squirrel Detection Survey in North East Scotland

Since 2015 an independent presence-absence survey has been carried out in the North East Scotland to further investigate the spread of grey squirrels in the grey-squirrel-preferred habitats of Aberdeen city and across Aberdeenshire. The primary aim of these surveys is to detect grey squirrels to inform grey squirrel control activities. A secondary aim is to build up an accurate picture of red and grey squirrel distribution across the region including in stretches of landscape not covered by the Spring Tetrad surveys.

For these surveys all significant areas of large-seeded broadleaved trees (c. 10ha or greater) and all small patches of habitat with good connectivity were targeted for survey, including broadleaved shelter belts around/within conifer blocks, from identification on 1:25,000 OS maps. Type of woodland was assessed using aerial photography on Google Maps. Sightings records, trapping records, and survey results that SSRS already held were collated and mapped and woodland stock maps consulted. This was followed up by ground-truthing the woodlands by driving/walking them to assess the habitat(s) present, the approx. age (i.e. new plantation or ancient woodland), and presence of squirrels evident from sightings or field signs. Whilst visiting the wood, posters were put up asking for sightings.

Feeder boxes were deployed in all woodlands in the first instance. In large blocks of conifer of cone-bearing age, areas of mature large-seeded broadleaved trees were prioritised and feeder boxes deployed at a density of around 1-3 per 10 ha. especially in habitat bottlenecks.

Once the rural areas were covered, the project also deployed feeder-box surveys within the built-up areas of the city at a density of at least one per ha., selecting the most likely habitat for grey squirrels.

As with the Tetrad Surveys, the feeder boxes were baited and equipped with a sticky hair-trap tab and visited three times at two week intervals. They were carried out twice a year in spring and autumn once they were all in place. Following hair identification each feeder-box was allocated to one of the four categories: “red squirrels only”, “grey squirrels only”, “both species” or “neither” species.

For the analysis we utilised feeder-boxes which were surveyed on both years/seasons for paired analysis. The paired analysis was done between similar seasons of different years. To identify any significant change in the seasonal occupancy of grey and red squirrels, we also compared the feeder-box results of spring and autumn surveys.

Results

Table 6 summarises the number of feeder-boxes detecting either squirrel species, both species or neither species in each survey season.

Table 6- Intensive Grey Squirrel Detection Survey results summary

	2015		2016		2017
	Spring	Autumn	Spring	Autumn	Spring
Red squirrel only	30	39	54	59	34
Grey squirrel only	28	65	50	51	35
Both species	3	4	6	5	5
Neither species	131	127	129	136	79
Total feeder-boxes surveyed	192	235	239	251	153

The increase in red squirrel occupancy between the beginning of the survey in 2015 and the following years in spring was found to be *significant* (p value=0.003 for 2016/2017 and p value=0.004 for 2015/2017). (Binomial Analysis table)

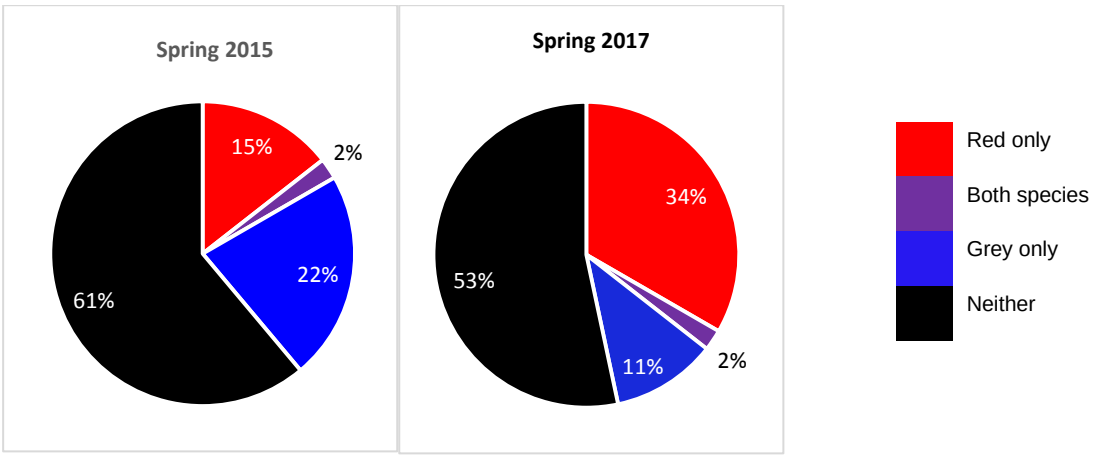
No significant difference was found between seasonal detection of either red or grey squirrels (Binomial Analysis table).

Table 7: Matrix of changes in Feeder-box occupancy between spring 2015 and 2017 for the North of Scotland

North Scotland 2015/2017		**Spring 2017**				
		Red	Both	Neither	Grey	**Total**
2Spring 2015	Red	6	0	7	0	**13**
	Both	0	0	2	0	**2**
	Neither	16	0	33	6	**55**
	Grey	8	2	6	4	**20**
	Total	**30**	**2**	**48**	**10**	**90**

Replacement Index = -0.298

Figure 3: Proportion of paired feeder-boxes returning both species, red squirrel, grey squirrel or neither for the Intensive Surveys (n=90)



Binomial analysis results:

Annual Proportions - Two-sample Binomial Test											
Hypothesis 1: the proportion of Reds in the two compared years are equal for the tetrads that have been sampled twice											
Hypothesis 2: the proportion of Greys in the two compared years are equal for the tetrads that have been sampled twice											
Species	Seasonal/annual	Year1	Year2	Season1	season2	N_1	X_1	N_2	X_2	z	p
Red	Seasonal	2015	2015	spring	autumn	170	31	170	40	-1.2008165	0.230
Grey						170	29	170	30	-0.1432057	0.886
Red	Seasonal	2016	2016	spring	autumn	233	59	233	59	0	1.000
Grey						233	55	233	56	-0.108747	0.913
Red	Annual	2015	2016	spring	spring	173	31	173	55	-2.9854747	0.003
Grey						173	31	173	22	1.3434107	0.179
Red	Annual	2015	2016	autumn	autumn	226	43	226	60	-1.9062805	0.057
Grey						226	66	226	53	1.3884076	0.165
Red	Annual	2015	2017	spring	spring	90	15	90	32	-2.8847649	0.004
Grey						90	22	90	12	1.9042342	0.057
Red	Annual	2016	2017	spring	spring	142	30	142	37	-0.9783403	0.328
Grey						142	49	142	38	1.4159865	0.157

Discussion

This is the first time our survey results have returned a significant difference in the occurrence of red squirrels (Spring 2015/16 and Spring 2016/17) in the binomial analysis results above and Figure 5. Since Figure 5 compares paired results, it can be seen that red squirrel detected occupancy increased at the expense of grey squirrels and colonisation of vacant habitat (or at least habitat in which squirrels had not been previously detected). This is made somewhat more significant by the reduction in feeder-box sample size between autumn 206 and spring 2017, which was achieved by discarding a number of boxes in habitat where no squirrels had been detected in any of the previous surveys or by any other means, as well as a number of boxes where only red squirrels were ever detected in habitat which clearly favoured red squirrels. The latter should have had the effect of increasing the proportion of boxes detecting greys.

This tallies with the findings of the Spring Tetrad surveys that grey squirrels have declined in Aberdeenshire over the period of the project. Because the intensive surveys are more focussed on detecting grey squirrels they omit some of the rural sites where red squirrels are regularly found in the tetrad surveys (no change over the years). It is therefore easier to pick up statistical significance in changes in favour of reds as such changes form a greater part of the sample.

Further statistical work is under way which aims at predicting the timescale for complete eradication of grey squirrels in the North East.