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### Purpose of the Series

The aim of this publication is to provide an opportunity for students to publish the findings of their undergraduate or postgraduate work. Guidance on publication will be given by staff who will act as second authors. It is hoped that by providing a guided transition into the production of papers that students will be encouraged throughout their future careers to publish further papers. Guest papers are welcomed in any field relating to the Built Environment. Please contact [E.A.Laycock@shu.ac.uk](mailto:E.A.Laycock@shu.ac.uk). A template will be provided on request.

### Acknowledgements

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# EDITORIAL

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Welcome to the second volume of the Sheffield Hallam University Natural Environment Research Transactions. The work presented here is from undergraduate dissertations, demonstrating the level of effort and determination that students have put into their chosen project. The additional commitment to produce a paper should not go unrecognised. By publishing their work these students have completed a vital link in the chain by allowing others to benefit from their findings. We hope that by providing this opportunity we inspire recent graduates to publish their own research work both after their studies at SHU and throughout their future careers.

The Editor would like to thank all contributing authors and staff co-authors for their efforts in writing and editing these papers, and to all of the members of the reviewers and the editorial team for their continued engagement and support and their constructive feedback to the authors. Without the help and support of colleagues none of this would be possible.

Prof. Elizabeth Laycock

Editor, Natural Environment Research Transactions

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# **INVESTIGATING THE INFLUENCES OF DIFFERING FIELD MARGINS ON THE ABUNDANCE AND SPECIES RICHNESS OF BRITISH GROUND BEETLES (*CARABIDAE*).**

**Samuel Gregory<sup>1</sup> and John Rose<sup>2</sup>**

*Samuel Gregory studied a BSc Degree in Environmental Conservation at Sheffield Hallam University and graduated in 2016 with a First-Class Honours. He has recently enrolled on an MSc in Geographic Information Systems at Sheffield Hallam University. John Rose is a member of staff at Sheffield Hallam University who specialises in ecology and environmental modules, he supervised the dissertation and provided support throughout the research period.*

This report investigates how the composition of field margins influences the abundance and species richness of British ground beetles (*Carabidae*). The study investigated the contrast between traditional field margin approaches and approaches dictated by a Natural England agri-environmental scheme. Results show that traditionally managed field margins, had lower abundances and species richness of *Carabidae* than those managed in accordance with Natural England's Organic Entry Level Stewardship Scheme (OELS). The research could prove important in aiding farms to increased levels of natural predation and help increase overall crop yields through the management of field margins. The study takes methods from previous similar studies on *Carabidae*, investigating further the differences between traditional methods and those promoted through environmental schemes.

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Key words: *Carabidae*, species abundance, species richness, margin composition.

## INTRODUCTION

This research investigates the impact of field margin composition on the species diversity and abundance of British ground beetles (*Carabidae*). The study focuses on four different types of field margins: hedge, ditch, pollen and nectar mix, and wild bird cover mix. Two of the margins, hedges and ditches, are common traditional agricultural field margins used frequently throughout the country to provide: important field boundaries (Packham, 2010). Pollen and nectar mix, and wild bird cover mix are planted seed margins used in the Organic Entry Level Stewardship Scheme (OELS), a government initiative to help provide widespread environmental benefits (Natural England, 2014). The research was conducted on Pollybell Organic Farm.

The aim of the research is to discover whether there is a relationship between the abundance and species richness of *Carabidae* and vegetation cover, vegetation species richness, vegetation type and soil type. The purpose of the research was to identify which margins may be more beneficial to organic farms looking to increase numbers of natural predators of pest species, in their field margins. The research should identify the main influences on *Carabidae* and whether stewardship scheme margins show differing results to traditional margins.

To reflect the aim of the research these individual objectives of the report aim to:

- Identify which species are present and in what abundance in the selected field margins.
- Ascertain conservation status of *Carabidae* sampled.
- Investigate how the composition of the margins, in particular, vegetation cover, floral species richness, vegetation type and soil structure may be influential on *Carabidae* abundance and species richness.

## RESEARCH METHOD

A stratified random survey technique was used, with quadrats measuring percentage cover of all species found. The species composition for each margin type was determined using National Vegetation Classification methods (Rodwell 2006). *Carabidae* data was collected using a wet pitfall trapping method (Greenside, 1964). Pitfall traps were located at random points along a field margin transect.

The research was conducted in the months July to September over a period of 8 weeks, It was deemed that sampling in this period would be successful as most carabids are long lived and do not show strong seasonal change (James Hutton Institute, 2011). All sampled fields adjacent to the margins had crops growing throughout the study period to provide a potential carabid food source (aphids, slugs, snails). Studies have found that a minimum period of 13 days can produce efficient catch data (Cheli & Corley, 2010) therefore it was deemed that a trapping period of 56 days would be a sufficient time period. Traps were collected once a week, *Carabidae* were retrieved and stored in sample bags, noted with trap location and date. *Carabidae* were identified using a microscope and comprehensive step-by-step guides on identifying British *Carabidae* 1: Ground Beetles (Forsythe, 2000) 2: The *Carabidae* (Luff, 2007).

A negative binomial, generalised linear regression model was performed on the *Carabidae* data using SPSS and the Bonferroni post hoc analysis was used to test for differences between individual pairs of means. SPSS is a widely-used package which allows many different types of analysis (Arkkelin, 2014).

Ethical consideration using wet pit fall traps had to be made. As wet pit fall traps are effectively a lethal method of trapping it had to be ensured that these complied with standard practises. Wet pitfall traps are widely used for catching and killing invertebrates (Animal Ethics Infolink, 2016 ). With the use of wet pitfall traps comes the risk of killing non-target species, so every reasonable measure was taken to reduce the risk of trapping non-target vertebrates (Animal Ethics Infolink, 2016 ). The field study did not involve any protected or endangered species; it was conducted on private farmland with the permission of the farm owners.

The methods used for the survey were based on common practises and guidelines. Where these guidelines could not be followed due to restrictions, such as time, manpower and equipment, the nearest possible alternative was used. The amount of data was sufficient enough to comprise a usable dataset.

Primary Data collected was supplemented by secondary data owned by the farm, soil structure tests and drilled seed records.

## **LITERATURE REVIEW**

### ***Carabidae* and Pest Control.**

It has been established that *Carabidae* can be used as a viable pest control agent (Game and Wildlife Conservation Trust, 2015). Most members of the *Carabidae* family are beneficial to agriculture, preying on other pest insects (Little, 1957). *Carabidae* can reduce pest damage to crops by as much as 40% (Carvalho & Garaeu, 2010). Understanding the habitats that increase the species diversity and abundance of *Carabidae*, could aid the agricultural sector in biological pest control.

### ***Carabidae* Distribution Patterns.**

Two studies by the Game and Wildlife Conservation Trust (GWCT) proved how beneficial *Carabidae* can be, using them as a viable method of aphid control. Study one showed how a specific species of *Carabidae*, *Pterostichus melanarius*, responded to aphid populations. Aphids occurred in small-scattered patches throughout the field, *P.melanarius* was found to dynamically respond to the distribution of aphids. *P.melanarius* navigated towards patches of dense aphid activity and avoided low density patches; this resulted in the conclusion that *P.melanarius* caused a measurable decrease in aphid growth, responding directly to aphid numbers and could consequently be used as a viable pest control agent (Game and Wildlife Conservation Trust, 2015)

Study two was undertaken to further understand movement patterns of individual *Carabidae* to evaluate their values for aphid controls. The study used an automated laser to mark each beetle with a unique three-digit code. The *Carabidae* were tracked by pitfall trap recaptures and aphids at each trapping location were monitored. In 2003 a total of 8,046 *Carabidae* specimens (*Poecilus cupreus*) were marked and 2,270 were recaptured within the 2.75 hectare field. The field distribution of the *Carabidae* showed high population activity-density towards the centre of the field (Figure 2.1). On the contrary, the distribution of cereal aphids was lowest in the middle and highest towards the field edges (Figure 2.2), this suggested a clear correlation between the total number of *P.cupreus* and maximum number of cereal aphids. It was doubted by the GWCT whether aphid control was down to the one individual species of beetle, due to the fact many species of beetle eat



aphids but it was clearly shown that *Carabidae* can be used reduce cereal aphid numbers. (Game and Wildlife Conservation Trust, 2015)

### **Field Margin Management and Its Influence on *Carabidae* Diversity and Abundance.**

A study by Hof and Bright (2010) investigated whether the presence of grassy field margins positively affects the abundance of *Carabidae* in the field margin and adjacent arable fields. A total of 18 species were found, of which 72% were predatory. It was established that *Carabidae* were more abundant on arable fields that had grassy margins than on fields without. It is thought that these uncultivated borders serve as overwintering reserves from where *Carabidae* can disperse (Hof & Bright, 2010) The GWCT (2015) found that a presence of a six- metre wide, flower rich field margin, made little difference to the abundance of predators in an area where there was plenty of natural habitat surrounding (Game and Wildlife Conservation Trust, 2015).

Thomas and Marshall (1999) measured *Carabidae* abundance and diversity in differing cropped margins. Diversity was lowest in the drilled crops, low in the crop edge, higher in the more diverse field margin plots of wildflower/grass and highest in natural hedges bordering the crop. Their results indicated that the presence of botanically diverse field margin strips and hedges could be an important method of increasing the *Carabidae* diversity in semi-natural habitat in farmland. The study found that species *Pterostichus melanarius*, *Poecilus cupreus* and *Harpalus rufipes* were all found to have higher mean abundance in natural regeneration and mixed grass and wildflower plots than other margins (Thomas & Marshall, 1999).

A field experiment conducted in North Yorkshire by Meek *et al.* (2002) compared the invertebrate biodiversity of five types of field margins. Statistically significant results were obtained for invertebrates, the most obvious being the avoidance of the ‘cropped’ areas, this could be demonstrated in many species including *Carabidae*. Margins often contained double, or more *Carabidae*, compared to the cropped areas. Of 19 predatory species, on which statistical analysis was performed, 14 did not show a significant preference. Of the five species that showed preference there was a tendency to avoid the crop, two species preferred a grass and wildflower mix, two preferred a tussocky grass mix and one preferred a split margin of both treatments (Meek, *et al.*, 2002).

The impact of habitat type and landscape structure on biomass, species richness and functional diversity of ground beetles was investigated by

Woodcock *et al* (2010). Over the sampling period 42 species of ground beetle (Phytophagous =13 Predatory = 29) were identified. Phytophagous (plant eating) ground beetle biomass responded significantly to local habitat type. Both natural regeneration and wild bird margins supported significantly higher biomass of phytophagous beetles than the crops. The predatory beetle species showed no response to local habitat type. There was a negative correlation between the biomass of predatory beetles and the diversity of habitat types within the landscape. The biomass of both predatory and phytophagous ground beetles showed a negative correlation with the proportion of tussock grass field margins. There was no influence on the functional diversity of phytophagous beetles from landscape structure. It seems predatory beetles in agricultural landscapes are typically food limited, this allows them to follow resources that show a high degree of spatial and temporal variability. As habitat diversity increases, so will the variability in potential prey insects, this variability seems to have a negative effect on carabid total biomass.

Increasing habitat diversity has a negative effect on total biomass of *Carabidae*, as the cover of their primary habitats is reduced (Woodcock, *et al.*, 2010). It is argued by Lengyel, Deri and Maguira (2016) that vegetation height, vegetation structure, prey, shade and humidity are all more important than the taxonomic diversity of plants to carabid species. Although results found by Zou *et al.* (2013) found that herb diversity was positively correlated with beetle abundance, conversely shrub diversity was the opposite, and negatively correlated.

Studies comparing different sown field margins had varying results. Meek *et al.* (2002) claims that in their study predatory insects showed no preference to the margins such as wildflower, tussocky grass, and mixed grass and wildflower mix. The only trend shown in predatory insects was that they avoided the cropped areas. Woodcock *et al.* (2010) found similar results, their study revealed although phytophagous beetle species showed response to margins, predatory beetles showed little response to local habitat type. This is believed to be because predatory beetles are typically food limited, so will show high degrees of spatial and temporal variability. As the diversity of the habitat increases so will the variability of their prey. Woodcock *et al.* (2010) concluded that if you increase the habitat diversity for ground beetles it will have a negative effect on their biomass. It was found in a separate study by Yanahan (2013) that the degree of canopy cover at a site was an important factor explaining carabid distribution, responses of ground beetles on both disturbed land and savannah were positively influenced by grass ground cover

and canopy percentage cover. This would agree with Deri and Maguira (2016) whose theory that height, structure and shade are more important aspects for *Carabidae*.

Research by Asteraki *et al.* (2004) contradicts that of Woodcock *et al.* (2010), as their study on a Royal Agricultural College farm in the west of England found that margins with complex vegetation produced a greater diversity and abundance of beetles, opposed to that increasing the habitat diversity for ground beetles will have a negative effect on their biomass.

Research completed by Asteraki *et al.* (2004) at a Royal Agricultural College, on a farm in the west of England, compares the factors influencing the plant and invertebrate diversity of arable field margins. Two field margins were managed for each conventional and organic method. Over a two-year period plant and invertebrate species were recorded. The data collected on invertebrates showed a strong positive correlation between predatory insect abundance and plant species richness. Also, that predatory insect abundance was significantly higher in the organically managed plots than the conventionally managed ones. In the second year of study significantly more predatory species were trapped in the natural regeneration plots. Farming system and crop type influenced beetles, with the species being significantly correlated with plant diversity. Margins with a complex seed mixture and reduced agricultural input had a higher diversity and abundance of beetles (Asteraki, Hart, Ings, & Manley, 2004).

Research on wildflower strips has been shown to increase the abundance of predatory species, but there is little evidence on the impacts on pest populations. Research by Skirvin *et al.* (2011) for the University of Warwick investigated aphid numbers on lettuce plots with and without adjacent wildflower strips. The plots with adjacent wildflower strips led to a decrease in aphid numbers within 10 metres during July and June, but less of an effect in August and September. Results suggested that wildflower strips can lead to increased natural regulation in lettuce crops but more research is needed to determine how this is mediated and changes during the growing season (Skirvin, Kravar-Garder, Reynolds, Wright, & Mead, 2011).

The research by Skirvin *et al.* (2011) found that having diverse wildflower marginal strips around a field of lettuce lead to decreased aphid numbers in the crop, this was deemed to there being more predatory species present in the margins. Studies by Zurbrugg and Frank (2006) and Thomas and Marshall (1999) also agreed that the promotion of diverse margins such as wildflower

mixes would help increase abundance and diversity of beneficial insects and reduce pests.

‘The enemies hypothesis’ states that predatory insects are more effective at controlling populations of pest species in diverse systems of vegetation than in simple ones. Results by Russell (1989) found that 69% of studies showed higher mortality rates of pests in more diverse systems of vegetation. This could suggest that more diverse field margins could see higher rates of predation in adjacent fields.

## Summary

Research into *Carabidae* could further aid in producing more suitable habitats and increase biological controls. This could prove vital to the development of pest control techniques and crop protection, especially in organic agriculture where pesticide use is limited. It seems studies regarding field margin management have led to differing views. Studies by Asteraki *et al.* (2004) and Thomas and Marshall (1999) agree complex margins produce greater diversity and abundance of beetles, this would agree with the ‘enemies hypothesis’, of which Russell (1989) investigated. Zou *et al.* (2013) found that beetles abundance had a positive relationship with herb diversity. Conversely, Studies by Woodcock *et al.* (2010) and the GWCT (2015) show the presence of complex margins have a negative effect on biomass and abundance, or make little difference to abundance respectively. The study by Meek *et al.* (2002) concluded *Carabidae* have no preference towards differing field margins.

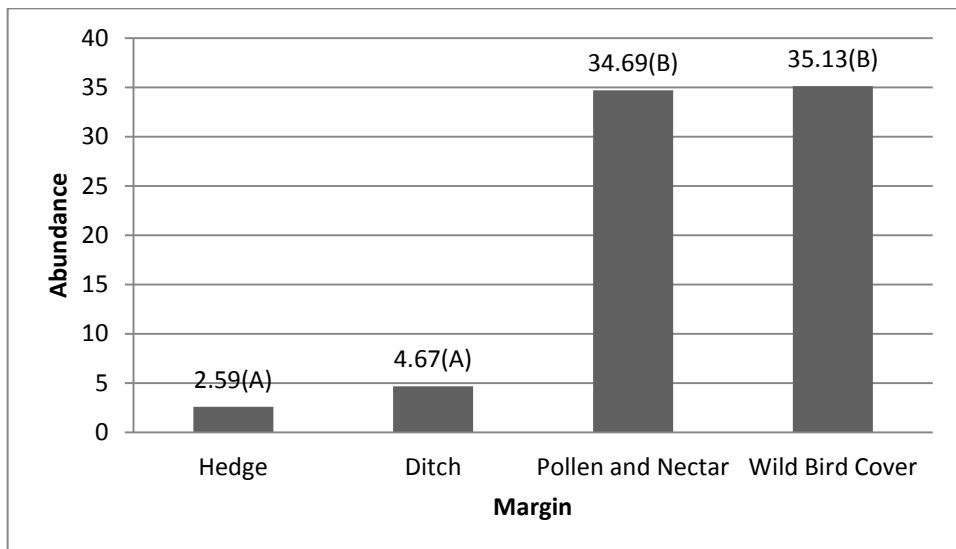
Studies mainly focus on the effects of sown grass and wildflower strips. There is little mention of hedges apart from Zou *et al.* (2013) who found shrub diversity had a negative effect on *Carabidae* abundance. There was no mention of ditches and their effects on *Carabidae* abundance and species richness. There is no definitive answer as to which field margins hold the most diverse populations of *Carabidae*, and many studies contradict each other. This forms a good basis for investigation into how differing field margins compared to each other and their effect on *Carabidae* diversity. The absence of studies into ditches and hedges and their effects on *Carabidae* diversity and abundance leaves a gap in research where investigation would be beneficial. Comparing traditional methods such as hedges and ditches, to methods in environmental stewardship schemes, such as pollen and nectar and wild bird cover mixes, could provide evidence on what margins organic

farmers could use to increase natural predation and consequently crop protection.

## RESULTS

### *Carabidae* Abundance

A total of 6165 individuals from eighteen species were identified from the 40 pitfall traps over the sampling period. The mean abundance was calculated for each field margin type. Figure 1 shows the mean number of individuals per replicate for each margin type. It was found that pollen and nectar, and wild bird mix cover margins had significantly different means from hedge and ditch margins ( $P < 0.001$ ).



**Figure 1** Mean *Carabidae* Abundance per Margin Type (Source: Author 2016)

Species	<i>Pterostichus niger</i>	<i>Pterostichus melanarius</i>	<i>Harpalus rufipes</i>	<i>Clivina fossor</i>	<i>Carabus violaceus</i>
Total Count	2137	2305	1401	252	26
Hedge	0.875 <sub>a</sub>	0.963 <sub>a</sub>	0.438 <sub>a</sub>	0.137 <sub>a</sub>	0.038 <sub>a</sub>
Ditch	2.075 <sub>a</sub>	1.463 <sub>a</sub>	0.950 <sub>a</sub>	0.163 <sub>a</sub>	0.013 <sub>a</sub>
Pollen & Nectar	11.725 <sub>b</sub>	12.150 <sub>b</sub>	8.288 <sub>b</sub>	1.950 <sub>b</sub>	0.238 <sub>b</sub>
Wild Bird Cover	12.038 <sub>b</sub>	14.238 <sub>b</sub>	7.838 <sub>b</sub>	0.900 <sub>ab</sub>	0.038 <sub>a</sub>
Significance	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001

**Table 1** Total Count and Mean Numbers of Statistically Significant Carabidae in Differing Margins. Source: Pitfall Trap Data.

(NS – Not Significant. NT – Not Tested P = P Value of significance. Numbers with no letters in common are significantly different to one another)

Twelve of the eighteen species found over the sampling period were not statistically analysed, due to there being counts of less than ten for those individual species which is not a large enough sample to analyse for abundance. *Amara similata*, *Calathus rotundicollis*, *Demetrias atricapillus*, *Harpalus affinis*, *Leistus ferrugineus*, *Leistus terminatus*, *Loricera pilicornis*, *Nebria brevicollis*, *Nebria salina*, *Platynus assimilis*, *Trechus obtusus* and *Trechus quadristriatus* were the species omitted from the generalised linear model.

All species found were native species and classified as ‘least concern’ by Natural England’s Red Data Book species list (Natural England, 2016). Species were all found to prefer a mix of agricultural land, hedgerows, grasslands and peaty soils. No species were deemed ‘out of place’ as the locations matched the species’ autecological requirements (Naturespot, 2016). Of the 18 species found, 17 were polyphagous (predatory) species, which prey on aphids, slugs and snails. Only one species *Harpalus rufipes* was granivorous, which feed on seeds.

### ***Carabidae* Species Richness**

*Carabidae* species richness was highest in pollen and nectar margins where ten species were found during sampling, eight species were found in hedge margins, seven species were found in wild bird cover margins and four were found in ditch margins (Table 2).

### **Floral Species Richness**

Hedge and ditch margins provided the highest mean cover percentage at 144.75% and 134.5% respectively (Table 3). These two were not significantly different to each other, but were statistically different to pollen and nectar. Wild bird cover provided a mean cover of 131.25% this was not statistically different to either hedge, ditch or pollen and nectar. Pollen and nectar margins provided a cover of 103.1%. The floral species richness was highest in pollen and nectar with 17 species, Hedge margins provided an average of 15.5, ditch margins 14 and wild bird cover 13.

Margin Type	Carabidae Species Richness	Species Richness Excluding Individual (1)	Carabidae Abundance per Replicate	Mean Carabidae per Replicate	Significance
Hedge 1	5	4	89	2.225 <sup>a</sup>	P<0.001
Hedge2	8	6	207	2.59 <sup>a</sup>	P<0.001
Ditch 1	3	3	99	2.475 <sup>a</sup>	P<0.001
Ditch 2	4	4	274	4.67 <sup>a</sup>	P<0.001
P&N1	8	7	1197	29.93 <sup>b</sup>	P 0.085
P&N2	10	7	1578	34.69 <sup>b</sup>	P<0.05
WBC 1	7	5	1932	48.3 <sup>c</sup>	P<0.05
WBC 2	6	5	2810	35.13 <sup>b</sup>	P<0.05
			878	21.95 <sup>b</sup>	P<0.05

**Table 2** Carabidae Species Richness and Abundance Per Margin. Source: Pitfall Trap Data.

(NS – Not Significant. NT – Not Tested P= P Value of significance. Numbers with no letters in common are significantly different to one another. <sup>?</sup> Not statistically significant <0.05, but close to being significant)



*Table 3 Species Type and Mean Percentage Cover Per Margin.  
Source: Vegetation Sample Data.*

Margin Type	Floral Species					Mean Cover	Mean Cover Combined
	Forbs	Grass	Trees & Shrubs	Total	Mean		
<b>Hedge 1</b>	10	4	4	18	15.5	163% abc	144.75% b
<b>Hedge2</b>	6	3	4	13		126.5% abc	
<b>Ditch 1</b>	8	6	1	14	14	125.5% abc	134.5% b
<b>Ditch 2</b>	9	4	1	14		143.5% abc	
<b>P&amp;N1</b>	13	0	0	13	17	117% ab	103.1% a
<b>P&amp;N2</b>	17	4	0	21		89.2% a	
<b>WBC 1</b>	15	4	0	19	13	106.0% ab	131.25% ab
<b>WBC 2</b>	6	1	0	7		156.5% abc	

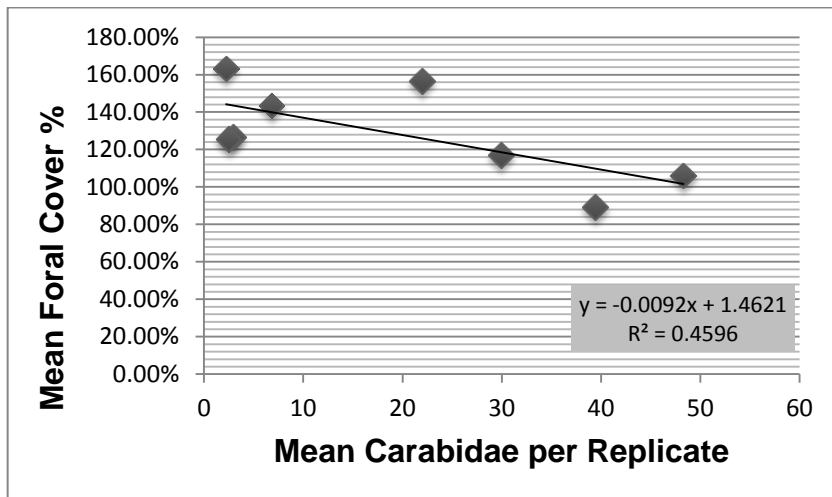
### **Relationships Between Vegetation and *Carabidae*.**

Figure 2 represents the relationship between the mean percentage cover of floral species per margin and the mean *Carabidae* found per replicate. The R<sup>2</sup> value (0.46) indicates a significant negative linear relationship.

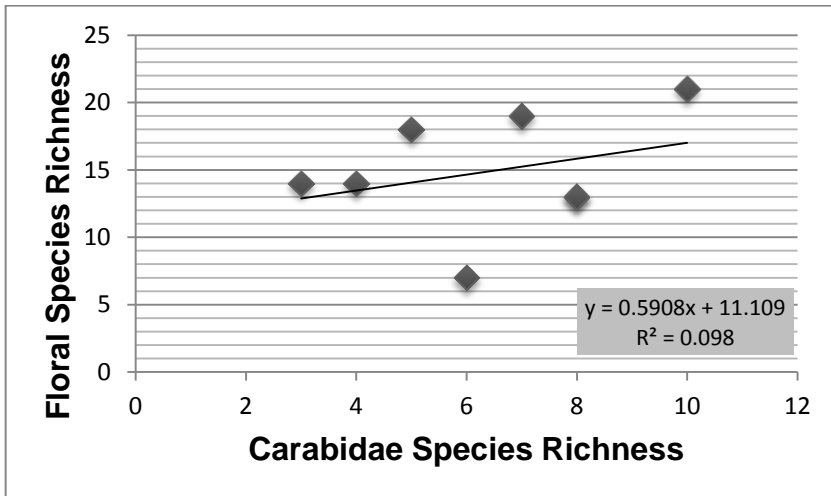
Figure 3 represents the relationship between floral species richness and *Carabidae* species richness. The R<sup>2</sup> Value (0.01) indicates a very weak almost non-existent relationship.

Figure 4 shows the relationship between total percentage of floral cover and *Carabidae* species richness. It is shown that as cover decreases, *Carabidae* species richness increases, this is reflected in the moderate negative linear relationship ( $R^2$  0.41)

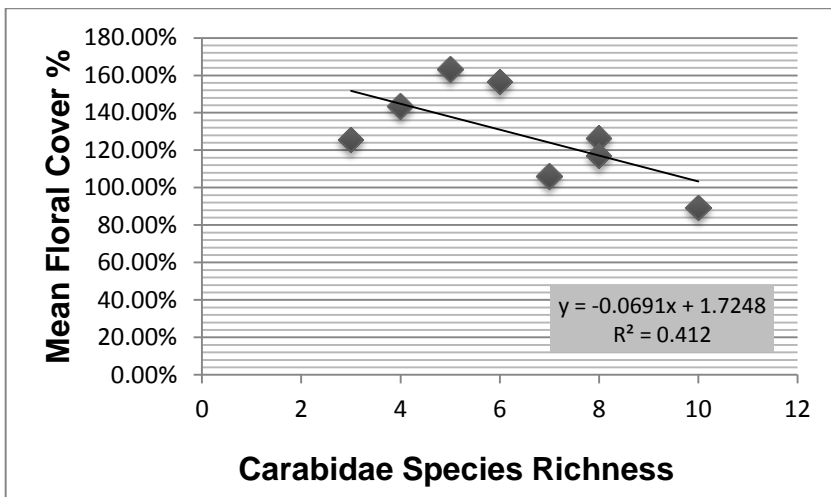
Figure 5 shows the relationship between *Carabidae* species richness and the total abundance of *Carabidae*. As species richness increases, total abundance increases, this is represented by a moderate positive linear relationship ( $R^2$  0.4).



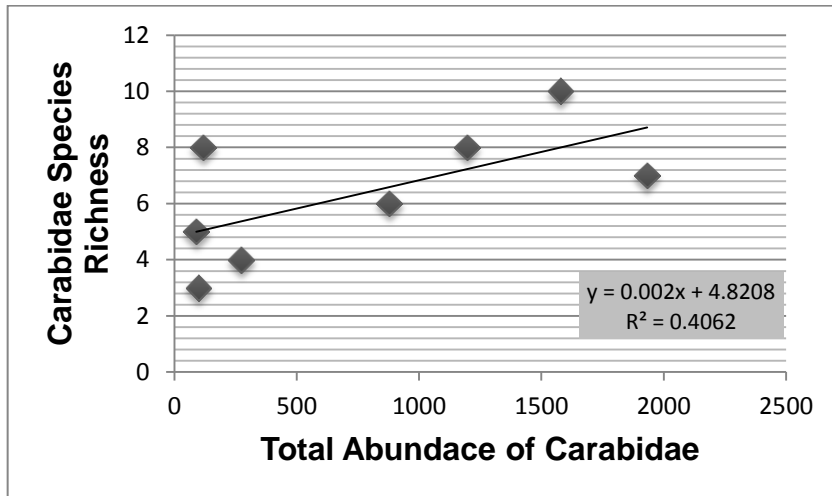
**Figure 2** Floral Cover v Mean *Carabidae*. (Source: Author, 2016)



**Figure 3** Floral Species Richness v *Carabidae* Species Richness (Source: Author, 2016)



**Figure 4** Mean Floral Cover v *Carabidae* Species Richness (Source: Author, 2016)



**Figure 5** *Carabidae* Species Richness V Total *Carabidae* Abundance (Source: Author, 2016)

## DISCUSSION

### Relationships between *Carabidae* and vegetation cover.

Vegetation cover seemed to influence the mean abundance of *Carabidae* substantially. Margins with significantly higher average percentage covers, in this case hedge and ditch, produced the lowest average abundance of *Carabidae* in the study. These findings disagree with Kirby (2001) who found the greater complexity and variety in vegetation structure, the greater the variation of species. It also differs from Hill *et al.* (1995) who found unmanaged areas of grassland to be the most beneficial margin to *Carabidae* abundance. In this case the unmanaged grass margins (ditch margins) had lower *Carabidae* abundance. The two remaining margins (pollen and nectar and wild bird cover) produced the highest mean abundance. From Figure 2 it can be observed that there is a moderate negative linear relationship between cover and mean *Carabidae*. These findings are similar to that of Zou *et al.* (2003) who found increased beetle abundance in diverse herbaceous areas and Asteraki (2004) who found wildflower areas increased natural predatory species compared to others. It could be argued that as cover decreases it would be easier for *Carabidae* to hunt their prey due to more open areas; it has previously been stated by Kirby (2001) that bare ground areas are

important places for invertebrates to bask, higher cover may reduce the areas suitable for basking.

Vegetation cover had a similar effect on *Carabidae* species richness; it was observed that as percentage cover increased, the number of carabid species found decreased. This was represented by a moderate negative linear relationship (Figure 3). Species richness was highest in pollen and nectar margins, which were the margins with the lowest vegetation cover. Margins with the highest cover percentage such as hedges and ditches provided significantly lower species richness on average. It could also be argued this is down to the same reasons as the trend found for abundance; margins with higher cover may prove difficult to hunt in and provide less areas suitable for basking.

### **Vegetation Cover and Floral Species Richness**

Vegetation cover had a moderate effect on floral species richness, as cover percentage increased on margins, floral species richness declined. Margins such as hedges were dominated by large shrub species such as *Crataegus monogyna*, this contributed for most of the cover percentage, with small amounts of other grass and forbs species present. This may be down to competitive species dominating the margins cover percentage, species such as *Crataegus monogyna* will outcompete other species such as forbs and grasses for light, water and nutrients (Craine & Dybzinski, 2013). In margins where cover was spread over a range of different species, for example wild bird cover and pollen and nectar, there were no shrub species. All species found were grasses or forbs, these margins lead to the most floral species being found, this suggests that the presence of shrubs negatively affected floral species richness. Ditch margins had the lowest floral species, this may be due to the fact that they relied totally on natural establishment, with all other margins being planted with a planned species mix. Ditch banks were dominated by a mix of grasses and forbs, which provided most of the cover and subsequently most of the floral species richness. Margins such as the pollen and nectar mix and wild bird cover have a higher species richness, as they are specifically drilled from calculated seed mixes, this coupled with no dominating large species being present provides an opportunity for smaller forb species to thrive.

### **Vegetation Species Richness and *Carabidae***

Vegetation species richness as vegetation cover seemed to influence the mean abundance of *Carabidae*. However unlike vegetation cover, the link between

floral species richness and *Carabidae* abundance is a positive correlation, albeit a weak relationship. These findings agree with Kirby (2001) who found a greater complexity and variety of floral species, the greater the possibility of a large variation in invertebrate species. This relationship may be due to higher vegetation species richness providing a larger number of prey species. It has been found that plant species richness increases insect herbivores and consequently predators such as *Carabidae* (Ohgushi, 2012).

Vegetation species richness had no effect on *Carabidae* species richness. Pollen and nectar margins had the highest number of floral species and the highest species richness of *Carabidae*. Conversely, in ditch margins where floral species were at their lowest, so was *Carabidae* species richness.

### **Vegetation Type and *Carabidae*.**

Vegetation type influenced the average abundance of *Carabidae*, margins dominated by large populations of forbs (pollen and nectar and wild bird cover) held the highest abundance of *Carabidae*. This agrees with Zou *et al.* (2013) who found herbaceous diversity increased abundance of *Carabidae* and Skirvin *et al.* (2011) that wildflower strips show increases in natural predatory species, yet is contrary to the GWCT (2015) which found flower rich margins made little difference on abundance of *Carabidae*. Ditch margins dominated by grasses with small populations of forbs had a significantly lower abundance of *Carabidae*, these findings matched those of Woodcock *et al.* (2010) who found a negative correlation between grassy margins and predatory species. These findings on grassy margins contradicted Hof and Bright (2010) who found grassy margins to have the highest abundance of *Carabidae*. Finally hedges, which were primarily large tree and shrub species with small amounts of grasses and forbs, had the lowest average number of *Carabidae*. Thomas and Marshall (1999) found the opposite, their study found that hedge margins held the highest abundances and wildflower margins were lower.

Vegetation type also influenced *Carabidae* species richness. Pollen and nectar margins, populated mostly by forbs, held the highest species richness. Hedges dominated by large shrubs species with small amounts of grasses held the second highest species richness in the study, level with wild bird cover, although it should be noted that more single species counts were found in the hedge, whilst species found in wild bird cover were in greater abundance. Species richness was lowest in the margins compiled mostly of grasses. Ditches provided the lowest species richness of all the four margins. These

findings differ to that of Hof and Bright (2010) who found grassy margins to be the most beneficial. The margins with the more complex mixture of species seemed to have the greatest species richness, this complimenting the findings of Asteraki *et al.* (2004) that complex seed mixtures increased *Carabidae* abundance and diversity.

## **Soils and *Carabidae*.**

Soil results were omitted from the results and analysis as there was no significant trend.

## **Species present**

Over 6000 individual beetles and 18 species were trapped and identified during the research period. Only five species were found in enough number to be statistically significantly different to other species in terms of abundance: *Carabus violaceus*, *Clivina fossor*, *Harpalus rufipes*, *Pterostichus melanarius* and *Pterostichus niger*. Another 13 species were found in the study *Agonum muelleri*, *Amara similata*, *Calathus rotundicollis*, *Demetrias atricapillus*, *Harpalus affinis*, *Leistus ferrungineus*, *Leistus terminatus*, *Loricera pilicornis*, *Nebria brevicollis*, *Nebria salina*, *Platynus assimilis*, *Trechus obtusus* and *Trechus quadristriatus*.

## **Conservation value**

All species found during the sampling were classified as 'least concern' by Natural England's Red Data Book species list.

## **Margin Composition**

Overall *Carabidae* abundance seemed to be greatly affected by field margin composition and the species richness mildly affected. Field margin compositions were comprised of four variables: vegetation cover, floral species richness, vegetation type and soil structure. Each of the four variables were investigated to understand their influences. Vegetation cover had a 'moderate negative' relationship with abundance and species richness. As vegetation cover increased the two variables decreased. Floral species richness had very weak positive relationship with both average *Carabidae* abundance and species richness. Vegetation type proved to be influential in determining both the abundance and species richness of *Carabidae*. Margins dominated by forb species held the highest average abundances and species richness of *Carabidae*. Grass dominated margins held the second lowest average abundance and the lowest species diversity whilst Tree/Shrub

dominated margins held the lowest abundance and the second lowest species diversity. Soil structure did see differing effects on carabid abundance and species richness although it was investigated using only basic secondary data, therefore should only be used as a guideline. *Carabidae* abundance was highest on clay/loam soils, second highest on sandy soils and the lowest on deep peat soils. Species richness showed a different trend, being highest on sandy soils, clay/loam soils provided the second highest species richness and deep peat soils again providing the lowest value

## CONCLUSION

Vegetation cover proved to be the variable with the most influence on *Carabidae* abundance and species richness. Margins with higher average covers such as Hedges and Ditches saw lower abundance and species richness, this was reflected in a moderate negative linear relationship. These areas of lower cover percentage could provide ideal hunting and basking places for *Carabidae*. Vegetation species richness seemed to affect *Carabidae*, as floral species richness increased so did *Carabidae* abundance, although this was represented by a weak trend. Vegetation species richness had no effect on *Carabidae* species richness.

Statistically significant results were obtained between the different margins, with the average abundance of the five species of *Carabidae* significantly higher in the two OELS schemes than that of traditional methods. The abundance of *Carabidae* could be linked with two independent variables: vegetation cover and floral species richness. Margins in the OELS scheme had a significant difference in both abundance and species richness of *Carabidae*. The conditions provided by both pollen and nectar mix and wild bird cover mix margins found a substantially larger average abundance of *Carabidae* than hedge and ditch margins and higher average species richness.

If the research project were to be carried out again it would be useful to investigate the vegetation in more depth. Vegetation height and bare ground could be sampled to give a more accurate representation of the vegetation structure. Soils could also be investigated further, soils in this research project were profiled using solely secondary data and it would be beneficial to take samples at the same sites as vegetation samples. More traps in a gradient from the field margin in to the crop centre would give some insight into the abundance and species richness of *Carabidae* in the crop, and the investigation of yield assessment of crops in relation to abundance, distribution and diversity of *Carabidae* would be beneficial to organic



farming. GPS grid references could be taken at each trap location to enable mapping programmes to be used. Weather conditions during the survey period could be analysed to investigate the influence on sample numbers and species diversity. It may also be beneficial to investigate a twin study on a conventionally managed farm, to establish the differences in *Carabidae* between the two.

The project has been successful in answering the research questions. It has investigated the relationships between the composition of field margins and their effects on ground beetle abundance and species richness. It has been learned from the report that OELS schemes host a greater abundance and species richness of *Carabidae* than traditional field margin methods. Evidence from the literature review and the survey results suggest it that the introduction of more OELS margins could increase the numbers of natural predators, and consequently reduce pest species. This would improve overall crop yield for organic farmers. The project serves as a good basis for potential research in the future. Working closely with representatives from Pollybell Organic Farms throughout the study it had been clear that the results will prove valuable to them and aid them in making commercial decisions.

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# **THE CLEARFELLING OF EXOTIC CONIFER TREES: THE EFFECTS ON SOME SOIL CHEMICAL PROPERTIES AT SNAKE WOODLAND IN THE PEAK DISTRICT.**

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In several cases the clearfelling of non-native conifer plantations in Britain has resulted in soil acidification and soil nutrient losses when brash is left to decompose *in situ*. It is important to understand the implications of clearfelling to inform future felling techniques and land-use planning. There are no published studies on the effects of clearfelling in the Peak District. This study was therefore sited at Snake Woodland in the Peak District. The aim was to examine the effects of clearfelling on selected soil properties including soil acidity, soil organic matter content and soil nitrate, phosphate, potassium and magnesium concentrations. A chronosequence methodology was used. The study showed that soil acidity and magnesium concentration initially increased following clearfelling, later falling. Soil nitrate concentration declined and remained at this level for the whole chronosequence period. Soil organic matter content and soil phosphate and potassium concentrations were not affected by clearfelling. The results support the theory that clearfelling can cause soil nutrient depletion and soil acidification.

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Keywords: Acidification, Clearfelling, Forestry, Leaching, Nutrient, Soil organic matter, Soil quality

## INTRODUCTION

In Britain, a great decline in timber stocks occurred during the First and Second World Wars, largely owing to timber use in trench warfare and the cessation of imports. Following the wars, to restore stocks, much afforestation with non-native conifer species took place, mostly in the uplands where soil was widely unsuitable for agriculture (Forestry Commission, 2015). During the 1980s, it began to emerge that conifer forestry was having catchment-wide effects, the initial concern being the acidification of surface waterbodies (Nisbet and Evans, 2014). The changed, more conservationist attitude to the environment of the 1990s led to the focus of forestry being more than simply commercial (Elands *et al.*, 2010). The new focus was, and still is today, sustainable management practice - one where production, recreation and environmental conservation should be achieved synergistically at both the standing crop stage and on felling (Forestry Commission, 2015). The Forestry Commission (2016a) now encourages the planting of native broadleaf species in forestry, often incorporating them into second conifer crop rotations. This is to improve biodiversity and restore some native woodland habitat (Forestry Commission, 2016b). Conifer trees are generally harvested once they reach 60 years of age so much clearfelling of post-war plantations has taken place in the past three decades (Nisbet and Evans, 2014). Problematically, the brash which is commonly left behind after clearfelling can provoke soil nutrient losses and acidify the soil (Stevens *et al.*, 1995; Nisbet and Evans, 2014; Hornung, Stevens and Reynolds, 1987) (when clearfelling is mentioned hereafter it is meant in the sense that brash was left behind).

Soil nutrient losses and soil acidification are likely to have an impact on soil quality (Brady and Weil, 2014). The understanding of such impacts is essential if broadleaf and second rotation conifer species or any other vegetation species are to be grown on clearfelled plantation soils. Such an understanding can also inform future felling techniques and post-clearfelling management of the land. Soil quality itself cannot be directly measured and is instead investigated using a minimum dataset of chemical, biological and physical soil properties as indicators. It can only be determined if the 'ideal'

state of the soil is known so that an inherently similar, largely undisturbed soil can be used to derive benchmark values from. The indicator values can then be assessed against these benchmark values. How the results are interpreted in terms of soil quality depends on the future land-use of the site (Karlen, Ditzler and Andrews, 2003; Kinyangi, 2007; Soil Quality, 2011a). Benchmark values were not available for the study site's soils nor was its future land-use ascertained. Therefore, the purpose of this study is not to draw firm conclusions regarding soil quality itself, but to provide insight into some effects of clearfelling as step towards achieving this. This study thus aims to examine some of the effects of clearfelling on some soil quality indicators. To do so, two objectives have been set, focussing on soil quality indicators (Soil Quality, 2011b):

- To determine if soil nutrient concentrations and soil organic matter (SOM) content change with time since clearfelling relative to unfelled conditions.
- To determine if soil acidity changes with time since clearfelling relative to unfelled conditions.

## **LITERATURE REVIEW**

### **The Issues with Conifer Afforestation**

A predominant issue with conifer planting is soil acidification. In Britain, the majority of conifer afforestation has taken place in the uplands, where the land use was previously moorland or rough pasture. As the trees are taller than previous shorter vegetation, they reach the height where atmospheric acidic pollutant concentrations are potentially higher. Acidic pollutants are absorbed by the conifer trees and can acidify the soil when needles drop and decompose (Nisbet and Evans, 2014; Emmet *et al.*, 1993). Additionally, conifer trees take up a higher quantity of base cations than shorter vegetation due to their larger size, potentially reducing the soil's buffering capacity. The rate of uptake is at its highest in the first 15-20 years of the trees' standing crop phase, as this is when they experience the fastest growth (Nisbet and Evans, 2014).

### **The Issues with Conifer Clearfelling**

Problems do not merely occur at the standing crop phase of conifer forestry, but also following clearfelling (Nisbet and Evans, 2014). There has not been a

large market for non-timber parts of trees in Britain and thus brash is usually left to decompose *in situ* after clearfelling. This is convenient as the crown of the tree is rich in nutrients which can be returned to the soil (Stevens *et al.*, 1995; Bormann *et al.*, 1968). However, brash can promote soil acidification and soil nutrient losses (Nisbet and Evans, 2014).

### *Soil Acidification*

The shading caused by the brash creates generally warmer and moister conditions immediately above the soil and better protects the soil from temperature extremes. Such conditions allow the improved functioning of nitrobacter in the nitrification process (Emmett, Anderson and Hornung, 1991; Hornung, Stevens and Reynolds, 1987; Brady and Weil, 2014). An implication of an increased nitrification rate is soil acidification because of the hydrogen ions released during the oxidation of each ammonium ion. Once added to the soil, hydrogen ions can replace exchangeable nutrient base cations on the cation exchange sites of colloids. This leaves the base cations vulnerable to leaching which eventually can lead to a reduction of the soil's buffering capacity (as well as soil nutrient losses) (Ashman and Puri, 2002). When hydrogen ions are adsorbed onto clay colloids they can cause dissolution of the colloid. Aluminium is a major constituent of clay particles and during this process, inorganic aluminium ions are released and adsorbed onto other colloids' cation exchange sites. Aluminium ions are highly toxic to most organisms. Moreover, they tend to hydrolyse, releasing more hydrogen ions and further acidifying the soil (Brady and Weil, 2014). Acidification of catchments through conifer planting has caused elimination of many plant and invertebrate taxa and the distribution and density of some higher animal species have been reduced (Hock and Elstner, 2005).

### *Soil Nutrient Losses*

Soil nutrient losses may increase after clearfelling because the under-brash microclimate commonly inhibits the regrowth of vegetation. As a result, any nutrients leached from the brash are not immobilised by plants and, depending on the nutrients' mobility, can be leached from the soil (Hill, 1986; Bormann *et al.*, 1968; Emmet, Anderson and Hornung, 1991). Additionally, soil throughflow may increase following clearfelling because of the large reduction in transpiration associated with tree elimination, washing nutrients from the soil. The trees' roots no longer take up nutrients, leaving them prone to leaching (Bormann *et al.* 1968; Emmett, Anderson and Hornung, 1991; Stevens *et al.*, 1995). The most immediate cause of ecosystem nutrient



depletion though is the removal of the tree trunk because of the nutrients immobilised within it (Bormann *et al.*, 1968; Stevens *et al.*, 1995).

Not all nutrients behave in the same way after clearfelling in Britain by three key studies. Adamson *et al.* (1987) measured nutrient concentrations in water draining an entire clearfelled Sitka spruce plantation for two years. Building upon this by measuring nutrient concentrations in leachate from individual horizons, Stevens *et al.* (1995) investigated soil nutrient losses of clearfelled Sitka spruce plantations for five years following clearfelling. Rather than measuring soil nutrient losses in leachate or plot drainage water, Titus and Malcolm (1991) focused on LFH (litter, fermentation, humus) horizon nutrient concentrations of three former Sitka spruce plantations clearfelled at different times. The time since clearfelling ranged from zero to five years, the purpose of this being to investigate the five year effects of clearfelling using a chronosequence methodology.

A nitrate pulse in soil leachates following clearfelling has been widely reported, often attributed to increased nitrification rates under brash and a consequent increase in soil nitrate concentration (e.g. Neal *et al.*, 1992; Emmet, Anderson and Hornung, 1991; Stevens and Hornung, 1988). Unlike base cations, nitrate ions are negatively charged - as are the majority of colloids. Therefore they are rarely adsorbed onto exchange complexes and so are more vulnerable to leaching (Brady and Weil, 2014). Despite these theories, Stevens *et al.* (1995) found that nitrate concentrations in LFH horizon leachate were unaffected by clearfelling. Similarly, Adamson *et al.* (1987) did not find a change in plot drainage water nitrate concentration. Nonetheless, the loss of soil nitrate is a particularly prevalent issue because of the ion's high mobility, and such a loss can reduce the soil's plant available nitrogen source (Brady and Weil, 2014). Furthermore, a high concentration of nitrate in catchment streams can cause eutrophication (Likens *et al.*, 1970).

In acid soils phosphate tends to react with aluminium or iron ions. In these aluminium- and iron-bound forms, soil phosphate is insoluble and largely unavailable for plant uptake (Brady and Weil, 2014). In Britain, current and former conifer plantation soils are commonly acidic (Nisbet and Evans, 2014) which could pose a problem for the plant availability of soil phosphate (Brady and Weil, 2014). Stevens *et al.* (1995) recorded a phosphate concentration pulse in LFH horizon leachate during the year after clearfelling coinciding with the peak in phosphate concentration in brash leachate. In subsequent years its concentration declined. Adamson *et al.* (1987) found that drainage water phosphate concentrations were higher relative to pre-felling and control

plot measurements in the two years following clearfelling. In most soils, the majority of soil phosphate does not leach (Brady and Weil, 2014; Neal *et al.*, 2003; Hornung, Stevens and Reynolds, 1987) due to its insolubility, so these results may be surprising. However, a small fraction is soluble and leachable (Brady and Weil, 2014), and this may have been what was detected in these studies.

Unlike soil phosphate, soil potassium rapidly leaches (Brady and Weil, 2014), a theory supported by all three of the key studies. Stevens *et al.* (1995) found that potassium concentrations in the LFH horizon leachate peaked during the first year post-clearfelling. In subsequent years the concentration decreased to less than pre-felling levels. According to Adamson *et al.* (1987), drainage water potassium concentration was elevated during the first two years post-clearfelling relative to the control plot's drainage water's concentration. Titus and Malcolm (1991) found that potassium concentrations declined with time since clearfelling in the LFH horizon. Potassium losses *via* leaching tend to be greater in acid soils where there is a high concentration of aluminium ions. On the exchange complex, aluminium ions are more difficult for potassium ions to replace compared to ions more greatly associated with alkaline soils, for example magnesium and calcium. Thus, potassium ions are more prone to leaching in acid soils (Brady and Weil, 2014).

Titus and Malcolm (1991) concluded that LFH horizon magnesium concentrations were largely unaffected by clearfelling. Plot drainage water concentrations were found to decrease relative to pre-felling and control levels by Adamson *et al.* (1987) although this was because of the increased volume of water draining the plots following tree elimination. The overall output of magnesium increased, thought to be because of increased litter and root decomposition and the cessation of root uptake.

### *The Role of Soil Organic Matter*

Soil organic matter (SOM) is a source of colloidal material, providing exchange complexes allowing the soil to retain and provide plant nutrients - this being one of its key roles. SOM content only tends to change through long-term site management (Brady and Weil, 2014). Conifer forestry, including clearfelling, is an example of long-term site management. Landsberg and Sands (2011) predicted that after an initial increase in SOM from brash decomposition, eventually clearfelling could lead to an overall reduction in SOM. This was attributed to growth and increased activity of the microbial community stimulated by the moister and warmer under-brash microclimatic conditions, increasing SOM decomposition.

## **RESEARCH METHOD**

Samples were taken from three former conifer plantations clearfelled in 2005, 2012 and 2013, along with an unfelled control conifer plantation in Snake Woodland, The Peak District (Figure 1). Snake Woodland was selected as the study site because, as seen in Figure 2, it has areas which have been clearfelled at different times meaning that a chronosequence of clearfelling effects can be made, allowing the long-term effects of clearfelling to be studied over a shorter time period (Titus and Malcolm, 1991). The site was also selected because it is in an upland area of Britain (plot altitudes range from 390-430 m AOD (Ordnance Survey, 2016)), increasing its representivity of other upland sites where the majority of conifer afforestation and clearfelling in Britain has taken place (Nisbet and Evans, 2014).

It is assumed that the plots represent a timeline: plots clearfelled in 2013, 2012 and 2005 represent the two, three and ten year effects, respectively, of the clearfelling of the unfelled plot (samples were taken in November 2015). Any differences in the measured soil properties between the unfelled and clearfelled plots are assumed to be because of clearfelling. Differences between the clearfelled plots are assumed to represent temporal changes following clearfelling.

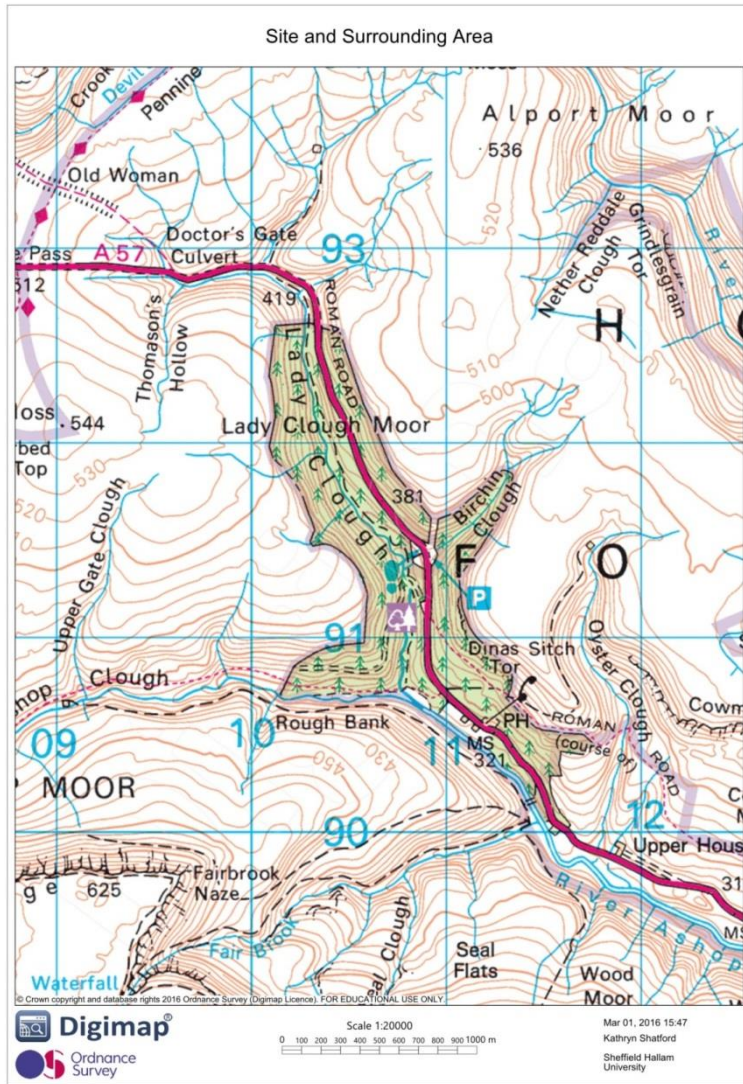


Figure 1. Snake Woodland and surrounding area. Scale 1:20000 (Ordnance Survey, 2016)

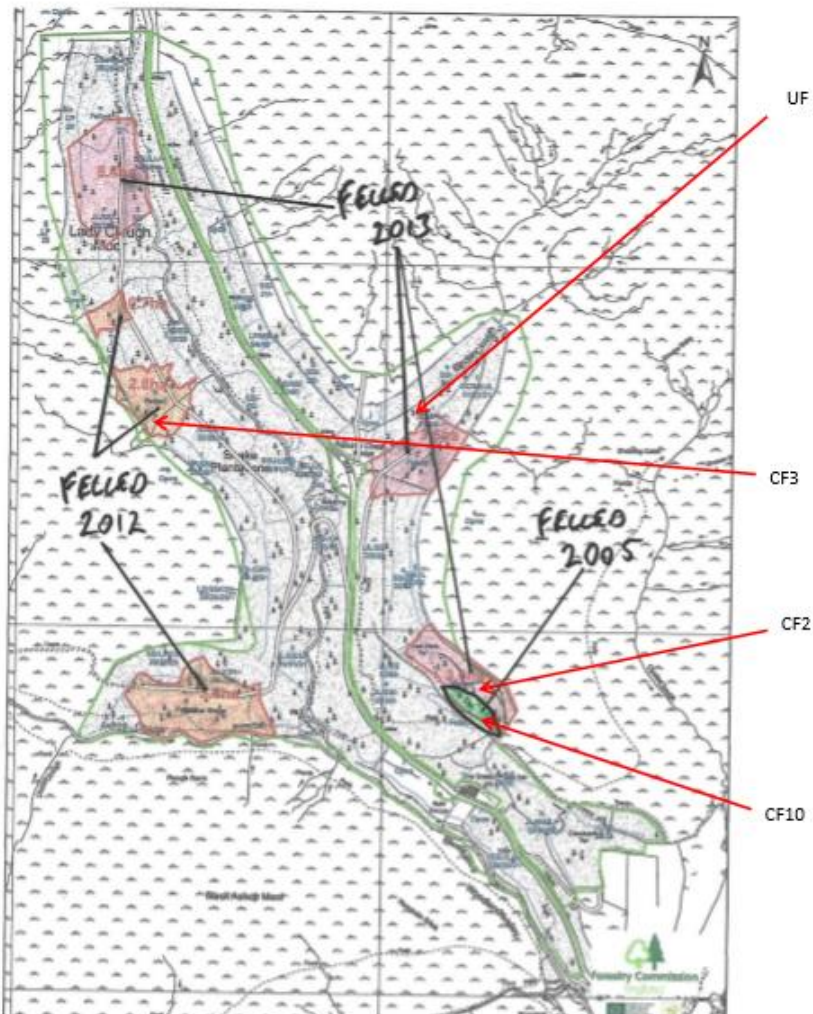


Figure 2. Clearfelled areas, dates of clearfelling and sampling plots. Adapted from Forestry Commission (no date).

To ensure comparability as much as possible plots were selected which, before clearfelling, consisted of the same planted species of Sitka spruce (*Picea sitchensis*) and Japanese Larch (*Larix kaempferi*), with the control plot's current species matching these (Albin Smith, 2015. *pers. comm.*) All plots overlie the same geology of Shale Grit - Sandstone (BGS, 2016) and all





have the same classification of broad soil type of sandy podsoils (Sherwood and Lincs Forest District, no date) with a wet, peaty and dominantly organic surface layer (Cranfield University, no date). Soil acidity, SOM content, soil nitrate, phosphate, potassium and magnesium concentrations were analysed; these are chemical soil quality indicators (Soil Quality, 2011b). Samples were taken from the A horizon as it is sensitive to above-ground changes (Blaser, 2010).

ADAS (1981) methods were used to determine soil acidity and SOM content: soil acidity was measured using a pH electrode and meter and SOM content was determined by loss on ignition. Photometry, using the Palintest (no date), was used to measure all soil nutrient concentrations.

The statistical significance (where the  $p$  value is  $\leq 0.05$ ) between the results for each plot was determined using the Mann Whitney U test. The plots are labelled as follows, reflecting their treatments:

- UF: Unfelled (control plot) (Figure 3a)
- CF2: Clearfelled two years prior to sampling (Figure 3b)
- CF3: Clearfelled three years prior to sampling (Figure 3c)
- CF10: Clearfelled ten years prior to sampling (Figure 3d)



	
<p><i>Figure 3a) UF: Unfelled (control plot)</i></p>	<p><i>Figure 3b) CF2: Clearfelled two years prior to sampling</i></p>
	
<p><i>Figure 3c) CF3: Clearfelled three years prior to sampling</i></p>	<p><i>Figure 3d) CF10: Clearfelled ten years prior to sampling</i></p>
<p><i>Source of images: Author, 2016</i></p>	

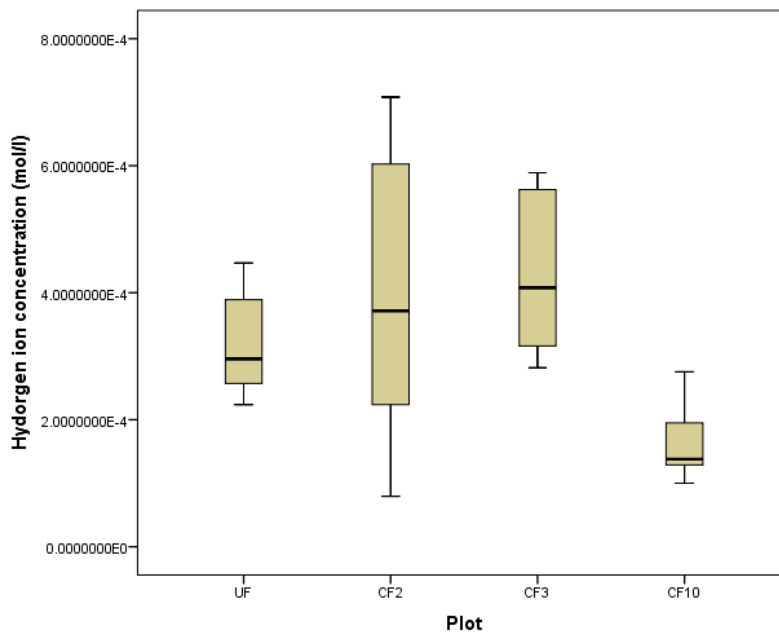
## RESULTS

The results of the soil analyses are presented by soil property using box and whisker plots. As a chronosequence methodology has been used, results are

interpreted as though they represent one plot - before clearfelling and two, three and ten years after.

## Soil Acidity

Clearfelling increased soil acidity, but not until three years after the year of clearfelling; CF3 was significantly more acidic than UF ( $p=0.037$ ). Over the next seven years it decreased to a level which was lower than all other plots; CF10 was significantly lower than UF ( $p=0.002$ ), CF2 ( $p=0.006$ ) and CF3 ( $p<0.001$ ) (see Figure 4).



*Figure 4. Soil acidity, shown as soil hydrogen ion concentration*

The significantly higher soil acidity at CF3 than at UF ( $p=0.037$ ) supports the theory that clearfelling can increase soil acidity, possibly due to the improved under-brash microclimate for nitrification (Nisbet and Evans, 2014; Emmett, Anderson and Hornung, 1991; Hornung, Stevens and Reynolds, 1987). That the soil at CF10 was significantly less acidic than that of UF ( $p=0.002$ ) may seem surprising initially because the trees growing there are, according to Nisbet and Evans (2014), in the growth stage where there is highest base



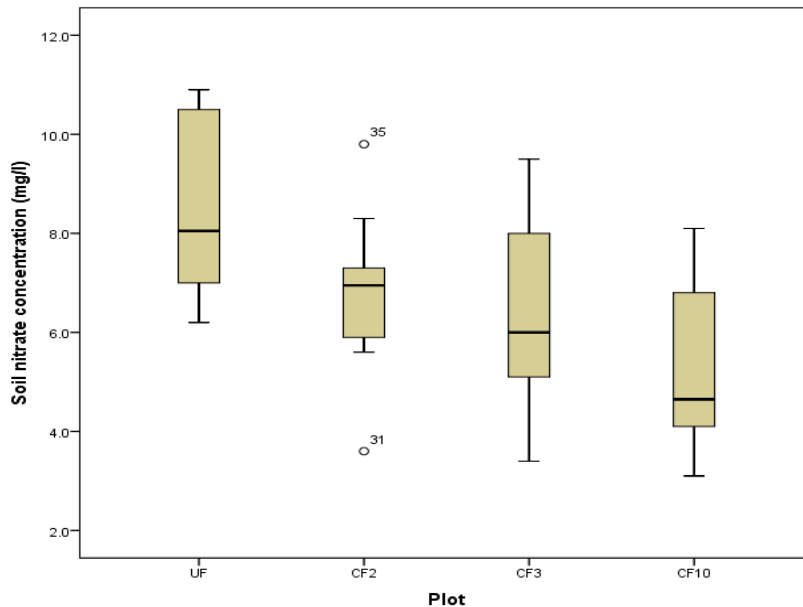
cation uptake, potentially reducing the soil's buffering capacity (Brady and Weil, 2014). However, acidic pollutant scavenging is at its most significant for taller trees and can acidify underlying soils when needles are dropped (Emmet *et al.*, 1993; Nisbet and Evans, 2014). If pollutant scavenging is prevalent at Snake Woodland and more so with taller trees, then it is possible that CF10 no longer experiences this to the same extent as UF. As CF10 was clearfelled earlier than CF2 and CF3, it would have had a longer period without the extent of atmospheric pollutant scavenging perhaps associated with pre-felling conditions, suggesting a possible explanation for the significantly higher acidity at CF10 than at CF2 ( $P=0.006$ ) and CF3 ( $P<0.001$ ).

## **Soil Nitrate**

The soil nitrate concentration (Figure 5) at UF was significantly higher than that at CF2 ( $p=0.049$ ), CF3 ( $p=0.021$ ) and CF10 ( $p=0.003$ ). There were no significant differences between any of the clearfelled plots. Stevens *et al.* (1995) and Adamson *et al.* (1987) found that nitrate concentrations of LFH horizon leachate and plot drainage waters, respectively, were largely unaffected by clearfelling. Yet statistical test results indicate that soil nitrate in this study was affected by clearfelling – by two years after its occurrence it had significantly decreased from its concentration at UF ( $p=0.049$ ). It then remained at this decreased concentration for the next eight years.

Several studies have reported a nitrate pulse in soil leachate or catchment streams of clearfelled sites soon after clearfelling (Neal *et al.*, 1992; Emmet, Anderson and Hornung, 1991; Stevens and Hornung, 1988), so the differences between UF and CF2 and UF and CF3 may be expected, as the soil could have experienced nitrate losses. Such losses may be due to an inhibiting effect on vegetation growth caused by the under-brash microclimate – something which has been reported for two-three years after clearfelling (e.g. Emmet, Anderson and Hornung, 1991; Stevens *et al.*, 1995; Bormann *et al.*, 1968). If this is the case at CF2 and CF3 then soil nitrate would not be immobilised by plants, leaving it prone to leaching (Stevens *et al.*, 1995; Emmet, Anderson and Hornung, 1991). The concentration is highest at UF - it might have been expected that any nitrate in the soil would have leached as it could have with other plots, or be immobilised by the trees. It is possible though that the unfelled trees are supplying the soil with inorganic nitrogen *via* canopy throughfall (Emmet *et al.*, 1993) so nitrates are being added perhaps faster than they are leaching/being taken up by trees.

According to Bormann *et al.* (1968), due to transpiration reductions clearfelled sites tend to have a higher water table than unfelled sites, so their conditions become more suitable for denitrification. Denitrification, although an anaerobic process, requires an aerobically generated nitrate substrate. The possible close proximity of aerobic and anaerobic conditions represented by the potentially higher water table and drier surface layers of soil (Bormann *et al.*, 1968), respectively, could thus have increased nitrate losses *via* denitrification in clearfelled plots compared to UF.



*Figure 5. Soil nitrate concentration*

Because of the young trees at CF10, soil nitrate losses may have resulted from tree uptake rather than leaching. According to Emmet *et al.* (1993) for conifer crop stands younger than 30 years old, the most important control on soil inorganic nitrogen losses is tree uptake, but in stands older than 30 years the trees are net soil nitrogen sources. Thus, the young trees present at CF10 could represent net nitrate sinks while the older trees at UF could represent net nitrate sources. Nisbet and Evans (2014) stated that the highest rate of

base cation uptake in conifer trees is during the first 15-20 years of growth. In order to maintain root charge balance during base cation uptake, roots can also take up nitrate ions (Brady and Weil, 2014). The young conifer trees are still in this stage of fast growth at CF10, so their rate of base cation uptake is likely to be high relative to trees at UF, promoting the co-uptake of nitrate, possibly explaining the significantly lower concentration at this plot compared to UF

## **Soil Phosphate**

Soil phosphate concentration (Figure 6) significantly increased between three and ten years after clearfelling ( $p=0.004$ ). However, even though this change occurred, no significant differences in concentration were found between UF and any clearfelled plot, implying that clearfelling did not have an effect on soil phosphate concentration. Adamson *et al.* (1987) found that plot drainage water phosphate concentration was significantly elevated for two years after clearfelling, suggesting soil concentrations may be significantly lower during this period (relative to unfelled conditions) but this has not been the case in this study.

Stevens *et al.* (1995) found brash to be a net phosphate source throughout five years post-clearfelling and it was predicted that it would continue to supply soil phosphate for several years. As soil phosphate is not readily leached (Neal *et al.*, 2003; Hornung, Stevens and Reynolds, 1987), the pool of exchangeable phosphate could have steadily increased over the ten years since clearfelling if the brash has indeed been a continuous soil phosphate source, maybe explaining the significant difference between CF3 and CF10 ( $p=0.004$ ). If this is the case and continues to be so, there could be an increase in soil phosphate concentration at clearfelled plots in the future relative to unfelled conditions, i.e. clearfelling could have a 'delayed' effect on soil phosphate concentration. Another possible explanation for the change between three and ten years post-clearfelling could be that soil acidity decreased over the same period, so the increase in soil phosphate may reflect an increased rate of desorption of phosphate from insoluble to soluble forms associated with a rise in pH (Brady and Weil, 2014).

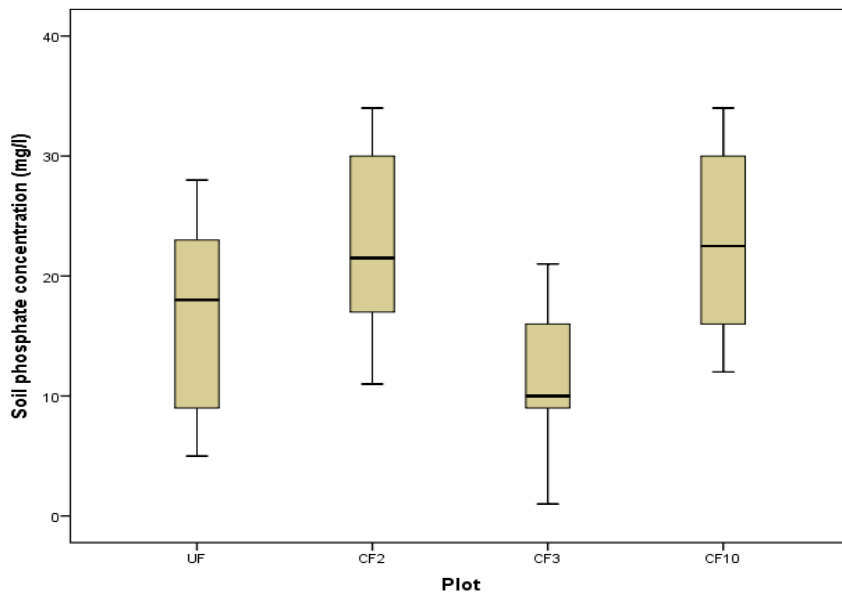


Figure 6. Soil phosphate concentration

## Soil Potassium

According to the statistical test results, soil potassium concentration did not significantly change over the ten years following clearfelling (see Figure 7). Potassium rapidly leaches (Stevens *et al.*, 1995; Adamson *et al.*, 1987; Titus and Malcolm, 1991) and Stevens *et al.* (1995) found that during the year following clearfelling there was a potassium flux through the LFH horizon after which its concentration in leachate declined to less than pre-felling levels. It is possible then that the peak in potassium concentration in the A horizon was during the first year post-clearfelling (and therefore undetected) in the clearfelled plots because of potassium additions from brash leachate and brash decomposition (Stevens *et al.*, 1995), after which additions were outweighed by leaching losses.

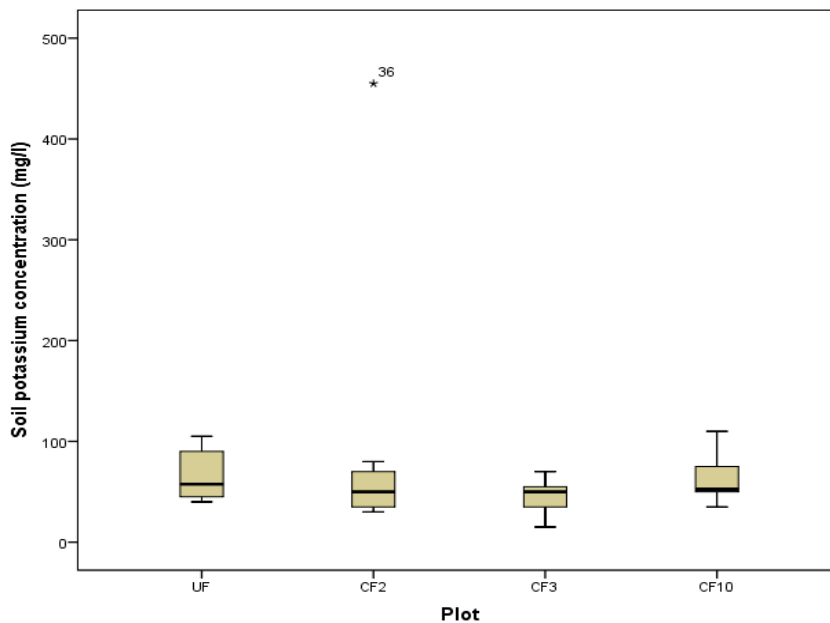


Figure 7. Soil potassium concentration

## Soil Magnesium

By two years after clearfelling soil magnesium concentration had significantly increased ( $p=0.003$ ) from its pre-felling concentration. Over the next year it significantly decreased ( $p=0.016$ ) back to a concentration which was not significantly different to UF. Over the next seven years it significantly decreased again to a concentration significantly lower than all other plots (UF:  $p=0.001$ , CF2:  $p<0.001$ , CF3:  $p=0.037$ ) (see Figure 8).

Soil magnesium concentration at CF2 is significantly higher than at CF3 ( $p=0.016$ ). As this is where the brash has been most freshly deposited, magnesium is perhaps being added to the soil through brash decomposition (Adamson *et al.*, 1987) faster than it is being lost in soil leachate. Conversely, at CF3, if magnesium pools in the brash are depleting, losses could outweigh additions, possibly explaining the significant difference between these plots. Both CF2 and CF3 soil magnesium concentrations are significantly higher than that at CF10. This may be due to the fresher brash input (Adamson *et al.*, 1987) at the two former sites compared to the latter. Concentrations at CF2 were significantly higher than at UF ( $p=0.003$ ) perhaps because magnesium

concentration in brash throughfall at CF2 is potentially higher than that in canopy throughfall at UF, something Stevens *et al.* (1995) found with other nutrients, which may also be the case for magnesium. The significantly lower concentration at CF10 compared to UF ( $p=0.001$ ) could be because the young trees at CF10 are in the stage of fast growth with associated high base cation (including magnesium) uptake, whereas at UF, nutrient uptake may have slowed as nutrients tend to be recycled in older trees (Nisbet and Evans, 2014).

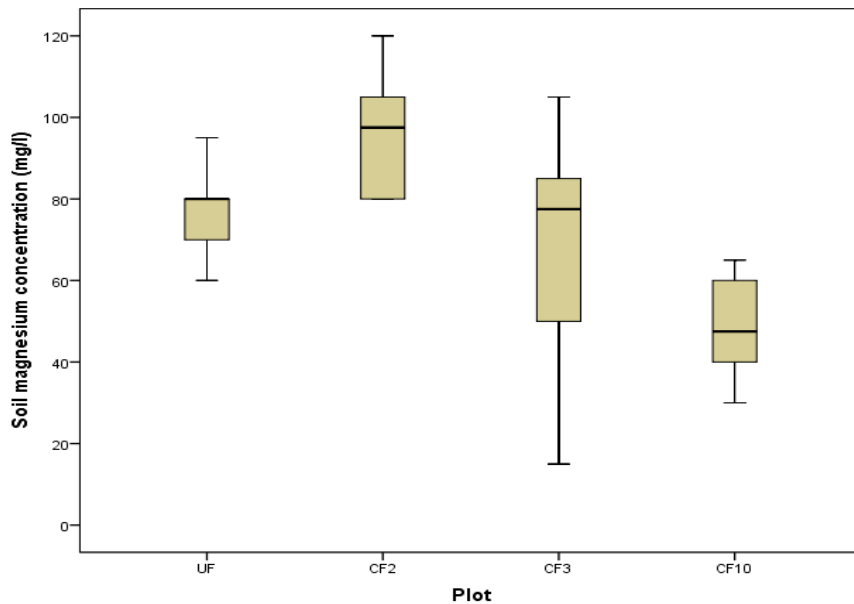


Figure 8. Soil magnesium concentration

## Soil Organic Matter

SOM content did not significantly change over ten years since clearfelling from unfelled levels (see Figure 9).

Landsberg and Sands (2011) theorised that eventually clearfelling could actually reduce SOM content because of the increased decomposition by the microbial community due to the change in microclimatic conditions created by brash. This has not been the case at the Snake Woodland experimental plots. SOM content tends to only change significantly through long-term site

management (Brady and Weil, 2014). It is possible that the management practice that is clearfelling has not had long enough to take effect.

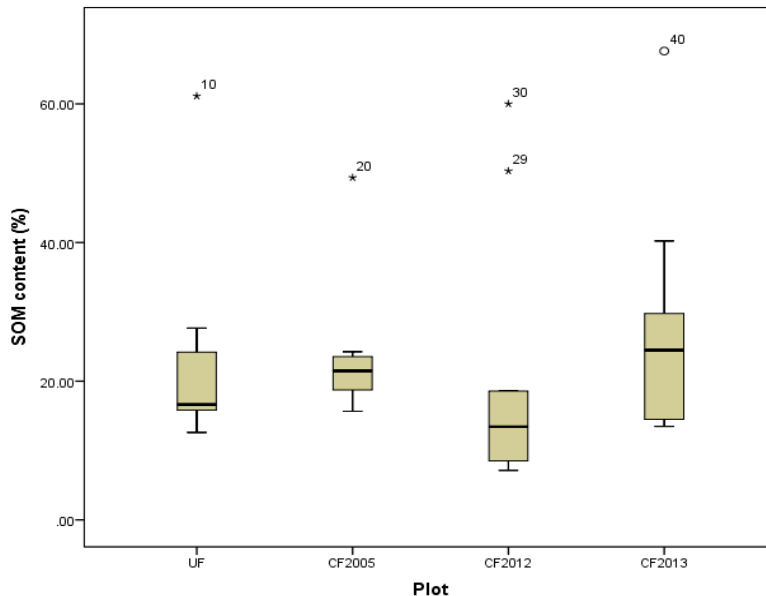


Figure 9. SOM content

## Summary: The Impact of Clearfelling on Measured Soil Properties

After an initial increase, the clearfelling of a conifer plantation resulted in an eventual decrease in soil acidity after ten years. Thus, clearfelling may have eventually improved conditions for future site flora species (depending on their levels of acid tolerance and affinity (Hill *et al.*, 1999) by potentially increasing plant nutrient availability and reducing aluminium toxicity (Brady and Weil, 2014; Hock and Elstner, 2005). The clearfelling of a conifer plantation affected individual soil nutrient concentrations differently. It caused an initial decrease in soil nitrate concentration, after which the concentration remained fairly constant over the next eight years. After an initial increase, clearfelling caused an eventual decrease in soil magnesium concentration by ten years after its occurrence. Clearfelling did not affect soil potassium or soil phosphate concentrations within or after ten years of its

occurrence. If brash is a phosphate source (Stevens *et al.*, 1995) and continues to be so, clearfelling could cause a lagged increase in soil phosphate concentration in the future. The clearfelling of a conifer plantation did not affect SOM content within or after ten years of its occurrence.

## CONCLUSION

Investigations of soil properties at four plots within Snake Woodland found that soil nutrient concentrations and soil acidity changed with time since clearfelling relative to unfelled conditions, while SOM content did not.

The chronosequence methodology used has some drawbacks: it cannot be known that each plot was truly comparable due to many potential extraneous variables, such as differing slope positions and aspects (Ellis and Mellor, 1995). Further, it cannot be pinpointed exactly when changes to soil properties occurred or if changes were linear, as changes are only detected at the selected chronosequence time intervals.

All measured soil properties are soil quality indicators (Kinyangi, 2007) so the study provides insight into how soil quality may be affected by clearfelling. Further research is needed to investigate the effects of clearfelling on soil quality itself: the soil-specific benchmark values need to be established, the future land-use of the site ascertained and a minimum dataset of soil quality indicators analysed (Karlen, Ditzler and Andrews, 2003; Kinyangi, 2007). The minimum dataset should include physical soil quality indicators (such as soil porosity), biological soil quality indicators (such as soil microbial biomass) and other chemical soil quality indicators (such as soil carbon-to-nitrogen ratio) (Kinyangi, 2007; Soil Quality, 2011b). The longer-term effects of clearfelling could also be investigated to identify any delayed or continuing changes at the sampled plots in order to better inform the planning of the future land-use of former conifer plantations.

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# **AN EVALUATION OF SECONDARY SCHOOL STUDENTS' PERCEPTIONS OF GEOGRAPHY AT KEY STAGES 3 AND 4.**

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This study is an investigation into a) How students perceive the teaching of geography at school, and b) Curriculum continuity and progression between Key Stage 3 and Key Stage 4. The effectiveness of the Geography National Curriculum in achieving its aim to inspire a curiosity and fascination about the world (National Curriculum, 2014) is evaluated. Pupils' perceptions for three year groups (Years 7, 9 and 11) were collected using a mixed-methods approach to gather mainly rich qualitative data, alongside further qualitative and quantitative data, principally through posters and questionnaires at two schools. Interviews were also conducted with geography staff. Using a phenomenographic approach to analyse the data, the differences between students' perceptions of geography were identified. The main findings revealed that students' perceptions of geography at school are focused on the everyday study of the world and its relevance to their daily lives. These perceptions originate from a variety of sources, although teachers appear to have the greatest influence. While students do appear to have

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genuine curiosity and fascination about the topics encompassed in school taught geography, by re-evaluating the balance of the opportunity for productivity and creativity, the relationship between students and geography can be heightened. These findings provide an insight into the potential for improving students' perceptions to learning geography and the skills necessary to continue academic and personal development. Furthermore, this evidence can be used to implement changes to students' learning processes in secondary education.

Keywords: Geography, Education, National Curriculum,

## **INTRODUCTION**

The key aim of this research paper is to investigate how secondary school pupils perceive geography and the implications for the subject. The question 'What is geography?' has been debated throughout the years, as the discipline has changed and developed over time. The debate around the content of the subject continues to influence teaching and learning at all levels.

From the age of ten, children have the language skills and cognitive ability to gather information and formulate concepts that are well organised and thought-out (Lee, 2015). They have the ability to formulate their own opinion on a number of things, including school subjects. However, research suggests that while consultation with students is high on political agendas, perspectives on a key area of the daily school experience – the content of school subjects – is rarely considered (Butt, 2011). Particularly over the last few years, school taught geography has undergone some major changes in the form of a new National Curriculum for geography. This claims to inspire a curiosity and fascination about the world (Department for Education, 2014). Despite this, not all the changes have been deemed effective by researchers. A recent Ofsted report, 'Key Stage 3: the wasted years?' published in 2015, found that geography teaching at Key Stage 3 often fails to challenge and engage pupils (The Geographical Association, 2015).

This paper examines changes in the geography curriculum and its teaching at secondary school level, and some of the challenges identified by current educational research. Following a review of relevant literature, the following section explains the primary research. A mixed methods approach was used to with a strong emphasis on qualitative techniques to explore school students' own perceptions of the main aims of geography teaching, along with interviews with teaching staff to examine the effectiveness of the teaching curriculum and delivery. The paper concludes with some key findings which have the potential to improve students' enjoyment and learning of geography at this level.

## **LITERATURE REVIEW**

### **The need for geographical education research**

Teaching geography plays a key role in helping students to understand the world and their place within it. Stannard (2015) argues that the social sciences have never been more important and should be given more prominence in the curriculum. For many, teaching geography provides an opportunity to teach for a better world (Lambert and Morgan, 2011). Across England there are five stages of education: Early Years, Primary, Secondary, Further Education and Higher Education. The relationship between these stages, year groups and age is shown in Table 1. However, in secondary education, school taught geography has had mixed reviews. Despite the number of students studying geography having risen for the fourth consecutive year, making it the eighth most popular General Certificate of Secondary Education (GCSE), Cassidy (2011) found that 11 to 14-year-olds were most likely to complain that their geography lessons were boring. Statistics from 2015 show geography entries decreased for students aged 15 and under (by 11.1%). The performance by students aged 15 and under was also lower than for those aged 16 and over (Weeden, 2015). This suggests a trend of decreasing interest and academic ability in the younger generations of geography students.

*'Key Stage 3: the wasted years?'* (Ofsted, 2015) explores whether students are sufficiently supported and challenged to make the best start to secondary school. The report found that geography at Key Stage 3 often fails to challenge and engage pupils. This in turn, impacts on the take-up of the subject at GCSE. This is supported by Scott (2016) who found that like students, teachers found year 9 (the last year of Key Stage 3) to be a strange time, when young people do not know who they are and feel everything is changing. But Haubrich (2000) argues that future generations will need a

geographical education that stresses key skills as well as enjoyable learning to accomplish the joint goals of personal happiness and the sustainable development of the world. Walford and Haggett (1995) see the future of the teaching of geography in schools as relying on three variables: the effect of legal structures in the curriculum, the extent to which the subject continues to motivate students and the future coherence and rationale for the subject. There is clearly a need for research into students' perceptions of geography addressing these three factors.

Stage of Education	Year Group	Key Stage	Age
Early Years	-	-	0-5 years
Primary	Year 1 and Year 2	Key Stage 1	5-7 years
	Year 3, Year 4, Year 5, Year 6	Key Stage 2	7-11 years
Secondary	Year 7, Year 8, Year 9	Key Stage 3	11-14 years
	Year 10 and Year 11	Key Stage 4	14-16 years
Further Education	Year 12 and Year 13	Key Stage 5	16-18+ years
Higher Education	Universities and Colleges	-	18+ years

*Table 1: Stages of Education in England (Adapted from Department of Education, 2012)*

## **Geography in the National Curriculum**

The Geography National Curriculum Framework states that:

*'A high-quality geography education should inspire in pupils a curiosity and fascination about the world and its people that will remain with them for the rest of their lives'*. (Department for Education, 2013. p1)

Before the introduction of the National Curriculum, geography was not considered worthy for inclusion as a separate subject in the so called 'core curriculum'. However, geography is today recognised as a 'core academic subject' (Department for Education, 2016). Government policy and public



examination boards play an important role in defining the current National Curriculum for geography. The most recent geography curriculum for Key Stages 3 and 4 was published in September 2013 and implemented from September 2014.

There is a diverse set of views on the aims, purpose and implication of the National Curriculum for geography at Key Stages 3 and 4, leading many involved in geographical education to speculate about the future of the subject.

Pupils in England study compulsory geography in primary school (ages 5-11) and for the first three years of secondary school (ages 11-14; Key Stage 3; Year 7-9), after which the study of geography becomes optional (ages 14-16; Key Stage 4; Years 10-11). With the introduction of the English Baccalaureate (EBacc), geography is now classed as a 'core academic subject' and results are used as a school measure (Department of Education, 2016). Therefore not only geography departments, but schools as a whole, have a vested interest in getting a high intake of students taking geography at GCSE.

Since its establishment in schools, geography has undergone many changes in its nature and delivery. 1968 was a pivotal year in the history of school geography during which the content of secondary school geography changed from a being dominated by regional geography (Taylor, 2009) to study involving the seeking of laws and theories. Graves (2001) states that there is a time lapse between geographical research and its incorporation into school textbooks, arguing that geography in schools tends to follow society, rather than lead it. Hopwood (2014) disagrees with Graves, stating that the shift in emphasis from pupil to society is 'radical' ideology in which education is seen as an agent for social change. It was hoped that the Geography National Curriculum might help to resolve some of these issues within the discipline.

Hamnet (2013) supports the content of the new curriculum stating that if well taught, the content provides a sound basis for later geographical study and knowledge of the key challenges that face our world. However, Lambert (2010) argues that the perceived gap between academic research and the teaching of geography in schools is widening as academic geographers play less of a role in constructing school geography. Rawling (2002) supports this by stating that although getting geography into the National Curriculum was a significant triumph for the subject, geographers paid a high price in a move back to the kind of 'information led' tradition included in the most recent curriculum published in 2014.

The Geographical Association's 2009 manifesto 'A Different View' acknowledges that because the world changes, so must the curriculum, also suggesting that young people and teachers need to help shape the geography curriculum to secure its success as a discipline. Paying greater attention to how pupils perceive geography will be a key factor in enhancing our understanding of how school taught geography is experienced and engaged with as a context for learning.

## **Students' Perceptions of Geography**

It is important to acknowledge that individual definitions of geography can vary greatly, as geography is an extensive field of science with a large number of subfields. Özgen (2013) defines perceptions of geography as the state of comprehending the interaction between man and environment in accordance with personal senses, opinions and needs.

Research suggests that perceptions of geography as a school subject arise from the process the learner undergoes throughout their geographical education. Hopwood (2014) states that due to the multiplicity of childhoods, childhood should be viewed as a social construction, and therefore, young peoples' views of geography will vary over space and time. He uses the examples of learned economic, cultural, political and environmental geographies, which he believes will reflect in a young person's actions later in life. Schoenfeld (2004) has suggested that deeper understanding of the nature of a subject can help students move away from learning a series of unconnected chunks, towards a more coherent approach, formed of big ideas and links between experiences.

Throughout secondary education, the teaching of geography expands in content and depth. Research into child psychology distinguishes the importance of a sense of chronology in education, as it enables children to place events and periods within time (Hodkinson, 1995). This suggests that continuity and progression throughout the process of learning school geography will result in a deeper understanding. Grossman and Stodolsky (1995) support this, identifying sequencing as one of the five aspects of perceiving a subject (definition, scope, static/dynamic and status of knowledge). The Royal Geographical Society (2015) praise the new curriculum in underpinning the understanding of more complex topics in later stages of study.

When looking at the continuity and progression within and between Key Stages 2 and 3, Chapman (2002) found that when asked 'what is geography?',

Key Stage 3 pupils described specific topics rather than a definition of the subject of geography as a whole. The study of the weather, settlements, places where we live, countries and reading maps were all popular answers. Norman and Harrison (2004) also found a varied response in keywords Year 9 pupils associated with geography, including video, textbook, globe, atlas, map, diagram, computer, compass, graph, earthquakes and volcanoes. In comparison, they found that most Key Stage 4 pupils tried to relate the study of geography to possible careers. Similarly to responses from pupils in Key Stage 3, Key Stage 4 pupils underlined natural hazards but also environmental issues including global warming.

However, it is clear that the majority of researchers agree with Lord (2003), who found that studies regarding pupils' perspectives and experiences of school taught subjects encompassed in the humanities, including geography, is lacking.

## **Summary**

This review of the literature draws attention to the fact that the development of geography in schools is an ongoing process, continually changing with regard to the content, nature and assessment methods used. Although there is a lot of research regarding students' experiences of geography as a school subject, very little has been published on the effect of the new national curriculum, as it was only published and implemented in schools in September 2014. Ofsted (2015) has criticised the changes to Key Stage 3 content as failing to challenge and engage pupils, with statistics supporting a dip in uptake and performance of this age group (15 and under) (Weeden, 2015). Key Stage 3 has also been branded as 'the wasted years' by the Geographical Association (2015).

Although the older literature surrounding students' perceptions of geography cannot be generalised to current classroom experiences, it is important to note that the themes presented, such as the changing nature of school-taught geography and the influence of students' perceptions, are still relevant. This research is an attempt to readdress these propositions within a contemporary context.

## **METHODOLOGY**

The qualitative nature of this study, exploring students' and teachers' perceptions, lends itself to small-scale inductive research. Using Gray's (2014) guide to the relationship between epistemology, theoretical

perspectives, methodology and research methods, the position of this research is placed firmly within an interpretivist theoretical perspective and utilising a phenomenographic approach to analyse the collected data.

The research tasks were undertaken in two local schools, during the spring term, 2016. The study design called for largely qualitative data. Semi-structured interviews with the heads of geography at each school were undertaken to explore their perceptions of (i) teaching this topic and (ii) issues relating to the delivery of the curriculum. All the students in the sample groups at each school (142 children in total) were asked to produce a poster to show what geography is to someone who has never studied it before.

Quantitative data was also integrated into the research design through a mixed methods questionnaire completed by the same students at the two schools.

The year group and Key Stages of these students, along with the sample size from each group, are shown in Table 2.

Year Group	Number of Students	Key Stage
Year 7	53	Key Stage 3
Year 9	40	
Year 11	49	Key Stage 4

*Table 2 Total Number of Student Participants*

Dowgill (1998) defines phenomenographic analysis as a research method for mapping the qualitatively different ways in which people experience, conceptualise, perceive and understand various aspects of a phenomenon. The analysis of this data looked for patterns and themes within the appropriate Key Stages (3 and 4). The final stage of data analysis involved a cross-comparison of the overall outcome of each research method, in order to aid understanding of the varying perceptions of geography.

Research ethics were a critical consideration in the research, as much of it was based on the ideas and perceptions of young people. Graue and Walsh (1998) state that in research with children, adult researchers must acknowledge that children are the knowledge holders, the permission granters and the rule setters. Ethical considerations that apply to adult research subjects must also apply to children. Sheffield Hallam University's own ethical guidelines were applied (SHU, n.d.), alongside Denscombe's (2003) guide to the ethics for small-scale social research projects. The following three main principles were enforced:

1. The interest of participants should be protected.
2. Researchers should avoid deception or misrepresentation.
3. Participants should give informed consent

On a more practical basis, a DBS (Disclosure and Barring Service) certificate was obtained by the researcher. This meant that research could be legally carried out with young people. Following discussion with the selected schools and teachers involved, it was also agreed that their identities should be kept anonymous, as this would allow for freer discussion about the issues.

## **MAIN FINDINGS**

### **Students' Perceptions of Geography as a Subject**

The main findings of this research focus on the students' perceptions of geography as a subject at the different Key Stages within their schools.

The questionnaire asked students at both Key Stages to respond to the question: *How would you describe what you learn in geography to somebody who has never done it before?* A component analysis of key terms mentioned in response to this question was undertaken as an indication of students' understanding of the subject of geography. This is clearly illustrative only, as many of these terms are subjective. But the analysis does provide some indication of the range of topics understood at each Key Stage.

The most frequent aspects mentioned by KS3 students in response to this question are shown in Table 3 and the most frequent aspects mentioned by KS4 students are shown in Table 4.

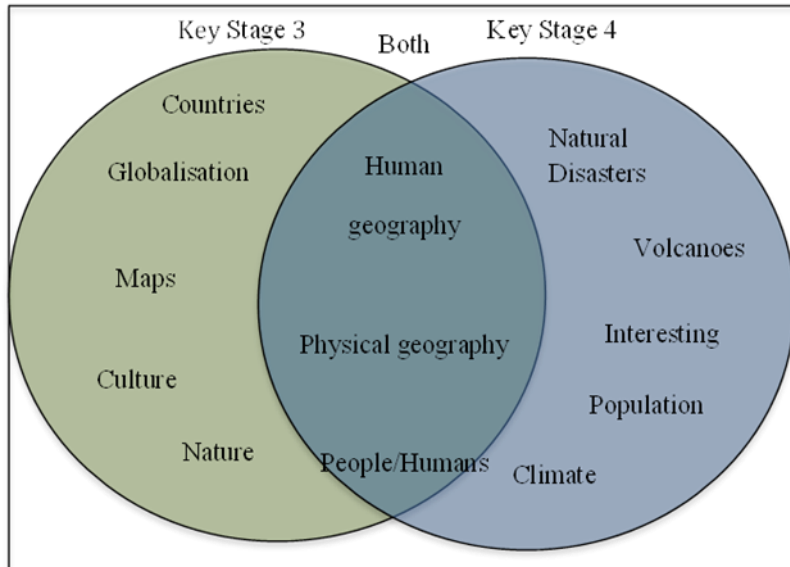
In both Key Stages, 'Human geography', 'Physical geography', 'People/Humans', 'Environment' and 'World/Earth' were some of the most frequently occurring words in response to question 1. Differences between the stages include, the inclusion of 'maps' in the explanations by Key Stage 3 but not Key Stage 4, and the use of the positive descriptive word, 'interesting', by only Key Stage 4 students.

<b>Rank</b>	<b>Topic</b>	<b>Frequency</b>
1	World/Earth	48
2	People/Humans	20
3	Physical geography	19
4	Countries	16
5	Human geography	15
6	Culture	14
7	Environment	12
8	Maps	12
9	Nature	10
10	Globalisation	10

*Table 3 Most frequently mentioned terms at Key Stage 3*

<b>Rank</b>	<b>Topic</b>	<b>Frequency</b>
1	World/Earth	30
2	Physical geography	13
3	People/Humans	10
4	Human geography	10
5	Volcanoes	8
6	Population	7
7	Climate	7
8	Environment	7
9	Natural disasters	6
10	Interesting	6

*Table 4 Most frequently mentioned terms at Key Stage 4*



*Figure 1 Comparison between topics mentioned at Key Stages 3 and 4*

Figure 1 compares the similarities and differences in the topics included by students at each Key Stage, in order to illustrate the progression between levels.

The poster task asked the students to create a poster that shows what geography is to someone who has never studied it before. The final posters varied greatly, in terms of content as well as formatting (for example, the inclusion of illustrations, sentences, individual words and spider diagrams). Examples of complete posters are shown in Figure 2. As with the questionnaire, a component analysis was undertaken to illustrate the topics most frequently mentioned by the students and thus identify those areas they felt were of most importance in the subject.

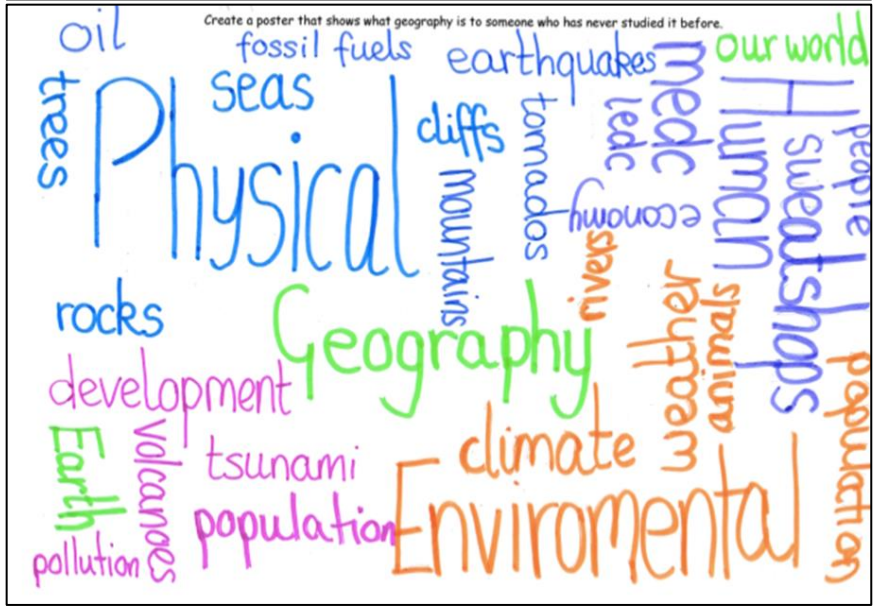
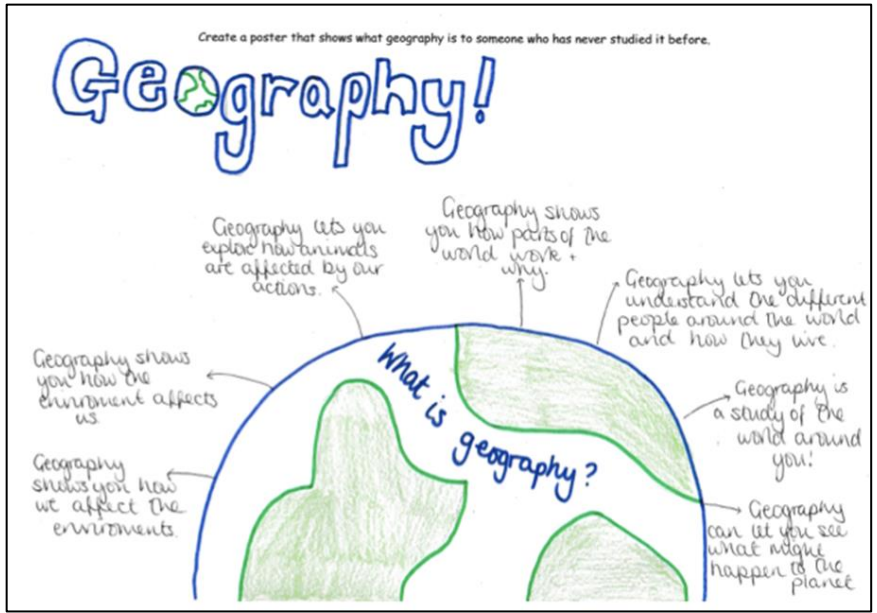


Figure 2 Examples of Students' Posters



Whilst some students focused on specific aspects of their geographical knowledge, a total of 103 different topics in Key Stage 3 and 84 in Key Stage 4 were recorded from the posters. These components ranged from rainforests and coastal erosion to forms of currency and energy. A component analysis was undertaken to identify the most commonly mentioned topics. This analysis also looked for patterns and themes within each of the Key Stages.

The ten most common components included by Key Stage 3 students are shown in Table 5, those included by Key Stage 4 students in Table 6.

<b>Ranking</b>	<b>Topic</b>	<b>Frequency</b>	<b>Percentage (%)</b>
1	Globe/Earth/World	78	76
2	Weather	31	30
3	Volcanoes	23	22
4	Human geography	20	19
5	Physical geography	20	19
6	Environment	19	18
7	Animals	18	18
8	People/Humans	18	18
9	Rivers	15	15
10	Map/Atlas	13	13

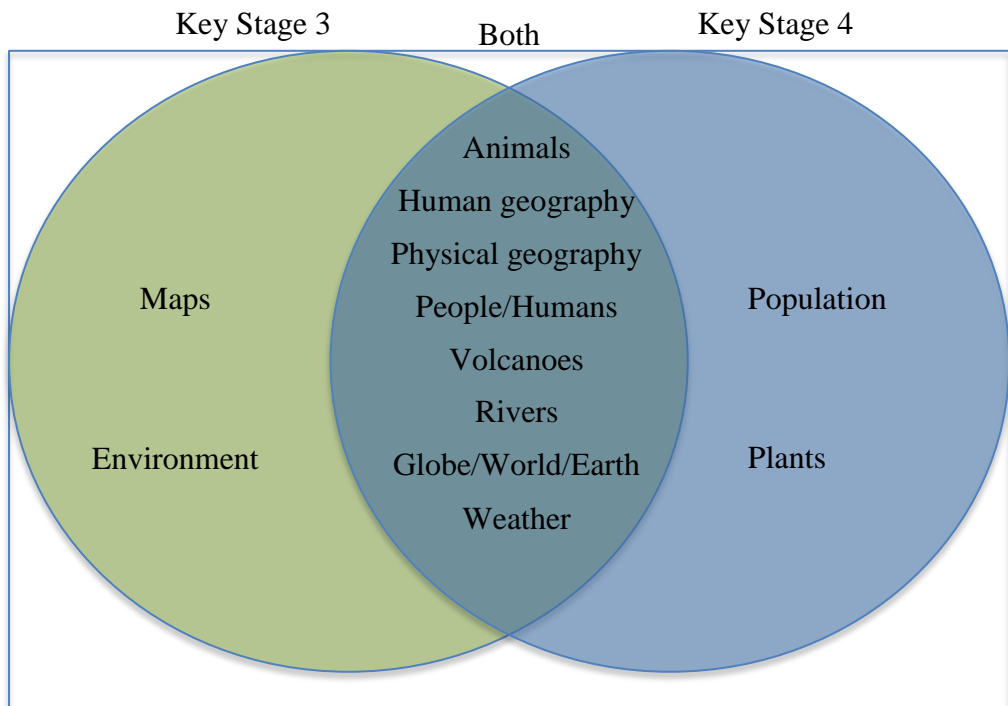
*Table 5 Ten most common components at Key Stage 3*

<b>Ranking</b>	<b>Topic</b>	<b>Frequency</b>	<b>Percentage (%)</b>
1	Volcanoes	21	25
2	Globe/Earth/World	21	25
3	Animals	19	23
4	Weather	15	18
5	Rivers	15	18
6	Plants	11	13
7	People/Humans	10	12
8	Human geography	8	10
9	Physical geography	8	10
10	Population	8	10

*Table 6 Ten most common components at Key Stage 4*

Figure 3 compares these results to show components included by both groups and the distinctions.

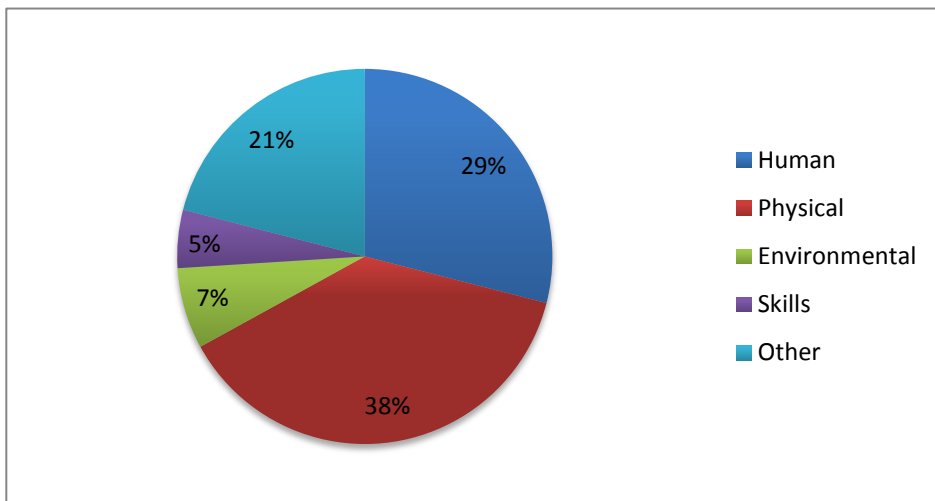
Although there are clear differences between the content of the artwork by students at each Key Stage, there are also a number of similarities. ‘Human geography’, ‘Physical geography’, ‘People/Humans’, ‘Weather’, ‘Rivers’, ‘Volcanoes’, ‘Animals’, and ‘Globe/World/Earth’ were all some of the most frequently occurring components in posters by both Key Stage 3 and Key Stage 4. ‘Maps’ and ‘Environment’ were more popular in Key Stage 3 than Key Stage 4. Instead Key Stage 4 posters included a greater amount of content on ‘Plants’ and ‘Population’.



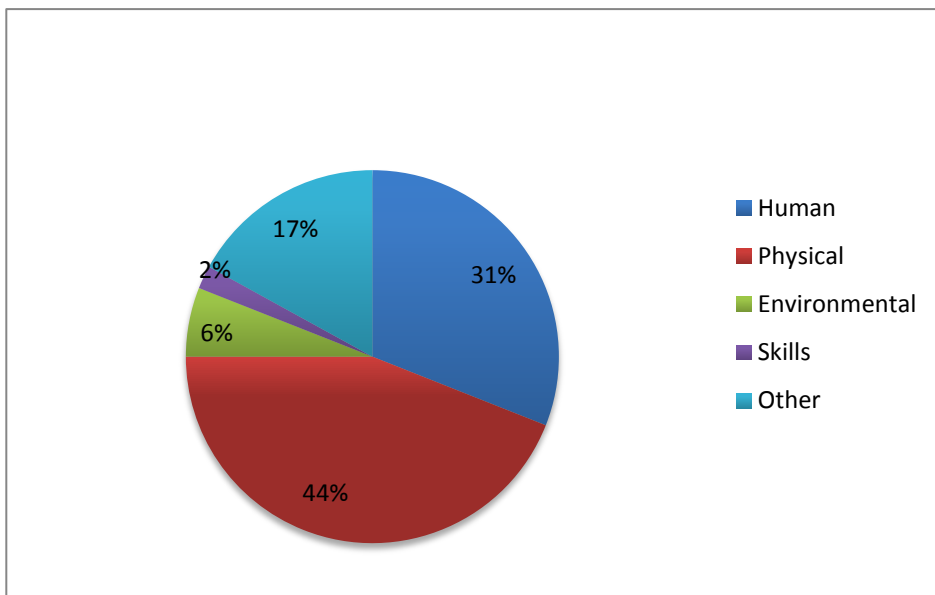
*Figure 3 A comparison of the images and terms included in students' posters*

Further analysis of the inclusion based on different branches of geography (physical, human and environmental geography) was carried out through coding topics and plotting them graphically. This is shown in Figures 4. and 5. All three branches can be identified in both Key Stages.

Topics encompassed in physical geography such as 'biomes', 'earthquakes' and 'coasts' accounted for 38% of the posters made by Key Stage 3 and 44% in Key Stage 4. However, topics included from human geography such as currency, development and conflict, were slightly lower, making up 29% of the content from Key Stage 3 and 31% at Key Stage 4. In comparison, environmental topics such as energy, sustainability and pollution made up significantly less than 10% (7% in Key Stage 3 and 6% in Key Stage 4) of the content of the open-ended poster task. This suggests that a more traditional view of geography still dominates students' perceptions of the subject. This is explored further below.



*Figure 4- Percentage of topics included in poster- task - KS3*



*Figure 5 - Percentage of topics included in poster- task - KS4*

Goudie (1986) provided a commonly used formal definition of the discipline; geography is the study of life on the surface of the earth. However, geography is an extensive field of science with a large number of subfields and therefore definitions of geography vary greatly from each other. Personal perceptions often drive these interpretations (Özgen, 2013). The traditional explanation of geography clearly dominated students' perceptions in this study. 84% of the 93 posters from Key Stage 3 and 58% of the 36 Key Stage 4 posters included the globe/earth/world as a component. The popularity of the globe/earth/world image in posters at both Key Stages is not a surprise due to its status as geography's icon (Cosgrove, 2006). These findings are supported by Norman and Harrison (2004) who also found that globes were often used by year 9 classes in their descriptions of geography. Wright (2000) argues that although an appreciation of our globe is arguably the most important topic in geography, because lessons are dominated by studying bits of the world, we are in danger of losing this global vision. This statement is supported by the findings of this study.

Dowgill (1998) found that geography, as the study of place, was popular in three-year groups (Year 7, Year 8 and Year 9). However, in this research specific countries were only mentioned by ten students from Key Stage 3 and six students from Key Stage 4. Specific countries were included in only 12% of all the completed posters. Despite this, both teachers introduced students' knowledge of locations when being interviewed. Teacher 1 referred to the study of countries as something '*you obviously have to include*' to '*meet the Key Stage 3 requirements*'. Teacher 2 suggested that the inclusion of countries such as 'Africa, Russia and the Middle East' was used by curriculum writers to inspire a curiosity and fascination about the world. This suggests that despite the new geography curriculum taking a 'knowledge turn' (Lambert, 2012), and teachers noting this approach, this factual curriculum has not infiltrated the perceptions of secondary school students.

Through the analysis of all of the results, the three branches of geography (human, physical and environmental geography) were identified in the perceptions of students from both Key Stages. However, despite the National Curriculum for Geography GCSE (2014) defining 'People and environment: processes and interactions' as one of the main topics to be included, the actual word 'environment' was only included in 18% of the artwork by Key Stage 3 and 2% in Key Stage 4. In addition, despite being the 7th (KS3) and 8th (KS4) most popular topic in the responses to the questionnaire (Tables 3 and 4), environmental topics were present in fewer than 10% of all completed posters.

In comparison, topics covered by physical geography received the highest number of mentions in both the questionnaire and poster task. However, despite human geography topics being less common than physical topics, in both the questionnaire and students' artwork, the results collected from several of the other questions directly contradict these results. Several students stated that human geography was the element that they most enjoyed throughout their geographical education.

*"The human aspects of geography rather than physical or environmental geography."*

(KS3 questionnaire)

*"I enjoy doing human geography so all of year nine has been good."*

(KS3 questionnaire)

Interestingly, both teachers used examples of human topics when asked 'can you tell me about an individual lesson that went well with either Key Stage 3 or 4 and why you thought that went well?' The examples given were China's one-child policy and trade. This suggests that possibly teachers perceive lessons on human topics to be more effective.

Perceptions of the skills learnt in geography were less detailed than other factors that make up a geographical education. The personal ambitions mentioned by some pupils include the variety of career possibilities, the desire to travel and learn more. Surprisingly only one student from Key Stage 3 referred to themselves as a 'geographer' despite the term being explicitly used in the GCSE subject content. Kneale (2014) states that it is important for students to remember studying geography is supposed to be exciting and fun as well as challenging.

Although no conclusions can be drawn about students' overall perceptions of geography, this data provides an idea of what students consider to be the most interesting or important aspects of geography.

## **Students' and Teachers' Perceptions of Geography Teaching at School**

Differences in attitudes, interests and aptitudes, rate of learning and the role of environment are all important considerations in educational research. As in Hopwood's (2004) study, this research does not attempt to draw conclusions about the influences of individuals, instead it highlights the dominant influences on students' perceptions of school taught geography throughout Key Stages 3 and 4.

In both Key Stage 3 and Key Stage 4, students rated teachers as being highly responsible for their learning. Students mentioned teacher characteristics such as enthusiasm, helpfulness, reliability and the ability to recognise students that are working hard, in both Key Stages.

As well as the characteristics of geography teachers, lessons also appear to influence students' perceptions of school taught geography. Students listed some of the following factors:

*'When the teachers interact with you'*  
(KS3, Questionnaire)

*'When we do more than one thing (for example we watch part of a documentary, then do book work)'*  
(KS4, Questionnaire)

Varied, interesting and interactive lessons were also mentioned by 32% of all the students that took part in the research.

The influence teachers have on students' perceptions of geography was also clear through the teacher interviews. Both teachers agreed that it is better for geography to be taught by teachers with a specialist background in geography as this has a direct influence on students' perceptions of the discipline as a whole. In interview 2, the teacher draws a comparison between the interest and enthusiasm of the teaching staff with the high intake of students choosing geography at GCSE and through to higher education. This success is reinforced by the fact that 90% of Key Stage 4 students said they had enjoyed studying geography in the previous year.

However, as well as enjoyment, it is clear in the analysis of the questionnaires that the pressure of GCSEs greatly affects Key Stage 4 students' perceptions of geography. Exam preparation was included as one of the key differences between students' current and previous year of study. The pressure of achieving good results in Key Stage 4 was further supported by the teacher interviews. In interview 1, the teacher states that *'there is obviously a level of accountability in a sense that GCSE results get scrutinised quite closely'*.

The pressure on teachers to produce good academic results is significantly greater at Key Stage 4 than Key Stage 3. In interview 1, the teacher states that at Key Stage 4, it would *'be foolish to stray away from the case studies that the exam board recommend'*, describing the reduction in choice of topics at that Key Stage and the content that can be chosen, as prescriptive.

In comparison, both teachers emphasised the ability to influence the content of geography at Key Stage 3 through shortening, deleting and adding new topics, based on students' interests. So much so, that school 2 has actively made the decision to lengthen the period of Key Stage 4 geography by shortening Key Stage 3 from three years to two.

## **Continuity and Progression between Key Stages**

As previously discussed, the continuity and progression between stages may influence students' perceptions and interest in geography.

The teacher interviews highlighted the repetition of several topics such as weather and climate, coasts and natural hazards throughout secondary geography. Interestingly all these topics were something that students from both Key Stages enjoyed learning about. However, a topic that was previously being taught throughout both Key Stages, population, is being removed from the Key Stage 4 curriculum despite being a topic that 65% of Key Stage 4 students enjoyed. 'Population' was also the 10th most common component of the poster task completed by Key Stage 4. The popularity of population as a topic was significantly less in Key Stage 3. This suggests that perhaps the repetition of this topic and the opportunity to study it in more depth may be responsible for prevalence in Key Stage 4 students' enjoyment and overall perceptions of geography. This is supported by the interviews with teachers who showed a willingness to continue this continuity and progression by incorporating the study of population into a Year 8 (Key Stage 3) unit because they believe it to be an important topic.

Lambert (2005) has argued that one particular problem with geography is that its power as an educational resource is not fully realised. This research found that for the majority of students, skills that are learnt throughout secondary school geography, such as statistics and map reading, were more explicitly recognised than personal ambitions like becoming a 'geographer' and travelling. This suggests the possibility that the pressure of education and employability on young people might be removing the passion and love for the world in which we live. Support for this statement can be seen throughout this piece of research in the review of previous studies on students' perceptions of geography, as well as in the primary research findings.

Corney (2000) found that only after travelling to different countries, did student geography teachers develop an environmental conscience. In this research, only a small percentage of students mentioned the countries of the world in their definition of geography, despite both teachers stressing its



importance in the curriculum. The majority of those that did refer to locational geography focused on their local surroundings, with only one student acknowledging that '*geography is everywhere*'. This suggests that perhaps curiosity and fascination is not being inspired beyond a local level. Lambert (2005) states that unlocking the full potential of school taught geography as an education resource can literally change the way we see the world, for example, the meaning of place and the significance of scale (local, regional, national, international and global). The willingness of both Key Stages 3 and 4 students to expand their perceptions is evident through the additional comments made by the students in that watching videos helped them to visualise what it is that they were learning about.

*'You can see for yourself how things are'* (KS3, Questionnaire)

*'Where you can see geography taking place'* (KS4, Questionnaire)

Undoubtedly, school taught geography has been successful with the number of students studying geography having risen for the fourth consecutive year, making it the eighth most popular GCSE (Weeden, 2015). However, it still remains in the bottom half of the top 10 GCSE subjects, beneath history (Weeden, 2015).

On the other hand, responses in this survey suggest that the only subjects Key Stage 4 students rated as more important than geography were Science, Maths and English. Whereas data from Key Stage 3 shows that as well as Science, Maths and English, Physical Education (PE) and Information and Communications Technology (ICT) were also rated as more important than geography. In interview 2, the teacher highlighted the success in using ICT to contribute towards students' learning of geography through online research. However, more students mentioned fieldwork/fieldtrips in KS3 (11) and KS4 (2) than computer work, which was not mentioned anywhere in this research. This demonstrates a willingness of students to embrace the curiosity and fascination that geography provides with the opportunity to learn outside the classroom.

## **CONCLUSION**

This research has resulted in the following key findings:

- Although students' perceptions of geography are similar in many ways, there are significant differences. The majority of Key Stage 3 and Key Stage 4 students' perceptions of geography are focused on

the everyday study of the world and its relevance to their daily lives, but their knowledge beyond a local scale is limited.

- There are evidently many influences on how students perceive geography, including parents, the media and personal experiences. However these findings suggest that teachers appear to have the most significant influence, in relation to the content and delivery of geographical material included in the National Curriculum. Examinations and future prospects also appear to play a role in the perceptions of Key Stage 4 students.
- Curriculum continuity and progression does occur between Key Stage 3 and 4 in secondary school geography. When this is successful (through the four topics mentioned: weather and climate; natural hazards; coasts and population), students enjoy and are more engaged with the content.
- Students are using skills learnt in the early stages of their geographical education. Therefore, describing Key Stage 3 as the 'wasted years' is inaccurate, with topics and skills that allow for continuity and progression being viewed as enjoyable and important by students. Rather, these findings supports the Royal Geographical Society in stating that geography is, in the broadest sense, an education for life and for living (Royal Geographical Society, 2016).
- Achieving the right balance between productivity (exam success) and creativity (such as broader geographical awareness, travelling, and becoming a 'geographer') remains a challenge.
- Leading students through a geographical education, during which their understanding of the subject is broadened, may increase the likelihood of student engagement and encourage them to bring their own interests and experiences to the curriculum.
- By drawing on students' own experiences and issues that interest them through activities they identify as interactive and engaging, the full potential of school taught geography can be achieved.

These findings provide an insight into what students perceive to be geographical knowledge, the factors that influence these perceptions and how this translates practically into the classroom. The extent to which the new geography curriculum will affect students' perceptions of the subject in the future is largely unpredictable. Only by conducting similar research on a local, regional and national level can valuable insights into the balance of a productive but creative relationship between students and the subject matter

be discovered. An exciting prospect would be to follow a similar research design on a longitudinal scale, using case-studies of individual students, in order to see the impact of school taught geography on individual perceptions.

As a final conclusion, and as this study was inspired by Hopwood, it seems only right that this research concludes with this quote:

*'We must face up to the fact that conceptions of geography education cannot be straightforwardly reshaped by simply changing what is taught or how. Young people lie at the heart of geography's future and must play a role in shaping it'* (Hopwood, 2011).

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# **THE PROPOSAL THAT NUDIBRANCH *JORUNNA FUNEBRIS* 'JUVENILE' IS PRECOCIOUS, A DISTINCT PHENOTYPE OR A NEW SPECIES.**

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During a survey of nudibranch diversity and abundance in Cambodian waters, two pairs of what has been heretofore regarded as the juvenile form of *Jorunna funebris* (Kelaart, 1859) were observed mating. At that time, it was not possible to collect specimens for further physiological investigation, so it cannot be concluded that this is actually a new species. This paper brings considerations from previous works to bear on the options that can explain this situation and suggests a course of action to investigate the hypotheses.

Keywords: Nudibranch, juvenile form, heterometaboly, taxonomy

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## INTRODUCTION

Nudibranchs are very diverse in appearance and habit. They are often brightly and exquisitely coloured; each family different in colour, ornamentation and body shape, often with considerable variation in number or size of identification features (Camacho-Garcia and Gosliner, 2008; Wells and Bryce, 1993). Nudibranchs are often referred to as sea slugs and are soft bodied animals within the subclass *Opisthobranchia*, and have mostly evolved the loss of the protective shell present in some members of the *Gastropoda* class (Behrens, 2005; Karuso, 1987). Nudibranch means “naked gill”, as that structure is usually exposed towards, or at, the rear of the mantle (although some nudibranch families, e.g. *Phyllidiidae*, have hidden gill structures, between their mantle and foot) (Behrens, 2005). Taxonomic investigations have concluded that phenotypical variation is common and plasticity between juveniles and adults occurs (Camacho-Garcia and Gosliner, 2008). Across the group, nudibranch nutritional strategy ranges from herbivory, carnivory (including cannibalism) and omnivory. Most species are specialist feeders and many have the ability to incorporate their prey’s defence mechanism and use it to defend themselves from predators. Examples of this include sequestration of prey defence toxins (or their toxic metabolites), and even the consumption and subsequent incorporation of functioning nematocysts (Ottuso, 2009; Wells and Bryce, 1993; Faulkner and Ghiselin, 1983). Not all nudibranch defences are derived from their food. Cryptic- as well as warning-colouration is evident and some species, such as *Jorunna funebris*, have developed patches of unpalatable spines, known as spicule-bearing tubercles (Figure 1) (Behrens, 2005; Rudman, 1991).

Nudibranchs can be found all over the marine world, in a range of habitats including the Polar regions and the tropics; they are found in both shallow, coastal areas and the oceanic depths (Chavanich *et al.*, 2013). However, despite their global distribution, little is known about their biology and ecology. The study of nudibranchs is comparatively in its infancy, with new species regularly being discovered and genetic data records on individual species still at a rudimentary stage (Picton, pers. com., 2014; Wells and Bryce, 1993). It is therefore not surprising that revisions in the taxonomic status of specimen forms are currently likely.

**Figure 1:** Spicule-bearing tubercles found in circular patches on *Jorunna funebris* 'adult' (Cobb and Willan, 2006).



## OBSERVATION

In the summer of 2015, a general survey was carried out, with Marine Conservation Cambodia, to investigate the abundance and diversity of the nudibranch species found populating the coastal waters surrounding Koh Rong Samloem Island, Cambodia, as little, if any such work had previously been carried out in Cambodian waters. Diversity and distribution have been observed in neighbouring Thailand (Chavanich *et al.*, 2013), and this provided preparatory insight. The survey at Koh Rong Samloem took place over nine months starting in Cambodia's monsoon season (June 2013) and ending during the windy season (March 2014). In this study, the most abundant species was recorded as *Jorunna funebris* (Kelaart, 1859), which was also the only species with a preference for blue sponge, *Xestospongia* sp. (Figure 2). An interesting observation was made of the activity of individual specimens of *J. funebris*, which are formally regarded as juvenile and adult forms (Debelius and Kuitert, 2007). 'Juveniles' were twice observed mating (Figure 3).

**Figure 2:** *J. funebris* on its common choice of substrate, blue sponge *Xestospongia* sp. The 'adult' form is on the left, the 'juvenile' form is on the right and, in this case, slightly smaller (Kilburn, 2015).



**Figure 3:** Two 'juvenile' *J. funebris* in the act of mating. Scale divisions: 10mm. (Kilburn, 2015)



## HYPOTHESIS

What is currently regarded as the juvenile form of *J. funebris*, is a different species.

### **Taxonomic Status of *Jorunna funebris***

The genus *Jorunna* has recently been reviewed through a phylogenetic analysis based on two historic specimens in taxonomic collections and twenty more recent specimens from a wide variety of locations in Australasia, Oceania, Indian Ocean, East China and Philippines Seas and the Gulf of Thailand (Camacho-Garcia and Gosliner, 2008). In this process, the description of *J. funebris* has been consolidated, but with no mention of the juvenile form:

*"Background colour of dorsum and foot white to yellow/cream.*

*Notum with several dark brown to black rings of different sizes, larger in middle portion of middle body.*

*Dark rings not completely covered with pigment, instead each ring composed of several minute dark brown to black spots homogeneously distributed inside. Border of notum and hyponotum scattered with similar dark spots all around margins. No rings present on sole of foot; however a couple of dark brown dots at each side of notched upper lip in some specimens.*

*Rhinophores white with black clubs. Branchial leaves white, rachises of first and second pinnae of each leaf with black line.*

*White mantle glands present around margin of notum." (ibid., p150)*

A superficial comparison of the 'juvenile' form with the description of *J. funebris*, above, shows the following:

- Same background colour of dorsum and foot.
- Notum (mantle) does not bear dark rings, although similar dark spots - probably spicule-bearing tubercles (Cobb and Willan, 2006) - occur singly, or in groups of up to three, widely spaced across the notum.
- Rhinophores are white, but only bear black clubs on the distal half, as opposed to along the full length.
- Branchial leaves are similarly positioned and coloured.

## Considerations in Support of Hypothesis

1. At two times, pairs of individuals of what has been regarded as the juvenile form were observed in mating positions. Unless the form is precocious or a phenotypical variant, this suggests an alternative adult species. Mating individuals (of both 'adult' and 'juvenile' form were only observed with like forms), so there is no evidence that the two forms can mate with each other.
2. In the surveys of this study, 84 individuals of *J. funebris* were observed, when the next most abundant species registered only 49 times, whilst the majority of species were recorded only in single figures. The high abundance would be explained by the counting of two fairly frequent species as one.
3. *J. funebris* was the species present at the most sites in the Koh Rong Samloem study.
4. The species description compiled by Camacho-Garcia and Gosliner (2008) closely fits that of the adult form, but not so closely the 'juvenile'. We have not been able to find an exact description of the 'juvenile' form in current taxonomy guides.

## Considerations Against the Hypothesis

1. Some nudibranch species are very specific in their choice of nutritional substrate, and there are records where mature individuals of a species exhibit different preferences to the younger (Folino, 1993). This is unlikely to be true for *J. funebris*, as the two forms were observed apparently feeding on *Xerospongia* sp. No other nudibranch species were present on the *Xerospongia* sp. throughout the survey, suggesting it as a specialised food source for adult and juvenile *J. funebris*.
2. Nudibranch biology is not exhaustively understood and it is conceivable that these juvenile individuals may be sexually precocious.
3. Camacho-Garcia and Gosliner (2008) recount and perform a number of synonymisations as a result of microscopic examination. One such formerly distinct species, *J. zania* whose description has some similarities with the 'juvenile' is now accepted as *J. funebris*. Thus the 'juvenile' may be found to be a different phenotype of the species.

4. The two forms were of similar size range, and although the 'juvenile' form was often larger than the local 'adults', this is a misleading distraction. Mating is a very energetic process, for which individuals can divert somatic resources to reproduction, even to the extent of losing body mass (Cobb, pers. com., 2017). It is probable that nudibranchs grow until sexual maturity, after which time size varies, depending on a ratio of food availability against the energy used in mating.

## CONCLUSION

Closer examination of the specimens is required to ascertain how vital *J. funebris* characteristics (e.g. radula serrations, atrium, copulatory spine and lip notches) compare between the two forms. Until this is done the hypothesis can be neither accepted nor refuted, but there is a case for this discrete taxonomic investigation. The abundance of this organism suggests that this will not be difficult to achieve.

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