SLGGS Royal Society Project: Does Biodiversity Make Us Happy?

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Abstract

Previous studies have suggested a correlation between experiencing nature and both physical and psychological well-being.

Participants, in groups of approximately 20, had their pulse rate and blood pressure taken after five minutes' quiet time, and were each given the shortened Spielberger STAI questionnaire. Each group was split into 3 roughly equal sets that walked one of three 400m paths (through the Orchard, along the track, or along the school corridors). Afterwards, participants rested for five minutes and had their pulse rate and blood pressure taken, and were given the same questionnaire and asked to consider how many different species they saw. 659 individuals in total, primarily girls aged 11-17, participated. Data were collated according to year group. For each year group, approximately one third of participants walked each of the three routes.

Using the two sample Wilcoxon test the change in self assessed STAI was statistically significant for the orchard in comparison to the track ($W=27858$, $p=0.0003$). There was no apparent pattern in the data on pulse rate, and no statistically significant difference between pulse change in the Orchard compared to the track, ($w=22870$, $p=0.6851$). Statistically, the difference between blood pressure change in the Orchard and track was not significant for systolic blood pressure ($w=21162$, $p=0.6465$) or for diastolic blood pressure ($w=21162$, $p=0.6447$). However, in individuals with systolic blood pressure of 120mmHg or above, blood pressure decreased significantly for all three walks with the greatest reduction for the Orchard group. However, the difference between the Orchard and Track was not significant ($W = 1271$, $p = 0.4073$). The Orchard area was found to have a higher mean species richness than the track using the paired samples Wilcoxon test ($v=27$, $p=0.03125$)

It was concluded that the Orchard area was more biodiverse than the track. Walking for just ten minutes in the Orchard had a significant, positive effect on psychological well-being compared to the same time spent walking around the track. We believe that the species-rich nature of the Orchard environment contributes to this positive effect.

Introduction

Does Biodiversity make us happy?

There are several studies that suggest experiencing nature increases feelings of well-being and improves physical health. Barton and Pretty demonstrated that activity in the presence of nature leads to positive short and long-term health outcomes. They found that for self-esteem, the greatest change was in the youngest and in the mentally ill [1]. Mitchell and Popham found income deprivation related health inequalities in all-cause mortality and mortality from circulatory diseases were lower among populations resident in the most green areas [2]. Some studies suggest that walking in forested areas can even increase human natural killer activity and expression of anti-cancer proteins [3]. Work by Gaston in 2007 showed psychological benefits increased with the species richness of urban green spaces [4]. However, later work by Gaston demonstrated the lack of a consistent relationship between actual plant, butterfly, and bird species richness and the psychological well-being of urban greenspace visitors. Instead, well-being showed a positive relationship with the richness that the greenspace users perceived to be present [5].

In 2007 UNICEF's Report Card 7 put the UK at the bottom of the child well-being league table. UNICEF UK commissioned Ipsos MORI and Dr. Agnes Nairn to undertake research, talking to children from all walks of life across Spain, Sweden and the UK. They found child well-being centres on time with a happy, stable family, having good friends and plenty of things to do, especially outdoors [6]. According to the department for education one in ten children and young people aged 5 to 16 have a clinically diagnosed mental health disorder and around one in seven has less severe problems [7].

Humans are causing the sixth global extinction crisis. Students are taught about the theory and indirect consequences of species loss, but may find it challenging to link this to personal experience. At Simon Langton Girls' School we are building our own nature reserve, working with stakeholders to design and increase the variety of habitats and increase biodiversity. There are many reasons to maintain biodiversity: for environmental processes i.e. agricultural and economic importance, for possible future benefits and scientific understanding, and for moral reasons. However, we wanted to investigate the direct impacts of experiencing outside areas of high biodiversity compared to those that are lower.

We are interested in finding out if we could use our school grounds, not just to increase biodiversity for the sake of conservation, but as a way of improving the well-being of our students. E.O. Wilson defined his term *biophilia,* as 'the innate tendency [in human beings] to focus on life and lifelike process….our existence depends on this propensity, our spirit is woven from it, hopes rise on its currents' [8].

We aim to investigate the effect of spending a short time in a species-rich outside area compared to one less species-rich. We will measure both physiological and psychological indicators of well-being.

Physiological indicators

Stress can cause high blood pressure (hypertension) through repeated blood pressure elevations as well as by stimulation of the nervous system to produce large amounts of vasoconstricting hormones that increase blood pressure and heart rate [9,10]. Although anxiety does not cause long-term hypertension episodes of anxiety can cause dramatic, temporary spikes in your blood pressure. If those temporary spikes occur frequently, such as every day, they can cause damage to your blood vessels, heart and kidneys, as can chronic high blood pressure[11]. Studies have shown that calming activities such as meditation can help to reduce blood pressure [10].

We plan to measure blood pressure and pulse rate as well-being indicators.

Psychological indicators

THE STATE-TRAIT ANXIETY INVENTORY was developed by C.H. Spielberger for his work on the links between anxiety and learning ability [12]. The STAI distinguishes between state anxiety (how a person is

feeling at the time) and trait anxiety (a general tendency to perceive situations as threatening). Marteau and Bekker developed a shortened form of the stait anxiety, comprising six questions [13]:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the most appropriate number to the right of the statement to indicate how you feel **right now, at this moment**.
There are no right or wrong answers. Do not spend too much time on *any one statement but give the answer which seems to describe your present feelings best.*

Not at all (1) Somewhat (2) Moderately (3) Very much (4)
1. I feel calm 1 2 3 4
2. I am tense 1 2 3 4
3. I feel upset 1 2 3 4
4. I am relaxed 1 2 3 4
5. I feel content 1 2 3 4
6. I am worried 1 2 3 4
Please make sure that you have answered *all* the questions

They found that the shortened six question form of the STAI produced similar results to the full 20 question state anxiety questionnaire [13]. A study by Court *et al* analysed the 6-item STAI and also found it to be a valid alternative to the 20-item scale [14].

Spielberger state anxiety scale has four response categories ("not at all," "somewhat," "moderately," and "very much") which are assigned numerical values (1–4). These values are added together to produce an anxiety score (Likert scoring). Question 1, 4 and 5 are positive statements and questions 2, 3 and 6 are negative statements. To produce the STAI score the negative statement scores are reversed (1=4, 2=3, 3=2, 4=1). The limitation of this scoring system is that the difference between "not at all" and "somewhat" may be different to the difference between "somewhat" and "moderately." It is not known if all the items measure equal levels of anxiety. This approach limits the interpretation of the anxiety score because the difference between a score of 6 to 8 on an ordinal scale may not represent the same distance as a score between 8 and 10 [14].

Biodiversity

We will sample our two outside areas using a variety of ecological sampling techniques to assess plant and invertebrate species richness. We will also ask participants to estimate the number of species they saw during their walk. This will enable us to investigate the impact of actual species diversity and perceived species diversity.

Methods

1.1 Procedure to assess physiological and psychological well-being in areas of different biodiversity.

Each group of participants (approximately 20) will sit quietly for 5 minutes, after this time they will have their pulse rate and blood pressure taken three times to produce a mean. Each participant will be given a questionnaire with an individual participant number. The questionnaire will assess variables that may influence the results but are difficult to control and will include the shortened Spielberger state-trait anxiety inventory questions

Each group will be split into 3 roughly equal sets (O, T and S). Each participant in set O will be asked to walk along the 400m orchard path (Fig 1.1.3) on their own with no distractions (no phone, ipod etc); at a leisurely pace making sure they look around them. They will be asked to consider how many different species they can see. Each participant in set T will be asked to walk along the 400m Track on their own, with no distractions (no phone, ipod etc); at a leisurely pace making sure they look around them. They will be asked to consider how many different species they can see. Each participant in set S will be asked to walk along the 400m route within the school building, on their own, with no distractions (no phone, ipod etc); at a leisurely pace making sure they look around them. They will also be asked to consider how many different species they can see.

After the walk each participant will sit quietly for 5 minutes within the area they have been walking, after this time they will have their pulse rate and blood pressure taken three times to produce a mean. They will then answer a post-walk questionnaire, which will include the shortened Spielberger state-trait anxiety inventory questions and a drawing exercise.

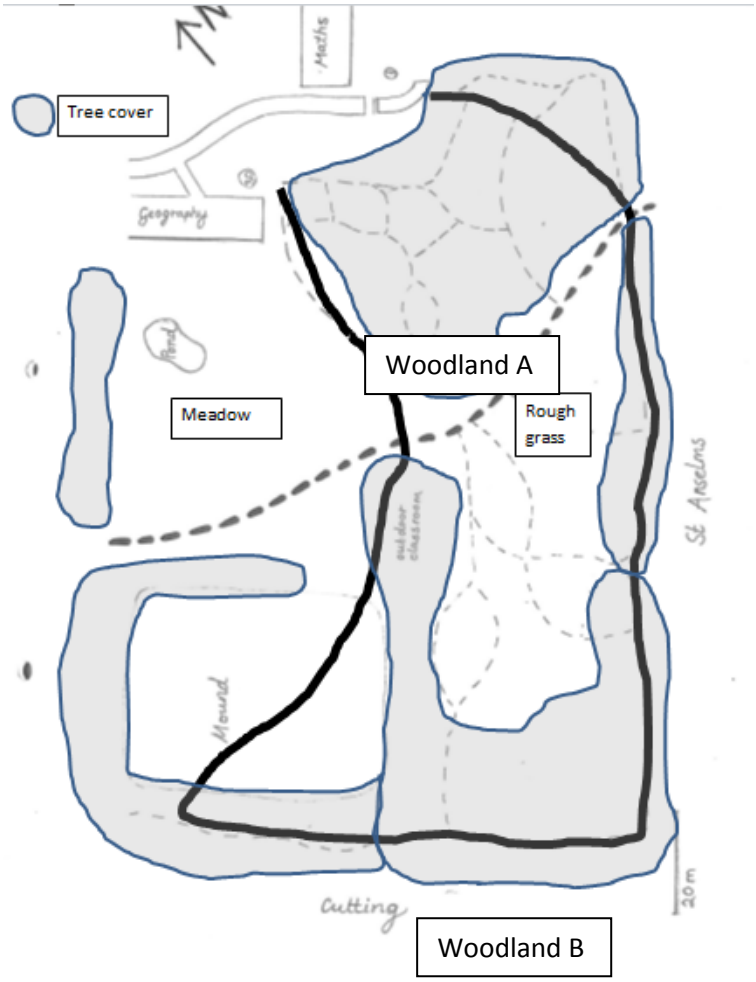
Ideally all participants will eventually complete the test for all three walks to allow the well-being data to be compared; unfortunately time constraints may make this impossible. Ideally these tests should be completed at the same time and in the same environmental conditions, but again this is impossible. We will measure the abiotic factors most likely to influence well-being (temperature, light intensity, wind speed and precipitation). The questionnaire will indicate other factors which may influence the results such as lack of sleep or consumption of caffeine.

A copy of the participant questionnaire can be found in Appendix 2

Fig 1.1.1 Blood pressure data being recorded

Fig 1.1.2 Height of students being recorded

1.2 Procedure to assess Biodiversity in the Orchard and the School Field.



Areas:	Ratio
Woodland A	1
Woodland B	1
Rough grass C	2
Mound D	1
Meadow E	2
Field - 400m track F	7

Fig 1.1.3 Map of Part of School Grounds including Planned Walking Routes.

Plant survey:

- **Tree survey.**

To be completed along the 400 m Orchard path and 400m track. All species of over 10cm diameter at breast height within 5m of the path will be identified and counted. A tree is defined as having a clearly defined trunk that branches over 2 metres above ground level [15].

- **Random sampling using a quadrat.**

Random coordinates will be generated to cover the area 3m either side from the path. A 0.25m^2 quadrat will be used. Species and percentage cover of each species within each transect will noted. The areas within the orchard and the 400m track will be sampled using the following ratio:

A:B:C:D:E:F

1:1:2:1:2:7

Groups of four students will take 7 quadrat samples. This will be repeated 5 times in the orchard and 5 times in the area of the 400m track. This will give us 35 repeats from the orchard (5 woodland A, 5 woodland B, 10 rough grass, 5 mound, 10 meadow) and 35 repeats from the 400m track.

Invertebrate survey:

- **Random sampling using pitfall traps (Figs 1.2.1, 1.2.2)**

Random coordinates will be generated to cover the area 3m from the path (at the same locations as the quadrat samples). The traps will be set up between 9:00-10:00am and left for 24h. At each coordinate 2 disposable cups (one fitted inside the other for ease of removal) will be sunk into the ground. The rim of the cup will be at ground level. Water to the depth of 3cm and a few drops of detergent will be added. A flat stone supported on 2/3 small stones will be placed over the top. After 24h the inner cup will be removed and species and number of individuals noted.

Groups of four students will take 7 samples. This will be repeated 5 times in the orchard and in the area of the 400m track. This will give us 35 repeats from the orchard (5 woodland A, 5 woodland B, 10 rough grass, 5 mound, 10 meadow) and 35 repeats from the 400m track.

Fig 1.2.1 Pitfall trap and description

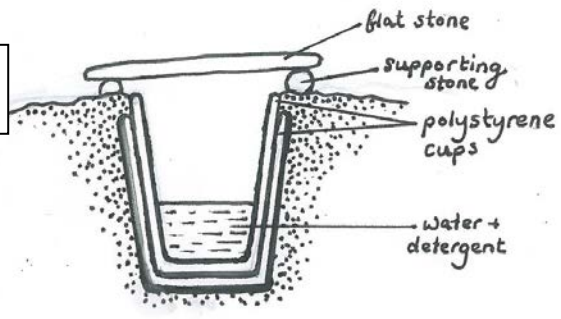



Fig.1.2.2 Pitfall trap in wooded area of Orchard being examined

- **Random sampling using a sweep net (Figs 1.2.3, 1.2.4)**

Random coordinates will be generated to cover the area 3m from the path (same as quadrat and pitfall samples). At each coordinate the sweep net will be swung through an 180^{o} arc, 5 times. The net will be held at an angle which allows the bottom edge to hit the vegetation before the top edge. The net will strike the top 15cm of vegetation (approximately). After 5 sweeps have been completed the net will be kept moving to prevent the escape of flying insects and then the net bag will be grasped half way down. The net will then be inverted and the contents emptied into a specimen jar or zip-lock bag. The species and number of individuals will be noted.

Groups of four students will take 7 samples. This will be repeated 5 times in the orchard and in the area of the 400m track. This will give us 35 repeats from the orchard (5 woodland A, 5 woodland B, 10 rough grass, 5 mound, 10 meadow) and 35 repeats from the 400m track).

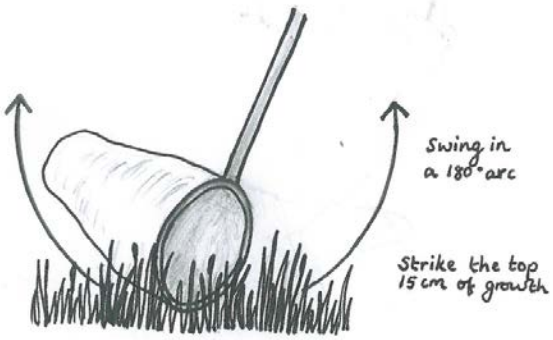


Fig. 1.2.3 Diagram to show how to use a sweepnet. The actual movement will be demonstrated by lead students


Fig.1.2.4 Sweepnetting

Sampling invertebrates from trees and shrubs using a beating tray (woodland areas within the Orchard only)

The beating tray will be placed on the ground below a leafy branch. One member of the group will give the branch three sharp taps with a stick. The other three members of the group will collect the invertebrates from the beating tray with pooters and collecting jars. The orders and number of individuals will be noted.

Groups of four students will take 2 samples (one from woodland area A and one from woodland area B). This will be repeated 5 times, giving us 10 repeats in total.

- **Butterfly transect**

To be completed along the 400 m Orchard path and 400m track. The transect route will be walked at a slow, steady pace. All butterfly species seen 2.5m either side of the path and 5m ahead will be identified and counted. The transects will be undertaken between 11:00 and 16:00 when conditions are suitable for butterfly activity i.e. dry, warm with little or no wind. They will be repeated 10 times for each transect.

- **Moth trap**

Two 6W actinic bulb moth traps will be used (Fig.1.2.5). One trap will be set in the centre of the orchard and one in the centre of the running track. They will be switched on just before dark and left overnight. The contents of the traps will be collected in specimen jars, identified and counted early next morning. This will be repeated 3 times.


Fig. 1.2.5 Moth Trap set in Orchard

Procedures for Data Analysis

Data will be entered into Microsoft Excel 2010 spreadsheets, which will also be used to sort data and generate tables and graphs. Statistical analyses will be performed using statistical software R Commander. Two sample Wilcoxon tests will be run on all comparative data apart from the final test comparing total biodiversity per sample, for which a paired sample Wilcoxon test will be used.

1.3 Preliminary Data and Changes to Method

Year 10 data collected 10th June 2015

A year 10 Science class was used for trialling method and data collection.

Two staff and seven year 12s were available to guide year 10 students. The same BP monitor was used before and after the walk. Several monitors were used in the class as a whole.

Results: See spreadsheet 9 in Appendix 1.

Positive comments on preliminary study

Data were collected from corridor walk and orchard

Students enjoyed the activity

Questionnaire seemed to go well - straightforward and most showed a change in score

Students produced interesting pictures

Notes for improvement on preliminary study and amendments to plan

It was more time consuming than expected to set up. Some blood pressure data was omitted. Modify by:

- Training year 12 researchers further before more data collected
- Just take one pulse rate and blood pressure reading at start and end rather than 3
- Staple sheets together rather than keeping separate
- Rest for longer at end (3 minutes *in situ* recommended)
- More blood pressure monitors sought
- Add track data
- Double period preferred (50 minutes difficult and can lead to rushing at end (could lead to higher pulse/bp)

Additional Amendments to Methods

Due to time constraints and the vandalism of over 20 pitfall traps laid around the track, fewer pitfall traps than planned were collected. The planned ratio of samples was used, but number of repeats was reduced (2 woodland A, 2 woodland B, 4 rough grass, 2 mound, 4 meadow, 14 track (school field)) i.e. 14 orchard and 14 field samples.

Beating tray samples were reduced to 6 rather than 10 as planned. The Orchard butterfly transect was completed 9 times and the track transect 7 times; we had planned to complete both 10 times. The track was more often in use than the Orchard, preventing butterfly data collection on two occasions. The moth traps were only set once rather than the planned 3 repeats, this was due to the risk of vandalism. They were set at dusk and collected at first light (approximately 5:30 am) to reduce the risk of our sample and equipment being damaged.

Results

2.1 Overview of Results on Wellbeing

2.1.1a Overview of Results on Self-Assessed Wellbeing (STAI)

In total, 659 individuals participated, yielding a substantial data set which can be divided according to the type of 400m walk completed: Indoors (221 individuals), outdoors on a track (215 individuals) or outdoors in the orchard area (223 individuals). See Results of Participant Wellbeing Data (Spreadsheet 9, Appendix 1)

The data collected were analysed as a whole and also separately according to year group. Data were collected on the following year groups: year 7 (aged 11-12); year 8 (aged 12-13); year 9 (aged 13-14); year 10 (aged 14-15); year 12 (aged 16-17) and year 13 and over (range of ages from 17 and above). For each year group, approximately one third of participants walked each of the three routes.

The STAI questionnaire gives a numerical value for wellbeing, which can vary between 6 (unhappy) and 24 (very happy). In general, participants tended to be happy at the start of the study (mean was 18.1 for each of the 3 walks. Results show that mean initial wellbeing was high and that it increased after walking for all groups. However, both the actual mean increase and the number of individuals for whom STAI increased was higher in the Orchard group than other groups (Table 2.1.1a, Figure 2.1.1 a and b)

Table 2.1.1a Mean values of wellbeing score (STAI) before and after walks

Walk	Mean STAI at start	Mean STAI at end	Mean difference in STAI
Orchard	18.1	20.0	1.9
Track	18.1	19.0	1.0*
Indoors	18.1	18.5	0.4

(*Apparent discrepancy due to rounding of final figures. Number given is more accurate)

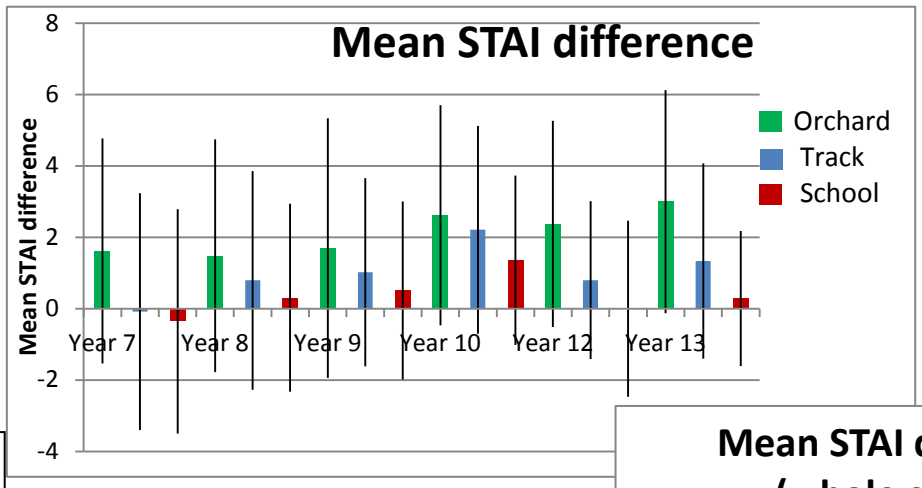


Fig 2.1.1a

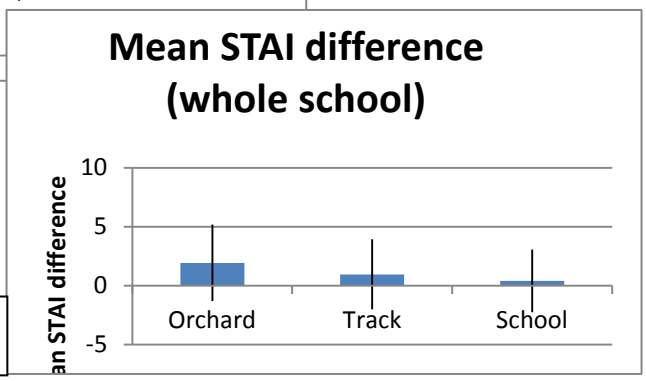


Fig. 2.1.1b

Figure 2.1.1 Mean difference in STAI including standard deviation for a) each year group b) whole school

The change in self assessed STAI was statistically significant for the orchard in comparison to the track, (2 sample Wilcoxon test, n1=219, n2=210, W=27858, p=0.0003).

Pie charts were also produced to show the proportion of individuals whose STAI score increased, decreased of stayed the same for every year group and for the whole school (Figure 2.1.1c).

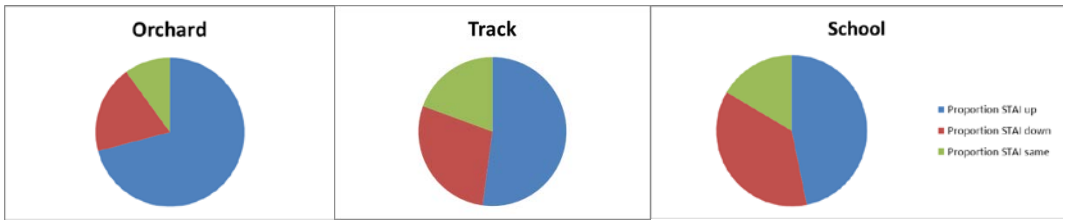


Figure 2.1.1c Pie charts to show direction of change in STAI for each group (whole school)

2.1.1b Wellbeing data compared with perception of Biodiversity

While we sampled actual biodiversity, we also considered perception of biodiversity by participants. Between 206 and 208 participants completed an estimate of species for each area walked. Results show that most species were estimated in the Orchard, then the track, with the lowest estimates in school. However, within each area, there was no correlation between perceived number of species and change in self-reported wellbeing (Table 2.1.1b).

Table 2.1.1b Changes in wellbeing compared to perception of biodiversity

Number of species estimated by participant	Orchard	Track	School
0	0	10	93
<10	17	102	93
10 -20	62	57	18
21-30	53	23	2
>30	74	15	2
Total	206	207	208
Range considered 'high'	>30	>21	>10
Range considered 'low'	<10	<10	0
P value	0.1516	0.2339	0.4737

2.1.2 Overview of Results on Wellbeing: Physiological Data

2.1.2a Pulse Rate

There was no apparent pattern in the data on pulse rate, which was extremely variable both before and after walking and showed no discernible pattern either up or down (see Table 2.1.2a below)

There was no statistically significant difference between pulse change in the orchard compared to the track, (2 sample Wilcoxon test, n1=214, n2=207, w=22870, p=0.6851).

Table 2.1.2a Changes in pulse rate for each walk (whole school)

Area Walked	Pulse Down (%)	Pulse Up (%)	Pulse Unchanged (%)	Total (%)
Orchard	101 (47.6)	103 (48.6)	8 (3.8)	212 (100)
School	101 (45.9)	105 (47.7)	14 (6.4)	220 (100)
Track	84 (40.0)	110 (52.4)	16 (7.6)	210 (100)

2.1.2b Blood pressure

There was considerable variability in blood pressure, both systolic and diastolic, between and within year groups. However there was a measured drop in systolic blood pressure after all three walks when considering whole school data (Fig 2.1.2bi, Table 2.1.2b below). Walks in all areas resulted in lowered blood pressure in the majority of participants, nonetheless more individuals showed lowered blood pressure in the Orchard group than in other groups. Statistically, the difference between blood pressure change in the Orchard and track was not significant for systolic blood pressure, (2 sample Wilcoxon test, n1=213, n2=204, w=21162, p=0.6465 or for diastolic bp, w=21162, p=0.6447).

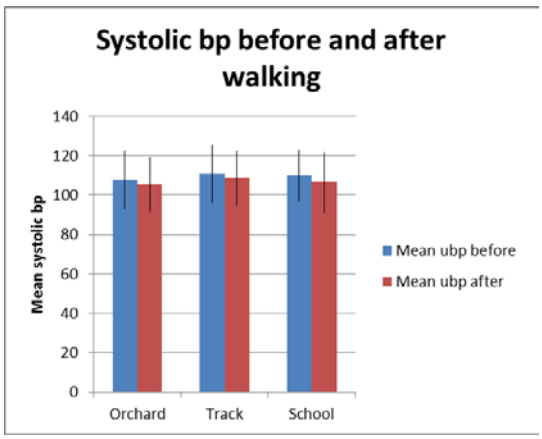


Fig 2.1.2bi Changes in systolic blood pressure after walk, showing mean and standard deviation

Table 2.1.2b to show changes in systolic blood pressure with each walk (whole school)

Area Walked	Systolic bp Down (%)	Systolic bp Up (%)	Systolic bp Unchanged (%)	Total
Orchard	126 (59.0)	83 (39.0)	5 (2.0)	214
School	109 (51.4)	90 (42.5)	13 (6.1)	212
Track	110 (53.1)	83 (40.1)	14 (6.8)	207

On reviewing the blood pressure data and the literature, we considered that for individuals with low blood pressure, a decrease would neither be likely nor advantageous. We then analysed the effect of the three walks on participants with systolic blood pressure of 120mmHg or above only. This figure was chosen as our cut off point with the rationale that 120mmHg is cited by several sources as an upper limit for children [17,18].

Using these data, we maintained a large enough cohort to do a statistical test and considered that a decrease in blood pressure could provide most benefit. For these participants, blood pressure decreases significantly for all three walks (Fig 2.1.2bii) and the reduction in blood pressure is greatest for the Orchard group, although the difference between for the Orchard and Track is not significant (Two sample Wilcoxon test, n1=49, n2=53,W = 1271, p = 0.4073). Interestingly the standard deviation lines show us that it is very unlikely to see any individual show an increase in systolic blood pressure following a walk in the Orchard, whereas this is more common when walking around the Track or within School.

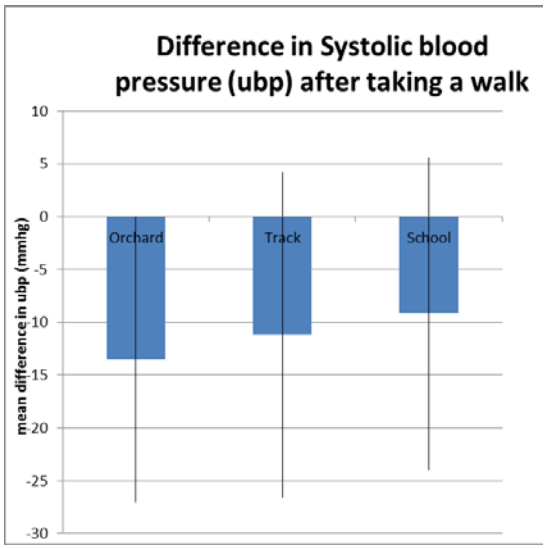


Fig 2.1.2bii Mean change in systolic blood pressure before and after a walk where initial systolic pressure ≥120mmHg, showing mean and standard deviation

2.2 Overview of Results on Biodiversity

Biodiversity was measured using the following range of techniques to allow comparison between the Orchard area and the Track:

Butterfly transects (n=7 paired +2 additional);

Moth traps (n=1 paired);

Sweepnet data (n=35 paired)

Pitfall traps (n=14 paired);

Plant survey using quadrats (n=35 paired)

Tree survey (1 paired)

Beating trays (n=6 for orchard area only; not relevant for track).

For raw data see Appendix 1.

Results of Butterfly Surveys

More individuals and more species were observed in the Orchard transect than the Track, as visualised in figure 2.2.1a below.

Species identified in the Orchard area were: small white, large white, gatekeeper, speckled wood, meadow brown, red admiral, small tortoiseshell, comma, ringlet and Essex skipper, whereas only two species, small white and large white, were observed around the Track.

Results of Moth Traps

Moth traps were set on the same night (21st July 2015) in the orchard area and on the playing field.

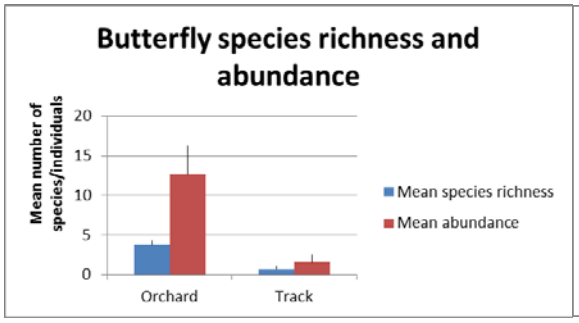
While not all species were identified, different morphs were separated and counted, see Table 2.2.1 and Fig 2.2.1b.

Table 2.2.1 Results for Moths Trapped in the Orchard and in the playing field

	Total morphospecies	Total individuals
Orchard	11	20
Track	5	9

Of the species caught, only one was found in both traps/areas. The orchard had more individuals and more species present.

a)



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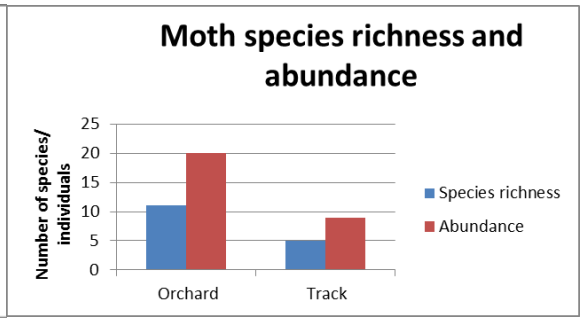

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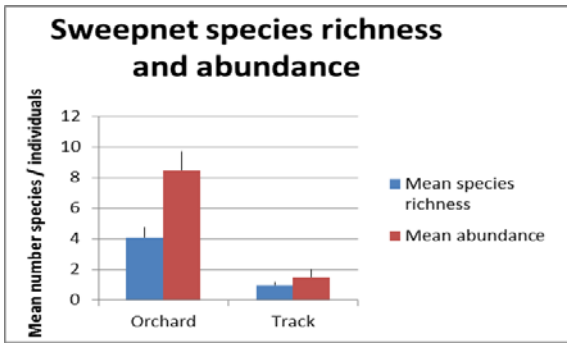

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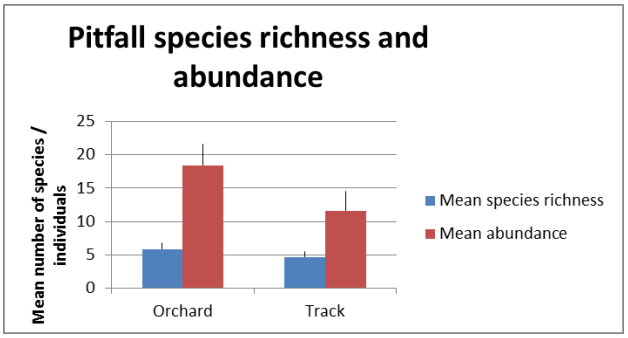

Fig 2.2.1 Invertebrate biodiversity in Orchard compared to Track (playing field

a) Butterfly transects b) Moth traps; c) Sweepnet d) Pitfall traps

Sweepnet data

The Orchard area was far more species rich than the field, as expected (Fig 2.2.1c). In addition, different habitat types within the orchard area yielded vastly different orders (Fig2.2.2)

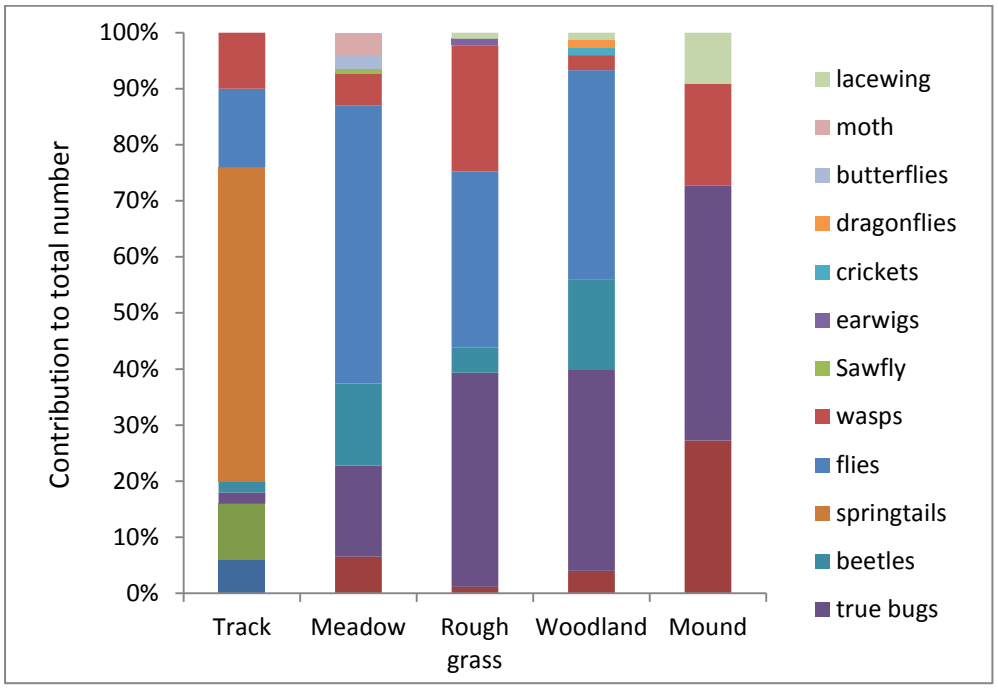

Fig2.2.2 Sweepnet Data showing percentage contribution of individuals identified orders of invertebrates within subsections of the Orchard and in the whole Orchard Area

Pitfall Traps

See Figure 2.2.1d above and Table 2.2.2 for results.

Table 2.2.2 Mean number of invertebrates per trap in the Orchard compared to track (Playing Field)

Site	Mean Number of Orders	Mean Number of individuals
Orchard woodland A	10.0	18.5
Orchard woodland B	6.0	12.5
Orchard Mound	3.0	8.5
Orchard Meadow A	5.0	20.0
Orchard Rough Grass	6.0	24.8
Orchard total	5.9	18.4
Playing field total	4.6	11.6

It was not possible to assess total species but for all subsections of the Orchard apart from one (the mound), the mean number of orders and mean number of individuals per sample was higher in the Orchard than in the field.

It is also worth noting that the different areas within the Orchard area yielded very different communities (see Fig. 2.2.3)

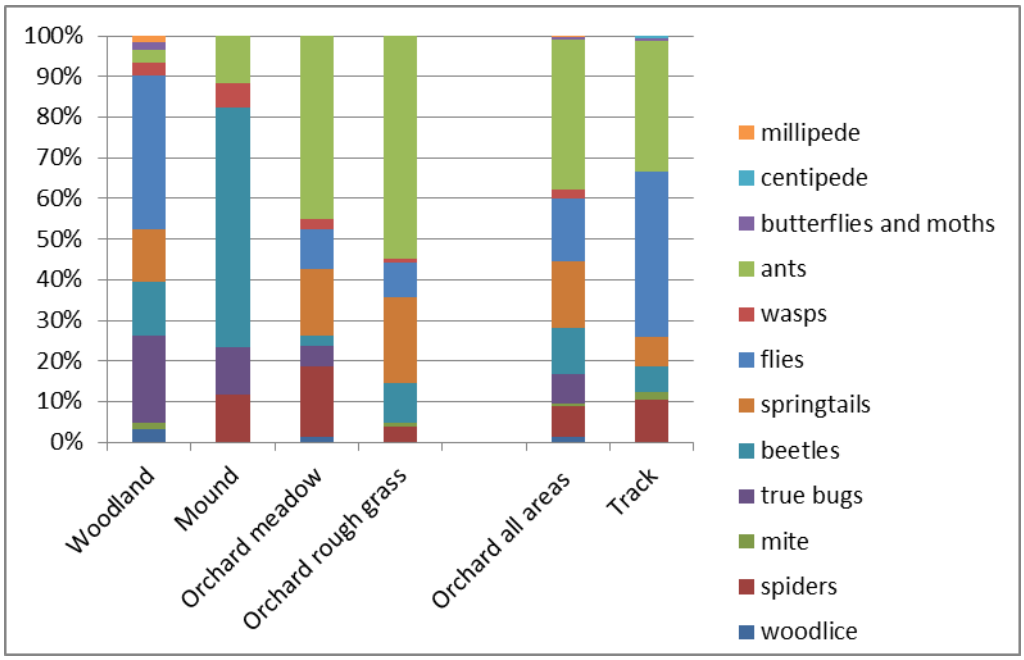

Figure 2.2.3 Pitfall Data showing percentage contribution of individuals identified orders within four subsections of the Orchard, the whole Orchard Area and the Field

Beating Tray Results

Again, more samples were collected from the Orchard as the field could yield no results for this method, Table 2.2.3. Mean number of orders per sample was 3.7; mean abundance 5.3.

Table 2.2.3 Beating Tray Results from wooded areas of the Orchard

	Sample reference	A	B	C	D	E	F	Total
Group of organism (based on Order)	Spider	2	1			1	1	5
	Harvestman		2	1				3
	True bug	2	3		1	2	2	10
	Beetle				1	1		2
	Springtail	1						1
	Fly			3	1			4
	Earwig					1		1
	Lacewing				1		4	5
	Snail						1	1
Total orders		5	3	2	4	4	4	9
Abundance		5	6	4	4	5	8	32

Plant Surveys

Herbaceous Plants: The plant survey showed that per quadrat sample (0.25m^2), the species richness was slightly higher in the field compared to the Orchard (Fig 2.2.4). However, on viewing Fig 2.2.5 it is clear that in terms of percentage cover, most of the field samples comprised a single species of grass. There was low abundance of several other species, giving a mean number of species per quadrat of just over 3. In contrast, the orchard areas were not dominated by a single species but much of each quadrat sample was taken up by few species (just under 3).

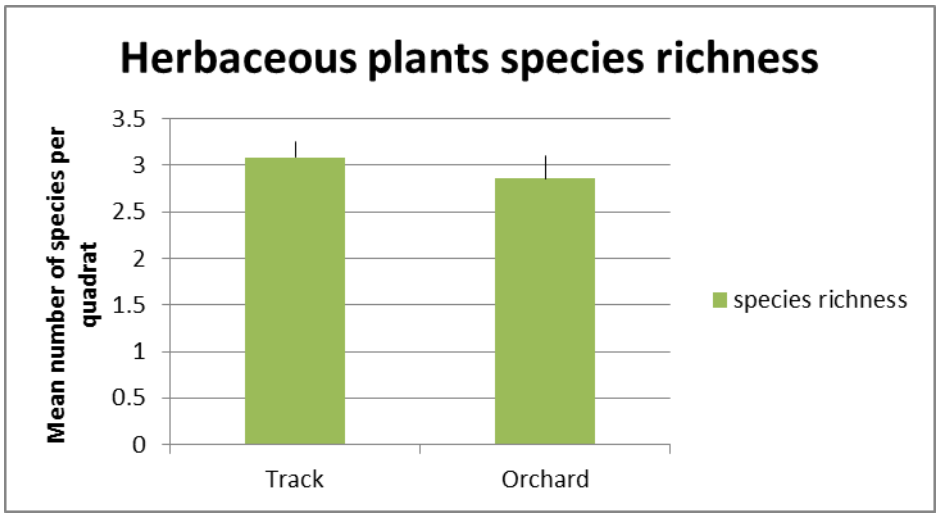

Fig 2.2.4 Herbaceous Plant Species Richness per sample in the Orchard and Field

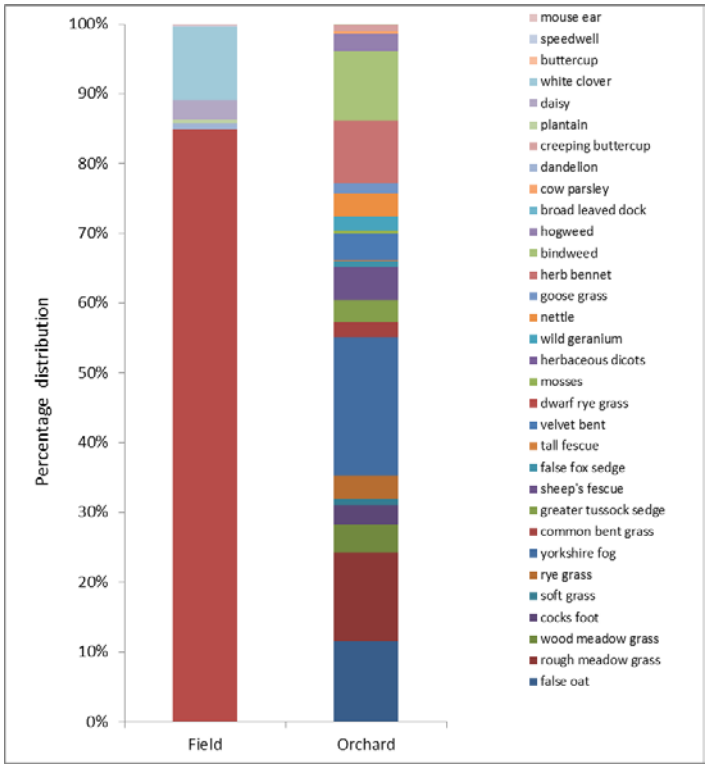

Fig 2.2.5 Species as Total Percent Cover in the Orchard compared to the Field

Tree Survey

There are more trees in the Orchard than around the track. Results from the transect survey are shown in Fig 2.2.6.

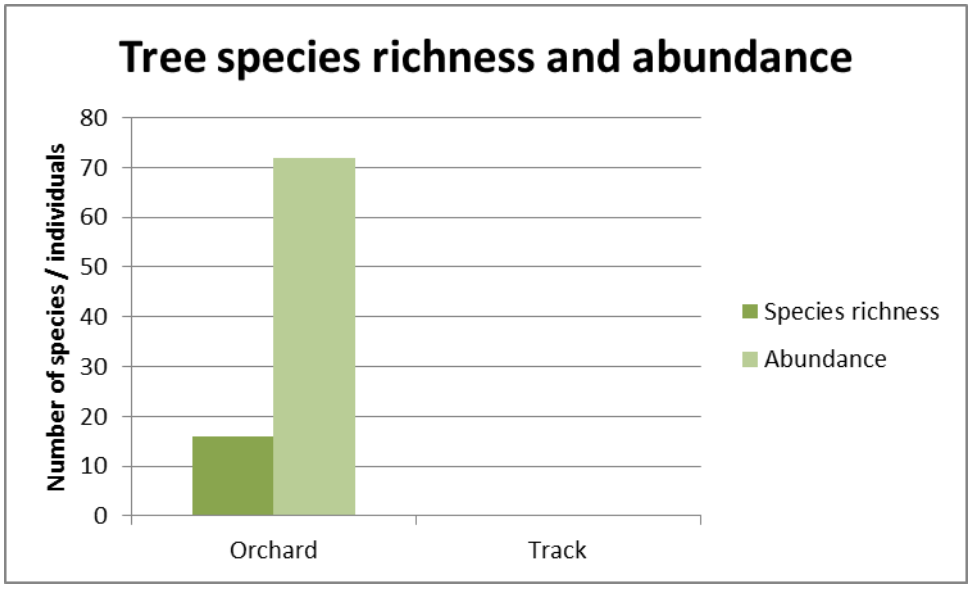

Fig 2.2.6 Tree Survey Results

Total Biodiversity Estimates

Due to differences in sampling methods and the wide range of methodologies used, including pitfall traps, to transect walks, quadrats, sweepnetting, it is impossible to accurately sum up a figure for the Biodiversity Index of each area, or to directly compare biodiversity in the Field and Orchard. The difficulty is compounded by the variety of identification techniques used, for example plants and butterflies were identified to the level of species, whereas other invertebrates were identified only to the level of order (sweepnetting, beating trays, pitfall traps) or morphs (moths). A third consideration is that many areas within the Orchard were not sampled at all, for example individual trees, canopies, woodpiles and the pond. Fourthly, it is also likely that many species we know to be present were missed [27,28,29] for a range of reasons eg time of year, time of day and lack of comprehensive sampling techniques. For example all mammals, amphibians including newts and frogs, a wide range of birds, some butterflies, grasshoppers, bees and leaf miners were not quantified for a range of reasons including those outlined above.

Nonetheless, all samples we collected were paired in the sense that we can compare equal numbers of similar sample types collected at equivalent times in the Orchard area and playing field. We can see that species number is clearly higher in the Orchard for many sampling techniques, such as tree surveys beating and sweepnetting, yet that, perhaps surprisingly, the field seems more biodiverse in terms of plant species per sample than the Orchard. Pitfall traps were comparable showed 4.6 compared to 5.9 orders of invertebrate per trap. This has been discussed above and in Fig 2.2.1 a,b,c and d.

Using all the data from each technique, including the tree survey and beating trays (for which species count in the field is zero) we can calculate mean morphospecies per sample (Fig 2.2.7).

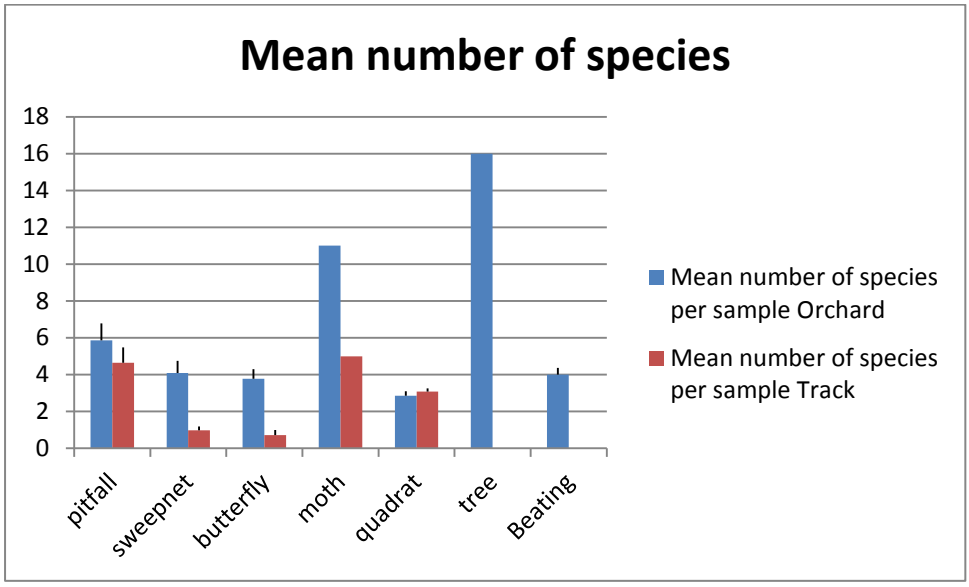

Fig2.2.7 Mean Species Number per Sample for all Methods

Using a matched pairs test, we can see that biodiversity is significantly higher in the Orchard than the Field, (Paired samples Wilcoxon Test, n=7 V=27, P=0.03125).

We can also calculate a conservative estimate for the number of species sampled. Where species were identified we can use these data directly, and where morphospecies were used we can make a minimum estimate of the maximum number of morphs of that order in any one sample. For this, we have decided to use the data from sweepnetting, beating and pitfall traps as a whole, to avoid duplication of our count. Although these techniques target different invertebrates, there is doubtless some overlap in terms of the organisms caught. We went back to our raw data and used the maximum number of morphs for each order in both playing field and Orchard to calculate a figure. Thus the final species number calculated is a highly conservative estimate: 91 for the Orchard and 33 for the Field, Table 2.2.4. Some assumptions and limitations are discussed in the Evaluation.

Table 2.2.4 Minimum Estimate of Total Number of Species Sampled in Study

Sampling technique	Minimum Total number of morphs	
	Orchard	Field
Butterfly transect	10	2
Moth trap	11	5
Pitfall/sweepnet/beating trap	28	17
Plant survey	26	9
Tree survey	16	0
TOTAL	91	33

Conclusions

3.1 Psychological data

We found that in general the students are happy. The mean measure of self-reported well-being at the start of the study was 18.1 for all groups, a high score, given that the possible range is 6-24.

Wellbeing started high, yet for the Track and School it increased for the majority of year groups and for the Orchard group it increased in all year groups (Fig2.1.1a). Possible reasons for this are discussed below. The size of the STAI index increase was particularly dramatically in the Orchard group compared to other groups. Walks of the same length were being completed on the same day and time in each class, controlling extraneous factors as best we could. All walks were completed between 10th June and 15th July 2015. Some students walked in the morning and some in the afternoon. Weather was warm (19-26°C) and ranged from sunny to overcast. Weather data were collected but not analysed.

The increase in STAI in the Orchard was significantly higher than that in the field, both outside spaces. The only differences we could pinpoint between these two areas were biodiversity, number of trees and the difference in ability to see other walkers at any given point.

Not only was the mean increase in STAI index significantly greater in the Orchard than in other groups, but a higher number of participants increased their STAI index in the Orchard compared to the track or school corridor. Table 2.1.1b Perception of Biodiversity suggests that in this case the reported increases in wellbeing in the Orchard area are due to actual experience rather than conscious perception of aspects of the environment including biodiversity.

STAI started high and increased in all groups. This may indicate a benefit to walking, or it might be that students appreciate a lesson that is 'a bit different', or that they can focus on themselves for a short time. There are known benefits to walking but the literature usually reports such benefits to regular walking rather than just one walk [16,19]. The unusual lesson structure we used could be perceived as more exciting; it was 'action packed' yet structured, required use of exciting equipment (sphygmomanometers) and going out of the classroom, allowed students to consider their feelings, give their opinions and draw an image of themselves. The walk may have allowed a chance to daydream or think freely – a bit of free space in an otherwise packed day. It has been reported that green spaces[1,2,3,4,20], daydreaming [21], walking, active lessons and even the volatile chemicals released from plants[3,20] can impact positively on individuals' wellbeing[3,20, 21,22,23] .

The fact that STAI was significantly higher in the Orchard than elsewhere could provide an answer to our original question, yes, biodiversity does make you happy. However, causation has not been demonstrated and as outlined above, there are many factors that could have contributed to the increase in STAI, several of them coming together in those students walking the Orchard.

3.2 Physiological data

3.2.1 Pulse Rate data

There was no apparent pattern in the data on pulse rate, which was extremely variable both before and after walking and showed no discernible pattern either up or down (Table 2.1.2a)

We feel that this could be at least partly due to differences in the time taken to measure the pulse on return from the walk. Some individuals may have rushed, while others waited longer. This time period was difficult to control in practice, and different individuals would possibly have required different time frames. Fitness of participants would also have affected the increase in pulse rate during the walk and the time taken to return to resting pulse rate.

3.2.2 Blood Pressure Data

For individuals with systolic blood pressure higher than 120mmHg we saw that this was reduced after a short walk. Benefits to hypertensives of green spaces and of walking have been reported and a reduction in blood pressure is not surprising in the light of studies on the health benefits of exercise including walking[15,16], although it is perhaps surprising that it is measurable after just one walk. It would be interesting to do a longer term study to see if the effects are consistent and sustained. It is not clear whether the reduction in blood pressure is due to the biodiversity, the exercise or a combination of both.

3.3 Biodiversity Data

Table 1.2.2 shows an estimate of the difference in biodiversity between the Orchard and Field, based on samples taken. When interpreting data, it is worth mentioning that the ecological community in the playing field has undoubtedly been more thoroughly sampled than the Orchard, as some areas of the Orchard remained inaccessible or difficult to sample as there is a larger range of microhabitats including individual trees and tree canopy in the Orchard area.

As expected, when all the data are considered, the plant and invertebrate surveys in the Orchard area yielded many more species than the playing field. We have shown that the Orchard is more biodiverse than the field by many measures, and significantly so. While this may not be surprising, we were not expecting the playing field, (which is flat and was mown weekly during the sampling period) to have such high biodiversity, by several measures (Fig. 2.2.4, Fig 2.2.7).

It is impossible to isolate the components of trees, the outdoors and biodiversity from each other in a reductionist way, to determine which component provides the benefit, as they are all interdependent, so although we cannot definitively say that 'Biodiversity makes you happy', it does seem that taking a walk in an area of natural beauty may well make you happy, keep blood pressure low and potentially yield other benefits.

In fact, as outlined above, there is a lot of published research on the potential benefits of open spaces on rehabilitation, pain control, healing, reducing blood pressure and cholesterol, improving immunity and mental health[24, 25].Some of the studies involve physical activity, and others just experiencing the environment, or 'forest bathing' as the Japanese describe it. Several suggestions have been put forward to explain benefits, including some of those mentioned above, but research is still ongoing as to how the environment affects key physiological markers.

Increasingly, many universities internationally seem to be conducting this sort of research, in fact there is a whole programme at the University of Essex dedicated to physical activity in natural surroundings[26].

Evaluation of the Project

4.1 Limitations of the Size and Quality of Data sets

Due to the time of year we were unable to maximise the data set by collecting data from year 11 and year 13 students, who were on study leave. However, the time of year was conducive to conducting the other aspects of the project (walking outdoors, sampling biodiversity).

Also, it should be mentioned that year 9 data were collected in a slightly different way to the rest of the school in that all year 9 data were collected in one day, during which students were outside in the orchard for most of the time. This may have affected data, though no clear differences were observed. If time and resources had allowed it would have been interesting to include mammal, bird, bat and pond surveys as well, as we know that many additional species have been recorded here [27,28,29]. It would also be interesting to conduct a longer term study, with participants taking regular walks, and monitoring STAI and blood pressure over a prolonged period.

It is possible that participants' adherence to the plan was variable, for example, some participants did not necessarily walk alone or without phone/ipod. Also, several Orchard-walkers did not know the area particularly well, and so tried to keep the person in front in view at all times. This may have had an effect.

It should also be mentioned that the vast majority of participants were female, ie every year group but one (ie. year 13 and above). We have not considered the influence of gender on results.

4.2 Limitations of data on STAI

Participants may have, consciously or not, wanted to help prove the hypothesis correct – it was not exactly a secret that we were looking to see if biodiversity had a positive effect, and this may have biased the STAI scores. Equally, some students may have wanted to disprove the hypothesis.

Self-report techniques have pitfalls and it is possible for participants to lie in order to appear 'better'. It is possible some students may have lied about how happy they were feeling to prevent enquiry or concern, whether from peers or researchers. However, many of the participants did record low scores and some seemed genuinely surprised at any difference in STAI.

It would also be interesting to look at changes in STAI for those students with lower initial scores, to see if walking has a greater benefit to more anxious or less happy individuals. Eg we could analyse participants with initial STAI scores of 18 or below. It may be that spending time or walking in the Orchard could be used as a therapy or recommended pastime for such individuals. Results could be monitored to assess potential benefits.

4.3 Limitations of Data on Blood Pressure

Blood pressure varies from person to person, developmentally and dependent throughout the day, depending on circumstances, height, build, frame of mind and body position, even within the 'normal' range. We cannot take into account all the possibilities for differences in blood pressure, and have not analysed the data according to height and weight of participants. Thus there may well be a range of explanations for the differences in starting blood pressure as well as the changes seen. Also the value of 120mm Hg cut off we used was selected after research but some experts would probably prefer a centile measure for a given population to determine a cut off value for prehypertension/hypertension. Nonetheless, we chose a logical value and worked with the information to which we had access. The pattern is interesting, and again, a longer term study might yield more information.

4.4 Limitations of Biodiversity Analysis

The limitations of the biodiversity work included the difficulty in identifying organisms and species. We thank our Partner, Dr. Turner for his help in this, and also used a range of identification tools [30, 31,32.] It is not ideal to identify organisms to different levels of classification but this was inevitable, due to differences in

the ease of identification of different orders, and according to the BWARS website, seems to be quite common[30]. Some of the organisms we had particular issues with deciding on including the springtails, tiny flies and wasps, some of which may have been, unfortunately, grouped together as a single morphospecies within their respective orders.

It is possible that several different species of each order were caught using the techniques of sweepnetting, pitfall traps and beating trays. In fact, this is quite likely, considering the differences in habitat targeted. However, we recognised that some species caught by more than one method appeared indistinguishable to us (eg some ants, bugs, flies) so to avoid duplication we erred on the side of caution. Our estimate of total species is therefore likely to be an underestimate.

Also, students doing the vegetation surveys were using field guides[31,32] and the internet. It is possible that some of the species were not correctly identified. In particular, some students found some of the grasses were hard to identify. However, while a species name may not be accurate, it is likely that the number of species is representative of the true sample.

It is not straightforward to come up with a meaningful number for a measure of biodiversity, and data cannot be interpreted in a simple fashion[33]. (However, we have used a range of methods which allow us to compare the two areas under investigation in an equivalent way and time period.

4.5 Limitations on interpreting pictures

The pictures produced by participants of themselves while walking were interesting and sometimes seemed fun to draw and observe. Some images included other organisms and environment, some included thought bubbles and others were simpler. However, the images were not analysed in any way, due to a lack of expertise as well as time. With appropriate expertise, these might yield interesting insights in to wellbeing or the perception of our surroundings.

Experience and Skills

Our lead students researched and presented reviews, planned and developed methodology. They worked with our Partner, Dr Turner, many of them having the opportunity to visit Madingley Hall in Cambridge to learn about and practice ecological techniques. Students conducted a huge amount of data collection and developed expertise using a wide range of sampling techniques. They also supported the younger students, guiding them in use of the sphygmomanoneters, helping with logistics and providing guidance.

Lead students were also involved in abstract writing, data analysis, performing statistical tests on the physiological, STAI and biodiversity data. Several of them are helping to write of their own experiences, present findings to the School, primary schools in the area and the wider community. Some of the students are planning on submitting selected aspects of the work for publishing. They have worked incredibly hard and achieved a wealth of experience. Blogs, including some interesting photographs can be found on the School website[34] and records of personal experience can be found in Appendix 3.

Acknowledgements

Students helped plan, the project, collect and analyse data, work on the abstract and give feedback. These are Cally Proctor, Gannat Fahmy, Jomana Fahmy, Benny Liu, Ciara Leonard-Booker, Catherine Newell, Georgie Selwood, Heidi Cole, Chloe Picton, Nisha Thapa, Zoe Pattison, Tolu Oyewole-Eletu, Charlotte Harbour, Rosie Rutherford, Ioana Kovacs, Esme Feurtado, Ethan Norman, Rebecca Smith, Brianna Lynch, Ella Sbaraini, Georgie Redford, Camille Flavell, Charlotte Muehlschlegel and Ruth Nicholls Pike. Staff directly involved are Mrs S Goodfellow and Dr H Vaughan. We would like to thank our Partner, Dr Edgar Turner from the University of Cambridge for his input, expertise and enthusiasm, and all participants in the project, including staff and students.

A big thank you to Mr Michael Albury, Parent Governor and all the volunteers who have helped develop and maintain the Orchard grounds.

We thank the school IT team, Mr Elliot Sherman, Assistant Headteacher; Mrs Lucy Homerston, Head of Psychology; the leadership of SLGGS and the Royal Society for their support. Thanks also must go to the providers of the statistical software R, and Dr Douda Bensasson at Manchester University for helping with the statistics in our hour of need.

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Appendix 2 Participant Questionnaire

Questionnaire (pre-walk) Participant number

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the most appropriate number to the right of the statement to indicate **how you feel right now, at this moment.**
There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1	2	3	4
Not at all	**Somewhat**	**Moderately**	**Very much**

a) I feel calm 1 2 3 4
b) I am tense 1 2 3 4
c) I feel upset 1 2 3 4
d) I am relaxed 1 2 3 4
e) I feel content 1 2 3 4
f) I am worried 1 2 3 4

Location of walk	Pulse rate before walk (bpm)	Blood pressure before walk (mmHg)	Pulse rate after walk (bpm)	Blood pressure after walk (mmHg)

Walk ……. Participant number……

1. Date …….
2. Time ……
3. Age ……
4. Year group ……..
5. Gender ……
6. Height (m)……..
7. Weight (kg)……
8. Hours sleep last night …….
9. Usual number of hours sleep per night ……..
10. Have you consumed caffeine (coffee, tea, cola, red bull etc) today? **Yes/No**

If yes, how many drinks? ……

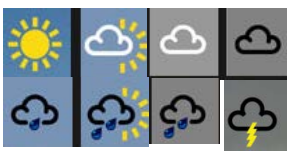
11. Do you regularly consume caffeine? **Yes/No**
12. At this time of year, how much time do you spend outside each day?

Under 1 hour / between 1 and 2 hours / over 2 hours

13. Do you live in an **urban/ suburban/ rural environment?**
14. Do you suffer from any circulatory diseases (such as arrhythmias e.g. WPW syndrome)? **Yes/No**

If yes, please give brief details:

……

Location of walk	
Temperature (^{o}C)	
Light intensity (Lux)	
Wind speed (mph)	
Weather conditions	

Questionnaire (post-walk) Participant number

1. A number of statements which people have used to describe themselves are given below. Read each statement and then circle the most appropriate number to the right of the statement to indicate **how you feel right now, at this moment.** There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1	**2**	**3**	**4**
Not at all	**Somewhat**	**Moderately**	**Very much**

a) I feel calm 1 2 3 4
b) I am tense 1 2 3 4
c) I feel upset 1 2 3 4
d) I am relaxed 1 2 3 4
e) I feel content 1 2 3 4
f) I am worried 1 2 3 4

2. Approximately how many different species of organisms (different types of plants and animals) do you think you saw during your walk?

Zero **Less than 10** **between 10 and 20** **between 21 and 30** **over 30**

3. Spend **2 minutes** drawing a picture of yourself during your walk

Appendix 3

Students' evaluation of their experiences as part of the Royal Society Partnership

'Though I couldn't always put in as much time as I would have liked, I have greatly enjoyed what I have been able to do and the whole experience has helped me find what may well be the area of biology that I would like to study more deeply at university and later on. I can honestly say it has been a pleasure, and though a fair few tasks were well outside my comfort zone (eg. Y9 Focus Day) I *did* survive them, and they may even have boosted my self-confidence. In that spirit, I anticipate future presentations of the findings with both determination and anxiety in equal measure.'
Cally Proctor

'Dr Turner is an inspiration. With a wealth of knowledge and an enthusiastic address, he captivates us all.
I really enjoyed the ecology day and was surprised to find such a diversity of species in the smallest areas of a garden.'

'I took part in the devising of control variables and the wellness questionnaire. Not only did this improve my team work skills but helped me to be innovative and think outside of the A Level curriculum. I felt that being part of this research has given me more confidence in my abilities to carry out research and appreciated being stretched to an area of biology that I was not fully familiar with. I have improved my sampling skills when measuring the biodiversity using quadrats and my knowledge of plant species when carrying out their identification. I enjoyed working with other year groups and improving my communication skills for acting as a leader and a team-player. Thank you for this opportunity.'
Catherine Newell

'The project showed me the importance of green spaces in our lives, especially with the increasingly urban environment. Also the day we spent at Madingley taught me about the various methods of measuring biodiversity to ensure a more complete look at species richness. I really enjoyed taking part in a project, which not only has given scientific results but has also renovated the orchard so it is more accessible to the students again.' Ciara Leonard-Booker

'I ended up learning so much more from this project than I had initially imagined. During the planning of the investigation, I appreciated the fact that there are so many factors we have to consider. I was surprised at the level of detail we had to think about, for example the type of area the students live. I realised the enormity of the project around this time and I started to wonder how we were ever going to achieve it! The answer was thorough planning, systematic procedure, and careful analysis of results.

During the investigation, I developed so many practical skills such as doing sweep nets and pitfall traps as different ways of taking biodiversity measurements. On a trip to Cambridge, I gained an insight into the world of beetles, springtails, and butterflies, something which I had never learned about before. I had to work with younger students, taking their blood pressure measurements and helping them do the STAI by explaining what we were investigating.

Ultimately, seeing the results displayed in pie charts and graphs was proof that there is a statistical improvement in wellbeing after taking any walk. Importantly, a walk in the orchard, the most bio-diverse area, brought about the largest increase in wellbeing. The satisfaction of seeing the outcome of the study was worth all of the work. As a result of the study I can safely say I will be choosing to eat my lunch outside in the orchard and take more walks in green spaces in the future.'

Gannat Fahmy

'Our day in Cambridge was both eye opening and entertaining. We spent our time doing a mixture of practical and theory work, which was incredibly helpful in educating us on the skills we will need to complete our project. Dr Turner was a wonderful host and teacher and, thanks to him, the day exceeded all my expectations.'

Georgie Selwood

'The stunning grounds of Madingley Hall, heaving with wildlife, provided every student with the invaluable opportunity to observe real-life applications of the scientific ideas previously learnt in the classroom. Throughout the day, the evident passion of Dr Turner helped us to expand upon our current knowledge of ecology, allowing us to explore what 'biodiversity' really means and the effects our current actions are having on the future of the natural world.'

Esme Feurtado

'The course was tremendous fun, but also highly informative. It deepened my understanding of ecology which is a subject which I am now able to see the pressing importance of. It's easy to become apathetic regarding nature because it's increasingly difficult to find time to connect with it; but the day taught me just how vital it is that we do accommodate wildlife into our modern lives. The day really piqued my interest in the subject and I hope that I will go on to join one or more of the many conservation schemes across Kent. It was an invaluable day that was greatly enjoyed by all.'

Rosie Rutherford