Faculty of Science and Technology

Impact of Land Use and Environmental Variables on Odonate Abundance in the Lower Stour Catchment

A dissertation submitted as part of the requirement for the BSc Ecology and Wildlife Conservation

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Abstract

Intensive land use by humans is causing biodiversity loss, which is directly impacting local species' abundance and diversity. Adverse effects in and around freshwater ecosystems can be mitigated, provided current environmental data is monitored. Species in the Odonata order (dragonflies and damselflies) are frequently used as indicators of aquatic ecosystem health due to their amphibiotic (aquatic and terrestrial) lifecycles stages, intolerance to pollution and species' specific preference in habitat. Assemblages of odonates were studied within 26 sites in Stour Valley, Bournemouth (comprising 13 Suitable Alternative Greenspaces (SANGs), nine Publicly Accessible Areas (PAAs), and four Sites of Special Scientific Interest (SSSIs)). 12 odonate species were identified, the most abundant being Banded Demoiselles (*Calopteryx splendens*), Azure Damselflies (*Coenagrion puella*) and White-legged Damselflies (*Platycnemis pennipes*). Abundance of *C. splendens* was positively correlated with vegetation, and negatively correlated with humidity and bare ground. Abundance of *C. puella* was positively correlated with vegetation cover and negatively correlated with vegetation height. Abundance of *P. pennipes* was negatively correlated with shade and humidity. Copulation was observed at four SANGs, four PAAs and none of the SSSIs, and there was no substantial difference between the spread of odonates from the different land use categories.

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List of Abbreviations

BCP Council	Bournemouth, Christchurch and Poole Council
BDS	British Dragonfly Society
BMX	Bicycle Motocross
BVP	Survey points at Bellevue Plantation
CP	Survey points at Canford Park
DEFRA	Department for Environment, Food and Rural Affairs
EA	Environment Agency
EU	European Union
FSC	Forest Stewardship Council
GC	Survey points at Dudsbury Golf Course
GIS	Geographic Information System
GPS	Global Positioning System
HP	Survey points at Holmwood Park
IBM	International Business Machine
IF	Survey points at Iford Meadows
KBVC	Kingfisher Barn Visitor Centre
LL	Survey points at Longham Lakes
LNR	Local Nature Reserve
NBN Atlas	National Biodiversity Network Atlas
NE	Natural England
PAA	Publicly Accessible Area
RDAA	Ringwood and District Anglers' Association
SAC	Special Area of Conservation
SANG	Suitable Alternative Natural Greenspace
SPA	Special Protected Area
SPSS	Statistical Service and Product Solutions
SSSI	Site of Special Scientific Interest
SVNP	Stour Valley Nature Park, including survey points at Stour Valley Nature Park
TBH	Thames Basin Heaths

1. Introduction

Biodiversity loss is a global issue, with threats facing freshwater environments such as habitat loss, fragmentation, and overexploitation of resources (Raebel et al. 2012; Biggs, von Fumetti and Kelly-Quinn 2016; Villalobos-Jiménez, Dunn and Hassall 2016). The combination of anthropogenic activities (for example the burning of fossil fuels, urbanisation and agricultural intensification (Jere et al. 2020)) and increasingly severe stochastic events (driven by climate change) ultimately affect ecosystem function and biodiversity of ponds, lakes and streams (Biggs, von Fumetti and Kelly-Quinn 2016). Land management is closely related to habitat degradation (Merritt, Moore and Eversham 1996; Brooks 2001; Raebel et al. 2012; Córdoba-Aguilar and Rocha-Ortega 2019), prompting scientists, landowners, and policymakers to collaborate to implement large- and small-scale schemes to reduce biodiversity loss (Raebel et al. 2012; Biggs, von Fumetti and Kelly-Quinn 2016).

Sites of Special Scientific Interest (SSSIs) are designated under the Wildlife Protection Act 1981 (Brooks 1997), and legally enforced by Natural England (NE) (NE 2012; NE 2016) for the protection of one or more ecologically important features within the site (Cottam 2019). This may be for geomorphological reasons (such as the prevention of rock erosion) or biological reasons (such as the existence of a rare species). The sites must remain in a healthy state (defined as ‘favourable condition’) through suitable management, for the features they are designated to protect (NE 2016). Intentional damage or refusal by the landowner to improve or maintain suitable conditions on a SSSI can result in different levels of penalty (NE 2016). Responsibility falls on the landowner to decide which activities are allowed or prohibited on the site (NE 2016).

To relieve pressure on SSSIs, the concept of Suitable Alternative Natural Greenspaces (SANGs) was embraced - initially by Natural England to protect the Thames Basin Heaths (TBH) Special Protected Area (SPA) over a decade ago (TBH Joint Strategic Partnership Board 2008; Bracknell Forest Council 2009; Bournemouth Christchurch and Poole Council (BCP Council) et al. 2016). SANGs are now increasingly seen in the South of England, including around Dorset, as an extension of heathland protection. The development of a SANG cannot be approved until it can be confirmed that no net harm will come to biodiversity in its proposal (BCP Council et al. 2016). The recent increase in number of SANGs accompanies Publicly Available Areas used for recreation, for example, playgrounds, BMX or biking trails and fishing activities (BCP Council et al. 2016; Fields in Trust [a] 2023).

Nowadays, the habitats surrounding Avon and Stour Valleys are vulnerable to possible threats, including: an increase in urbanisation (for example, the building of water mills and bridges); aggregate extraction; farming practices; groundwater changes (due to rivers being at abstraction capacity); and land-use changes, resulting in the land becoming highly fragmented (Dorset Council 2011; BCP Council et al. 2016; Heart of England Forest 2022; South East Water 2022). Although different land uses can enhance wildlife abundance (for example, crop rotation providing diverse food sources for pollinators, and natural ecological succession creating more submerged aquatic vegetative habitats (Harabiš and Dolný 2012)), it predominantly reduces abundance through habitat degradation and/or loss (Villalobos-Jiménez, Dunn and Hassall 2016). For instance, odonate abundance is impacted by isolation (Schutte, Reich and Plachter 1997), their dispersal rate is negatively affected by fragmentation (Angelibert and Giani 2003; Raebel et al. 2012) and local extinctions can occur from changes to secondary habitats (Harabiš and Dolný 2012). Furthermore, species in this order are highly intolerant to pollution and tend to be sensitive to multiple environmental factors (such as light, temperature and river flowrate). These points, and the fact that they are an easily identifiable order of exopterygotes – undergoing incomplete metamorphosis through both aquatic and terrestrial life stages – means that odonates can be used as bioindicators for both freshwater and habitat health (Brooks 1997). An effective ecological survey should therefore consider their presence, absence, diversity or abundance.

Stour Valley Local Nature Reserve is a three-mile stretch of river comprising meadows, woodland, and an arboretum, and is known by locals for the herbivores grazing on the fields surrounding the river Stour within the 1,240km^2 catchment area (Environment Agency (EA) 2021; BCP Council [a] 2023). Nearby, over 46 hectares of previously privately owned land are now available to the public at Canford Park Riverside SANG, to reduce pressures on sensitive heathland habitats (Chapman Lily

Planning 2015). For the same reasons, Holmwood Park SANG, comprising seven hectares of land, adjoins to Poor Common and acts as a buffer between housing and the main road (Dorset Council 2014; Fields in Trust 2022). In addition to SANGs and Nature Reserves, local land has been developed for other recreational uses, such as Bellevue Plantation – a park sitting opposite Dudsbury Golf Course, which itself is laid out over 160 acres of mature parkland crossed with streams from the river Stour (Dudsbury Golf Club 2023). In close proximity to this, Longham Lakes sit: one side primarily managed and conserved for wildlife, the other managed for angler use, with a good reputation for its coarse fishing (South West Lakes Trust 2020), although both sides are used as back up reservoirs for public water security (Ringwood and District Anglers' Association (RDAA) [a] 2017). Downstream, the urbanised area of Iford is adjacent to Iford Meadows, a public park and playing field (Fields in Trust [b] 2023), where the river Stour sits to the Northeast, flowing Southeast towards Christchurch Harbour.

The wide variety of land use and management practices around the lower Stour catchment area has direct effects on freshwater species, such as odonates. To ascertain how land use impacts diversity and abundances of common species in the Odonata order, surveys were carried out at 13 SANGs, nine PAAs and four SSSIs within the catchment. Because environmental factors are intrinsically linked to the development and behaviour of both Anisoptera and Zygoptera, multiple variables were measured. In addition, any notable features of the landscape were recorded, as well as whether copulation occurred.

2. Research Questions

This manuscript examines empirical data collected from primary research on abundances of odonate species recorded at SANGs, SSSIs and PAAs around Stour Valley, and seeks to address 12 research questions via data manipulation and statistical analyses. This dissertation will contribute to a greater understanding of how odonate diversity and abundance is influenced by land used in different ways.

Firstly, this paper contextualises the research by providing background information on land use around Stour Valley and how odonates may be utilised in conservation surveying. The next section concerns the methodology of the study, followed by analysis of the gathered data and presentation of the findings, which will aid in addressing the research questions. Prior to conclusion, constraints of the survey and method are raised, and improvements proffered.

Table 1. Research questions for the project

Research question	**Expected observation and reasoning**
How does land use affect the diversity of odonate species at a location?	It is expected that odonate diversity will be greater at SSSIs than at SANGs and PAAs because SSSIs are more closely regulated and managed specifically for wildlife and conservation, hence habitat will be in better condition. It is also expected that damselflies will be observed more frequently than dragonflies because they cannot migrate as far from a waterbody due to their smaller body size.
What is the statistical relationship between ambient sound levels and odonate species abundance?	It is assumed that the abundances of the three most common species will be higher in quieter locations because noise levels are associated with disturbance levels. Therefore, the higher the ambient sound levels, the more disturbance is expected, which may interfere with odonate foraging, reproduction and dispersal.
What is the statistical relationship between lux levels and odonate species abundance?	It is expected that the abundances of the three most common species will be greater in locations that receive more insolation, because sunlight generates warmth and odonates are ectothermic.
What is the statistical relationship between windspeed and odonate species abundance?	It is presumed that the abundances of the three most common species will be lower in locations where windspeed is greater because odonates struggle to fly in stronger winds.
What is the statistical relationship between shade and odonate species abundance?	It is assumed that the abundances of the three most common species will be lower in locations where shade is greater because shaded areas receive less insolation, and odonates are ectothermic invertebrates.
What is the statistical relationship between humidity and odonate species abundance?	It is expected that the abundances of the three most common species will not be affected by humidity because the UK clime is temperate and rarely suffers from extreme humidity levels.
What is the statistical relationship between temperature and odonate species abundance?	It is expected that the abundances of the three most common species of odonate will be higher in warmer locations because UK species are Southerly distributed and will likely seek warmth at their Northern range margin.
What is the statistical relationship between soil moisture and odonate species abundance?	It is expected that the abundances of the three most common species will not be affected by soil moisture because odonates reproduce in aquatic habitats rather than on terrestrial habitats, and foraging usually takes place on the wing.

What is the statistical relationship between vegetation cover and odonate species abundance?	It is assumed that the abundances of the three most common species will be higher in locations where vegetation cover is greater because odonates require places to perch, and dense vegetation indicates little habitat disturbance and good ecological conditions.
What is the statistical relationship between height of vegetation in the riparian zone and odonate species abundance?	It is expected that the abundances of the three most common species will be higher in locations where vegetation height is greater because this implies little habitat disturbance from management practices.
Does the presence of bare ground impact upon odonate species abundance?	It is expected that the abundances of the three most common species will be lower in locations where bare ground is present because of reduced prey availability and less vegetation available for perching.
Does land use influence odonate copulatory behaviour?	It is presumed that odonates will be observed in tandem more at protected SSSIs because of the likelihood of reduced human disturbance compared to SANGs and PAAs, where highly disruptive activities are not necessarily prohibited.

3. Methods

Prior to data collection, risk assessments and ethics checks were undertaken for the wellbeing of humans and animals involved in the project and to mitigate harm towards them – for example, any manual handling of live invertebrates, whether they were to be caught and rereleased afterwards, and any disease control measures. Data were collected by four students over the course of five days in June 2021 from 26 sites around the Stour Valley catchment. The design of the survey was to yield data from a variety of areas with different land use, all within 100m of a water body (either a lake, river, pond or ditch). Locations were selected from a colour-coded map provided by the Stour Valley Nature Partnership, (Figure 1, Figure 2 and Figure 3): 13 locations surveyed from Suitable Alternative Natural Greenspaces (SANGs), nine locations surveyed from Publicly Accessible Areas (PAAs), four locations surveyed from Sites of Special Scientific Interest (SSSIs).

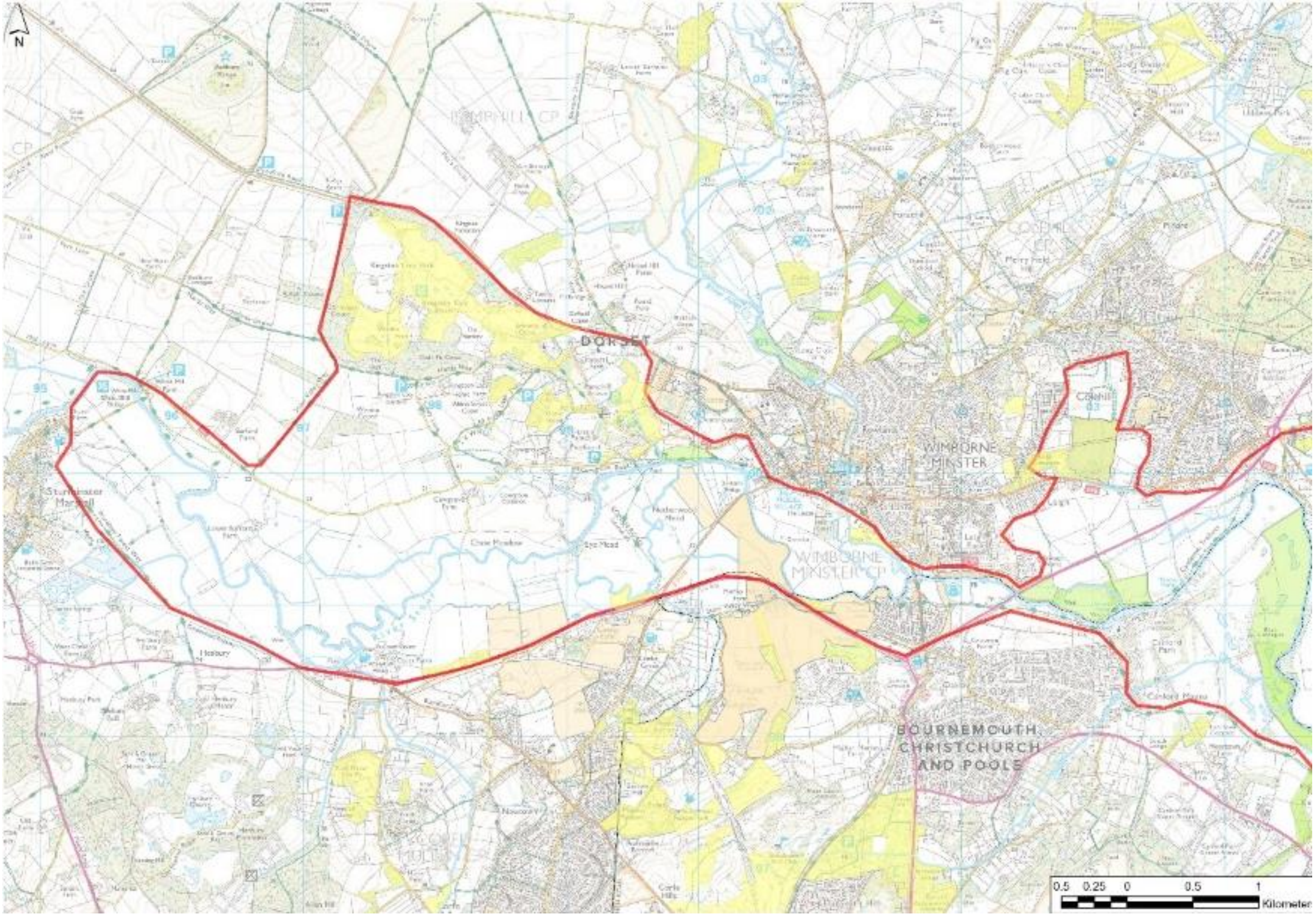

Figure 1. A map provided by the Stour Valley Nature Partnership. The red outline displays the North-western limits of the Lower Stour catchment area. Green sections are Suitable Alternative Natural Greenspaces (SANGs), orange sections are Publicly Accessible Areas (PAAs) and yellow sections are Sites of Special Scientific Interest (SSSIs).

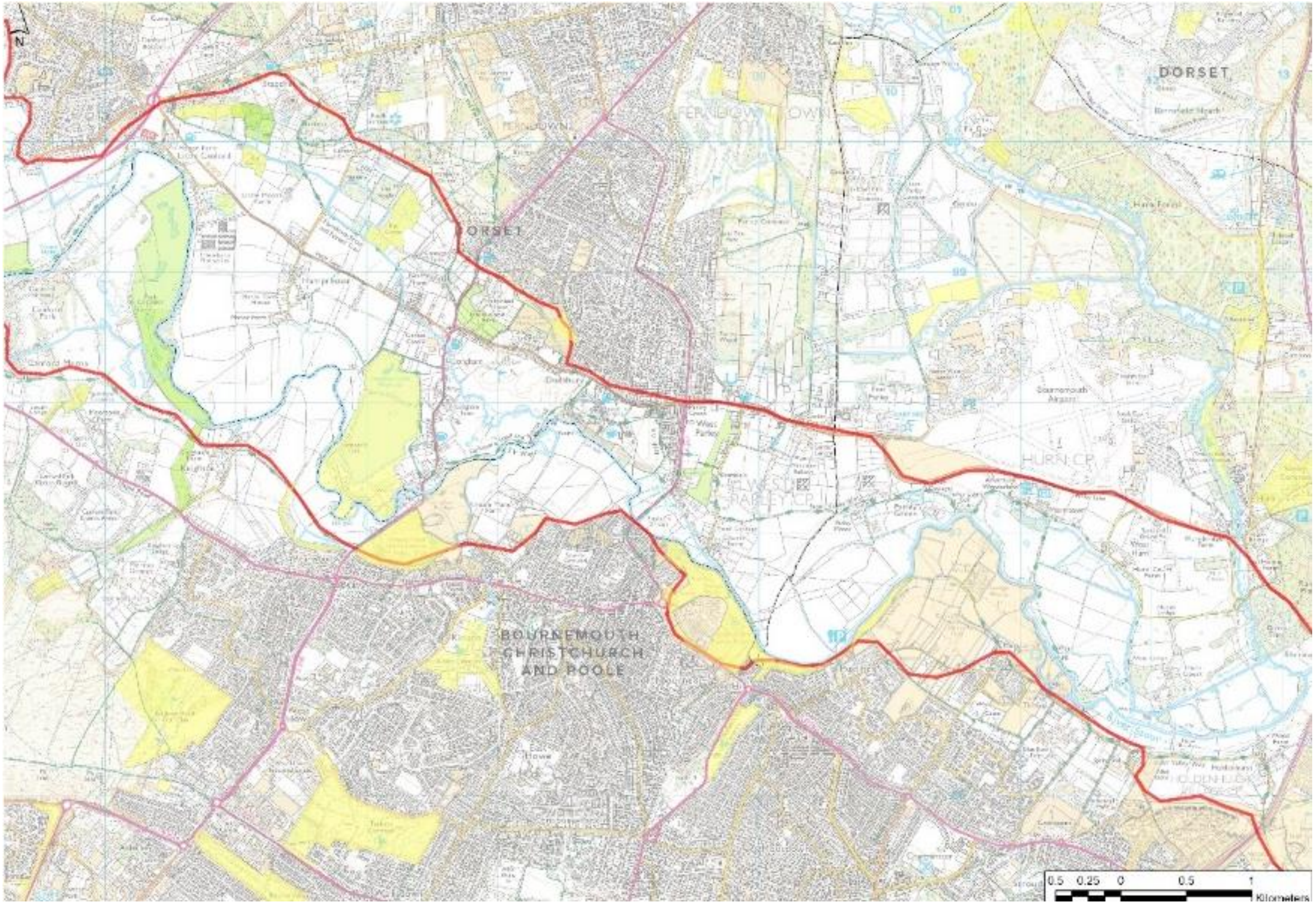

Figure 2. A map provided by the Stour Valley Nature Partnership. The red outline displays the mid-section of the Lower Stour catchment area. Green sections are Suitable Alternative Natural Greenspaces (SANGs), orange sections are Publicly Accessible Areas (PAAs) and yellow sections are Sites of Special Scientific Interest (SSSIs).

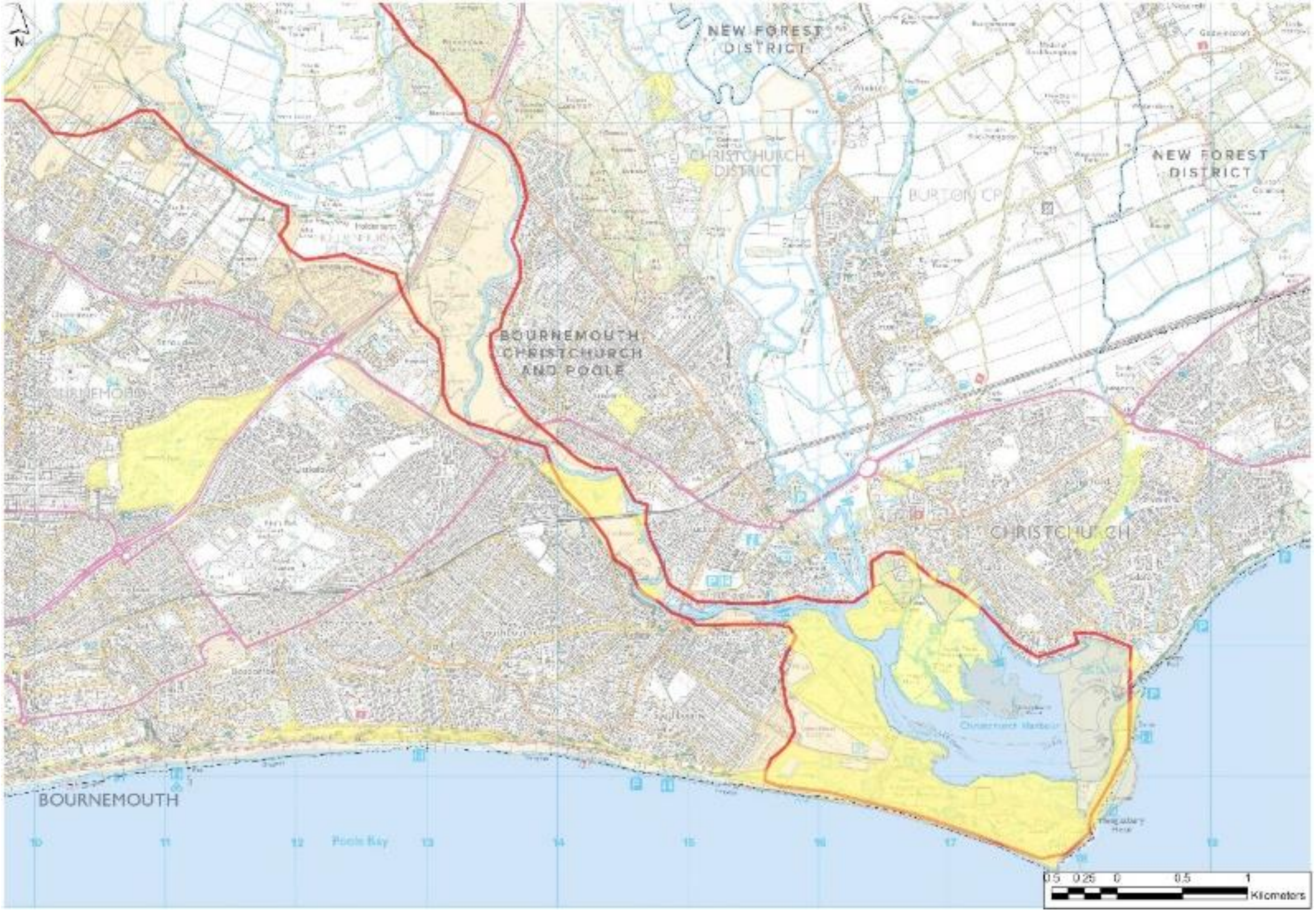

Figure 3. A map provided by the Stour Valley Nature Partnership. The red outline displays the South-eastern limits of the Lower Stour catchment area. Green sections are Suitable Alternative Natural Greenspaces (SANGs), orange sections are Publicly Accessible Areas (PAAs) and yellow sections are Sites of Special Scientific Interest (SSSIs).

At each site, a Garmin GPS Map 64s, accurate to within 15m 95% of the time, was used to note GPS location, and a 1m² quadrat was placed into an area that appeared representative of the wider surroundings. Vegetation cover (in percentage) was estimated, and plant species were identified using the revised and expanded second edition of Rose's book The Wild Flower Key (1981) and prior knowledge. A mean soil moisture percentage from three points within the quadrat were recorded using a Lutron PMS-714 soil moisture meter. A metre rule was used to measure average vegetation height from the four corners of the quadrat. Within the quadrat, the percentage of shade cover was estimated, and bare ground was marked either present or absent. Lux level (in Lux) was measured using a Standard ST-1300 lux metre set to 5000 lux, and background noise measured in decibels with a decibel meter; sound was assumed to be related to levels of disturbance at each site. A Kestrel 3000 environmental meter was used to measure windspeed in ms^{-1} (metres per second), humidity in % (percentage) and temperature in ˚C (degrees Celsius) at a height of 1m above ground level for each site. Each environmental measurement was recorded once the reading had settled for a minimum of three seconds. Any notable features of the site were recorded, which included the type of waterbody nearby, relevant landscape features and any emergent and bankside vegetation, before carrying out a ten-minute visual survey of species in the Odonata family. Due to the visibility of the sections of the river and the sizes of the waterbodies, point-counts were the chosen method, as suggested by Smallshire and Beynon in 2010. Where a species could not be identified in a point-count (either with or without Pentax-XCF binoculars), a butterfly net was used to capture the live specimen and accurately identify it using FSC dragonfly and damselfly identification guides, as suggested by the British Dragonfly Society (BDS) (BDS [a] 2019). Species name, number of individuals present, and gender (if recognised) were recorded. Copulation was noted as an event or a non-event: odonates in tandem were not identified at species level due to difficulty in identification accuracy in large aggregations, and where species were in tandem, both individuals were counted separately.

The ten-minute survey duration included time spent net catching Odonata and, hence, observation time was shorter if this was the case. When there were too many odonates to individually count, it was decided (post data collection) to categorise odonate numbers using the standard abundance categories from the dragonfly recorders network, suggested by Gillingham et al. in 2015 (Table 2). Group members aimed to standardise the data collection method by recording set factors identically at each site, however, the environmental factors recorded using the Kestrel device were measured by different group members if the original recorder was absent and may not have been recorded consistently.

Table 2. Standard abundance categories used by the dragonfly recorders network for the new millennium recording scheme. Shown here is the number of individuals (*N*) in each category for each scheme, and the ordinal category allocated to each in this study, taken from Gillingham et al. 2015.

Category	*N* (odonates)	*N* (butterflies)	Ordinal category
A	1	1	1
B	2–5	2–9	2
C	6–20	10–29	3
D	21–100	30–99	4
E	101–500	100+	5
F	>500	NA	6

Once collected, the data were put into a shared spreadsheet and cleaned: the coordinates were formatted from decimal degrees into OS grid references, plotted on a map using ‘MAGiC’ GIS (Department for Environment Food and Rural Affairs (DEFRA) 2023), and their names edited to represent the name of the location they belong (Figure 4, 4.a, 4.b and 4.c). Using ‘MAGiC’, layers were selected including OS colour mapping, RAMSAR sites, Sites of Special Scientific Interest (SSSIs), Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Local Nature Reserves (LNRs), coastal and floodplain grazing habitats, and a 250m National Historic Landscape Characterisation grid was layered to classify coordinate points. The coordinates were checked against the Climate Change category in case there were any relevant observations, and these layers were used only for visualisation during discussion.

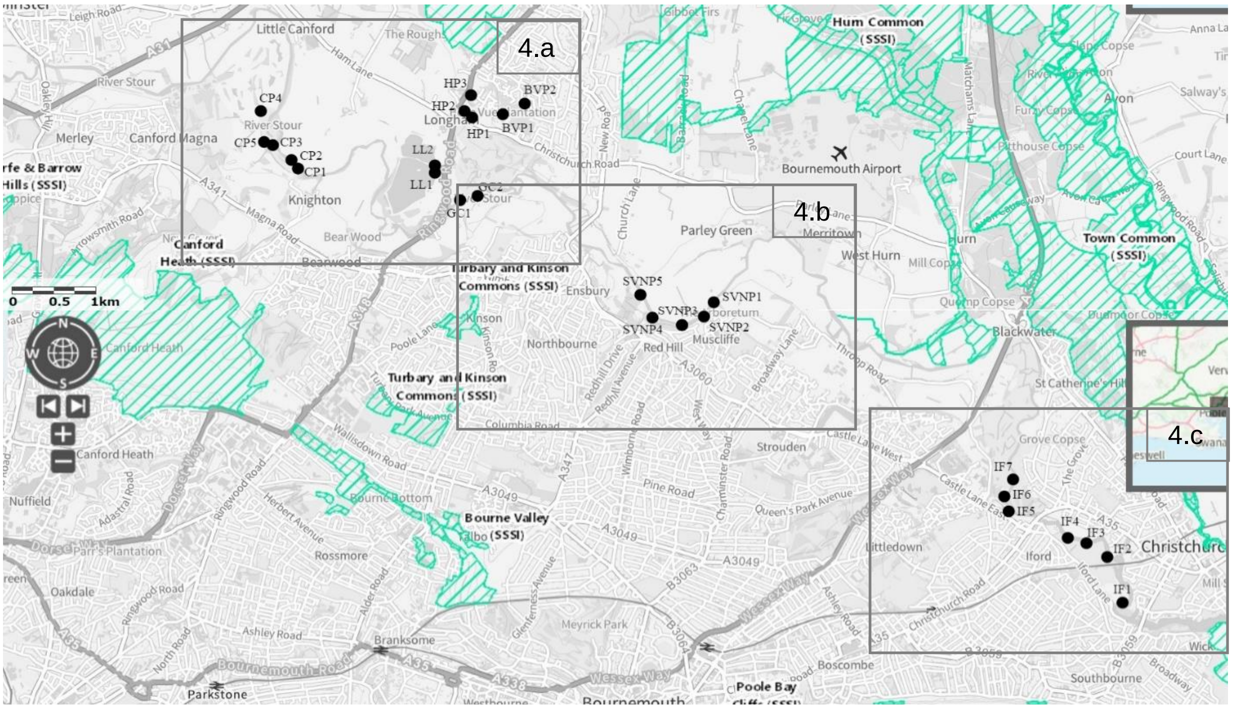

Figure 4. A map produced by the author on 'Magic' GIS displaying the 26 survey points in the Lower Stour catchment area. The blue hashed areas are designated SSSIs on the 'Magic' database (DEFRA 2023).

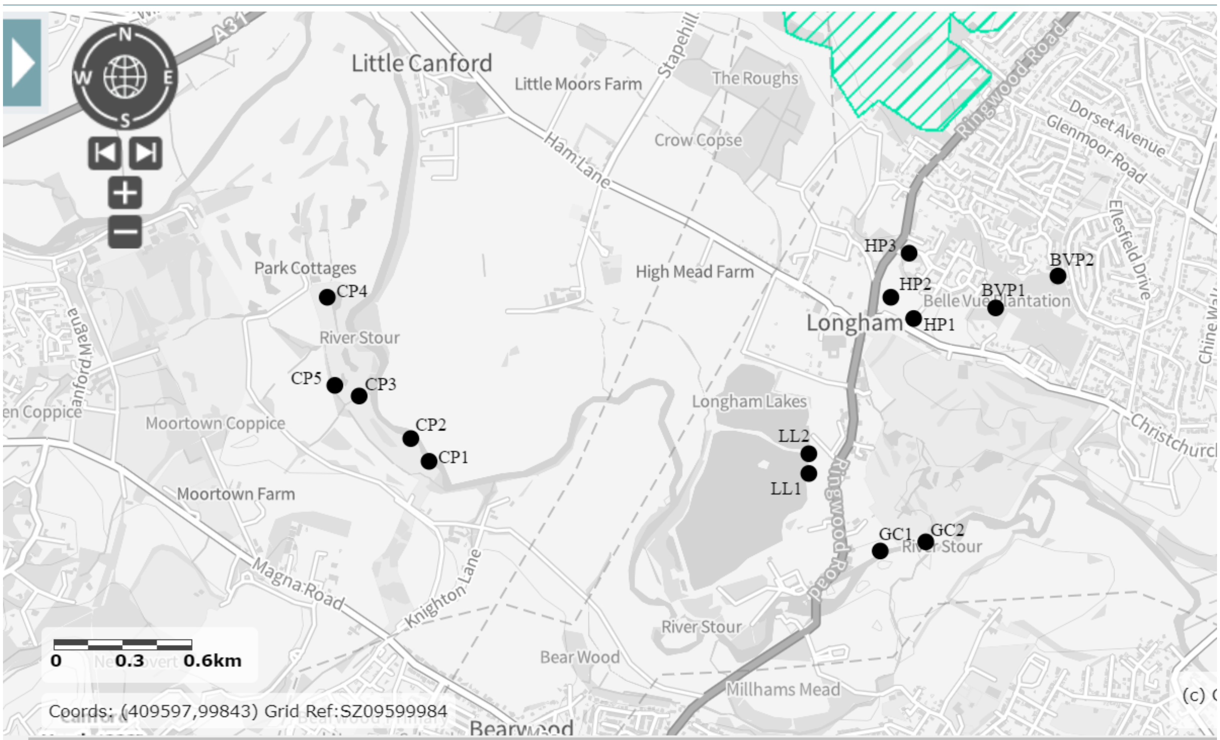

Figure 4.a. A finer scale map of: SANG sites CP1, CP2, CP3, CP4, CP5, HP1, HP2, and HP3; PAAs GC1, GC2, BVP1 and BVP2; and SSSI sites LL1 and LL2. The blue hashed areas are marked as SSSIs on the 'Magic' database (DEFRA 2023).

Figure 4.b. A finer scale map of the five SANG sites at Stour Valley Nature Park: SVNP1, SVNP2, SVNP3, SVNP4 and SVNP5. The blue hashed areas are marked as SSSIs on the 'Magic' database (DEFRA 2023)

Figure 4.c. A finer scale map of: PAA sites IF1, IF2, IF5, IF6 and IF7; and SSSI sites IF3 and IF4. The blue hashed areas to the Northeast and East of the survey points are marked as SSSIs on the 'Magic' database (DEFRA 2023).

The top three most common species were selected for statistical analysis. Due to the small sample size and non-normal distribution of data, non-parametric tests were used on IBM SPSS Statistics software version 26. Spearman’s Rho test was used to measure correlation between the abundances of the three key species and: sound levels, lux levels, windspeed, shade, humidity, temperature, soil moisture, vegetation cover, vegetation height and bare ground. A chi-squared test was not appropriate to determine association between observations of odonates in tandem across the three land use categories by reason of the small sample size. A Kruskal-Wallis test was conducted to examine any significant differences in distribution of the three most common species per each land use category. On account of the small sample size (less than 30), a *p* value of 0.1 was considered significant when running the statistical tests.

4. Results

4.1 Land Use Categories, Abundance, Density and Diversity

A total of 12 Odonate species were identified at the 26 locations, comprising of ten confirmed Zygoptera and two confirmed Anisoptera members. Unidentified species were recorded but not included for the statistical analysis. The three most common species in the overall study were *Calopteryx splendens*, *Coenagrion puella* and *Platycnemis pennipes*, each recorded at nine sites out of 26 (Table 3). Of the nine sites *C. splendens* were present, five were SANGs and four were PAAs, and none were SSSIs. *C. puella* was also recorded at five SANGs, however just three PAAs and one SSSI, and *P. pennipes* was present within five SANGs, two PAAs and two SSSIs. *Calopteryx virgo* was present in six sites overall (four SANGs and two PAAs). The highest number of individual odonates was recorded at SVNP5, where both *C. splendens* and *C. virgo* species were assigned category 5, their numbers in excess of 101 but below 500 (Appendix V). Of all the survey sites, one SANG (SVNP2), two PAAs (IF7 and BVNP2) and two SSSIs (IF3 and IF4) had no odonate observations. Within the four SSSIs, *Enallagma cyathigerum* were ascribed category 2 in LL1, and

C. puella ascribed category 2 in LL2. There were no odonate observations at sites IF3 and IF4. Kruskal-Wallis rank-sum test revealed no statistical difference ($H = 3.683$ $N = 26$, $p = .159$) between the number of odonate species from different land use categories (SANG, PAA, SSSI).

Table 3. A table to show how frequently the individual species were observed within the 26 sites surveyed. The three most abundant species from all 26 survey sites are highlighted in bold text.

Species	**SANGs (out of 13)**	**PAAs (out of nine)**	**SSSIs (out of four)**	**Total number of sites (out of 26)**
***Calopteryx splendens* (Banded Demoiselle)**	**5**	**4**	**0**	**9**
Calopteryx virgo (Beautiful Demoiselle)	4	2	0	6
Ceriagrion tenellum (Small Red Damselfly)	0	1	0	1
***Coenagrion puella* (Azure Damselfly)**	**5**	**3**	**1**	**9**
Coenagrion pulchellum (Variable Damselfly)	1	0	0	1
Enallagma cyathigerum (Common Blue Damselfly)	3	1	1	5
Erythromma najas (Red-eyed Damselfly)	1	0	0	1
Ischnura elegans (Blue-tailed Damselfly)	4	1	0	5
Libellula depressa (Broad-bodied Chaser)	2	1	0	3
Orthetrum cancellatum (Black-tailed Skimmer)	2	0	0	2
***Platycnemis pennipes* (White-legged Damselfly)**	**5**	**2**	**2**	**9**
Pyrrhosoma nymphula (Large Red Damselfly)	3	2	0	5
Unidentified species	3	0	2	5

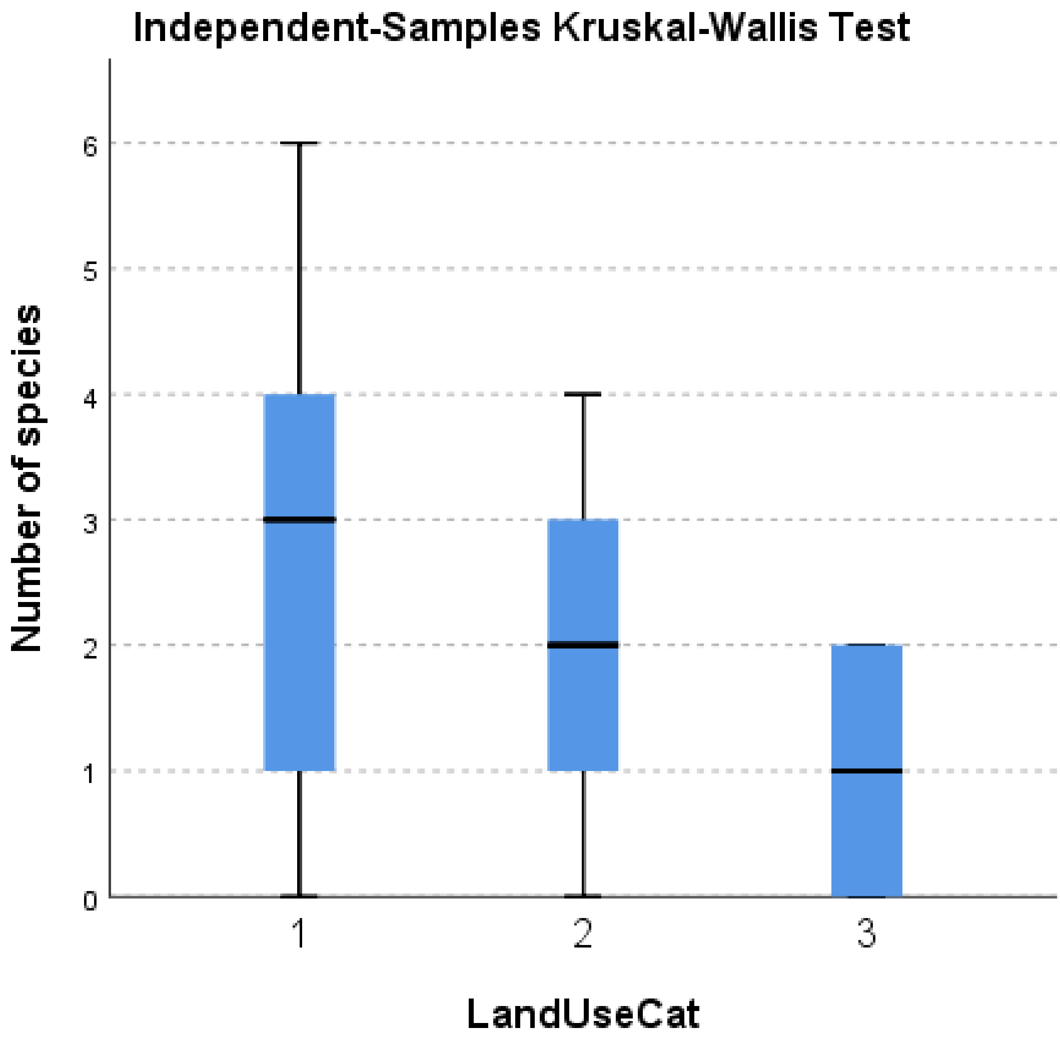

Figure 5. Boxplots detailing the number of odonate species at each survey site, arranged by land use category: SANGs (1), PAAs (2), and SSSIs (3).

4.2 *Calopteryx splendens*

Statistically significant correlations, both positive and negative, are highlighted in bold (Table 4). There was a significant negative correlation between *C. splendens* numbers with both humidity and presence of bare ground: abundance decreased as humidity increased, and similarly, abundance was lower when bare ground was present. The results show a positively correlated relationship between the amount of vegetation cover and abundance of *C. splendens*: as vegetation cover increased, so too did the number of individuals of this species. The fact that vegetation cover and bare ground are both significant is appreciable, as they are the inverse of one another.

Table 4. A table to show how abundance of *C. splendens* was correlated with abiotic variables. Statistically significant correlations, both positive and negative, are highlighted in bold.

Variable	N	Correlation coefficient	*p* value
Sound (dB)	26	0.096	.642
Lux (L)	26	0.219	.282
Windspeed (ms^{-1})	26	-0.04	.847
Shade (%)	21	-0.334	.139
Humidity (%)	**26**	**-0.416**	**.034**
Temperature (˚C)	26	0.278	.17
Soil moisture (%)	26	0.158	.442
Vegetation cover (%)	**21**	**0.378**	**.091**
Vegetation height (cm)	25	0.187	.37
Bare ground (%)	**17**	**-0.464**	**.06**

4.3 *Coenagrion puella*

There was a significant, negatively correlated relationship between vegetation height and abundance of *C. puella*: their abundance decreased as vegetation height increased.

Table 5. A table to show how abundance of *C. puella* was correlated with abiotic variables. Statistically significant correlations, both positive and negative, are highlighted in bold.

Variable	N	Correlation coefficient	*p* value
Sound (dB)	26	-0.321	.11
Lux (L)	26	-0.9	.663
Windspeed (ms^{-1})	26	0.069	.737
Shade (%)	21	0.206	.369
Humidity (%)	26	-0.215	.293
Temperature (˚C)	26	0.134	.513
Soil moisture (%)	26	-0.087	.672
Vegetation cover (%)	21	-0.182	.43
Vegetation height (cm)	**25**	**-0.431**	**.031**
Bare ground (%)	17	-0.186	.475

4.4 *Platycnemis pennipes*

Significant negative correlations were observed between abundance of *Platycnemis pennipes* and both shade and humidity: as both variables increased, abundance decreased.

Table 6. A table to show how abundance of *P. pennipes* was correlated with abiotic variables. Statistically significant correlations, both positive and negative, are highlighted in bold.

Variable	N	Correlation coefficient	*p* value
Sound (dB)	26	-0.029	.888
Lux (L)	26	0.269	.184
Windspeed (ms^{-1})	26	0.052	.8
Shade (%)	**21**	**-0.481**	**.027**
Humidity (%)	**26**	**-0.365**	**.067**
Temperature (˚C)	26	0.295	.144
Soil moisture (%)	26	0.136	.508
Vegetation cover (%)	21	0.306	.177
Vegetation height (cm)	25	0.032	.879
Bare ground (%)	17	-0.223	.389

4.5 Insignificant Variables

Temperature was the only statistically insignificant variable that was positively correlated with the abundances of the three most common species. However, other variables that were insignificant (in either direction) to each of the three species' abundances were: sound levels; lux levels; windspeed; and soil moisture. Of these variables, sound, humidity, and bare ground were consistently negative.

In addition to temperature, abundance of *C. splendens* increased with higher lux levels, soil moisture and vegetation height but decreased with higher sound levels, windspeed and shade. Abundance of *C. puella* decreased as sound levels, lux levels, humidity, soil moisture and presence of bare ground increased. There were insignificant positive correlations between this species' abundance and windspeed, shade and temperature. Abundance of *P. pennipes* decreased with higher sound levels and presence of bare ground, but abundance was positively correlated with increased lux levels, windspeed, temperature, soil moisture, vegetation cover and vegetation height.

4.6 Copulation

Copulation was observed across all species at four SANGs, four PAAs and none of the SSSIs. In each land use category, odonates were more often observed independently than in tandem (Figure 6).

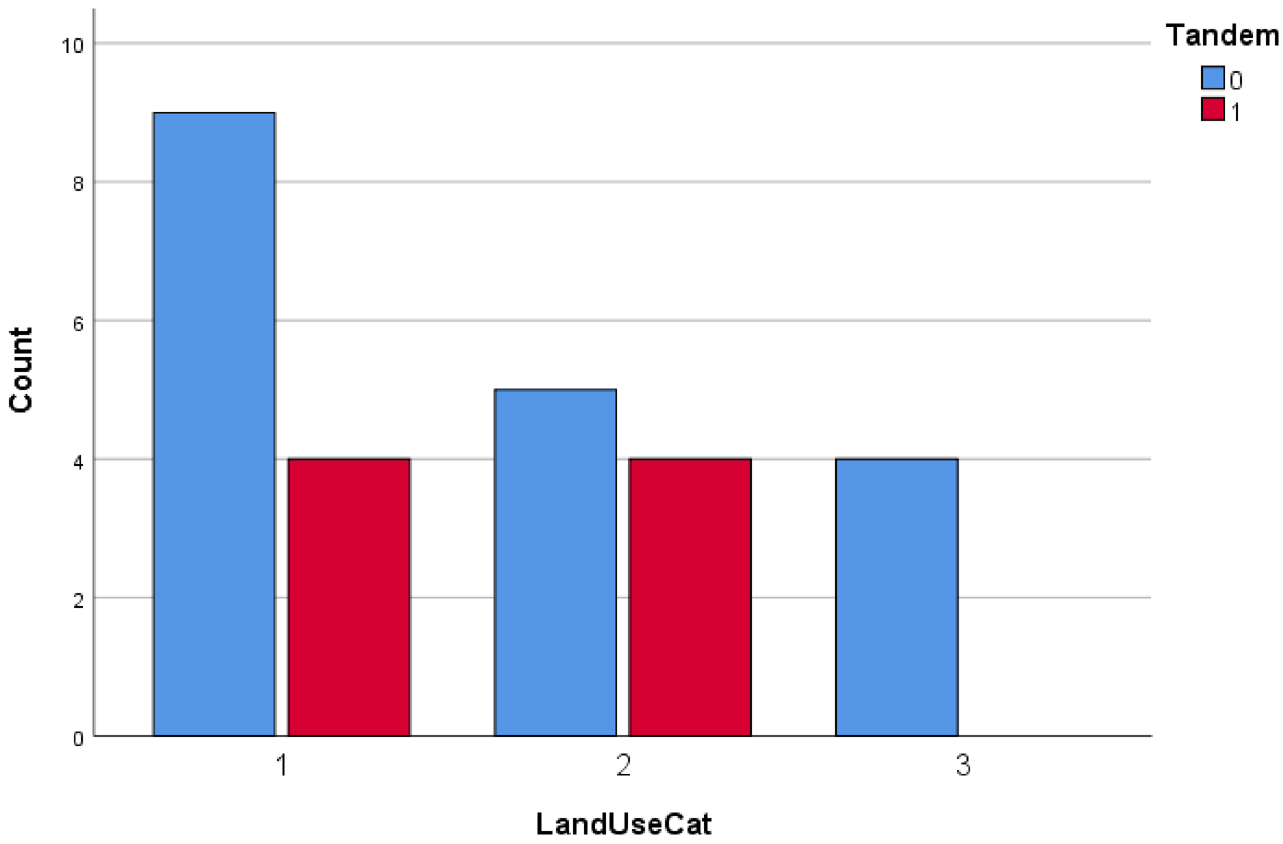

Figure 6. A bar chart to display the spread of odonates independently (0/blue) or in tandem (1/red), at the three separate land use categories: SANGs (1), PAAs (2) and SSSIs (3).

5. Discussion

5.1 Land Use Categories

Odonate observations were expected to be higher in SSSIs than in both SANGs and PAAs due to the likelihood of reduced disturbance through a more regulated approach to land management, yet the results show no considerable difference between the spread of odonates from different land use categories. In terms of land use, although much of the area surrounding the waterbodies surveyed is agriculturally used, all three categories of sites (that is, SANGs, PAAs and SSSIs) are available to the public, although SSSIs are not required to be (NE 2016). The number of odonate species might be similar across land use because public access is not prohibited at any of the sites, regardless of designation. This means that the possibility of disturbance by people using the area is still high. If, for example, sections of a park were closed to the public in order to keep a protected feature in pristine condition in a SSSI, odonate abundances may increase during such a time.

It is likely that the popularity of Bournemouth as a summer holiday destination, and an increase of visitors at peak times of the year, motivates the maintenance of land around the river Stour, and therefore impacts on habitat quality. Despite general heathland use in the South of England changing to suit agricultural and horticultural need (Merritt, Moore and Eversham 1996), the areas surveyed did not reflect this, instead representing land that is used by the public to access parks or other green spaces. Modifications like the reworking of water meadows, drainage, channel realignment and construction of weirs (EA 2019; Firth and Firth 2020), particularly in areas managed for specific amenities (such as local parks and angling sites), have resulted in a more homogenous, disconnected habitat and a slower river flowrate (Hofmann and Mason 2005; EA 2019). Within the lower Stour conurbation, urbanisation and development have intruded onto the natural floodplain, putting increasing pressure on flood storage as risks for flooding (including surface flooding) of local properties and transport increases (EA 2012).

Most sites visited in the current experiment were at lotic waterbodies (SVNP1, SVNP2, SVNP3, SVNP4, SVNP5, GC1, GC2, CP1, CP2, CP3, IF1, IF2, IF3, IF4, IF5, IF6, IF7, HP1 and BVP 2). Some were lentic (LL1, LL2, CP4, HP2 and HP3). Few sites were not in direct proximity of a waterbody (CP5, HP2, HP3 and BVP1). Modifications made to the Stour Valley conurbation could harm stenotopic species (if a section of river now has a slower flow rate and is attracting lentic species to lotic waterbodies) by novel predator or competitor introduction (Hofmann and Mason 2005). Alternatively, eurytopic species, such as *C. puella*, are more likely to succeed in these conditions (Hofmann and Mason 2005). However, the urbanisation of the areas surrounding the survey sites may have unexpected benefits to odonate diversity (Jere et al. 2020). Gause's law states that sites exposed to little disturbance will have low species diversity owing to competitive exclusion, whereas sites exposed to high disturbance will have low diversity due to rapid recolonisation (Jere et al. 2020). The Intermediate Disturbance Hypothesis suggests a moderate level of ecological disturbance will have minimal impact on local species diversity compared to relatively large or small disruptions, due to the fluctuating states of ecosystems (Townsend, Scarsbrook and Dolédec 1997; Jere et al. 2020). For this to take effect, there must be a dynamic landscape (here, justified by the urbanisation of railway and road traffic near the survey sites) and a trade-off between a species' ability to colonize and compete (Wilson 1994; Townsend, Scarsbrook and Dolédec 1997), justified by the high dispersal abilities of odonates. Fewer stenotopic odonates should be associated with land used extensively by humans due to their intolerance to various stressors (Villalobos-Jiménez, Dunn and Hassall 2016), or by land exposed to minimal human disturbance as befitting these disturbance theories. Disturbed environments are likely to be occupied by more eurytopic species (Futuyma and Moreno 1998), leading to a reduction of local species richness (Villalobos-Jiménez, Dunn and Hassall 2016). Referring to the present study, both specialist species (for instance, *P. Pennipes* (Steiner et al. 2000; Smallshire and Swash 2014) and generalist species (such as those in the Coenagrionidae and Libellulidae families, which are associated with disturbed sites (Šigutová, Šipoš and Dolný 2019)) were observed throughout, thus substantiating these hypotheses. Further validation of the results is reinforced by analysing the latest data provided by the EA. Waters within the lower Stour conurbation were prevented from reaching a 'good' status due to wastewater pollution from the water industry (two cases), and agriculture and rural land management (two cases) (EA [a] 2022). There were no recorded cases of pollution from recreational activities (EA [a] 2022), which are likely to occur in SANGs, PAAs and SSSIs alike, albeit to varying degrees. Compared to Anisoptera, Zygoptera are more sensitive to waterbody-related variables such as pollution (Nagy et al. 2019, Smallshire and Swash 2014), hence the lack of pollution cases in the present survey are not likely to detriment abundances of *C. splendens*, *C. puella* or *P. pennipes*. Diversity per land use category was not analysed from the results. Applying map layers on 'MAGiC' (DEFRA 2023) revealed that none of the surveyed areas were SACs or SPAs.

5.1.1 SANGs

Two of the three SANG surveys (SVNP and CP) – ten sites – were conducted beside sections of the river Stour where coarse fishing is seasonally permitted (with valid licensing), and members of the public can allow their dogs off the lead (Kingfisher Barn Visitor Centre (KBVC) 2019). SVNP is designated a LNR for its importance to either wildlife, geology, or enjoyment – however, this must not be at the detriment to wildlife (NE and DEFRA 2014; DEFRA 2023). Hence, these restrictions are likely to reduce human impact on total odonate abundance. They are supported and enforced by the Environment Agency as part of a plan to significantly promote biodiversity and river quality by 2025 (EA [b] 2022): specific launching bays along the Stour are patrolled for use in water sports. Site CP4 was beside a small lake, prohibiting swimming and requesting dogs do not trample the bankside (Canford Park Sang 2022). The three sites at Holmwood Park SANG (HP) included one deep, narrow, stagnant ditch and two areas of improved grassland (Plantlife et al. n.d.) (site HP3 had the second tallest average vegetation height (Appendix V)). HP1, HP2 and HP3 were located next to a busy main road on a small housing estate. While HP1 contained a ditch, the lack of odonates observed at HP3 may be due to the thick deciduous tree line that relevantly reduced sunlight exposure to the survey area (Appendix V).

The purpose of a SANG is to relieve pressure on a SPA, a SAC and/or a Ramsar site (BCP Council et al. 2016). Although the 'MAGiC' designation reveals which SANGs are LNRs, it cannot quantify how beneficial they are to wildlife, which may explain the high median and high variability in number of species at SANG sites. For example, odonate abundance was expected to be lower in SVNP as a SANG, however, because it is also a LNR there are features of importance both to locals and visitors. Therefore, it is in best interest to ensure biodiversity loss is minimised; achieved through land use management by the local council (BCP Council [a] 2023).

5.1.2 PAAs

Sites GC1 and GC2 were beside a golf course and a busy main road, unlike the PAAs at Iford Bridge and Bellevue Plantation, where their proximity to housing estates were buffered by a playing field and a small woodland, respectively. Sites IF2, IF5, IF6 and IF7 were located above Iford Bridge, where fishing is not permitted from boats (RDAA) [a] 2017), whereas IF1 was located below the bridge. A train track crossed over the river, which itself ran through a multi-use sports field near an infant school, suggesting a higher capacity for exposure to human disturbance than other sites, hence a lower total odonate abundance was expected. The PAAs at Bellevue Plantation (BVP1 and BVP2) were surrounded by housing and developments. BVP1 was approximately 250m away from the nearest waterbody in an extremely shaded woody area dominated by oak, birch hazel, occasionally pine trees, and invasive rhododendron. At this point, cloud cover was extremely high compared to previous survey sites, where there were fewer (or no) clouds (personal observation by the author), and predictably no odonates were observed at this site, due to the combination of adverse conditions (high shade, no waterbody and reduced temperature).

The small pond at BVP2 was surrounded by dense vegetation and trees, providing good shelter from any wind, with aquatic plants covering at least 50% of the waterbody. It was expected that the high cover of vegetation over the surface of the water would hinder odonates (Rouquette and Thompson 2005), however *C. puella* and *Pyrrhosoma nymphula* were observed and identically ascribed standard abundance category 3 due to the visual estimation of their aggregation numbers. It is noteworthy that *P. nymphula* are known to be a Spring species, often emerging in April and peaking in May, compared to *Ceriagrion tenellum*, a Summer species (Cham 2012). The later emergence of *C. tenellum* (present at one site) explains why *P. nymphula* were observed more throughout the study (present at five sites).

5.1.3 SSSIs

The Northern side of the reservoir at Longham Lakes permits fishing with licenses, except by the railings next to the fishing Lodge (in very close proximity to site LL2) (RDAA [a] 2017). Dogs are allowed at both lakes, provided they remain on a lead (RDAA [a] 2017; South West Water n.d.), and the Southern side of the reservoir is used for recreational use, such as flying model aircrafts (Christchurch and District Model Flying Club 2019). The SSSI sites IF3 and IF4 were located above Iford Bridge, where fishing is not permitted (RDAA [b] 2017). When the four location coordinates for sites LL1, LL2, IF3 and IF4 were plotted on 'MAGiC', along with the 'SSSI' layer, it appeared that they were not officially classified as SSSI. Survey site HP3 was the nearest to a SSSI, at approximately 0.5km distance away, followed by IF2, approximately 1km distance away (DEFRA 2023). Cross referencing this with the Natural England website (NE n.d.) confirms as such. The map provided by Stour Valley Nature Partnership presenting some areas as SSSIs did not corroborate with the 'MAGiC' database, and so none of the surveyed sites were designated SSSI protection sites for odonates. Once this was discovered, the application of the LNR layer on 'MAGiC' revealed sites SVNP1, SVNP2, SVNP3, SVNP4, SVNP5, IF3 and IF4 were a LNR (Appendix V). Seven of the locations were marked as Sites of Special Scientific Interest (SSSI) on the Stour Valley Nature Partnership map: SVNP1, SVNP2, SVNP3, SVNP4, SVNP5, IF3, IF4. However, subsequent information found on 'MAGiC' GIS (DEFRA 2023) revealed the land use categories ascribed by the Stour Valley Nature Partnership map did not align with those from the online database. This was not discovered until after the statistical comparisons, and so data yielded from the supposed SSSIs may provide inaccurate results.

5.2 Density, Abundance and Diversity

Odonate species density was established for each land use category based on the standard abundance classification used by the dragonfly recorders network (Table 2). From all 26 survey sites, aggregates of *C. splendens* and *C. virgo* had the highest density (ascribed category 5 at SVNP5) (Appendix V). These were also the data points with highest density of all 13 SANG sites. Within the nine PAA sites, the species with the highest density (ascribed category 4) were *C. splendens* and *P. nymphula* at GC2, *C. puella* and *Ischnura elegans* at IF5, and *P. pennipes* at IF6. Within the four SSSIs, unidentified odonates were ascribed category 3 at LL2, however, because these were not included in the statistical analysis, the highest densities belonged to *E. cyathigerum* and *P. pennipes* at LL1 and *C. puella* at LL2 (all ascribed category 2). *P. nymphula*, *C. puella*, *E. cyathigerum* and *I. elegans* have a very broad distribution around the UK (Brooks 1997), so it was expected that they would be observed in the survey.

Examining the National Biodiversity Network (NBN) Atlas database, within a ten-kilometre radius of KBVC (a central point to all 26 locations) the ten most recorded odonates (Table 7) are within the top 100 recorded insects in the area (NBN Atlas 2021).

Table 7. A table complied by the author, comprising data taken from NBN Atlas (NBN Atlas 2021) displaying the top ten recorded odonates within ten kilometres of Kingfisher Barn Visitor Centre, a central location to the 26 survey sites.

Species	**Number of records**
Sympetrum striolatum (Common Darter)	2628
Coenagrion puella (Azure Damselfly)	1537
Ischnura elegans (Blue-tailed Damselfly)	1199
Pyrrhosoma nymphula (Large Red Damselfly)	1024
Aeshna mixta (Migrant Hawker)	1005
Anax imperator (Emperor Dragonfly)	889
Libellula depressa (Broad-bodied Chaser)	782
Aeshna cyanea (Southern Hawker)	763
Enallagma cyathigerum (Common Blue Damselfly)	697
Calopteryx splendens (Banded Demoiselle)	323

Just two species of Anisoptera (*Libellula depressa* and *Orthetrum cancellatum* – frequently seen inhabiting the same spaces (Merritt, Moore and Eversham 1996)) – were observed in the survey. Species in the Anisoptera suborder prefer to breed in lentic waters; *Libellula* are a particularly stagnicolous species (Smallshire and Swash 2014) and can themselves be used as an indicator of high water transparency, along with *C. puella* (Vanacker et al. 2018). *L. depressa* was observed at three sites - one being adjacent to a deep ditch (one of five lentic waterbodies). It is not surprising that *L. depressa* was also observed at two lotic sites, because this species is known for migrating on a smaller scale for different habitat requirements at separate life stages – for example, whether they are breeding, or when prey availability is low, they will colonise new ponds (Brooks 1997). Both *L. depressa* and *O. cancellatum* are very territorial (Merritt, Moore and Eversham 1996; Smallshire and Swash 2014), a possible explanation as to why their densities and abundances were low throughout the surveys.

Variance in interspecific distribution patterns of odonates may be attributed to species-specific differences in shade preference and environmental limits (Hofmann and Mason 2005). For example, *I. elegans* can survive under conditions which no other (European) dragonfly species can tolerate, such as higher cloud cover and pollution levels (Smallshire and Swash 2014). This data was not analysed because *I. elegans*, being observed in five of the 26 sites, were not one of the top three most common species. However, species-specific tolerances and preferences should be considered in potential future studies.

Despite being globally uncommon, *P. pennipes* was locally frequent in the survey, aligning with results from other studies conducted around the Lower Stour, a location of low concern for this species which preferentially breeds along gravel streams and requires highly oxygenated water (Steiner et al. 2000; Smallshire and Swash 2014; BDS [b] 2019). It is logical that this species was observed in the lower Stour catchment frequently. *P. pennipes* were observed less at PAAs than at SSSIs, a possible explanation being that they are vulnerable to physical disturbance to the bankside (Brooks 1997), and this is likely to be greater in a PAA (where leisure activities like fishing and biking are often permitted) than at a SSSI.

Within the SANGs, *C. splendens*, *C. puella* and *P. nymphula* were the most common species appearing in five locations (at three of these, they were the species with highest abundances). These results were not all separate from each other, in some cases the standard abundance categories were equally weighted for two species at a time. From the 12 species observed throughout the study, the least common in the SANGs was *C. tenellum* (the only Zygoptera not observed at any SANGs), while *Coenagrion pulchellum* and *Erythromma najas* appeared in one survey out of 13. At PAA sites, the most common species was *C. splendens* identified at four sites, followed by *C. puella* observed at three sites. No *C, pulchellum*, *E. najas* or *O. cancellatum* were observed in PAAs. The most common species in SSSIs were *P. pennipes*, recorded at two of four SSSIs, followed by *C. puella* and *E. cyathigerum*. These were the only three identified species observed in SSSIs.

C. splendens, C. puella and *P. pennipes* (that is, all three most common species) show preferences for moderate to slow-flowing rivers (Merritt, Moore and Eversham 1996; Brooks 1997; Schutte, Reich and Plachter 1997; Smallshire and Swash 2014). It is more likely that water quality is going to affect the lifecycles of damselflies and dragonflies than land use affecting the spread of odonates around the catchment.

Stressors originating from land management practices around freshwater environments (for example, infilling of ponds, drainage, pollution from agricultural runoff with fertilisers and metals (Raebel et al. 2012; Villalobos-Jiménez, Dunn and Hassall 2016) directly affect water quality. The tolerance of each odonate species to different stressors will vary depending on whether they are specialist or generalist.

5.3 Significant Variables

5.3.1 Shade

Records of shade in this survey are incomplete, with five records missing from SANG sites HP1, HP2, HP2 and PAA sites BVP1 and BVP2. Shade was significant to the abundance of *P. pennipes* - as shade increased their abundance decreased. The results are compatible with existing research on the behaviour of *P. pennipes*, which shows a preference for unshaded sections of streams (Merritt, Moore and Eversham 1996; Brooks 1997; Cham 2003) where this species is highly abundant when vegetation conditions are favourable (Brooks 1997).

Individual choice to perch in sunlight and actively avoid shade may increase a female damselfly's chances of detection to males (Winfrey and Fincke 2017). Despite a weak and insignificant relationship, the sign of the correlation coefficient appeared as predicted for species *C. splendens*: shade was inversely correlated to their abundance, a species under threat from overshadowing from tree growth, and less tolerant of shade (compared to other damselflies in the Calopterygidae family, for instance, *C. virgo*) (Merritt, Moore and Eversham 1996; Brooks 1997; Schutte, Reich and Plachter 1997; BDS [c] 2019). The abundance of *C. puella* was not significantly impacted by the amount of shade throughout the study, although as shade increased, so, too, did their abundance. Existing studies on this species found that females only participate in reproductive activity on sunny, warm days, hence rainy, cold, or windy weather interferes with female damselflies' egg production and clutch size (if adults are unable to lay more eggs in adverse weather) (Banks and Thompson 1987; Merritt, Moore and Eversham 1996). In hotter climates shade may be paramount to odonate thermoregulation (Córdoba-Aguilar and Rocha-Ortega 2019), however, most species in the UK are Southerly distributed (Brooks 1997; Ward and Mill 2005), and so less shade and maximum warmth is likely to be preferable.

5.3.2 Humidity

Humidity was significantly negatively correlated to two of the three key species' abundances: *C. splendens* and *P. pennipes*. Sensilla styloconica found in adult Zygoptera and Anisoptera have similar mechanisms and structures to thermo-hygroreceptors (Rebora, Piersanti and Gaino 2009). Since odonates exhibit pond-abandonment behaviour immediately prior to rainstorms, it is probable that sensing changes to humidity as well as temperature, windspeed and lux as cues (Goforth 2010) helps odonates gauge risk of flight and energy expenditure. As warmer air can hold more moisture, humidity is another environmental factor that influences damselfly behaviour, despite minimal research being carried out on relative humidity and the presence of hygroreceptors in odonates (Merritt 2006; Rebora, Piersanti and Gaino 2008). Humidity may potentially decrease when riparian vegetation is removed (da Silva Monteiro Júnior et al. 2013), so the effects of environmental variables on multiple landscape features are likely to be impacting damselfly behaviour (Jonsen and Taylor 2000; Angelibert and Giani 2003).

5.3.3 Vegetation Cover

Records of vegetation cover in this survey are incomplete, with five records missing (the same sites that are missing records for shade). Two of the three key species' abundance was positively correlated with vegetation cover, significantly for *C. splendens* but not *P. pennipes*. However, as vegetation cover increased, abundance of *C. puella* decreased. Several studies of *C. splendens* demoiselles record the importance of both emergent and bankside vegetation (Mayhew 1994; Brooks 1997; Schutte, Reich and Plachter 1997; Ward and Mill 2005). The results from the current study agree with previous research conducted by Rouquette and Thompson (2005), which investigated some damselflies within the Coenagrion genus and found that fewer damselflies were present when vegetation cover increased. However, other references suggest that *C. puella* require a profuse amount of emergent vegetation to complete their metamorphosis (Brooks 1997). More research must be conducted to verify or deny either claim.

Egg deposition in an optimal habitat may be reliant on a male's choice of territory based on vegetation structure (Schutte, Reich and Plachter 1997), hence more vegetation cover may be needed to facilitate maximum dispersal. Evidence indicates *P. pennipes* favour dense vegetation along banksides (Cham 2003; Smallshire and Swash 2014) and sheltered margins (Merritt, Moore and Eversham 1996; Brooks 1997). Their flight style appears weaker and slower than other damselfly species, and so thick vegetation would be favoured as there are more perches to use as frequent rest areas (Merritt, Moore and Eversham 1996).

5.3.4 Vegetation Height

It is inferred that *C. puella* do not favour tall vegetation. Existing research observing density of damselflies in the Coenagrion genus have found similar results – particularly with presence of trees (Rouquette and Thompson 2005). Despite not being a territorial species, males fly near the water's surface when patrolling, but will also perch close to the top of vegetation (Brooks 1997), likely to stay near to oviposition sites to maximise mating opportunities. Hence, shorter vegetation is preferable, reflected in the results of this study. The height of vegetation (and therefore the height at which a damselfly perches) can impact the visibility of a damselfly to a potential mate and/or predator (Winfrey and Fincke 2017). Despite this, perch height is likely to have little effect on thermoregulation in both damselflies and dragonflies (May 1976), however, obelisk pose behaviour was not recorded in this study, so cannot be considered relevant to the results.

For both *C. splendens* and *P. pennipes*, as vegetation height increased, so did their abundances, insignificantly. *C. splendens* require healthy vegetation for egg deposition and perching, and vegetation height has been shown to be an important factor in habitat selection (Brooks 1997; Ward and Mill 2005). *P. pennipes* favour tall, dense vegetation along riverbanks where they gather after emergence (Smallshire and Swash 2014). Insignificance of this result may be due to the species being present at sites where vegetation was over 10cm, and entirely absent where vegetation was below 10cm (Appendix V), exhibiting binary results despite vegetation height being a non-binary variable.

Although vegetation cover and height should be considered separate factors it is likely that, in terms of land use, they are linked. Similarly, physical changes caused by local land management (like the removal of vegetation buffers in riparian zones, removal of water for extraction creating changes to the water cycle) are highly likely to impact other biota such as soil formation, water residence time and aquatic plant growth and predation intensity (Merritt et al. 1997; McPeek 2008; Song et al. 2013). The grass will be cut on a PAA intended to be used for football games, whereas on a SSSI, the grass may be kept long prior to summer if the protected feature requires it.

5.3.5 Bare Ground

For all three most common species, as bare ground increased, their abundances decreased – significantly, for *C. splendens*. This species orientates itself using landmarks, hence areas free of vegetation should have notable effect on mobility of adult populations (Schutte, Reich and Plachter 1997). Often, odonate habitat recognition involves the use of light cues (such as contrasting sunlight-shade patches) to identify suitable habitat (Hofmann and Mason 2005; Rouquette and Thompson 2005), which may be a factor of site selection in odonates, and this contrast is probably more easily detected over bare ground. As bare ground is the inverse of vegetation cover, it would be reasonable to assume that, considering *C. puella* favoured less vegetation, they would be more abundant in areas where bare ground was present. While it was present at five sites and absent at 12 sites, nine records of bare ground were incomplete, which may account for the unexpected result for *C. puella*, although they have been observed to prefer flying closer to water (Brooks 1997) and in some instances, the bare ground may act as an ecological trap if a waterbody dries up (Harabiš,and Dolný 2012). Human settlements along the Stour can be traced back to 10,000BC (Dorset Council 2011), suggesting the river is a mature stream. Mature streams tend to be more vegetated, and so completion of the records would likely show the absence rather than presence of bare ground, thus supporting the results obtained.

5.4 Insignificant Variables

The following are all mutually insignificant for all three key species observed in the study.

5.4.1 Sound Levels

Average sound levels ranged from 31dB to 61dB, however, at site IF2 (PAA) sound levels rose to 70dB when a train crossed the tracks. Here, one individual *C. splendens* was observed (Appendix V). Lack of causal relation between sound levels and abundance in this survey may be due to the ineffectual result of noise on their behaviour in the absence of tympanal organs (Futahashi 2016) in odonate species. Despite this, the use of mechanoreceptors - via sensing vibrations through tarsal hairs (Vasserot 1957, as cited by Villalobos-Jiménez, Dunn and Hassall 2017) - in prey detection may be influenced by highly noisy environments (Villalobos-Jiménez, Dunn and Hassall 2017). Previous studies have observed relationships between underwater noise levels and increased handling time between Zygoptera larvae and their prey, and despite attack rate remaining unchanged, the feeding rate was ultimately reduced (Villalobos-Jiménez, Dunn and Hassall 2017). There may, therefore, be selective cues for females when deciding on suitable sites to lay eggs, which implies that predator-prey interactions, for species that inhabit different ecosystems during different life stages – in this case, progressing from aquatic to terrestrial areas – is impacted (Rebora, Piersanti and Gaino 2004; Knight et al. 2005;

Iwai et al. 2017). Despite this, the current study did not account for abundance of larvae of any observed species. A reduced sense of audition and olfaction may be accounted for by the smaller antennae size on Anisoptera and Zygoptera compared to those on most other insects (Villalobos-Jiménez, Dunn and Hassall 2017). As opposed to touch or smell, their main function is to measure air speed when in flight, and tarsal hairs to detect prey (BDS [d] 2019). Despite antennal sensilla and visual acuity varying between odonates, vision is their most reliable sense, and behaviour is strongly dependent on visual cues (for example, mate recognition, predator avoidance, flight control, damage avoidance during storms (Goforth 2010; Futahashi 2016; Winfrey and Fincke 2017; Kassner and Ribak 2018; Piersanti and Rebora 2018). Furthermore, noise levels generated during the study cannot be attributed to disturbance levels without conducting a more extensive survey to collect data on footfall and human activity at each site.

5.4.2 Lux Levels

With all three key species, there was no correlation between abundances and lux levels. Male *C. splendens* are active on highly sunny days (Córdoba-Aguilar and Cordero-Rivera 2005), and studies by Waringer (1982) and Angelibert and Giani (2003) report that *C. puella* do not fly if light levels fall below 6000 Lux – the current study measured lux levels ranging from 105,000 to 5,015,000 Lux. Often, lux levels are regarded in collaboration with temperature (Lutz and Pittman 1970) as the two factors are difficult to decouple, and some odonates are heliothermic or ‘perchers’ (gaining heat from the sun), while others are thermal conformers or ‘fliers’, changing body temperature to suit environmental fluctuations in temperature (Heinrich and Casey 1978; Waringer 1982; da Silva Monteiro Júnior et al. 2013; Henry et al. 2018). It can therefore be accepted that, if temperatures throughout this study were consistently comfortable, then lux levels would be similar. A reduction in lux levels in relation to diel times acts as a photoperiodic cue for both Anisoptera and Zygoptera to return to the roost overnight, hence flight may cease during such time (Goforth 2010). As mentioned in section 5.3.5., light cues are used in odonate navigation (Hofmann and Mason 2005; Rouquette and Thompson 2005), including ultraviolet light to find reflective surfaces indicative of waterbodies (Brooks 1997; Horváth and Varjú 1997). Nevertheless, sampling occurred at times of the day when odonates are most active, on mostly sunny days during peak flight season. Therefore, the lack of correlation between lux and any three of the key species would not be evident from these results. If repeated, insolation may be measured via radiance across anisotropic surfaces (such as perches facing different orientations) using modelling techniques (Brunger and Hooper 1993) and thermocouples to measure invertebrate body temperatures (Sinclair, Coello Alvarado and Ferguson 2015) and determine correlation.

5.4.3 Windspeed

Windspeed had no impact on abundances of the three most common species. Damselfly activity, condition and orientation can be compromised by high winds, (Goforth 2010; Smallshire and Beynon 2010; Chapman et al. 2011; Mason 2017; Pearce-Higgins and Chandler 2020), and they are less likely to fly in inclement weather compared to calm weather days. This display of rheotaxis is presumably to reduce drag during flight (Mason 2017). The minimum and maximum windspeed limits in the study were $0.3ms^{-1}$ and $2ms^{-1}$ (Appendix V). This may explain why there was no relationship with windspeed: these were low measures in regard to maximum windspeed limits for Zygoptera flight (suggested less than $8ms^{-1}$ for *C. puella* by Waringer (1982), supported by Goforth (2010)).

5.4.4 Temperature

There was no significant relationship between any of the three most common species' abundances and temperature.

Lutz and Pittman (1970) suggest comfortable minimal temperatures for odonate activity are between 20˚C and 28˚C. Temperatures in the current study ranged from 19.5˚C to 25.2˚C and were therefore suitable enough that odonates (as ectotherms) would already be active. Although extreme changes in temperatures can have major effects on behaviour (Smallshire and Beynon 2010; Pearce-Higgins and Chandler 2020), such as dietary changes (Start et al. 2017), surveying occurred between 09:00 and 16:00 each day to ensure a high chance of odonate observation. In any case, temporal variation in dragonfly and damselfly counts can ensue since their activity varies significantly at different times throughout the day (Lutz and Pittman 1970; Smallshire and Beynon 2010; Pearce-Higgins and Chandler 2020). Surveys conducted by Pearce-Higgins and Chandler (2020) and Corbet 1963 (as referenced by Lutz and Pittman 1970) yielded similar results: ambient temperature was the most influential environmental factor that affected abundance of nine different damselfly and dragonfly species, as well as total abundance and species' richness. Temperature plays a pivotal role in reproductive success (Brooks 1997), as evidenced by work conducted by Banks and Thompson in 1987, whose research showed that female *C. puella* damselflies lay more eggs when the temperature is warmer. Maximum temperature limits for odonates, proposed by Lutz and Pittman (1970), are between 30˚C and 40˚C, however, the temperatures in the present study did not exceed 25.2˚C, therefore higher temperatures in this survey were not likely to be responsible for reduced dragonfly or damselfly abundance.

Odonates adopt the obelisk pose at high temperatures to thermoregulate by minimising surface area exposed to solar radiation (May 1976; Smallshire and Swash 2014), but both the variable and the behaviour were not recorded in the surveys, thus providing little information on how temperature was impacting behaviour at each site.

There is a growing body of literature that recognises the impacts of climate change on the declination of numbers of odonate species (such as the emerald, black darter, common hawker, white-faced darter) (Brooks 1997; Hassall and Thompson 2008; McCauley et al. 2015; Taylor et al. 2021). In conjunction, some species groups (Banded and Beautiful Demoiselles, White-legged Damselflies and Scarce Chasers) are expanding Northwards, owing to a combination of improved water quality and habitat creation, driven by the EU regulations (Hickling et al. 2005; Smallshire and Swash 2014; Taylor et al. 2021; Heart of England Forest 2022), and warmer global temperatures (Heart of England Forest 2022). All 12 species recorded in the present survey are reported to have increased their range margin in the past 60 years, with *C. splendens* shifting 41km, *C. puella* shifting 103km and *P. pennipes* shifting 18km (Hickling et al. 2005). Shifting faster than odonate species at their Southern range margin (Hickling et al. 2005), these UK species at their Northern range margin are more likely to prosper in the warmer temperatures that come with climate change, encouraging ever-increasing Northwards advancement. It is possible that, in addition to range expansion, climate change will directly impact phenology (through advancement), behaviour such as cannibalism (Start et al. 2017), physiology (Sinclair, Alvarado and Ferguson 2015) and morphology of multiple odonate species (Hassall and Thompson 2008; McCauley et al. 2015).

5.4.5 Soil Moisture

There was no significant relationship between any of the key species' abundances and soil moisture. It is assumed substrate type is mostly relevant on the riverbanks, where it supports vegetation that, in turn, will impact dragonfly perching, resting, breeding and egg laying behaviour. Substrate grain size has been proven to be an important element to lotic damselflies and dragonflies (da Silva Monteiro Júnior et al. 2013), however, there is little relevance of substrate and moisture here, compared to humidity in the air.

5.5. Copulation

It was expected that odonate copulation would occur more often at SSSIs than at PAAs by reason of reduced human-wildlife interaction and/or disturbance. The results (Figure 9) do not show which species were most frequently observed in tandem (Appendix V). Understanding habitat preferences per species would help direct future studies on copulation. For example, some Zygoptera, like Calopterygidae, preferentially reproduce in fast-flowing water compared to Coenagrionidae and Libellulidae (McPeek 2008). In sites where water was observed to be fast flowing, such as SVNP2, no odonates were observed (Appendix V). However, as flow rate and larvae were not recorded, their correlation with abundance, diversity and reproductive success cannot be deduced here.

6. Limitations

Habitat preferences of specialist species were not accounted for prior to the study – for example, *C. puella* occupy a broad range of habitats (Merritt, Moore and Eversham 1996) while *P. pennipes* are more restricted and favour gravelly streams (Smallshire and Swash 2014), and *C. splendens* are more successful on sandy banks and gravelly rivers (Merritt, Moore and Eversham 1996; Ward and Mill 2008). The habitat preferences may not necessarily centre around substrate type entirely, but this is an example of an unmeasured variable.

As non-identifiable individuals (including juveniles) were excluded from the statistics, it is likely the counts for all species were underestimated, hence any numbers counting overall abundance are likely to be underestimates. Damselfly condition was not accounted for, such as body size and pigmentation, both influencing thermoregulation (May 1976; Hassall and Thompson 2008), weight, wing length and evidence of senescence, as in previous studies (Banks and Thompson 1987; Córdoba-Aguilar and Rocha-Ortega 2019). Sex was not recorded, whether an individual was identified or not: it is therefore possible that the odonate counts in this study would be higher for males than for females due to the ambiguity of colour through female polymorphism in multiple species (Brooks 1997), and the exclusion of unidentified individuals from the statistical analysis.

No interspecific interactions were recorded, which might explain how aggregations of Zygoptera are influenced indirectly by environmental factors. For example, models predict a declining persistence of *P. pennipes* with the establishment of *Erythromma viridulum* since the latter species' climate change-driven range expansion (Cranston, Isaac and Early 2023). As well as competitor interactions, predator species were not surveyed – for example, fish populations will alter odonate behaviour and abundance can fluctuate depending on predator population dynamics (Hassall and Thompson 2008) (observed in fish predating *P. pennipes* and Emperor dragonflies predating *E. cyathigerum* (Steiner et al. 2000)).

No samples from in-river populations were taken (that is, dragonfly larvae and exuviae), thus hindering the preciseness of estimating richness of dragonflies and damselflies, which would be useful in building an ecological profile for the three most common species. In this study, a more extensive list of bankside vegetation was recorded compared to aquatic plant communities (Appendix V) – this appears to be a variable worth exploring upon re-experimentation, as Vanacker et al. (2018) discovered that abundance of *C. puella* also increased with aquatic vegetation heterogeneity. Additionally, aquatic vegetation with tall bankside stems is preferred by *C. splendens* for emergence and support as larvae (Merritt, Moore and Eversham 1996) and as perches during adult life (Ward and Mill 2008; Smallshire and Swash 2014). This particularly predatory species requires a rich food source during their larval stages, which is likely to be more ample with increased richness of aquatic plant communities due to more habitat provided for a greater diversity (and number) of prey invertebrates (Ward and Mill 2008).

River samples should be recorded for the direct impact that river chemistry and hydrogeology have on larvae abundance and development, such as water depth, water temperature, pH, concentrations of metals, oxygen levels, substrate type, the presence of berms, and flow rate (Rouquette and Thompson 2005; Perron and Pick 2020; Vilenica et al. 2021). The fact that hydrological factors were not measured in this study means that claims from previous research (such as *C. splendens* having preference for slow flowing water (Merritt, Moore and Eversham 1996; Schutte, Reich and Plachter 1997) or having a greater tolerance for alkalinity compared to the closely related *C. virgo* (Goodyear 2000)) cannot be verified. However, there is a chance that, repeating the experiment more thoroughly, the results would align with speculated hypotheses for individual species. For example, the current study found that *C. splendens* favour flowing water surrounded by less vegetation, which was not observed in any surveys conducted besides lentic waterbodies (LL1, LL2 and IF5), and is corroborated by past literature (Merritt, Moore and Eversham 1996

Recording species behaviour at each site could help identify which factors influence species assemblages per location, such as time spent patrolling, feeding, mating or perching, in addition to intra- and inter-specific interactions.

Further limitations of the methods used in this experiment include the compromise of reliability – ideally, data collection would be repeated (Smallshire and Beynon 2010). The weather was consistently warm enough to observe odonates, therefore, if a repeat survey was to be carried out, a variety of days and weather patterns is required to examinate and compare the data per variable against each other. In addition, no account was taken for staggered flight periods of odonates, so repeating the surveys at least three times throughout the odonate flight period would contribute to a more accurate profile of all species present at each site (BDS [a] 2019). There was no standard area size set to observe Odonata, and, despite attempts to collect data from an identical number of sites per land use category, there were unequal numbers of SANGs and PAAs sites. Similarly, surveying was not carried out along the usual 100m transects, rather, only what was observed in the field of vision, which itself was neither uniform nor recorded at each site. Quadrat use in this study is prone to human bias, raising questions about how truly random the sample squares were. If repeated, survey sites should be mapped out and sectioned into at least ten quadrat-sized sections before using a random number generator to select one of the squares for sampling. Here, keeping the length or river studied (and the area surrounding the transect line) uniform throughout the experiment is key. It is likely that the minimal total area that needed to be sampled was not met, as suggested by the BDS (Smallshire and Beynon 2010). Two of the location points (IF5 and BVP2) fell outside of the catchment area on the maps yet were included as it was not obvious that this was the case when surveying. Despite only being used for visualisation in the discussion, the National Historic Landscape Characterisation was accurate to 250m and so any sites smaller than this may or may not be correctly recognised as an independent landscape. Additionally, there were discrepancies between the land use category provided by the Stour Valley Nature Partnership and the SSSI layer applied to the map on ‘MAGiC’ for the locations at Longham Lakes (LL1 and LL2) and Iford Meadows (IF3 and IF4). These sites were categorised as a SSSI by Stour Valley Nature Partnership but not according to the ‘MAGiC’ database. Despite this, the land use category and the land characterisation are not necessarily mutually exclusive - for example, all the SANG sites and SSSI sites are accessible to the public, which, in this study, is what ‘defined’ the PAAs. Since none of the land use categories prohibit public access, it would be best practice to repeat the study after conducting a preliminary survey on at least one area of similar size and geology, to measure baseline species abundances against environmental variables, so that any human impact can later be compared to these.

The assumption that individual environmental variables have an isolated effect on odonate abundance is naïve. It is likely that, as with lux and temperature, multiple factors are interconnected and have an additive or synergistic effect on species diversity and/or abundance.

No statistical analysis was performed on Anisoptera, primarily because of the lack of data collated for that suborder, hence, comparisons cannot be drawn between the abundances of Anisoptera and Zygoptera species in relation to either land use or environmental variables.

7. Conclusion

This study has shown that, of the environmental variables measured, shade, humidity, vegetation cover, vegetation height and bare ground were the main factors correlating with abundance of the three most common damselfly species around the lower Stour – corroborating numerous similar studies from other locations (Lutz and Pittman 1970; Mayhew 1994; Schutte, Reich and Plachter 1997; Angelibert and Giani 2003; Cham 2003; Hofmann and Mason 2005; Rouquette and Thompson 2005; Ward Mill 2005; Mcpeek 2008; Goforth 2010; Smallshire and Swash 2014). However, the relationships between these factors and abundance vary depending on the species due to their habitat preferences.

The three most common odonate species around the lower Stour catchment area were *C. splendens* (Banded Demoiselle), *C. puella* (Azure Damselfly) and *P. pennipes* (White-legged Damselfly) and there was no significant difference between the spread of odonates at SANGs, SSSIs and PAAs. While local variables influence Zygoptera diversity, compared to Anisoptera diversity, which is potentially more sensitive to landscape variability (Jonsen and Taylor 2000; Nagy et al. 2019), a more exhaustive survey method would be required to determine the relationships between land use category and damselfly and/or dragonfly abundance due to the inconsistencies with land designations. Climate change will likely further drive species' range expansions as a result of its pivotal role in the regulation of abiotic factors (such as those measured in the present study), which in turn is likely to shift disturbance regimes from what is currently understood (Shea, Roxburgh and Rauschert 2004). Hence, climate change itself must be considered in conjunction with multiple land use management schemes.

8. References

Angelibert, S., and Giani, N., 2003. Dispersal characteristics of three odonate species in a patchy habitat. *Ecography* [online]. 26(1), 13-20.

Banks, M.J., and Thompson, D.J., 1987. Lifetime reproductive success of females of the damselfly Coenagrion puella. *The Journal of Animal Ecology* [online]. 56(3), 815-832.

Biggs, J., Von Fumetti, S. and Kelly-Quinn, M., 2017. The importance of small waterbodies for biodiversity and ecosystem services: implications for policy makers. *Hydrobiologia* [online]. 793(1), 3-39.

Bournemouth Christchurch and Poole Council [a], 2023 *Stour Valley* [online]. Bournemouth: BCP Council. Available from: https://www.bcpcouncil.gov.uk/Leisure-culture-and-local-heritage/Parks-and-open-spaces/Nature-reserves/Nature-reserves-in-Bournemouth/Stour-Valley.aspx [Accessed 30/03/23].

Bournemouth Christchurch and Poole Council, Dorset County Council, East Dorset District Council, and Purbeck District Council, 2016. *The Dorset Heathlands Planning*

Framework 2015-2020 Supplementary Planning Document [online]. Dorchester: Dorset Council. Available from: https://www.dorsetcouncil.gov.uk/documents/35024/281756/sd79-dorset-heathlands-SPD-Oct-2015.pdf/c576c0bb-fb47-2086-275d-2dcd147b658d [Accessed 30/03/2023].

Bracknell Forest Council, 2009. *Shepherd Meadows Open Space Management Plan for Thames Basin Heaths Special Protection Area (SPA) Mitigation Works* [online]. Bracknell: Bracknell Forest Council. Available from: https://www.bracknell-forest.gov.uk/sites/default/files/2021-06/shepherd-meadows-osmp.pdf [Accessed 17/04/23].

British Dragonfly Society [a], 2019. *Dragonfly Survey Guidance* [online]. Aldershot: British Dragonfly Society. Available from: https://british-dragonflies.org.uk/wp-content/uploads/2019/04/Dragonfly-Survey-Guidance.pdf [Accessed 18/04/23].

British Dragonfly Society [b], 2019. *The White-legged Damselfly Investigation On the search for a mysterious river damsel 2019 report* [online]. Aldershot: British Dragonfly Society.

British Dragonfly Society [c], 2019. *Banded demoiselle* [online]. Aldershot: British Dragonfly Society. Available from: https://british-dragonflies.org.uk/species/banded-demoiselle/ [Accessed 02/02/23].

British Dragonfly Society [d], 2019. *Frequently Asked Questions* [online]. Aldershot: British Dragonfly Society. Available from: https://british-dragonflies.org.uk/odonata/frequently-asked-questions/ [Accessed 17/04/23].

Brooks, S.J., 1997. *Field guide to the dragonflies and damselflies of Great Britain and Ireland*. Hampshire: British Wildlife Publishing.

Brooks, S.J., 2001. Dragonflies and damselflies. *In:* Hawksworth, D.L., *The changing wildlife of Great Britain and Ireland* [online]. London: Taylor and Francis Limited, 340-354.

Brunger, A.P., and Hooper, F.C., 1993. Anisotropic sky radiance model based on narrow field of view measurements of shortwave radiance. *Solar Energy* [online]. 51(1), 53-64.

Canford Park Sang, 2022. **VERY IMPORTANT** New signs on the SANG. Please stop your dog's entering and leaving the river by using the riverbanks. The 2 new stepped areas are the only areas we want to see dogs in the river. *Instagram* [online]. 7 October 2022. Available from: https://www.instagram.com/p/CjaVjFRIEYI/?igshid=YmMyMTA2M2Y= [Accessed 29/03/2023].

Cham, S., 2003. Factors influencing the distribution of the White legged Damselfly Platycnemis pennipes (Pallas) in Great Britain. *Journal of the British Dragonfly Society* [online]. 19(1 & 2), 15-23.

Cham, S., 2012. *Field Guide to the larvae and exuviae of British Dragonflies Damselflies (Zygoptera) and Dragonflies (*Anisoptera*)*. Dorchester: The Dorset Press.

Chapman, J.W., Klaassen, R.H.G., Drake, V.A., Fossette, S., Hayes, G.C., Metcalfe, J.D., Reynolds, A.M., Yeynolds, D.R., and Alerstam, T., 2011. Animal Orientation Strategies for Movement in Flows. *Current Biology* [online]. 21(20), R861–R870.

Chapman Lily Planning, 2015. *Canford Park Suitable Alternative Natural Greenspace* [online]. Wareham: Chapman Lily Planning Limited. Available from: http://www.canfordparksang.co.uk/#:~:text=A%20SANG%20is%20similar%20to,to%20get%20to%20and%20enjoy [Accessed 16/04/23].

Christchurch and District Model Flying Club, 2019. *LONGHAM LAKES ACCESS, FLYING LOCATIONS MAP AND RULES* [online]. Christchurch: Christchurch and District Model Flying Club. Available from: http://www.cdmfc.org/html/map_and_rules.html [Accessed 22/02/23].

Córdoba-Aguilar, A., and Cordero-Rivera, A., 2005. Evolution and ecology of Calopterygidae (Zygoptera: Odonata): status of knowledge and research perspectives. *Neotropical Entomology*[online]. 34(6): 861–879.

Córdoba-Aguilar, A., and Rocha-Ortega, M., 2019. Damselfly (Odonata: Calopterygidae) population decline in an urbanizing watershed. *Journal of Insect Science* [online]. 19(3), 30.

Cottam, L., 2019. *SSSI definition: what is it and what does it mean for conservation and development?* [online]. Lincolnshire: Woodland Trust. Available from: https://www.woodlandtrust.org.uk/blog/2019/03/sssi-definition/ [Accessed 02/04/2023].

Cranston, J., Isaac, N.J., and Early, R., 2023. Associations between a range-shifting damselfly (Erythromma viridulum) and the UK's resident Odonata suggest habitat sharing is more important than antagonism [online]. *Insect Conservation and Diversity* [online]. 1-11.

da Silva Monteiro Júnior, C., Couceiro, S.R.M., Hamada, N., and Juen, L., 2013. Effect of vegetation removal for road building on richness and composition of Odonata communities in Amazonia, Brazil. *International Journal of Odonatology* [online]. 16(2), 135-144.

Department for Environmental, Food and Rural Affairs, 2023. *MAGiC* [online]. London: DEFRA. Available from: https://MAGiC.defra.gov.uk/MAGiCmap.aspx [Accessed 06/03/23].

Dorset Council, 2011. *Investing in green places South East Dorset Green Infrastructure Strategy* [online]. Dorchester: Dorset Council. Available from: https://www.dorsetcouncil.gov.uk/documents/35024/281684/Investing+in+Green+Places+SE+Dorset+Green+Infrastructure+Strategy+July+2011.pdf/270a8682-c729-b914-0555-8376f787e6d9 [Accessed 16/04/23].

Dorset Council, 2014. *Planning Committee: Schedule of Planning Applications* [online]. Dorchester: Dorset Council. Available from: https://moderngov.dorsetcouncil.gov.uk/Data/351/201409021830/Agenda/Schedule%20of%20Planning%20Applications.pdf [Accessed 16/02/23].

Dudsbury Gold Club, 2023. *Course* [online]. Ferndown: Dudsbury Golf Club. Available from: https://www.dudsburygolfclub.co.uk/golf/course/ [Accessed 16/02/23].

Environment Agency, 2012. *Dorset Stour Catchment Flood Management Plan* [online]. Exeter: Environment Agency. Available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/294167/Dorset_Stour_Catchment_Flood_Management_Plan.pdf [Accessed 06/03/23].

Environment Agency, 2019. *Middle and lower Stour: reach by reach restoration plan* [online]. Bristol: Environment Agency. Available from: file:///C:/Users/jenny/Downloads/Middle%20and%20Lower%20Stour%20River%20Restoration%20Action%20Plan.pdf [Accessed 10/04/2023].

Environment Agency, 2021. *Stour Dorset Operational Catchment* [online]. Bristol: Environment Agency. Available from: https://environment.data.gov.uk/catchment-planning/OperationalCatchment/3140 [Accessed 22/02/23].

Environment Agency [a], 2022. *Challenges data for Stour Dorset Operational Catchment* [online]. Bristol: Environment Agency. Available from: https://environment.data.gov.uk/catchment-planning/WaterBody/GB108043011040 [Accessed 16/04/23].

Environment Agency [b], 2022. *Corporate report Environment Agency EA2025: updates 2022 to 2023* [online]. Bristol: Environment Agency. Available from: https://www.gov.uk/government/publications/environment-agency-ea2025-creating-a-better-place/environment-agency-ea2025-updates-2022-to-2023 [Accessed 10/04/2023].

Fields in Trust, 2022. *Poor Common* [online]. London: Fields in Trust. Available from: https://www.fieldsintrust.org/FieldSite/Poor-Common [Accessed 16/02/23].

Fields in Trust [a], 2023. *Our history* [online]. London: Fields in Trust. Available from: https://www.fieldsintrust.org/history [Accessed 13/04/23].

Fields in Trust [b], 2023. *Iford Meadows Local Nature Reserve* [online]. London: Fields in Trust. Available from: https://www.fieldsintrust.org/FieldSite/Iford-Meadows-Local-Nature-Reserve [Accessed 13/04/23].

Firth, A., and Firth, E., 2020. *Historic watercourses: Developing a method for identifying the historic character of watercourses River Stour, Dorset* [online]. Portsmouth: Historic England. 85/2018.

Futahashi, R., 2016. Color vision and color format in dragonflies. *Current Opinion in Insect Science* [online]. 17: 32-39. ISSN 2214-5745. https://doi.org/10.1016/j.cois.2016.05.014

Futuyma, D.J., and Moreno, G., 1988. The evolution of ecological specialization. *Annual review of Ecology and* Systematics [online]. 19(1), 207-233.

Gillingham, P.K., Alison, J., Roy, D.B., Fox, R., and Thomas, C.D., 2015. High abundances of species in protected areas in parts of their geographic distributions colonized during a recent period of climatic change. *Conservation Letters* [online]. 8(2), 97-106.

Goforth, C.L., 2010. Behavioural responses of Enallagma to changes in weather (Zygoptera: Coenagrionidae). *Odonatologica* [online]. 39(3), 225-234.

Goodyear, K.G., 2000. A comparison of the environmental requirements of larvae of the Banded Demoiselle Calopteryx splendens (Harris) and the Beautiful Demoiselle C. virgo (L.). *Journal of the British Dragonfly Society* [online]. 16(2), 33-51.

Harabiš, F. and Dolný, A., 2012. Human altered ecosystems: suitable habitats as well as ecological traps for dragonflies (Odonata): the matter of scale. *Journal of Insect Conservation* [online]. 16(1), 121–130.

Hassall, C., and Thompson, D. J., 2008. The effects of environmental warming on Odonata: a review. *International Journal of Odonatology* [online]. 11(2), 131-153.

Heart of England Forest, 2022. *dragonflies and damselflies* [online]. Stratford-Upon-Avon: Heart of England Forest. Available from: https://heartofenglandforest.org/news/dragonflies-and-damselflies [Accessed 16/04/23].

Heinrich, B., and Casey, T.M., 1978. Heat Transfer in Dragonflies: 'Fliers' and 'Perchers'. *Journal of Experimental Biology* [online]. 74(1), 17-36.

Henry, E.R., Rivera, J.A., Linkem, C.N., Scales, J.A., and Butler, M.A., 2018. Damselflies that prefer dark habitats illustrate the importance of light as an ecological resource. *Biological Journal of the Linnean Society* [online]. 123(1), 144-154.

Hickling, R., Roy, D.B., Hill, J.K., and Thomas, C.D., 2005. A northward shift of range margins in British Odonata. *Global Change Biology* [online]. 11(3), 502-506.

Hofmann, T.A., and Mason, C.F., 2005. Habitat characteristics and the distribution of Odonata in a lowland river catchment in eastern England. *Hydrobiologia* [online]. 539, 137-147.

Horváth, G., and Varjú, D., 1997. Polarization pattern of freshwater habitats recorded by video polarimetry in red, green and blue spectral ranges and its relevance for water detection by aquatic insects. *The Journal of Experimental Biology* [online]. 200(7), 1155-1163.

Iwai, N., Akasaka, M., Kadoya, T., Ishida, S., Aoki, T., Higuchi, S., and Takamura, N., 2017. Examination of the link between life stages uncovered the mechanisms by which habitat characteristics affect odonates. *Ecosphere* [online]. 8(9), e01930.

Jere, A., Darshetkar, A., Patwardhan, A. and Koparde, P., 2020. Assessing the response of odonates (dragonflies and damselflies) to a tropical urbanization gradient. *Journal of Urban Ecology* [online]. 6(1), juaa029. https://doi.org/10.1093/jue/juaa029

Jonsen, I., and Taylor, P.D., 2000. Calopteryx damselfly dispersions arising from multiscale responses to landscape structure. *Conservation Ecology* [online]. 4(2).

Kassner, Z., and Ribak, G., 2018. Role of side-slip flight in target pursuit: blue-tailed damselflies (Ischnura elegans) avoid body rotation while approaching a moving perch. *Journal of Comparative Physiology A* [online]. 204, 561-577.

Kingfisher Barn Visitor Centre, 2019. *Dogs* [online]. Bournemouth: BCP Council. Available from: https://www.visitstourvalley.co.uk/Visitor-Info/Dogs.aspx [Accessed 15/03/23].

Knight, T.M., McCoy, M.W., Chase, J.M., McCoy, K.A., and Holt, R.D., 2005. Trophic cascades across ecosystems. *Nature* [online]. 437(7060): 880-883.

Lutz, P.E., Pittman, A.R., 1970. Some ecological factors influencing a community of adult Odonata. *Ecology* [online]. 51(2), 279-284.

Mason, N.A., 2017. Effects of wind, ambient temperature and sun position on damselfly flight activity and perch orientation. *Animal Behaviour* [online]. 124, 175-181.

May, M.L., 1976. Thermoregulation and adaptation to temperature in dragonflies (Odonata: Anisoptera). *Ecological Monographs* [online]. 46(1), 1-32.

Mayhew, P.J., 1994. Food intake and adult feeding behaviour in Calopteryx splendens (Harris) and Erythromma najas (Hansemann) (Zygoptera: Calopterygidae, Coenagrionidae). *Odonatologica* [online]. 23(2), 115-124.

McCauley, S.J., Hammond, J.I., Frances, D.N., and Mabry, K.E., 2015. Effects of experimental warming on survival, phenology, and morphology of an aquatic insect (Odonata). *Ecological Entomology* [online]. 40(3), 211-220.

McPeek, M.A., 2008. Ecological factors limiting the distributions and abundances of Odonata. *In:* Córdoba-Aguilar, A., Beatty, C.D., and Bried, J.T. *Dragonflies and damselflies: model organisms for ecological and evolutionary research* [online]. Oxford: Oxford Academic, 51-62.

Merritt, D.J., 2006. The organule concept of insect sense organs: sensory transduction and organule evolution. *Advances in Insect Physiology* [online]. 33, 192-241.

Merritt, R., Moore, N.W. and Eversham, BC., 1996. *Atlas of the dragonflies of Britain and Ireland*. London: HMSO.

Nagy, H.B., László, Z., Szabó, F., Szőcs, L., Dévai, G., and Tóthmérész, B., 2019. Landscape-scale terrestrial factors are also vital in shaping Odonata assemblages of watercourses. *Scientific Reports* [online]. 9(18196).

National Biodiversity Network Atlas, 2021. *Explore your area* [online]. Available from: https://records.nbnatlas.org/explore/your-area#52.9548|1.1581|11|ALL_SPECIES [Accessed 16/04/23].

Natural England, 2012. *Wildlife Crime written evidence submitted by Natural England* [online]. Parliamentary session 2012-13. London: House of Commons Select Committee. Available from: https://publications.parliament.uk/pa/cm201213/cmselect/cmenvaud/writev/140/wild51.htm [Accessed 19/04/2023].

Natural England, 2016. Sites of special scientific interest: managing your land [online]. York: Natural England. Available from: https://www.gov.uk/guidance/protected-areas-sites-of-special-scientific-interest#:~:text=It's%20an%20offence%20to%20deliberately,special%20features%20of%20an%20SSSI%20 [Accessed 16/04/23].

Natural England, no date. *Designated Sites View* [online]. York: Natural England. Available from: https://designatedsites.naturalengland.org.uk/ [Accessed 10/04/23].

Natural England and Department for Environment, Food and Rural Affairs, 2014. Local nature reserves: setting up and management [online]. York: Natural England. Available from: https://www.gov.uk/guidance/create-and-manage-local-nature-reserves [Accessed 15/03/23].

Pearce-Higgins, J.W. and Chandler, D., 2020. Do surveys of adult dragonflies and damselflies yield repeatable data? Variation in monthly counts of abundance and species richness. *Journal of Insect Conservation* [online]. 24(5), 877-889.

Perron, M.A.C. and Pick, F.R., 2020. Water quality effects on dragonfly and damselfly nymph communities: A comparison of urban and natural ponds. *Environmental Pollution* [online]. 263(Part B), 114472.

Piersanti, S., and Rebora, M., 2018. The antennae of damselfly larvae. *Arthropod structure & development* [online]. 47(1), 36-44.

Plantlife, Somerset Wildlife Trust, Northumberland Wildlife Trust, Wiltshire Wildlife Trust, Ulter Wildlife, Ymddiriedolaeth Genedlaethol National Trust, Cotswolds Conservation Board, Scottish National Trust, Royal Society for the Protection of Birds, Medway Valley Countryside, and Heritage Lottery Fund, no date. *How to identify different types of grassland* [online]. Wiltshire: Plantlife. Available from: http://www.magnificentmeadows.org.uk/assets/pdfs/How_to_identify_different_types_of_grassland.pdf [Accessed 23/02/23].

Raebel, E.M., Merckx, T., Feber, R.E., Riordan, P., MacDonald, D.W., and Thompson, D.J., 2012. Identifying high-quality pond habitats for Odonata in lowland England: implications for agri-environment schemes. *Insect Conservation and Diversity* [online]. 5(6), 422-432.

Rebora, M., Piersanti, S., and Gaino, E., 2004. Visual and mechanical cues used for prey detection by the larva of Libellula depressa (Odonata Libellulidae). *Ethology Ecology & Evolution* [online]. 16(2), 133-144.

Rebora, M., Piersanti, S., Gaino, E., 2008. The antennal sensilla of the adult of Libellula depressa (Odonata: Libellulidae). *Arthropod structure & development* [online]. 37(6), 504-510.

Rebora, M., Piersanti, S., and Gaino, E., 2009. A comparative investigation of the antennal sensilla in adult Anisoptera. *Odonatologica* [online]. 38(4), 329-340.

Ringwood and District Anglers' Association [a], 2017. *Longham Reservoir* [online]. Ringwood: Ringwood and District Anglers' Association. Available from: https://www.ringwoodfishing.co.uk/venues/view/longham-reservoir.html [Accessed 22/02/23].

Ringwood and District Anglers' Association [b], 2017. *Lower Stour* [online]. Ringwood: Ringwood and District Anglers' Association. Available from: https://www.ringwoodfishing.co.uk/venues/view/lower-stour.html [Accessed 13/03/23].

Rose, F., 1981. *The Wild Flower Key*. Second edition. London: The Penguin Group.

Rouquette, J.R., and Thompson, D.J., 2005. Habitat associations of the endangered damselfly, Coenagrion mercuriale, in a water meadow ditch system in southern England. *Biological Conservation* [online]. 123(2), 225-235.

Schutte, G., Reich, M., Plachter, H., 1997. Mobility of the rheobiont damselfly Calopteryx splendens (Harris) in fragmented habitats (Zygoptera: Calopterygidae). *Odonatologica* [online]. 26(3), 317-327.

Shea, K., Roxburgh, S.H., and Rauschert, E.S., 2004. Moving from pattern to process: coexistence mechanisms under intermediate disturbance regimes. *Ecology letters* [online]. 7(6), 491-508.

Šigutová, H., Šipoš, J., Dolný, A., 2019. A novel approach involving the use of Odonata as indicators of tropical forest degradation: When family matters. *Ecological Indicators* [online]. 104, 229-236.

Sinclair, B.J., Coello Alvarado, L.E., and Ferguson, L.V., 2015. An invitation to measure insect cold tolerance: Methods, approaches, and workflow. *Journal of Thermal Biology* [online]. *53*, 180-197.

Smallshire, D., and Beynon, T., 2010. *Dragonfly Monitoring Scheme Manual 2009 Pilot (Version 2)* [online]. Aldershot: British Dragonfly Society. Available from: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/Dragonfly-Monitoring-Scheme-2010-manual.pdf [Accessed 18/04/23].

Smallshire, D., and Swash, A., 2014. *Britain's Dragonflies: A Field Guide to the Damselflies and Dragonflies of Britain and Ireland* [online]. Third edition. Oxfordshire: Princeton University Press.

Song, Y., Zhou, D., Zhang, H., Li, G., Jin, Y. and Li, Q., 2013. Effects of vegetation height and density on soil temperature variations. *Chinese Science Bulletin* [online]. 58, 907-912.

South East Water, 2022. *The River Stour An introduction to our flagship chalk stream project* [online]. Kent: South East Water. Available from: https://cdn.southeastwater.co.uk/SewHousehold/Documents/The_River_Stour_Chalk_Stream_project_Introduction.pdf [Accessed 17/04/23].

South West Lakes Trust, 2020. *Longham Lake* [online]. Lifton: South West Lakes Trust. Available from: https://www.swlakestrust.org.uk/longham-lake#:~:text=Longham%20Lake%20is%20a%20great,and%20carp%20up%20to%2041lbs [Accessed 16/02/23].

South West Water, no date. *South west water limited reservoir regulations* [online]. Exeter: Southwest Water. Available from: https://www.swlakestrust.org.uk/Handlers/Download.ashx?IDMF=31f47fab-cc8a-4ca9-bcea-34482e025c7f [Accessed 11/04/23].

Start, D., Kirk, D., Shea, D., and Gilbert, B., 2017. Cannibalism by damselflies increases with rising temperature. *Biology Letters* [online]. 13(5), 20170175.

Steiner, C., Siegert, B., Schulz, S., and Suhling, F., 2000. Habitat selection in the larvae of two species of Zygoptera (Odonata): biotic interactions and abiotic limitation. *Hydrobiologia* [online]. 427(1), 167-176.

Taylor, P., Smallshire, D., Parr, A., Brooks, S., Cham, S., Colver, E., Harvey, M., Hepper, D., Isaac, N., Logie, M., McFerran, D., McKenna, F., Nelson, B., and Roy, D., 2021. *State of Dragonflies 2021* [online]. Aldershot: British Dragonfly Society. Available from: https://british-dragonflies.org.uk/wp-content/uploads/2021/09/State-of-Dragonflies-2021-final-website.pdf [Accessed 18/04/23].

Thames Basin Heaths Joint Strategic Partnership Board, 2008. *Thames Basin Heaths Special Protection Area Delivery Framework* [online]. Available from: https://www.surreyheath.gov.uk/sites/default/files/documents/residents/planning/planning-policy/JSP/JSPBFramework.pdf [Accessed 01/04/2023].

Townsend, C.R., Scarsbrook, M.R., and Dolédec, S., 1997. The intermediate disturbance hypothesis, refugia, and biodiversity in *streams. Limnology and Oceanography* [online]. 42(5), 938-949.

Vanacker, M., Wezel, A., Oertli, B., and Robin, J., 2018. Water quality parameters and tipping points of dragonfly diversity and abundance in fishponds. *Limnology* [online]. 19(3), 321-333.

Vilenica, M., Kerovec, M., Pozojević, I., and Mihaljević, Z., 2021. Odonata assemblages in anthropogenically impacted lotic habitats. *Journal of Limnology* [online]. 80(1).

Villalobos-Jiménez, G., Dunn, A.M., and Hassall, C., 2017. Environmental noise reduces predation rate in an aquatic invertebrate. *Journal of Insect Conservation* [online]. 21(5-6), 839-847.

Villalobos-Jimenez, G., Dunn, A., and Hassall, C., 2016. Dragonflies and damselflies (Odonata) in urban ecosystems: a review. *European Journal of Entomology* [online]. 113, 217-232.

Ward, L., and Mill, P.J., 2005. Habitat factors influencing the presence of adult Calopteryx splendens (Odonata: Zygoptera). *European Journal of Entomology* [online]. 102(1), 47-51.

Ward, L., and Mill, P.J., 2008. Substrate selection in larval Calopteryx splendens (Harris) (Zygoptera: Calopterygidae). *Odonatologica* [online]. 37(1), 69-77.

Waringer, J., 1982. Notes on the effect of meteorological parameters on flight activity and reproductive behaviour of Coenagrion puella (L)(Zygoptera: Coenagrionidae). *Odonatologica* [online]. 11(3), 239-243.

Wilson, J.B., 1994. The Intermediate Disturbance Hypothesis of species coexistence is based on patch dynamics. *New Zealand Journal of Ecology* [online]. 18(2), 176-181.

Winfrey, C., and Fincke, O.M., 2017. Role of visual and non-visual cues in damselfly mate recognition. *International Journal of Odonatology* [online]. 20(1), 43-52.

9. Appendices

9.1 Appendix I – Risk Assessment

Bournemouth University

Risk Assessment Form

About You & Your Assessment	
Name	Jenny Manley
Email	s5213308@bournemouth.ac.uk
Your Faculty/Professional Service	Faculty of Science and Technology
Is Your Risk Assessment in relation to Travel or Fieldwork?	Yes
Status	Approved
Date of Assessment	20/05/2021
Date of the Activity/Event/Travel that you are Assessing	07/06/2021

What, Who & Where	
Describe the activity/area/process to be assessed	Surveying dragonflies
Locations for which the assessment is applicable	Stour Valley Nature Reserve
Persons who may be harmed	Staff, Student

Hazard & Risk	
Hazard	Coronavirus
Severity of the hazard	Medium
How Likely the hazard could cause harm	Medium
Risk Rating	Medium
Control Measure(s) for Coronavirus: Social distance as much as possible, wear a face mask when indoors or when standing closer than 2m to somebody else, keep washing your hands, use hand sanitizer if that is not possible	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Medium	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	
Hazard	High/Low temps & weather factors
Severity of the hazard	Low
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for High/Low temps & weather factors: Check the weather for the day, bring suitable clothing (rainjacket for rain, windjacket for cold weather, lots of water and a sunhat and sun cream for hot weather)	

With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	
Hazard	Slips/trips
Severity of the hazard	Low
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for Slips/trips: Wear walking boots	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	
Hazard	Manual handling
Severity of the hazard	Medium
How Likely the hazard could cause harm	Low
Risk Rating	Low

Risk Rating	Medium
Control Measure(s) for Water/Drowning: Make sure somebody knows where you are (using GPS), check depth of waterbody, avoid going into water if possible, walk carefully around banks.	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Medium	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	
Hazard	Wildlife
Severity of the hazard	Medium
How Likely the hazard could cause harm	Medium
Risk Rating	Medium
Control Measure(s) for Wildlife: Bring insect bite cream, don't disturb nests, reptile tins, habitats. Stay away from wildlife not being surveyed.	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Medium	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Control Measure(s) for Manual handling: Lift heavy equipment by bending your knees and keeping your back straight, ask for help if it is too heavy to lift by yourself
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low
The residual risk rating is calculated as: Low

Hazard	Diseases
Severity of the hazard	Medium
How Likely the hazard could cause harm	Medium
Risk Rating	Medium

Control Measure(s) for Diseases: If coming into contact with a water source, wash hands afterwards, do not touch face. Wear long socks/trousers/sleeves to avoid small animals puncturing skin. Keep sanitizing hands.
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Medium
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low
The residual risk rating is calculated as: Low

Hazard	Water/Drowning
Severity of the hazard	High
How Likely the hazard could cause harm	Low

Review & Approval

Any notes or further information you wish to add about the assessment	
Names of persons who have contributed	Jenny Manley
Approver Name	Philippa Gillingham
Approver Job Title	Staff
Approver Email	pgillingham@bournemouth.ac.uk
Review Date	04/06/2021

Uploaded documents

No document uploaded

9.2 Appendix II – Ethics Checklist

Bournemouth University

Research Ethics Checklist

About Your Checklist	
Ethics ID	38320
Date Created	06/05/2021 15:08:53
Status	Approved
Date Approved	11/05/2021 11:51:25
Date Submitted	06/05/2021 15:39:48
Risk	High

Researcher Details	
Name	Jenny Manley
Faculty	Faculty of Science & Technology
Status	Undergraduate (BA, BSc)
Course	BSc (Hons) Ecology & Wildlife Conservation

Project Details	
Title	Monitoring Invertebrates at Stour Valley Nature Reserve
Start Date of Project	17/05/2021
End Date of Project	31/05/2022
Proposed Start Date of Data Collection	07/06/2021
Original Supervisor	Phillipa Gillingham
Approver	Ethics Programme Team

Summary - no more than 600 words (including detail on background methodology, sample, outcomes, etc.)

Main aims and objectives are to observe/survey/monitor invertebrates around different areas.

Data collection may involve handling live invertebrates and their habitats. Stress will be mitigated by keeping contact time as short as possible and returning the invertebrates to where they were found, staying at an increased distance where possible and not disturbing the habitat when possible. Data collection will be supervised to implement safer techniques.

Filter Question: Does your study involve experimentation on any of the following: animals, animal tissue, genetically modified organisms?

Additional Details	
Please describe the animal, animal tissue or genetically modified organisms	Beetles
Please describe the methodology of the experiment	Handling, observing

Final Review	
Are there any other ethical considerations relating to your project which have not been covered above?	No

Risk Assessment	
Have you undertaken an appropriate Risk Assessment?	Yes

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9.3 Appendix III – Learning Contract

LEARNING CONTRACT:

INDEPENDENT RESEARCH PROJECT

The learning contract is an agreement between student and supervisor: it should clearly indicate what is expected from both sides. The text in Sections 2 and 3 provides guidance and can be modified to give more details reflecting what has been agreed, such as deadlines for submission of drafts and provision of feedback, word count limits/exclusions and number/timing of meetings. Importantly, the document checklist helps students to follow the required procedures (e.g. ethical approval and risk assessment) and communicate what has been done to the supervisor. The student should submit a draft of the completed form to the supervisor and request a meeting to discuss and finalise the content. Both the student and the supervisor are responsible for keeping a signed copy of this document and following what has been mutually agreed.
1. YOUR DETAILS
Student name: Jenny Manley
Degree Programme: Bachelor of Science
Proposed IRP Title or Set Project: Monitoring Invertebrates SVNP
Supervisor name: Phillipa Gillingham
2. As the student undertaking the above project I agree to:
E-mail my supervisor on a fortnightly basis with a progress report Meet with my supervisor at least once a month to discuss progress and I understand that it is my responsibility to organise these meetings Comply with the terms of this learning contract and the guidance set out in the Guide to Independent Research Projects I understand that this is an independent project and that I am solely responsible for its completion

I agree to comply with all ethical, laboratory and fieldwork protocols established by the Faculty.

3. As the supervisor of this project I agree to:

Meet with the student undertaking this project on at least a monthly basis and to respond to the progress e-mails as appropriate

To meet formally with the student during the first week in November to undertake the interim interview

To provide guidance and support to the student undertaking this project bearing in mind that it is an independent research project. This is inclusive of commenting on drafts of the final report in a timely fashion.

3. DOCUMENT CHECKLIST

Research Proposal or Plan Attached? ☐ YES ☐ NO

YES	NO	
☒	☐	Risk Assessment for fieldwork and evidence of COSSH assessment for all laboratory procedures (online risk assessment completed)
☐	☐	Completed booking for all field equipment
☒	☐	Letters of permission where appropriate providing evidence of access to such things as field sites and/or museum archives
☒	☐	Completed Ethics Checklist

4. INTERIM INTERVIEW – Progress evaluation

Add here the key points of discussion and what has been agreed, particularly if different from Sections 2 and 3. Please indicate the date of your Interim Review (preferably in October within a month of starting Level 6).

Collect data, design fieldwork, identify gaps in knowledge, set final time frames, decide on an area of research.

Bullet point introduction topics and draft fieldwork methods

Interim Review Date: 08/11/2021
5. Variance from the Independent Research Project Guide
The IRP assessment is normally governed by the guidance provided in the Independent Research Project Guide. Any variance in terms of format (e.g. technical report, scientific paper) and word limit should be agreed and specified here. Submission date cannot be changed unless evidence of mitigating circumstances is provided in accordance with the standard BU Guidelines. Any changes? ☐ YES ☒ NO If YES please provide details below: Note References, Tables, Figures, Figure legends are not included in the word count

Both of the undersigned parties agree to be bound by this learning contract:	
Student Signature:	JM
PRINT NAME:	Jenny Manley
Date:	06/05/2021

Supervisor Signature:	P Gillingham
PRINT NAME:	P Gillingham
Date:	06/05/2021

9.4 Appendix IV – Interim Review

Independent Research Project

Interim Interview - Agreed Comments Form

Student Name: Jenny Manley	Programme: EWC
Date: 04/11/2022	IRP Title: Invertebrates on SVNP
Supervisor Name: Pippa Gillingham	

Agreed comments – to include progress and plans for completion:

Jenny has completed a draft of her methods and collected her data. Next steps are to summarise some of her data ready for statistical analysis, which we will discuss at the next meeting. She will also send me a bullet pointed list of topics to cover in the introduction and tidy up the drafted methods.

Two copies of this form are needed – student to retain one copy and include in the appendices of the dissertation the other is to be emailed to the supervisor.

Student Signature: Jenny Manley	Supervisor Signature: Pippa Gillingham

9.5 Appendix V – Data

Table 8. Original survey data prior to manipulation for statistical analysis, the boxes shaded in grey are measurements that were not recorded

Site	Land Use Category	GPS Co-ordinates	Sound (dB)	Lux (lux)	Wind speed (ms^{-1})	Shade (%)	Humidity (%)	Temperature (°C)	Soil moisture (%)	Veg cover (%)	Veg height (cm)	Vegetation	Bare ground	Notes	Odonates
SVNP1	SANG	N 50"45.961 W001" 51.766	67	635	0.9	25	64.3	19.5	10.1	80	40	Greater plantain, nettle, cocksfoot, wintercress, annual meadowgrass, common ragwort, greater spearwort	Y		2 *Calopteryx virgo* (2), Unidentified species (1)
SVNP2	SANG	N 50"45.857 W001"51.874	51	39	0.5	75	66	19.95	16.77	85	23.25	Nettle, bramble, meadow fescue	Y	Very shaded and no emergent vegetation on this side of bank, river is fast flowing	None observed
SVNP3	SANG	N 50"45.798 W001" 52.098	37	278	0.6	50	63.1	21.6	22.7	70	26.75	Greater plantain, dock, meadow fescue, red fescue, bindweed	Y	Open & sunny on path & right next to river	1 *Ischnura elegans* F born today. 2 *Enallagma cyathigerum* M&F. 2 *Coenagrion puella* M&F in tandem. 1 *Libellula depressa* F.
SVNP4	SANG	N 50"45.849 W001" 52.397	42	192	0.7	0	57.5	23.2	7.7	100		Cocksfoot, meadow fescue, dock, clover, buttercup, cow parsley	N	Open wilderness, river nearby, very hot	1 *Calopteryx splendens* F. 2 *Platycnemis pennipes* M&F. 2 *Calopteryx virgo*. 1 *Ischnura elegans*. 1 unidentified chaser.
SVNP5	SANG	N 50"46.005 W001" 52.522	42	269	0.7	0	64.9	20.2	10.3	90	52.7	Cocksfoot, annual meadowgrass, thistle, wintercress	N	Open (fenced off) field next to wide channel with slow flow	>150 *Calopteryx splendens* . >150 *Calopteryx virgo* . >50 *Ischnura elegans* M&F, young & adult. >25 *Platycnemis pennipes* M.
LL1	SSSI	N 50"46.832 W001" 54.635	40	243	1.1	0	70.7	19.5	24.8	90	29.75	Ribwort plantain, yellow flag iris, cocksfoot, oatgrass, daisy, moss	Y		2 *Platycnemis pennipes*. 3 *Enallagma cyathigerum*. *Multiple* unidentified juveniles
LL2	SSSI	N 50"46.878 W001" 54.635	39	890	1	0	53.3	24	7.4	100	13.5	Ox-eye daisy, wood meadowgrass, purple clover, moss, bee-mimic orchid	N		1 *Platycnemis pennipes*. 3 *Coenagrion puella*. *M*ultiple unidentified juveniles
GC1	PAA	N 50"46.648 W001" 54.372	38	74	2	75	55.2	21.7	15	100	59.3	Rye grass, dovesfoot cranebill	N	Narrow stretch of bushes next to river	>10 *Calopteryx splendens* M&F. >5 *Calopteryx virgo*. 1 *Libellula depressa*. >10 *Ceriagrion tenellum*.
GC2	PAA	N 50"46.671 W001" 54.202	50	721	0.5	50	57.2	25.2	14.6	100	39.5	Yorkshire fog		Tall scrub grass between golf course and river (rapids upstream), lots of human disturbance via walking/sitting & talking	>20 *Calopteryx splendens* M&F. >5 *Platycnemis pennipes* M. >20 *Pyrrhosoma nymphula* M&F.
CP1	SANG	N 50"46.861 W001" 56.043	43	1003	0.45	0	55.1	23	12.8	95	14	Rye grass, dandelion, shepherd's purse	N		>5 *Calopteryx splendens* M. 2 *Orthetrum cancellatum* M&F in tandem. 2 *Enallagma cyathigerum*
CP2	SANG	N 50"46.915 W001" 56.110	55	116	1.6	75	49.4	21.9	14.6	95	11.75	Annual meadowgrass, dandelion, shepherd's purse, bulbous buttercup	N		>10 *Calopteryx virgo* M&F. >10 *Calopteryx splendens* M&F. 1 *Platycnemis pennipes* M.
CP3	SANG	N 50"47.013 W001"56.303	32	952	1.8	0	41.2	23	12.5	100	36.13	Annual meadowgrass, dandelion, shepherd's purse, bulbous buttercup	N		1 *Calopteryx splendens* M. 1 *Platycnemis pennipes 'f. lactacex'*. 1 *Coenagrion puella* M. 2 *Pyrrhosoma nymphula* M.

CP4	SANG	N50"47.246 W001"56.423	39	31	0.8	100	48.6	24.5	7.3	20	7.75	Meadow buttercup, cow parsley, thistle, nettles, pignut		Ice cream van/lots of human activity concentrated at one end of waterbody	3 *Coenagrion pulchellum*. 4 *Orthetrum cancellatum*. 2 *Erythromma najas*. >10 *Enallagma cyathigerum*. 8 *Ischnura elegans*. >20 *Coenagrion puella*. Multiple unidentified species.
CP5	SANG	N 50"47.037 W001" 56.391	35	21	0.8	100	61.3	20.8	15.8	100	46	Meadow buttercup Nettle Rye grass Rough meadowgrass	N	Steep bank covered by trees & shrubs	1 *Coenagrion puella*.
IF1	PAA	N 50"43.930 W001"47.573	38	690	0.7	0	73.2	22	0	60	47.75	Bramble, lesser hawksbit, sweet vernal grass, moss		Thick high reeds (may act as an affecting factor)	1 *Calopteryx virgo* M.
IF2	PAA	N 50"44.237 W001"47.731	38	373	0.8	0	73.4	21.7	0	100	17.75	Ox-eye daisy, birdsfoot trefoil, ribwort plantain, bramble, annual meadowgrass, lesser hawksbit		Noise levels rose to 70dB when the train went by	1 *Calopteryx splendens* (M).
IF3	SSSI	N50"44.326 W001"47.952	45	120	0.4	100	75.1	21.7	10.7	95	28.13	Greater plantain, nettle, annual meadowgrass, dock		Wide channel, still water, houses opposite, occasional boat disturbance	None observed
IF4	SSSI	N50"44.369 W001"48.144	49	965	1.4	0	75	22.4	7.7	100	49.5	Yorkshire fog		Open sunny bank - on other side of river willow, rush, pignut, oak, lily & silver birch	None observed
IF5	PAA	N 50"44.548 W001"48.746	45	142	0.4	100	6708	19.9	7.9	50	9.5	Greater plantain, bramble, dock, cow parsley, cocksfoot, daisy		Out of catchment on Stour Valley nature Partnership map	>20 *Coenagrion puella* M&F flying & in tandem. >20 *Ischnura elegans* M&F flying & in tandem. >10 *Enallagma cyathigerum*.
IF6	PAA	N 50"44.643 W001"48.785	40	900	0.3	0	62.9	24.8	8.7	100	34.25	Meadowgrass, cocksfoot, perenial rye			>21 *Platycnemis pennipes* M&F flying and in tandem. >5 *Coenagrion puella*. >10 *Calopteryx splendens*.
IF7	PAA	N50"44.757 W001"48.698	42	355	0.5	100	66.2	21.6	10.6	100	28.3	Common ragwort, cocksfoot, perenial rye		Wide river, little emerging vegetation	None observed
HP1	SANG	N 50"47.196 W001"54.250	59	781	1.3		61.1	25.2	0		44.5	Bramble, cocksfoot, silverweed, ribwort plantain, common vetch, dandelion, Yorkshire fog	N	Next to roadside and houses, small well with old water in/ditch water around	1 *Libellula depressa* F. 1 *Pyrrhosoma nymphula* M.
HP2	SANG	N 50"47.246 W001"54.330	50	407	1		57	24	10.7		10	Dovesfoot cranebill, Yorkshire fog, meadow buttercup, meadow foxtail	N	Young oak trees, grey willow along field edge and occasionally along path	>5 *Pyrrhosoma nymphula*. 4 *Coenagrion puella* M&F in tandem (x2). 1 *Platycnemis pennipes*.
HP3	SANG	N 50"47.347 W001"54.266	57	258	0.8		70	22.5	9.13		56.83	Thistle, meadow buttercup, Yorkshire fog, rough meadowgrass, dock	N	Next to road, thick deciduous tree line (oak, something purple, sycamore)	None observed
BVP1	PAA	N 50"47.219 W001.53.941	40	77	0.6		68	20.6	8.87		5	Bramble, stickyweed, bare ground	Y	Invasive species such as rhododendron, quite shaded due to canopy (oak, hazel, birch, some pine)	None observed
BVP2	PAA	N 50"47.292 W001"53.715	43	77	0.9		68.4	20.5	10.3		19.38	Bramble, bracken, Yorkshire fog, soft rush, English ivy	N	Out of catchment on Stour Valley nature Partnership map	>12 *Pyrrhosoma nymphula*. >15 *Coenagrion puella*.

Table 9. A table to show the most abundant species at each site. If there were multiple species within the same category, both species are listed. If there were odonate observations, the box is marked with a '-'.

Site	Land Use Category	Most Abundant Species	Standard Abundance Ordinal Category
SVNP1	SANG	*Calopteryx virgo*	B
SVNP2	SANG	-	-
SVNP3	SANG	*Coenagrion puella*	B
SVNP4	SANG	*Calopteryx virgo,* *Platycnemis pennipes*	B B
SVNP5	SANG	*Calopteryx splendens,* *Calopteryx virgo*	E E
CP1	SANG	*Calopteryx splendens*	C
CP2	SANG	*Calopteryx splendens,* *Calopteryx virgo*	C C
CP3	SANG	*Pyrrhosoma nymphula*	B
CP4	SANG	*Coenagrion puella*	D
CP5	SANG	*Coenagrion puella*	A
HP1	SANG	*Libellula depressa,* *Pyrrhosoma nymphula*	A A
HP2	SANG	*Pyrrhosoma nymphula*	C
HP3	SANG	-	-
GC1	PAA	*Ceriagrion tenellum,* *Calopteryx splendens*	C C
GC2	PAA	*Calopteryx splendens,* *Pyrrhosoma nymphula*	D D
IF1	PAA	*Calopteryx virgo*	A
IF2	PAA	*Calopteryx splendens*	A
IF5	PAA	*Coenagrion puella,* *Ischnura elegans*	D D
IF6	PAA	*Platycnemis pennipes*	D
IF7	PAA	-	-
BVNP1	PAA	-	-
BVNP2	PAA	*Coenagrion puella*	C
LL1	SSSI	*Enallagma cyathigerum*	B
LL2	SSSI	*Coenagrion puella*	B
IF3	SSSI	-	-
IF4	SSSI	-	-

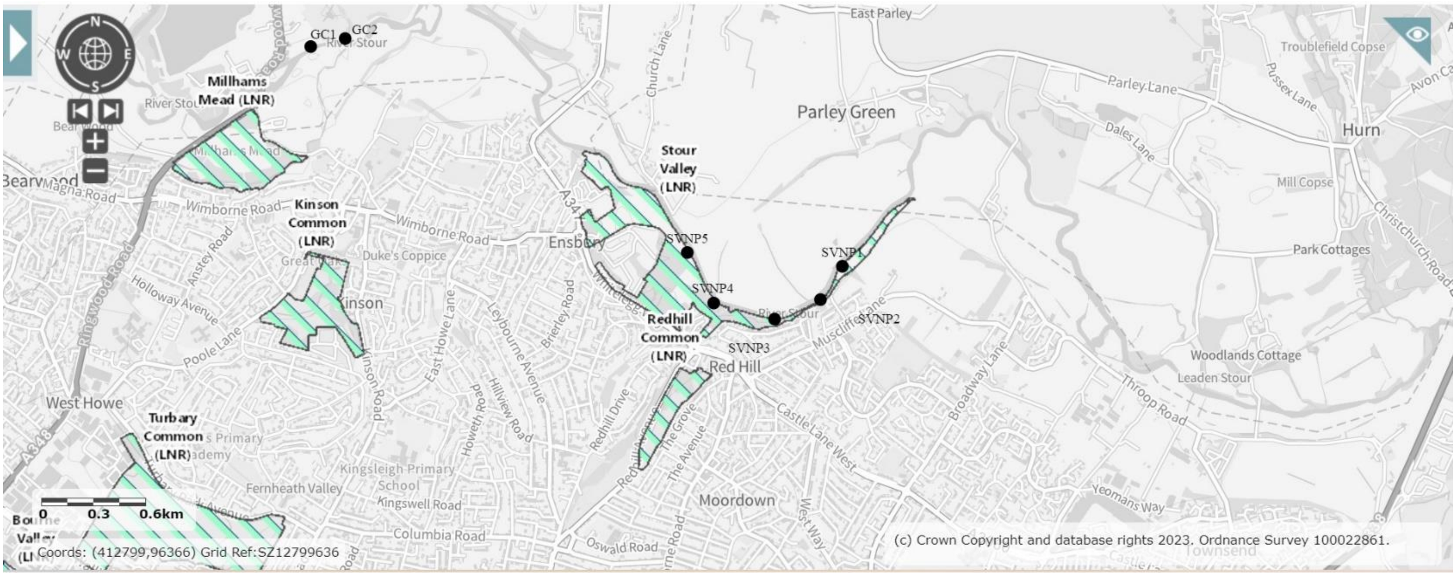

Figure 7. A map produced on 'Magic' (DEFRA 2023) displaying PAA sites GC1 and GC2, and SANG sites SVNP1, SVNP2, SVNP3, SVNP4, SVNP5. The blue hashed areas are marked as LNRs on the database.

Figure 8. A map produced on 'Magic' (DEFRA 2023) displaying PAA sites IF1, IF2, IF5, IF6 and IF7 and supposed SSSI sites IF3, IF4. The latter two were marked as LNRs and not SSSIs on the database.