River Avon Horseshoe Bat Monitoring Study

Final Report

carried out by

Clarkson & Woods Ecological Consultants

commissioned by

Bath and North East Somerset Council

March 2017

RIVER AVON HORSESHOE BAT MONITORING STUDY

FINAL REPORT

CONTENTS

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The information, data and advice which has been prepared and provided is true, and has been prepared and provided in accordance with the Chartered Institute of Ecology and Environmental Management's (CIEEM) Code of Professional Conduct. We confirm that the opinions expressed are our true and professional bona fide opinions.

EXECUTIVE SUMMARY

SURVEY REMIT

- Clarkson and Woods were commissioned by Bath and North East Somerset Council to carry out a suite of surveys during 2016 to investigate the value of the urban reaches of the river Avon to bats, with particular emphasis on lesser and greater horseshoe bats. The Bath Enterprise Zone (BEZ) encompasses 98 hectares of land on or close to the banks of the Avon in Bath which has begun, and will continue to be, the focus of extensive residential and industrial regeneration development in the city. As internationally important and legally protected populations of both lesser and greater horseshoe bats are present within a network of natural, built and post-industrial features in and around Bath it is important that the Council are able to consider fully the potential impacts of development upon these key natural heritage assets. This report sets out the findings of a seven-month survey programme and makes recommendations which can be used to inform planning guidance and policy regarding bats and development in Bath.

METHODOLOGY

- We conducted a static bat detector survey using five Wildlife Acoustics SM2+BAT and five Anabat Express devices deployed in ten bankside locations along the river corridor from New Bridge in the west and Cleveland Pools in the east. Detectors were deployed concurrently for a period of at least six consecutive nights each month from April until October inclusive. Six of the locations were opposite pairs to compare usage between opposing banks. A variety of natural and hard landscaped banksides were represented. A monthly walked transect survey was also undertaken, involving five surveyors concurrently walking a section of the riverside towpath on each occasion. Each survey lasted three hours and surveyors were equipped with two bat detectors to enable all calls to be recorded. A rapid assessment of the current state of vegetation cover and night-time illumination at the bankside and beyond was also undertaken so activity results could be compared to these observations.

HEADLINE FINDINGS

- The surveys recorded lesser horseshoe bats within the river corridor during *every* month, as well as at *every* static detector location (total of 1158 passes) and in three of the five transect locations. Greater horseshoe bats were again recorded in every month but in much lower numbers (total of 43 passes) and were more closely associated with western and eastern locations, being recorded at six static detectors and two transect locations.

- A strong association with activity during the spring and autumn months indicated that the Avon is of particular value to these species as a conduit for movement at a time when they are in transition between winter hibernation and summer breeding roosts. This is a key behaviour and the continued survival of those populations using the river relies on unimpeded passage between roosts in order to maintain a favourable conservation status. It is considered likely that this usage will involve a significant proportion of the populations associated with the Bath and Bradford on Avon Bats Special Area of Conservation (SAC) given its proximity to the site, likely numbers of individuals present and the habitat links between the river corridor and known roosts beyond. *Consequently it is recommended that the river corridor, including its banks and associated habitat, should be considered supporting habitat for the SAC*.

- Horseshoe bat activity was largely made up of commuting/dispersal behaviour according to a time-of-night analysis, although a significant amount of foraging activity was also recorded, particularly for lesser horseshoe bats and in the western and eastern ends of the survey area. This, together with an analysis of activity rates by location indicates that there are a number of roost sites used throughout the year in close proximity to the river. These include, the Cattle Market Vaults (near the Tramsheds development), buildings at South Quays, and suspected roosts in the vicinity of the Newton Brook/Avon confluence and Weston Island. These also become more important as transitional roosts for an increased number of individuals moving from and to hibernation sites closer to the city from further afield in the spring and autumn months.

- Horseshoe bat activity was greatest at locations where *ambient light levels were lowest and where vegetation was densest*, particularly where a 'green lane' effect was formed. Hard-edged banks were generally less favoured, although activity persisted where there was a dark 'shadow' zone afforded by a tall hard-edged bank to screen illumination, even in the absence of vegetation. Therefore light levels were seen to be a greater predictor of horseshoe activity rates although vegetation can be crucial in providing adequate light screening. Additionally, glare emitted from bright lighting tended to affect the opposite bank the most.

- Horseshoe bats were most often observed *flying within 2m above the water's surface and between 5m either side of the water's edge*, flying closer to the bank where bankside vegetation coverage was lowest. This indicates that the *bankside is the most* *important feature of the river for horseshoe bats*, probably as these species tend to require strong linear features for navigation through the landscape.

- In addition, at least eight other species were recorded, including exceptionally high activity rates from common pipistrelle, soprano pipistrelle and Daubenton's bats and activity from the rare barbastelle and Nathusius' pipistrelle bats.

CONCLUSION

- It is concluded that the integrity of the river corridor and its suitability for bats is likely to be threatened by two key factors associated with development in the BEZ; the increase in night-time illumination of the river and its bankside habitats, and the removal or change in bankside habitat structure and extent, removing key linear dispersal features and foraging habitat.

NEXT STEPS: THREE KEY RECOMMENDATIONS

Recommendation 1: Bath River Corridor – Ecological Design Guidance

- It is recommended that the conclusions and mitigation measures proposed in this report are developed into B&NES Council Design Guidance for riverside development in Bath. This Guidance will also provide steer on the provision of light modelling and ecological studies to support planning applications, and would supplement Placemaking Plan Design policy D.8. This will offer greatest clarity for developers on the baseline requirements that need to be met in order to avoid adverse impacts on the SAC bat populations, particularly horseshoe bats.

- In order to preserve the river corridor's importance to protected populations of rare bats it is recommended that all riverside development is subject to limits on the amount and type of lighting permitted and that landscaping in keeping with the character of the river at that particular location is promoted. To this end, this report proposes the implementation of the new design guidance including notional River Corridor Lighting Zones in cross section from water's edge to the urban environment, where upper limits on ambient light levels caused by light from the development (including light spill through windows) ranging from 0.5lux to 3.5lux are imposed. Departure from the Design Guidance and lighting limits will need to be supported by a full suite of survey information and reasoned justification for a change of approach. This should be applied across the entire BEZ to respect the value of the corridor as a contiguous natural feature and provide a common standard for developers. Adoption of this approach can be expected to have positive outcomes for the protection of habitat for other species, particularly otters (European Protected Species) and the inherent diversity of aquatic and terrestrial invertebrates associated with the river corridor. Other landscaping and land-use solutions can be suggested within the Guidance. Given that the effects of glare and obtrusive lighting tend to act greatest upon the opposite bank river bank, this should additionally be taken into account when considering the impacts of redevelopment.

Recommendation 2: Off-Site Lighting Mitigation Scheme

- Opportunities also exist for the remediation of existing developments which currently exceed light spill guidelines within Bath's River Corridor (e.g. glare and light spill from light columns in car parks in industrial and retail areas etc.). The use of funding and delivery mechanisms including Community Infrastructure Levy may be appropriate as part of an off-site mitigation scheme. Such an off-site mitigation scheme operated by the Council could also contribute towards the successful mitigation and net gain of ecological benefits, managing the impacts of light spill and supporting appropriate development in the River Corridor at very low cost.

- Baseline mapping of lighting conditions 1-3 hours after sunset when the initial nightly peak of bat activity occurs would be required to identify mitigation opportunities in the river corridor and identify specific sources of obtrusive lighting and glare, with a view to targeting remedial action. It is recommended that this evidence forms part of the development of the Design Guidance.

Recommendation 3: Winter Surveys To Establish Seasonal Bat Activity

- Further study is recommended during the winter months (NB currently underway during winter 2016-17), as bat activity is being impacted upon by mild winter weather and the consequential impact on hibernation patterns this brings. Bats, particularly horseshoe bats, are known to be active to some degree during the winter months. It is also considered that the river may be a valuable habitat for foraging at this time of year due to relatively mild conditions within the corridor and the heat-island effect. Use of the river during the winter months may have consequences for the application of above recommendations on a seasonal basis. An extension of the static detector element of the study only was recommended. Further survey work is currently underway and its findings are due to be reported in due course.

1 INTRODUCTION

1.1.1 Clarkson and Woods were commissioned by Bath and North East Somerset Council (B&NES) in April 2016 to devise and conduct an investigation into the usage of the River Avon Site of Nature Conservation Interest (SNCI) corridor through the city of Bath by bats. Of particular interest was the usage of the river by greater and lesser horseshoe bats for which the Bath and Bradford on Avon Bats Special Area of Conservation has been designated as an important complex of hibernation sites. These bats have complex lifecycles and depend on many man-made structures for breeding and hibernation and are known to be in decline in Europe due to loss of roost sites and changes in land use leading to habitat fragmentation.

1.1.2 The Bath Enterprise Zone (BEZ – see Figure 1) represents 98ha of land in close proximity to the Avon in central and western Bath and is anticipated to form the location for a series of regeneration developments on post-industrial land as well as the provision of up to 3,000 new dwellings. Riverside land commands a particularly high value, is highly desirable in terms of recreation and visual amenity and can be expected to form a key part of many developments.

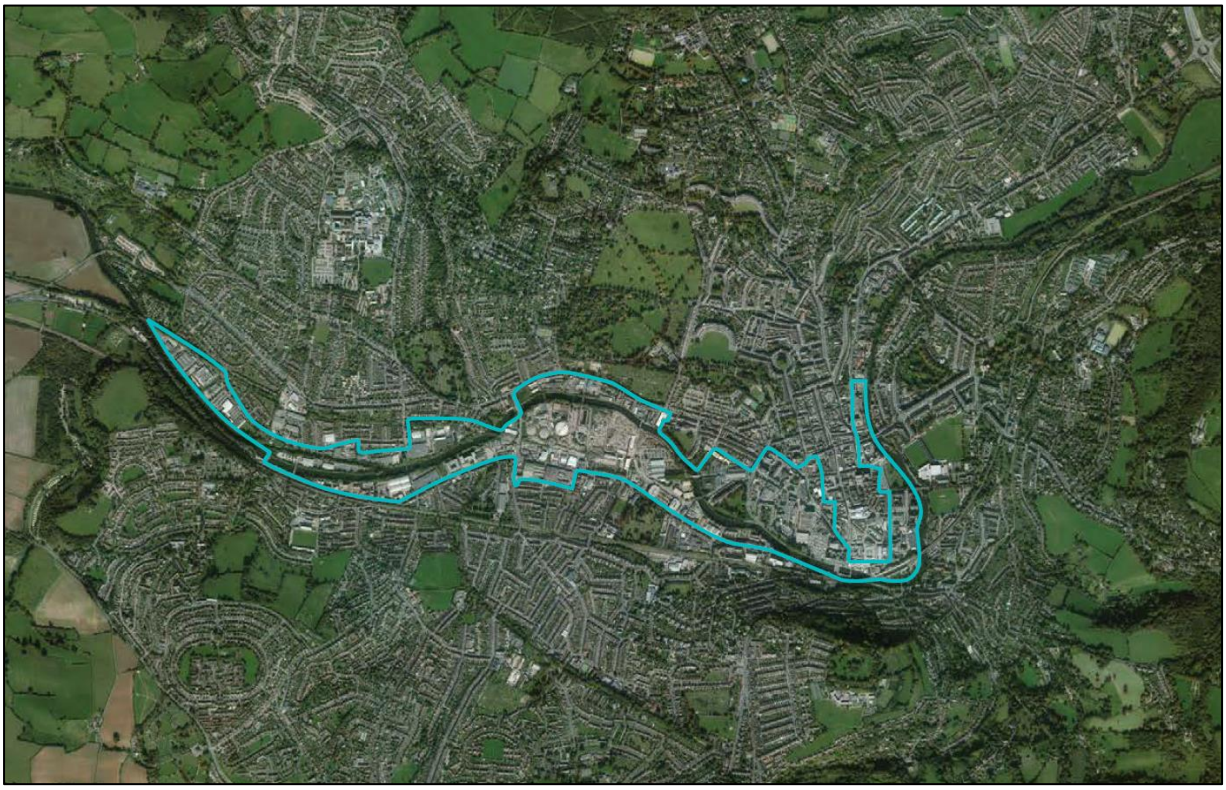


Figure 1. Aerial View of Bath and the River Avon, with the Extent of the Bath Enterprise Zone.

1.1.3 The River Avon is designated as an SNCI in its own right and is listed in the B&NES Placemaking Plan as a key green infrastructure and ecological network site. It has been the subject of a number of ecological studies in previous years, several of which have recorded the presence of horseshoe bats. In addition, a small number of summer roosts for these species have been noted from within or close to the city centre, and a small number of hibernation roost have been recorded very close to the riverside. However, it has not been established whether the Avon corridor is of particular importance for the long-term health of the population of these species.

1.1.4 All native British bats are predominantly nocturnal animals and an aversion to artificial lighting has been demonstrated in many species. Horseshoe bats are known to be particularly light-averse, with several studies showing that artificial lighting can pose a barrier to movement along previously-used routes in illuminance of as little as 3.6lux (0.1-1lux is generally acknowledged to be equivalent to a clear full moon). As horseshoe bats do not typically cross open space without a linear natural feature to follow, light barrier effects can severely disrupt nocturnal and seasonal movements to foraging, breeding or hibernation sites. Consequently, as the local planning authority with the duty to consider impacts of development upon legally protected species and designated sites, Bath and North East Somerset Council recognised that this study was necessary to provide a robust baseline of bat activity in the river corridor to guide future development proposals within the BEZ.

1.1.5 This study gathered a baseline of bat activity over an entire active season (April to October) across 10 locations on both banks of the river, from New Bridge in the west to Kensington Meadows in the east. The study aimed to investigate where and when through the year bat activity was greatest, as well as the relative value to bats (in particular horseshoe bats) of different bankside habitat types and bank structures. From this, an assessment of the value of the River Avon corridor to local bat populations and its relationship with the SAC can be made. On this basis, mitigation principles which aim to preserve this value for development have been outlined, with a view to underpinning future planning guidance.

2 SUMMARY OF PRE-EXISTING INFORMATION ON BATS IN BATH

2.1 Details of the Bath and Bradford on Avon Bats SAC

2.1.1 The Bath and Bradford-on-Avon Bats Special Area of Conservation (SAC) is a European-level multi-site designation, made up of several mine and cave entrances scattered mainly around the south and east of Bath as shown on Figure 2 overleaf. It receives its designation as the underground sites the entrances lead into are the hibernation roosts for approximately 15% of the British greater horseshoe bat population (although more recent observations suggest around 1,200 individuals in total[1]) in addition to a large population of lesser horseshoe bats (at least 500) and a significant number of Bechstein's bats (20+). All three species are considered rare and declining in the UK and declining in Europe. Component sites within the SAC include the nationally designated Sites of Special Scientific Interest (SSSIs) of Combe Down and Bathampton Down Stone Mines, Box Mine, Winsley Mines and Brown's Folly.

2.1.2 Research also indicates that these species use the underground sites for mating in the autumn prior to hibernation and as staging posts before dispersal into the wider landscape when the breeding population seek out maternity roosts, typically within a landscape dominated by cattle-grazed pasture and woodland. These are the most productive habitats for the flying beetles and large moths which are the preferred food items for horseshoe bats.

2.1.3 As seen in Section 2.2, a small proportion of the SAC bats remain resident within the underground structures year-round. These are likely to be either males, non-breeding females or juveniles, but some are members of small self-contained breeding colonies. Such colonies have been observed within some component sites including Combe Down and Bathwick Mines (Byfield, Mount Pleasant Pleasant and Grey Gables) and Box Mines, although many were from man-made 'incubator chambers' installed there in order to encourage breeding. Recent numbers and other detailed observations could not be obtained via a search of Bristol Region Environmental Records Centre survey records.

2.1.4 The grassland, watercourses, scrub and woodland surrounding the entrances are used by bats for feeding and commuting. Habitats and features which support the SAC population are protected in the same way according to the conservation objectives of the designated site as they are vital in providing forage and dark, natural navigation features to follow.

[1] Ransome, R. (2009). Bath Urban Surveys: Dusk Bat Surveys for Horseshoe Bats Around South-West Bath.

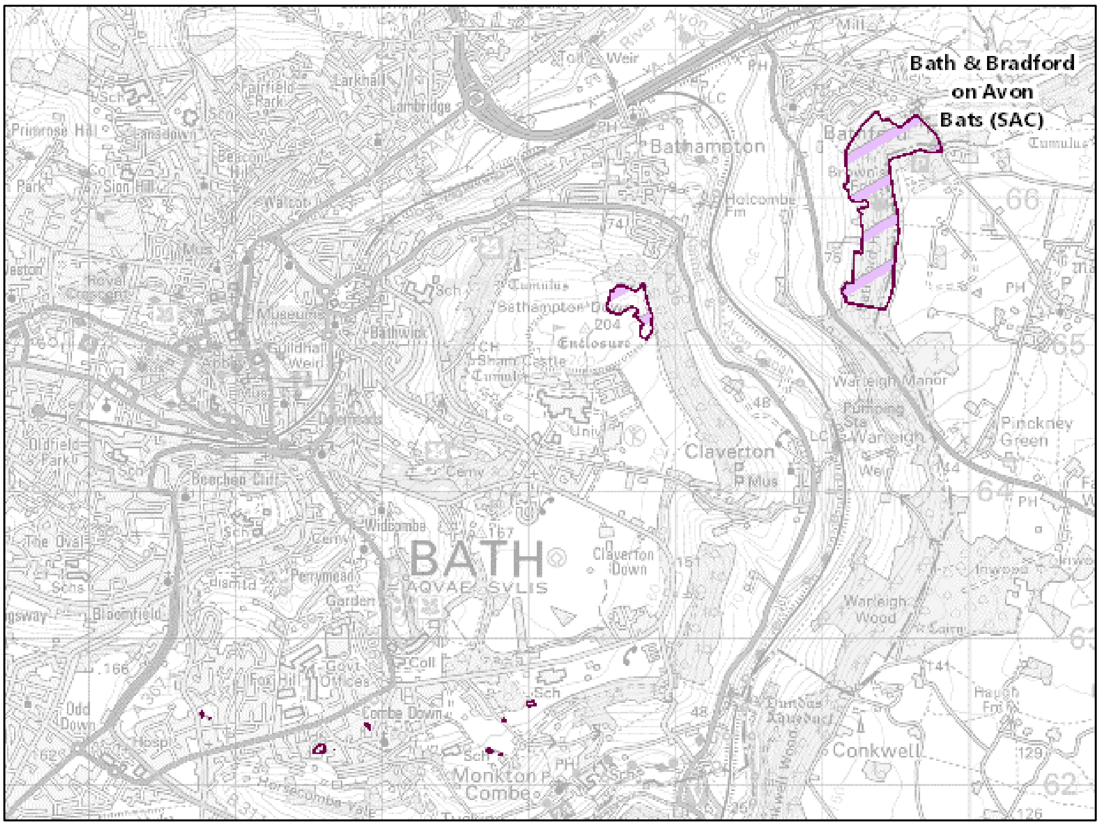


Figure 2. Location of Component Sites within the Bath and Bradford on Avon SAC (purple shapes and dots). Combe Down, Bathampton Down and Brown's Folly shown. Winsley and Box Mines not shown as they lie further east.

2.2 Results of Previous Bat Studies

Previous River Avon Studies

2.2.1 In 2013 and 2014, preliminary bat survey work was undertaken within Bath city centre along the Avon to collect species assemblage and activity information[2]. Three locations at which to install static detectors were selected each year. These were: Weston Island Bus Depot, Cattle Market Vaults and Kensington Meadows (2013) and Charlton Court, Victoria Bridge and Angel Place (2014) as can be seen in Figure 3 below. Static detectors were deployed simultaneously for four consecutive nights during the months of July, August and September. A single walked transect was carried out each of these months at one of the three locations.

2.2.2 The studies recorded at least eight species of bats, with lesser horseshoe bats featuring at four of the six locations and greater horseshoe bats detected at two. It was noted that bats were generally seen to favour darker areas with greater vegetation coverage and surveyors observed certain bats utilising the shading of a tall, concrete river wall where naturally vegetated habitat was sparse. It was concluded that the river formed an important wildlife habitat whose status needed preserving or improving.

2.2.3 Recommendations were made for the avoidance of lighting within 8m of the water's edge on both banks and for the creation of darker alternative flight paths in currently lit sections, either

[2] River Avon Corridor Project: Bat Activity Surveys. Simecology Ltd., 2014.

through retrofitted light attenuation or control measures or the planting of new vegetation screening.

Figure 3. Location of Detectors in 2013 and 2014 Study and Location of Lesser and Greater Horseshoe Bat Passes.

Studies of Horseshoe Bats at Underground Sites

2.2.4 This information has been collated in order to provide a background of the current understanding of the movements and behaviour of horseshoe bats which use underground sites in Bath and will be used as context for our discussion of survey results and recommendations.

2.2.5 Radio-tracking studies into the summer commuting and habitat use of greater horseshoe bats were carried out in the wider B&NES area between 2000 and 2003, specifically in the areas of Combe Down and Horsecombe. In the Combe Down study[3], 26 bats were ringed and tracked from the Byfield Mine site between May and August. They were seen to favour fields and tall hedgerows with scrub and woodland edge for foraging. Streams, rivers and canals were also used. Urban areas which were brightly lit were rarely used, even when close to the roost site, although some crossing of roads was observed to have occurred. Greater horseshoe bats were not observed to cross obstacles (open space with no linear natural features) over 10-12m in length, with the largest gaps being generally darker than smaller ones. It was found that the average distance these bats commuted to their foraging areas was <3km (mostly <1km) until the end of May, after which it increased to around 5km until August. The longest distance travelled was 10.5km to near Radstock (Ammerdown). For these bats, important summer foraging and dispersal habitat was within the Horsecombe Valley, Midford Valley, the Cam Valley to Radstock and areas towards Newton St. Loe. Little information on the presence of resident lesser horseshoe bats and their movements was collected although it was noted that very few female bats are present throughout the year, most only returning in October, presumably after breeding[4].

[3] Billington, G. (2000). Combe Down Greater Horseshoe Bats: Radio Tracking Study.
[4] Parsons, K. (2000). Bat Activity at Combe Down Mines During Summer and Autumn 2000.

2.2.6 The above work became the basis for the 2006-8 Batscapes initiative which sought to raise awareness of horseshoe bats in land management and development and also formed the basis for the adoption of the 4km sustenance zone around the SAC sites which is used by B&NES to inform planning decisions.

2.2.7 Further static detector studies and manned survey effort was carried out in 2008 and 2009[5] across six areas of the south and west of Bath, which were Horsecombe Vale, Southstoke area of Cam Valley, Odd Down (land east and west of the park and ride), the Tumps (north of Odd Down playing fields) and Newbridge/Twerton (south of the Avon at the western end of the BEZ). Findings corroborated the earlier research regarding commuting distances. Greater horseshoe bats were seen to favour dung beetles and chafer beetles during winter, spring and autumn, switching to larger moths (in woodland and waterways) and craneflies when beetles were less available. The most productive habitats were pasture and woodland edge with hedgerows, while arable was almost always avoided, although lesser horseshoe bats were more variable in their choice of foraging habitat. Surveys also showed that foraging and commuting activity was most intense during the first three hours after sunset, after which night roosting occurred. Lesser horseshoe bats foraged for longer than greater horseshoe bats and generally later after sunset. Lesser horseshoe bats were thought to utilise a greater number of roosting sites local to foraging grounds as their overall activity ranged over a wider area but their commuting distances were lower. Other observations included the avoidance of the field corner behind the clubhouse at Odd Down despite being a good site for moth production, likely due to the presence of bright floodlights used during matches as well as the park and ride. Windy conditions and temperatures below 10°C were associated with reduced horseshoe bat activity.

2.2.8 The above information was collated in an additional study in[6] of fields proposed for major housing development in the Weston and Ensleigh areas of north and north west Bath which did not find any significant relationship between the predominantly arable field habitats and horseshoe bat activity, although small numbers of horseshoe passes were recorded as well as an abundance of other species. It was surmised that the principal summer foraging grounds for much of the SAC population was focussed around the area to the south of the city bounded in green in Figure 4 below. It is interesting to note that this area extends northwest to the river Avon, incorporating the Newton Brook.

[5] Ransome, R. (2009). Bath Urban Surveys: Dusk Bat Surveys for Horseshoe Bats Around South-West Bath
[6] Ransome, R., (2013). Bath Urban Surveys: Dusk Bat Surveys for Horseshoe Bats Around Weston, Bath.

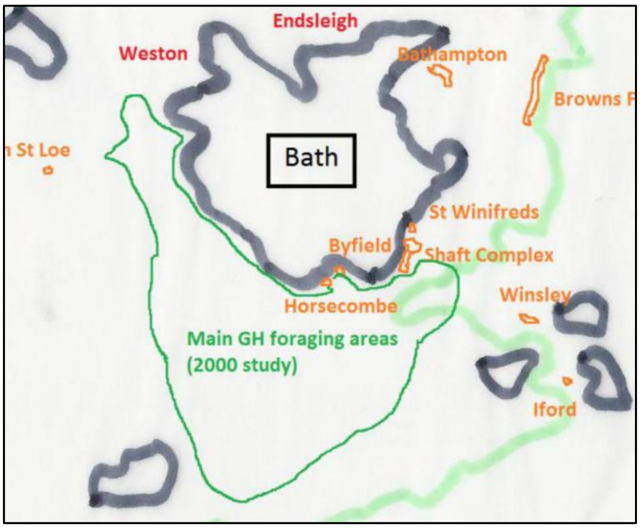


Figure 4. Sketch from Ransome, 2013 to Show Key Greater Horseshoe Bat Foraging Areas.

2.2.9 Recommendations of this study included the implementation of lighting restrictions to avoid light spill from development above 1lux onto retained and created habitat, as well as planting of hedgerows.

2.3 Details of Known Horseshoe Bat Roosts in Bath

2.3.1 Table 1 below gives the details of the known roosts for horseshoe bats present in Bath and nearby. The location in relation to the BEZ is given as well as the date of the most recent record available. Component sites within the SAC designation are not included as these have been described above. It is noted that very few records were derived from the Weston area of Bath probably due to the absence of significant underground tunnels, grottoes or mines nearby[7].

Table 1. Details of Known Horseshoe Bat Roosts in and Around Bath (<approx. 3km from BEZ)

Site Name	Species	Type	Location and Distance to BEZ	Date
Bath Quays South (Newark Works Building)	LHS	Night	ST74586451 Within BEZ	2016
Cattle Market Vaults	GHS & LHS	Unknown, likely transitional	ST 7513 6517 Within BEZ	2013
Roseberry Place	LHS	Night	ST 73492 64876 Within BEZ	2014
Crowe Hall, Widcombe Hill	GHS & LHS	Day (up to 20LHS), Transitional	ST 75983 63971 660m, South-west	2011

[7] Ransome, R., (2013). Bath Urban Surveys: Dusk Bat Surveys For Horseshoe Bats Around Weston, Bath.

Site Name	Species	Type	Location and Distance to BEZ	Date
Sydney Gardens	LHS	Night, probable day.	ST75766539 700m East	2016
Cranwell House	GHS LHS	Hibernation/Transitional Small Day	ST 73732 66121 860m North	2011
All Saints Church	LHS (probable)	Small Day	ST 7308 6634 1.2km North	2015
Claysend Barn, Newton St. Loe	GHS	Breeding	ST 7099 6430 1.4km South-west	1960s
Former Harvester Building, Bath	GHS & LHS	Small Day & Night	ST 7630 6654 1.9km North-east	2015
Midford Castle	LHS	Breeding	ST 75961 61329 3km South	2012
Tucking Mill	LHS	Hibernation	ST 766 616 3.01km, South-east	2007
Sulis Manor Potting Shed, Odd Down	LHS & GHS	Unknown, probable night roost minimum	ST73876150 3.1km	2015
Hodshill Outbuilding, Southstoke	GHS	Night	ST 7467 6096 3.3km South	2000
Upton Cheyney	GHS	Transitional	Unknown 3.5km north-west	2013
Upper Langridge Farm	LHS	Small Day/Night	ST 7322 6883 3.82km, North	2010
Mill House, Midford Hill	LHS	Small Day/Night	ST 7633 6058 3.85km South-east	2011
Combe Hay Manor Gasworks	GHS	Small Day	ST 7334 5985 4.8km, South	2000

Site Name	Species	Type	Location and Distance to BEZ	Date
Freshford Mill	GHS LHS	Small Day & Night Breeding	ST 7862 5961 5.73km South-east	2005
Iford Mill Barn	GHS	Breeding	ST79945885 7km South-east	2000
Old Iron Stone Works, Mells	GHS & LHS	Hibernation	ST 7389 4888 15.5km South	1987

3 SURVEY METHODOLOGY

3.1 Static Detector Study

3.1.1 10 static bat detectors (five Wildlife Acoustics SM2BAT+ and five Titley Anabat Express) were deployed along the river corridor on a monthly basis for at least five consecutive nights each month between April and October 2016 inclusive. The number of nights deployed ranged between six and nine. Eight of the detectors were deployed in pairs whereby a detector was placed on opposite sides of the river corridor to allow gathering of rates of bat activity on both sides of the river and a comparison of the use of the different banks and bank structures. One of the SM2BAT+ detectors (Location 2) was fitted with two microphones on extension cables to capture data from the north and the south banks of Weston Island.

3.1.2 The location of each static detector is shown on Figure 5 overleaf and is described in more detail in Table 2. Each location was chosen on account of its security and accessibility, as well as the presence of vegetation or structures to which the detectors could be mounted in order to allow a clear 'view' across the river from which echolocation could be detected. Additionally, locations represented a range of habits, bank structures and land use types including green space, industrial, residential and brownfield. In all cases, microphones were placed within 1m laterally from the water's edge and within 3m above average water level. Microphones have an inherent directionality in their sensitivity, although this has reduced in recent years with the introduction of 'omnidirectional' microphones as used in this study. To minimise any effect we aimed slightly downward and slightly up or downstream in order to increase the chances of recording quieter or more directional calls.

3.1.3 The study also aims to investigate the general spatial and temporal patterns of usage of the 10 detector locations by horseshoe bats in particular. A general indication of the intensity of activity by each species at each location can also be afforded by analysis of this data.

3.1.4 By deploying detectors using the above methodology it was intended that the ability of detectors to record bats flying on the opposite side of the river could also be tested where opposite pairs of detectors had been deployed.

3.1.5 Overnight weather conditions in Bath during the survey period are given in Appendix B at the end of this document with an indication of whether each evening was considered suitable. Unsuitable evenings will be considered to be where two or more of the following occur: light rain or heavier persisting through much of the night; wind above 28Km/h on average (Beaufort scale 5 or above) and where sunset temperatures are below 10°C. No such instance of unsuitable weather conditions were reported during the entire deployment. Appendix C also indicates whether a fault was detected in any of the detectors during the deployment. These will be discussed further within the Limitations section.

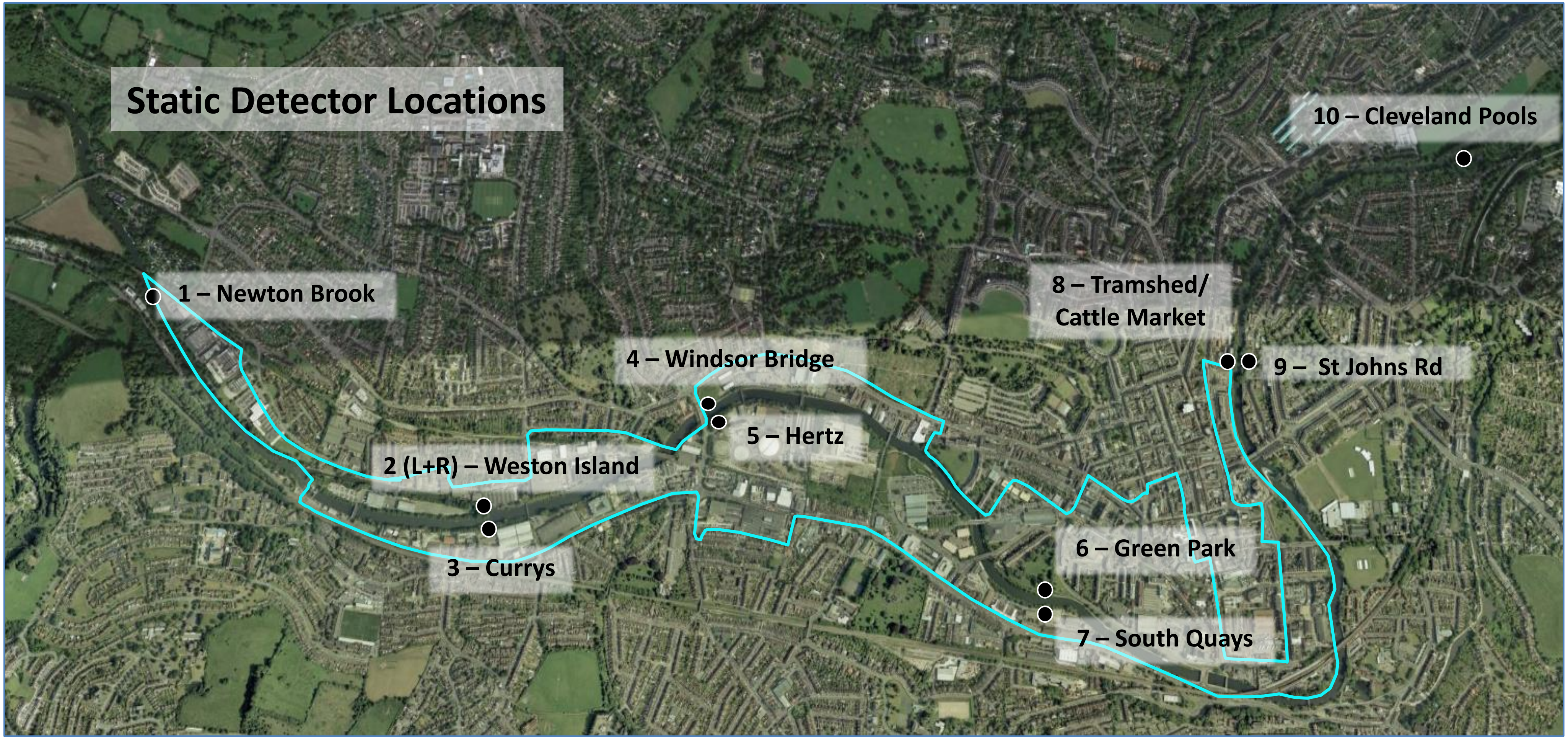


Figure 5 - Locations of Static Bat Detectors

NB. At location 2, the left-channel microphone was installed on the southern bank of the end of Weston Island and the right-channel microphone on the northern (overlooking The Cut)

Table 2. Location and equipment used during static detector study

Location	Description	Equipment Used
1	Attached to tree on N bank just E of cyclepath bridge at confluence of Newton Brook and Avon. 2m above water strapped to tree.	Titley Anabat Express.
2	At E end of Weston Island, covering both The Cut to the north (right microphone channel) and the south bank of the island (left microphone channel). Microphones attached to overhanging branches, detector attached to signage. Microphones 1m above water.	Wildlife Acoustics SM2BAT+
3	On bankside tree N from Currys (Weston Lock Retail Park) car park via gap in fencing. Strapped to tree with microphone 1m above water.	Titley Anabat Express
4	On structure of disused pedestrian bridge E of Windsor Road bridge. On N bank (towpath). Microphone hanging from bridge deck 3m above water.	Titley Anabat Express
5	On wire fencing to rear of Hertz depot on S bank of river. Microphone 2m above water.	Wildlife Acoustics SM2BAT+
6	On tree overhanging N bank of river off towpath near Green Park. 1.5m above water strapped to tree.	Titley Anabat Express
7	On overhanging branch of tree on S bank at South Quays site. 1m above water.	Wildlife Acoustics SM2BAT+
8	On overhanging branch of tree on steep bank down from car parking to rear of Tramshed. 1m above water.	Wildlife Acoustics SM2BAT+
9	Strapped to tree overhanging water on S bank adjacent to area of green space next to Bethel Chapel. 1m above water strapped to tree.	Titley Anabat Express
10	On bough of tree overhanging river at Cleveland Pools. 1m above water.	Wildlife Acoustics SM2BAT+

Automated Species Identification Protocol and Limitations

3.1.6 The data obtained from the static detectors is uploaded to Clarkson and Woods' data server within 24hrs following their collection. They then undergo automatic species recognition analysis through Wildlife Acoustics' Kaleidoscope Pro software.

3.1.7 Kaleidoscope Pro automatically identifies bat calls using various algorithms and provides statistical levels of confidence associated with each classified call. The confidence levels reflect the fact that there will be certain classification errors related to every classified bat call. With experience of using the software it is, on the whole, reliable when identifying certain bat calls, especially horseshoe bat calls due to their simple and unmistakeable parameters. Other straightforward species are common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *Pipistrellus pygmaeus*, noctule *Nyctalus noctula* and serotine *Eptesicus serotinus.* However, we have found the software to be less reliable when identifying other species (long-eared *Plecotus sp*., Leisler's *Nyctalus leisleri* and barbastelle *Barbastella barbastellus* bat species).

3.1.8 The software does not distinguish between the various *Myotis* species and simply classifies them to genus level (i.e. *Myotis* sp.). This is in line with classification that would be achieved by manual identification due to the similar nature of *Myotis* calls making species classification subject to a high degree of error. The on-board software used by the EchoMeter Touch does, however distinguish between *Myotis* species but this has been found to be inconsistent.

3.1.9 From experience of using the software, it appears that various species of bat are either under or over recorded and classifications can be inaccurate. Steps have been taken to compensate for this inaccuracy. All records of barbastelle, horseshoe bats, Leisler's, *Myotis* and long-eared species identified by the automated software have been manually verified and where appropriate the call identity corrected. Where the software is unsure of a bat call, it will classify the call as 'NoID'. For completeness, in this study all NoID files (many thousands) were manually double-checked to ensure that no horseshoe or other notable rare species was not wrongly classified by the software.

3.1.10 Additionally, automated detectors are triggered to record when suitable ultrasound is detected and will not cease recording until either a window of 1 second of silence is recorded (or if 30s elapses since the trigger, whichever is sooner). If more than one species is present within a trigger, the software is only able to classify one species per trigger and so is forced to decide which species is 'dominant'. This potentially results in an under-recording of species which are quieter (such as horseshoe bats) or have a longer pulse repetition rate. Consequently, all confirmed bat recordings and NoID files and approximately 20% of noise files have been re-analysed manually to look for horseshoe bat calls.

3.1.11 In conclusion, the classification data produced from Kaleidoscope Pro, along with any manual verification of certain problem/important species, is considered to provide a very accurate record of horseshoe species and an acceptably accurate record of other bat species recorded by a static bat detector and as such has been used within this report.

3.2 Walked Transect Activity Study

3.2.1 Five activity transects were walked concurrently once per month between April and October 2016 inclusive. Additionally, one pre-dawn activity transect was walked during the month of June. Survey teams included five ecologists from Clarkson and Woods Ltd.

3.2.2 The transects all followed linear routes along the Avon towpath through Bath, beginning at New Bridge in the west and ending at Grosvenor Bridge at the end of Kensington Meadows in the east. All transects except for transect four followed the northern bank of the river. Each transect measured between 700m and 1000m in length and consisted of between six and eight stopping points where surveyors stopped along the walk to listen for bats. The locations and approximate routes of each transect, including stopping points are shown in Figure 6 while Table 3 gives habitat and installation information.

3.2.3 Transects began at 15 minutes prior to sunset and continued for three hours. Surveyors walked the transect at a slow pace, stopping for 4 minutes at each of the prescribed stoppings points. The transects began at a different location each time in order to reduce the potential effect of pseudo-replication should certain stoppings point locations be favoured in terms of bat activity at certain times after sunset. At all times, surveyors were attentive to bats using the river corridor - the banks, banktop and the river itself - for foraging or commuting activity. Where possible, the behaviour and flight path of bats was noted, as well as species, time, and location.

3.2.4 The surveys aimed to focus on the activity of horseshoe bats in particular. Where horseshoe bats were recorded, these were followed as far as possible to determine flight paths, numbers and behaviour.

3.2.5 Surveyors were equipped with two detectors; an automated full spectrum device (either a Titley Anabat Express or a Wildlife Acoustics EcoMeter Touch) and a heterodyne detector (BatBox Duet or Pettersson D240x) attached to a recording device (Zoom H2n). This approach minimised the likelihood of faults affecting data and of bats echolocating at different frequencies being missed, especially where there are significant amounts of background noise or background activity by common species.

3.2.6 Data obtained by heterodyne detectors was analysed manually by surveyors using BatSound or Adobe Audition software. Data from automated detectors was analysed by Kaleidoscope Pro software as outlined for the static detector surveys above.

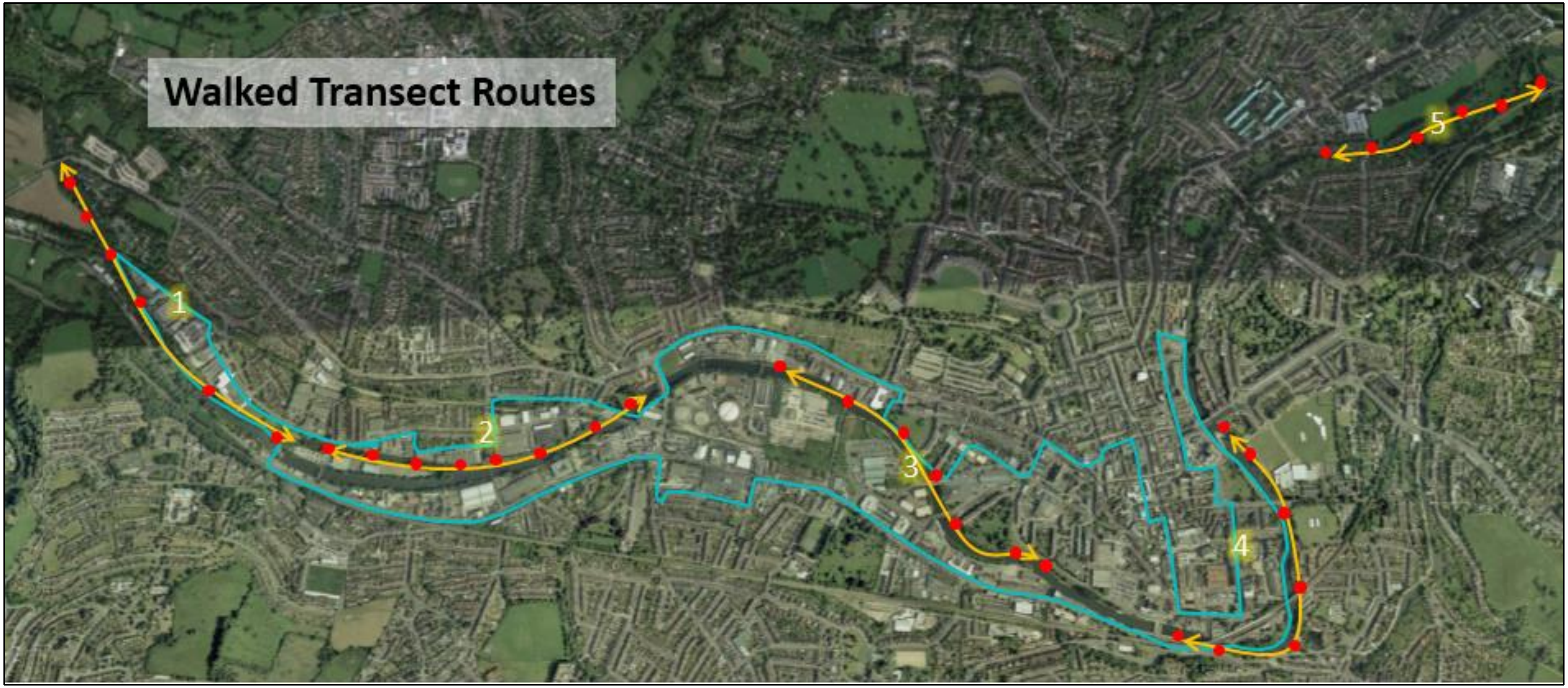


Figure 6. Locations of Activity Transect Routes and Stopping Points over the BEZ.

Table 3. Location and Description of Transects and Stopping Points (numbered W to E).

Transect No.	Stop No.	Description
1	1	Fishing point near New Bridge
	2	Bath Marina – Wooden bridge
	3	Bath Marina – Pump-out pontoon
	4	Under black Bristol-Bath Cyclepath bridge
	5	Fishing spot – low path by river, near picnic bench
	6	Fishing spot on lower path opposite “Rotork” warehouse.
	7	Riverside wall by bench down from lock.
2	1	Upstream lock gate (mooring by boat)
	2	Footbridge over Cut by Locksbrook Inn
	3	Mooring by bin – concrete
	4	Bankside clearing by bench – opposite end of the island
	5	By green pedestrian bridge
	6	Short section of railing by end of row of planted hornbeams
	7	Fishing spot by section of silver scaffold pipe rail.
	8	Walking around rows of trees in area of park
3	1	Hoarding by footpath to A4
	2	Under black pedestrian bridge.
	3	Clearing by orange SOS point
	4	Under pedestrian bridge with white sides
	5	SW corner of Green Park
	6	SE corner of Green Park
	7	Orange SOS point
4	1	Pedestrian bridge
	2	Turquoise railway bridge
	3	Bath locks bridge and around
	4	Railings beyond stone rail bridge by #17 Spring Gardens Rd
	5	By Penny Lane mooring
	6	By big sluice
	7	Walk up to Weir / Pulteney Bridge
5	1	By palisade fencing. Fishing spot on river. Informal path
	2	Path junction opposite boat hire
	3	Opposite Cleveland Pools
	4	Clearing by metal slide
	5	Bend by large horse chestnut tree
	6	Clearing by Grosvenor pedestrian bridge

4 LIMITATIONS

4.1 Bat Survey Limitations

4.1.1 Given the public nature of the locations used the detectors had to be well hidden, this meant that it was not always possible to ensure the microphone was unobstructed. Vegetation surrounding and in-front of the microphone may not only reduce the area the microphone can detect bats at but the level of noise also increases. Background noise such as leaves can make it difficult for the Kaleidoscope software to pick out bats which echolocate at lower frequencies such as noctule bats or quieter bats such as barbastelle and long-eared bats.

4.1.2 The need for hiding the detectors and variable bank heights meant that the microphones had to be placed at varying height from the rivers surface from 1-3m. The height of the microphone impacts the likelihood of detecting echoes of bat calls as they bounce off the water's surface,

4.1.3 Location 7 was changed in June due to the construction works underway in the area requiring boarded security fencing restricting access to the river bank. The detector was therefore moved approximately 30m east of the original location where it could be safely deployed and collected, the detector remained approximately 1m above the water.

4.2 Technical Issues

4.2.1 As expected different detectors recorded different amounts of data, this meant that during months and in locations with high levels of activity more memory was required and the batteries were used at a higher rate. The SM2+ bat detectors could only hold a maximum of 128 GB of memory, while the Anabat Express were less limited as these files take up significantly less space. This meant that the memory cards filled up on the SM2 detectors faster and so in some cases (seven events over 70 individual detector deployments) the final bat recording was up to 24hrs earlier than the Anabats. This did not represent a relatively large amount of data and so was not thought to be of major concern when comparing results between sites.

4.2.2 During the April deployment the SM2 at Location 5 (SM2F) failed after only two nights, the reason for this is unknown and although the detector was serviced immediately the fault could not be identified. As this deployment was late in the month it was not possible to redeploy to obtain replacement April data from this location.

4.2.3 During the June deployment the manufacturer informed us that a batch of faulty SM2+ high gain microphones were in circulation which causes sensitivity problems in recordings. As a precaution, the detectors were recovered and redeployed with replacement microphones to obtain additional data.

4.2.4 All technical faults experienced during the surveys are shown in Appendix C at the end of this document.

4.2.5 Full spectrum detectors are known to be more sensitive than zero crossing detectors (a full spectrum recorder is able to detect calls approximately -20dB quieter than a zero-crossing detector[8]). If placed side-by-side, a full spectrum detector will likely record more bat passes than would a zero crossing detector, making comparison between these detectors problematic.

4.2.6 Though the detectors were regularly calibrated each different microphone and detector recorded at a different sensitivity, though the difference in sensitivity was minor the difference may have affected the distance at which different species of bats could be recorded by the detectors.

4.2.7 Bat detectors are known to be more sensitive to certain bat calls than to others for reasons such as varying bat call loudness and directionality of certain calls. For example, a call from a horseshoe bat is directional and a bat detector will only be able to record the call if the bat echo-locates directly at the detector whereas a common pipistrelle call is less directional and can be recorded even when the call is aimed away from the microphone. This can result in certain bat species (notably horseshoe bats and long-eared bats) being under-recorded due to the limitations of the current bat detectors. The difference in recording efficiency may therefore bias any results and this has been taken into account where possible during any assessment of the results.

4.3 Kaleidoscope Software Limitations

4.3.1 Anabat Express and SongMeter2 static detector data has been analysed using the latest Kaleidoscope Pro automated analysis software. This software has been specifically designed to automatically classify the known bat calls of Britain and Ireland.

4.3.2 The programme automatically identifies bat calls using various algorithms and provides statistical levels of confidence associated with each classified call. The confidence levels reflect the fact that there will be certain classification errors related to every classified bat call. With experience of using the software it appears that, on the whole, it is accurate when identifying certain bat calls (common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *P. pygmaeus*, noctule *Nyctalus noctula*, serotine *Eptesicus serotinus*, Leisler's *Nyctalus leisleri*, lesser horseshoe *Rhinolophus hipposideros* and greater horseshoe *R. ferrumequinum* bats) but less reliable when identifying other species (long-eared *Plecotus* sp. and barbastelle *Barbastella barbastellus* bat species).

4.3.3 Where multiple species are recorded in one file, the software can only identify the loudest or clearest bat, meaning that under recording of busy locations is guaranteed. Quieter bats such as barbastelle and horseshoes are often overshadowed by pipistrelle bats which leads to under recording of the species.

4.3.4 Similarly, a very low number might indicate a reduced level of foraging activity by one bat in close proximity to the detector, but might also have derived from a small number of individuals commuting at speed past the microphone and so only one pass per bat is recorded, such is

[8] Ian Agranat (March 2015). Unravelling Zero Crossing and Full Spectrum What does it all mean? Wildlife Acoustics Inc.

the ambiguity of static detector data. Despite this, it is considered that the number of detectors, detector-nights and monthly repeats used within this study should enable a reasonable comparison of pass rates between locations over time to be made.

4.3.5 The software does not distinguish between the various *Myotis* species and simply classifies them to genus level (i.e. *Myotis* sp.). This is in line with classification that would be achieved by manual identification due to the similar nature of *Myotis* calls making species classification subject to a high degree of error.

5 RESULTS

5.1 Qualitative Assessment of Corridor Bank Structure, Lighting Conditions and Vegetation

5.1.1 A rapid qualitative assessment of the bank structure, lighting conditions and vegetation cover was made of the north and south banks of the Avon through Bath during the first three hours after sunset on the evening of 28th November 2016. The results of this assessment have been mapped overleaf in Figures 7a-d.

5.1.2 It is acknowledged that light levels at this time of night may have been influenced by an early sunset compared to that experienced during the study period. This means that lights from shops, dwellings or industrial buildings can be expected to be on for longer as business hours extend past sunset in November. Similarly, construction work around North Quays extended into the hours of darkness during the assessment and the use of arc lights was noted. However, the surveyor was very familiar with the lighting conditions typically encountered during the study period having completed multiple transect surveys and as such this was taken into consideration when determining light level categories.

5.1.3 Bank structure was divided into two basic categories, hard edged and soft edged, distinguished by the presence of significant vegetation or bare earth cover. Where the bank structure comprised pilings, concrete, gabion or other man-made material but had become significantly overgrown with scrub or trees, this was classed as being soft edged.

5.1.4 Bankside land was divided into two zones, firstly the water's edge and the banks themselves, up to banktop level. This covered approximately the first 0-5m from the water's edge depending on the angle and height of the bank. The second zone captured the land use from the banktop inland for approximately 15m.

5.1.5 Vegetation cover was divided into four categories from 0 to 4 as follows.

- 0 – Vegetation cover absent
- 1 – Field or amenity grassland
- 2 – Scattered vegetation (e.g. patchy scrub or shrubs)
- 3 – Moderate vegetation cover
- 4 – Dense vegetation cover (e.g. 'green lane' effect or woodland)

5.1.6 Lighting categories were determined subjectively and a lux meter was not used as rapid assessment was required and Clarkson and Woods are not qualified to undertake detailed lighting surveys. These were as follows.

- 0 – Unlit and fully dark
- 1 – Unlit but receives slight light spill
- 2 – Unlit but receives moderate-heavy light spill
- 3 – Directly lit – Low/moderate (e.g. domestic/suburban)
- 4 – Directly lit – High (e.g. urban centre).

5.1.7 Additionally, locations of significant glare were also noted. Glare is defined as a point source of light which, although it may not contribute significantly to the illumination of the observer's location, contrasts highly with its surroundings and so can cause discomfort or eyesight adaptation problems (in humans).

5.1.8 All the above categories are mapped using colour coded lines on Figures 7a-d overleaf together with the location of key sources of glare. It is not known whether glare causes significant impacts on bats, but it is reasonable to assume that for a nocturnal animal with known light-averse behaviour, glare is a potential source of conflict where bat flight paths and other habitat are concerned.

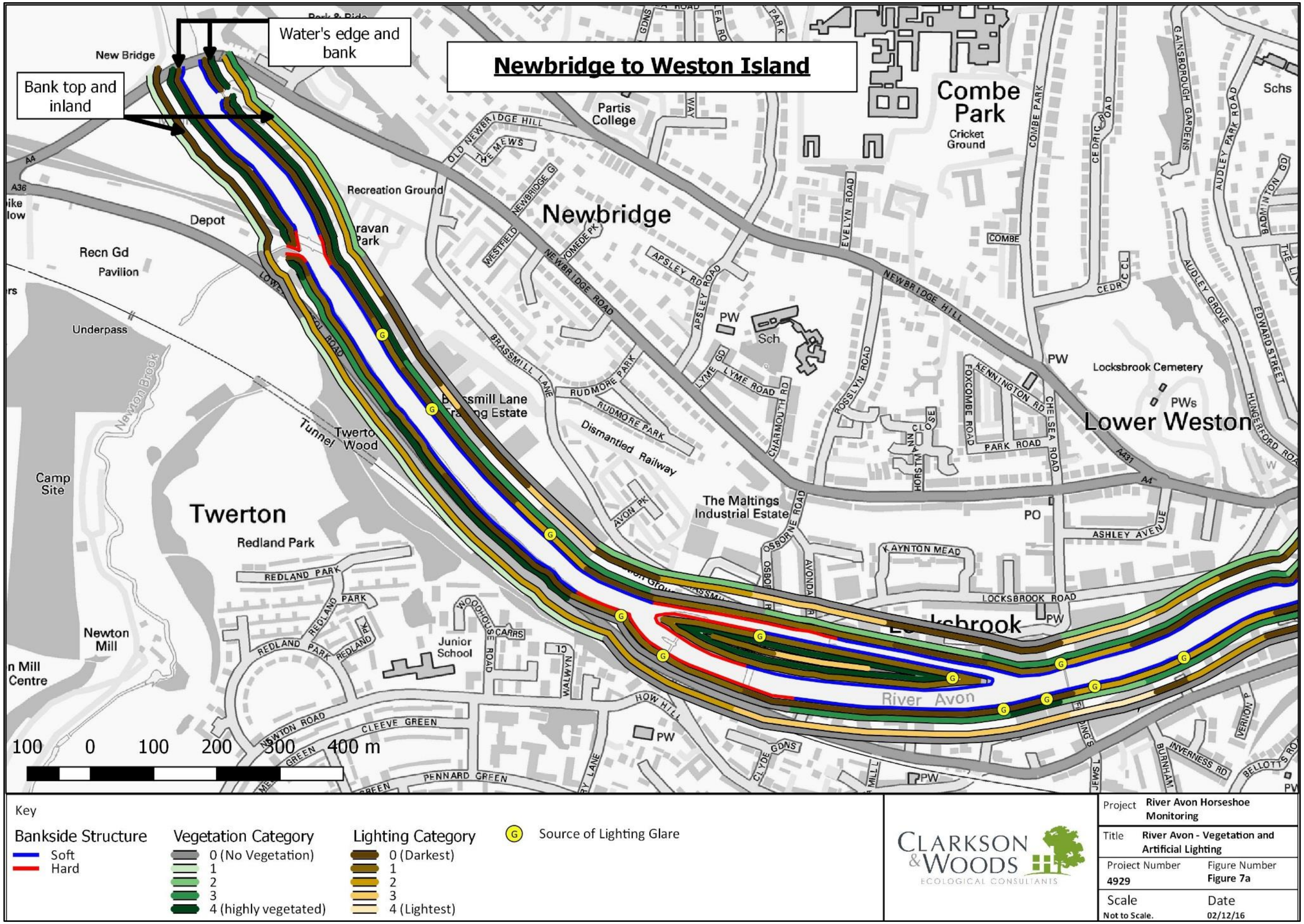
5.1.9 It is interesting to note that in most cases, major sources of glare results in illumination to some extent of the opposite bank. While the presence of light on a bank is determined by many factors including vegetation cover, angle, height and presence and design of luminaires in proximity, it was clear during the survey that glare was usually associated with light emission strong enough to cause light spillage onto the opposite bank. In many cases, the lighting conditions directly beneath the source of glare at the water's edge were very low (where there was no glare from the opposite bank), especially where the bank angle and height were high, creating a 'bank shadow' effect. This could be seen at Angel Place or active parts of South Quays, for example, where light trespass from the windows or spillage from security lighting was strong, but the high banks means that directly beneath, the shadowed zone was darker than the waterside vegetation on the opposite bank.

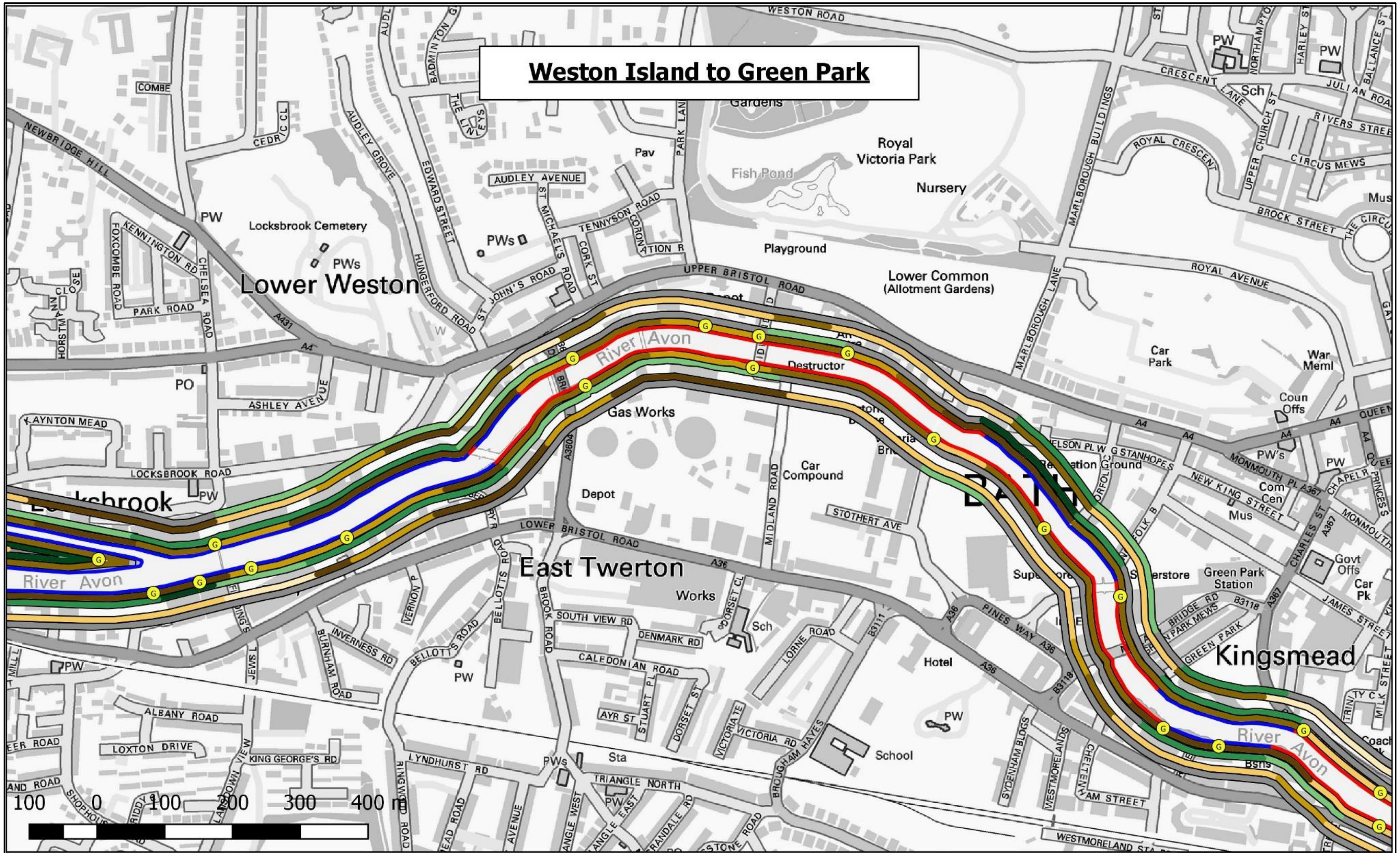
5.1.10 At the eastern end of the Bath Riverside housing development towards the Homebase car park on the south side of the river, there is a newly constructed wide riverside walkway lying opposite the vegetated towpath of Norfolk Gardens. The walkway is well lit and unvegetated, with a hard banktop only 0.5m above the water level thereby both illuminating the opposite vegetation and not providing a bank shadow. However, as the vegetation along the Norfolk gardens towpath is dense, there is a green lane effect further inland which is sufficiently screened from the opposing glare, although the use of this section by bats could not be investigated as no detectors were placed here.

5.1.11 The figures show the great extent to which vegetation cover increases and lighting decreases away from the city centre. Vegetation is at least more or less continuous on at least one bank from New Bridge to as far as the new Destructor Bridge at the location of the new Bath Riverside development. Vegetation then continues patchily to Green Park whereupon it is lost altogether until past the Railway Station where more intermittent managed habitat occurs. Past Pulteney Bridge, the vegetation cover remains mostly continuous until Grosvenor Bridge. The presence of vegetation cover further inland from either bank is also shown across much of the length, reflecting Bath's proximity to open countryside and its extensive green infrastructure running through the city, regularly intersecting with the river.

5.1.12 With lighting conditions, fluctuations are seen on a much finer scale, with densely vegetated sections punctuated by sources of strong glare and illumination, predominantly via light trespass from offices, industrial security lighting, and car park and street lighting. Illumination was generally greater as the river became more urbanised and harder edged as would be expected, although dark sections or sections with minimal spill still occurred in a few places approaching the city centre such as at Norfolk Gardens and parts of South Quays that are currently disused.

5.1.13 This information will be used in conjunction with the survey results to identify whether lighting, bank structure or vegetation cover are most important for the use of the river by bats and can also show where further survey or mitigation effort might be best targeted.


Newbridge to Weston Island
Water's edge and bank
Bank top and inland
New Bridge
Depot
Recn Gd
Pavilion
Underpass
Recreation Ground
Caravan Park
Partis College
Combe Park
Cricket Ground
Newbridge
Lower Weston
Locksbrook Cemetery
PWs
Twerton
Redland Park
Tunnel Wood
Dismantled Railway
The Maltings Industrial Estate
Camp Site
Newton Mill
Junior School
River Avon
100 0 100 200 300 400 m
Key
Bankside Structure
Soft
Hard
Vegetation Category
0 (No Vegetation)
1
2
3
4 (highly vegetated)
Lighting Category
0 (Darkest)
1
2
3
4 (Lightest)
Source of Lighting Glare
CLARKSON &WOODS
ECOLOGICAL CONSULTANTS
Project River Avon Horseshoe Monitoring
Title River Avon - Vegetation and Artificial Lighting
Project Number 4929
Figure Number Figure 7a
Scale Not to Scale.
Date 02/12/16



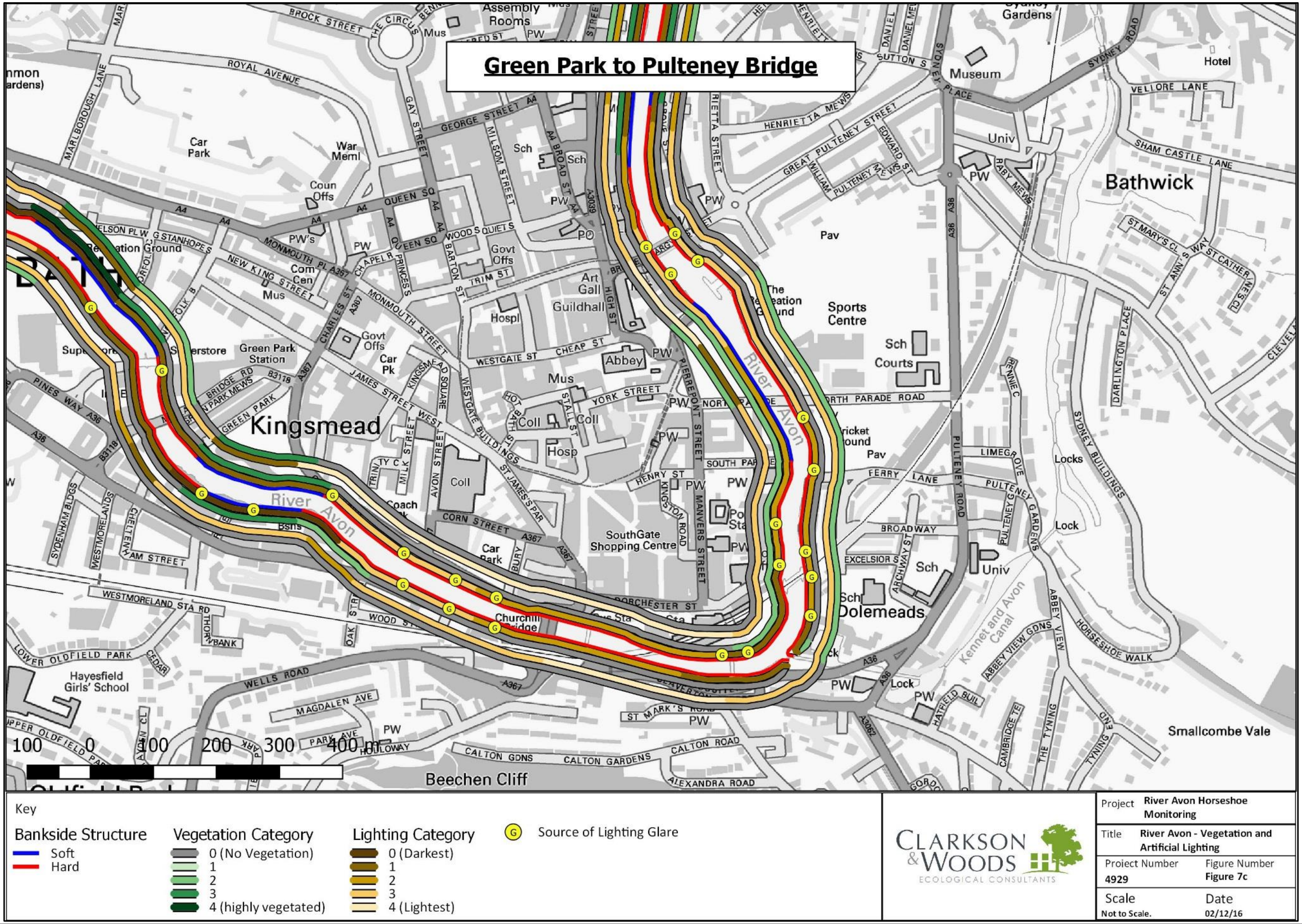
Key

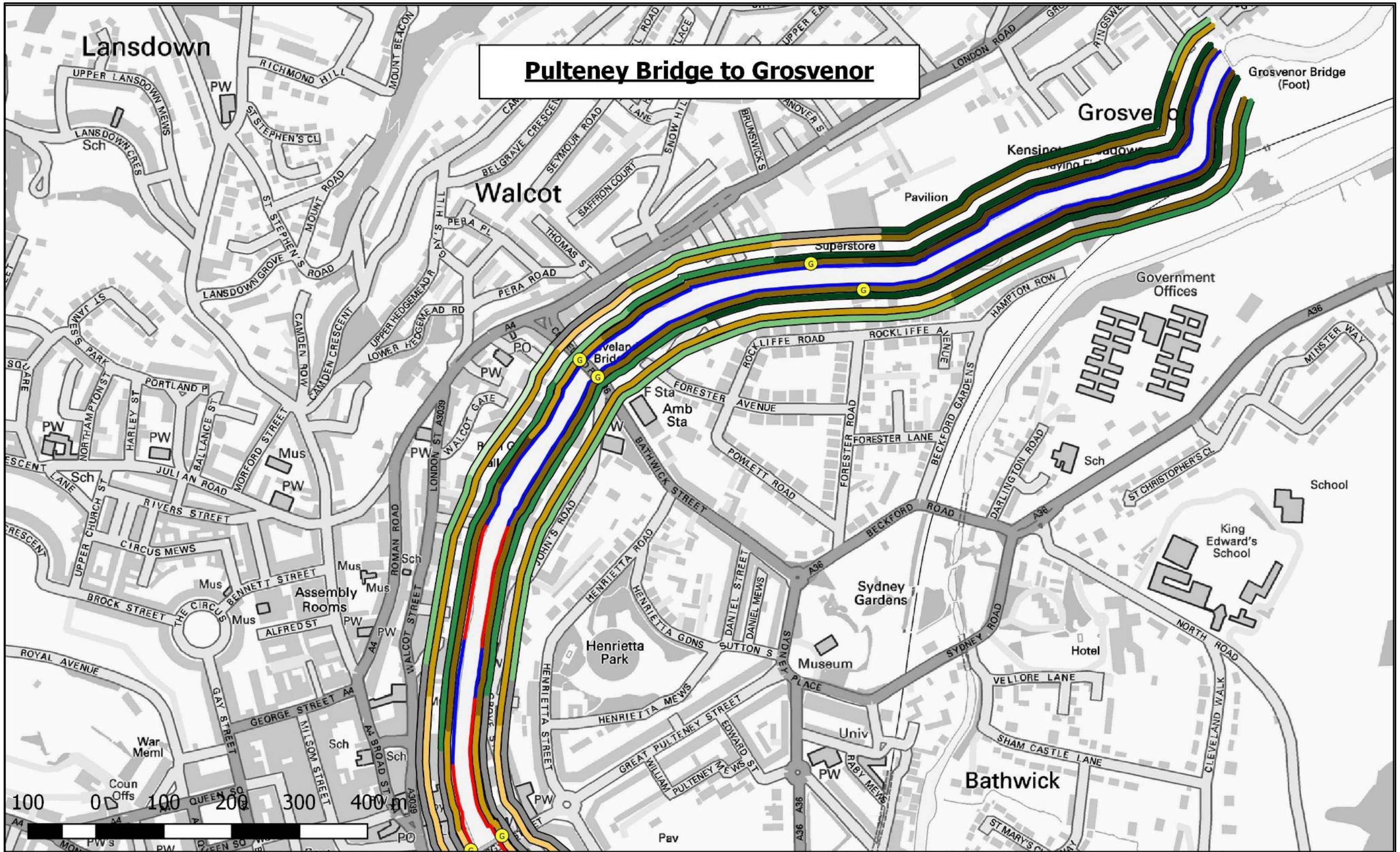
Bankside Structure	Vegetation Category	Lighting Category
Soft	0 (No Vegetation)	0 (Darkest)
Hard	1	1
	2	2
	3	3
	4 (highly vegetated)	4 (Lightest)

G Source of Lighting Glare

CLARKSON & WOODS ECOLOGICAL CONSULTANTS

Project	River Avon Horseshoe Monitoring
Title	River Avon - Vegetation and Artificial Lighting
Project Number 4929	Figure Number Figure 7b
Scale Not to Scale.	Date 02/12/16


Green Park to Pulteney Bridge
Key
Bankside Structure
Soft
Hard
Vegetation Category
0 (No Vegetation)
1
2
3
4 (highly vegetated)
Lighting Category
0 (Darkest)
1
2
3
4 (Lightest)
G
Source of Lighting Glare
CLARKSON &WOODS
ECOLOGICAL CONSULTANTS
Project
River Avon Horseshoe Monitoring
Title
River Avon - Vegetation and Artificial Lighting
Project Number
4929
Figure Number
Figure 7c
Scale
Not to Scale.
Date
02/12/16
100 0 100 200 300 400 m
River Avon
Kingsmead
Bathwick
Dolemeads
Green Park Station
SouthGate Shopping Centre
Abbey
Guildhall
Sports Centre
Beechen Cliff
Smallcombe Vale
Hayesfield Girls' School
Kennet and Avon Canal



Key

Bankside Structure	Vegetation Category	Lighting Category	
Soft	0 (No Vegetation)	0 (Darkest)	G Source of Lighting Glare
Hard	1	1	
	2	2	
	3	3	
	4 (highly vegetated)	4 (Lightest)	

CLARKSON & WOODS
ECOLOGICAL CONSULTANTS

Project	River Avon Horseshoe Monitoring
Title	River Avon - Vegetation and Artificial Lighting
Project Number 4929	Figure Number Figure 7d
Scale Not to Scale.	Date 02/12/16

5.2 Static Detector Survey

General Summary

5.2.1 In total 472,525 confirmed bat passes were recorded by all 10 detectors (11 microphones) during the entire deployment duration, aggregating 50 nights of detector data (550 microphone-nights) between April and October inclusive. At least ten species of bat were recorded during the static detector study, and this is likely to be higher as it is considered that at least two species of *Myotis* bats were detected, (including Natterer's, Daubenton's and potentially whiskered or Bechstein's bat) and that Leisler's bats are likely to have been present alongside their more common close relative the noctule bat. These species are notoriously difficult to differentiate through call sonogram analysis alone therefore we have listed them under their respective genus (*Myotis* and *Nyctalus*). Therefore of a possible 18 species, it is likely that 13 have been recorded during this study.

5.2.2 Table 4 overleaf shows the number of passes by bat species at each of the static detector locations aggregated over the entire deployment duration. It also highlights the locations with the top three pass totals for each species (gold, silver and bronze fills).

Table 4. Total Number of Bat Passes by Species at Each Location. Note: Gold, silver and bronze fills indicate the 1st, 2nd and 3rd highest detector totals per species.

Detector Location / Species	1	2L	2R	3	4	5	6	7	8	9	10	Total	%age of Total passes
Greater Horseshoe	11	3	0	0	0	0	0	1	18	1	9	**43**	0.01
Lesser Horseshoe	2	389	24	30	2	15	24	36	153	195	288	**1158**	0.2
Common Pipistrelle	17207	3312	5936	14071	6937	10871	4183	5398	3012	6130	3281	**80338**	17.0
Soprano Pipistrelle	30176	20974	12370	29827	40172	33807	25687	49724	34717	15288	43916	**336658**	71.21
Nathusius pipistrelle	0	3	1	11	2	6	7	3	4	3	1	**41**	0.01
***Myotis* sp.**	8931	7807	2536	3825	1192	2316	6042	4277	2966	1761	4804	**46457**	9.83
Serotine	53	16	19	62	23	18	101	19	54	109	112	**586**	0.12
***Nyctalus* sp.**	3696	356	641	998	247	191	544	110	88	413	153	**7437**	1.53
Barbastelle	2	3	0	2	2	1	2	1	0	1	0	**14**	0.00
Plecotus sp.	0	1	1	4	0	0	3	0	0	0	0	**9**	0.00
Total	**60078**	**32864**	**21528**	**48830**	**48577**	**47225**	**36593**	**59569**	**41012**	**23901**	**52564**	**472741**	
%age of Total passes	12.71	6.95	4.55	10.33	10.28	9.99	7.74	12.60	8.68	5.06	11.12		
No ID	20852	6524	9212	21047	13048	6142	16778	4826	6047	9292	5843		
Noise	7303	21382	36437	6956	2728	2426	7494	7132	9233	13530	9338		

Lesser Horseshoe Bats

5.2.3 Table 4 shows that lesser horseshoe bats were recorded 1158 times, with clear peaks in the far west and east of the study area (detectors, 2L, 10, 9 and 8 in particular). Greater horseshoe bats were recorded 43 times, again showing a clear association with locations 1, 8 and 9. This distribution has been graphically represented in Figure 9 overleaf. Overall, it can be seen from comparison with the vegetation and lighting maps in Figures 7a-d that the most productive detector locations tend to feature relatively well vegetated banks towards the western and eastern parts of the city.

5.2.4 Table 4 shows that the peak location for lesser horseshoe bats was 2L, which was the south bank of the eastern tip of Weston Island with 361 passes (the next highest umber being 82 at location 10). The data for the time-of-night breakdown of lesser horseshoe bat passes shown in Appendix D and summarised in Table 5 shows that in this location, 346 of the 361 passes occurred in the hour before sunrise, indicating a cluster of activity prior to returning to a nearby roost.

5.2.5 Large numbers of passes may result equally from a significant number of bats using an area or a small number of bats foraging particularly frequently in a location or habitually roosting in a nearby tree. Similarly, a very low number might indicate a reduced level of foraging activity in proximity to the detector, but might also have derived from a small number of individuals commuting at speed past the microphone and so only one pass per bat is recorded, such is the ambiguity of static detector data. Despite this, it is considered that the number of detectors, detector-nights and monthly repeats used within this study should enable a reasonable comparison of pass rates between locations over time to be made.

5.2.6 It should be pointed out that horseshoe bats are usually difficult to detect from echolocation alone owing to their relatively low amplitude calls, highly directional call projection and greater tendency for horseshoe echolocation to attenuate over a shorter distance because they utilise higher frequencies than other UK species. It has been suggested that for a time-expansion hand-held detector such as a Pettersson D240x, the detectable range for greater horseshoe bats is approximately 8m, and 5m for lesser horseshoe bats, head-on[9]. These factors combine to effectively restrict horseshoe bats to habitats with strong features along which they can navigate through the landscape and so should be factored into the interpretation of survey data. Calls from species which are more able to cross open ground and are less dependent on dark, featured environments tend to be louder and less directional, such as those from the pipistrelle bats or larger, noctule and serotine bats.

5.2.7 Figure 9, together with Table 6 shows that lesser horseshoe bats were recorded at every location in the study area, although only twice at Location 4 and four times at Location 5. Lesser horseshoe bats were almost exclusively detected in these central, urban and brownfield locations during September and October. Indeed, a trend towards higher rates of activity across nearly all detectors during the months of April, August, September and October can be

[9] Ransome, R., (2013). Bath Urban Surveys: Dusk Bat Surveys for Horseshoe Bats Around Weston, Bath.

seen clearly for horseshoe bats in Figure 8. These months represent the months during which the breeding members of a colony are not rearing dependent young and are in transition between winter and summer roosts, typically flying longer distances during movements between roost types. Rates fall to as low as only one pass in July and two in June. This pattern suggests that lesser horseshoe bats are more abundant in the river corridor during months where they might be expected to be dispersing to and from the hibernation roosts located around the city and that their movements permeate further into the river corridor than they do at other times of year. This increased permeation and abundance may reflect an importance of the corridor as a conduit for seasonal movement for those colonies roosting nearby or potentially a reliance on the river corridor for foraging when other locations are less productive.

5.2.8 The information contained in Figures 7a-d also shows that these central locations where the fewest passes were recorded (4 and 5) are hard-edged and receive a relatively high degree of glare or light spill, although some shading from the tall concrete bank is present. It is probable that this area is less attractive given the low vegetation cover and higher light levels and that bats only use this area during dispersal months as the benefit of the river as an efficient navigation route outweighs the increased perceived predation risk with higher light levels.

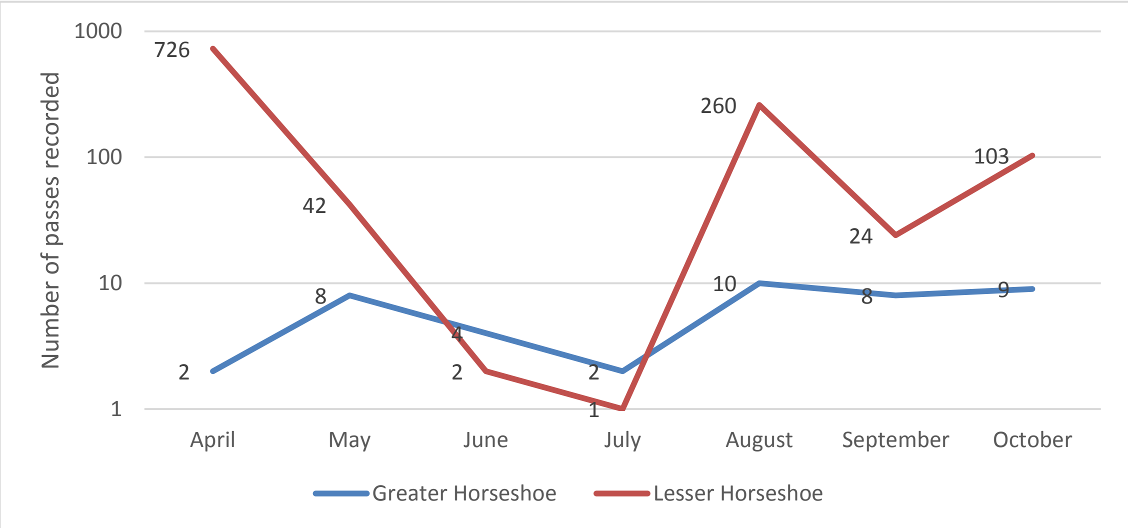


Figure 8. Graph to Show Total Monthly Horseshoe Bat Passes (*note logarithmic scale*)

5.2.9 The location of the peak in transitional activity in the east of the study area may indicate that the hibernation sites most likely to be used by these bats are the Bathampton Stone Mines and Brown's Folly as these are closest to the river corridor east of the city. These sites are part of the SAC designation. It seems unlikely that non-SAC sites would be used for hibernation by the recorded bats as the river provides the most direct natural unlit link to the vicinity of the underground sites. Furthermore, this species would be averse to crossing the urban areas which lie between the river and the more southerly SAC sites of Combe Down, but it is understood that horseshoe bats have been observed using the former railway tunnels of the Two Tunnels/Linear Park cycleway south of the city centre which potentially provides a secluded link from the river corridor. Formal data for this observation could not be sourced at the time of writing so this may be worthy of future study to determine whether bats using the tunnels originate/end up using the river corridor at certain times of year.

5.2.10 It is also interesting to note that more passes were recorded at Location 7 (South Quays – hard edged and darker) than at Location 6 (Green Park – soft edged and brighter due to light spill from the opposite banktop). This may indicate that while lesser horseshoe bats use both banks, light levels are a key in determining a preference for a certain bank and while bankside vegetation at Green Park screens light spill and glare from the city, it cannot screen light spill from the opposite bank.

5.2.11 The fall in pass rates in September is unexplained, however the number of the detectors which recorded lesser horseshoes at this time is the second highest throughout the study, continuing the trend of further permeation of the corridor in the transitional autumn and late summer months. The drop in activity may reflect a short-term change in the availability of food sources, forcing bats to switch back to non-riparian foraging grounds, or there may simply have been more favourable weather conditions during the August rather than September deployments. Another theory could be an initial peak (August) followed by a final, second peak (October) of movements back to winter habitats from breeding grounds, potentially differentiating males and females, juveniles and adults or breeding bats and non-breeding bats. It has been recorded that male bats do tend to arrive at mating or winter habitat earlier than females as mating usually occurs prior to the onset of hibernation[10].

5.2.12 Time-of-night analysis for the passes at each detector (Appendix C) shows that Lesser Horseshoe bats are most regularly detected in the middle of the night, which is more typically associated with foraging activity or commuting between foraging grounds rather than emergence or return-to-roost behaviour. However, more calls are picked up in the hours surrounding sunrise and sunset during the spring and autumn transitional peaks, lending further evidence to the hypothesis that while more bats are active in the river corridor at these times, they are probably also associated with more local transitional or satellite roosts which are typically smaller than hibernation or breeding roosts. Excepting the unrepeated peak for April at 2L, the locations with the most sunrise and sunset activity are usually 8, 9 (close to the cattle market vaults roost) and 10. Interestingly, small bursts of activity at these times are also recorded at locations 4, 5, 6 and 7 and almost never further west. This potentially indicates the presence of other roosts in the vicinity of Bath Quays and East Twerton/Bath Riverside (where there are many disused and historic buildings).

Table 5. Breakdown of Total Lesser Horseshoe Passes by Time of Night

Sunset -1hr to +1hr	Sunset +1hr to +3hr	Middle of Night	Sunrise -1hr to +1hr
37	93	354	510

[10] Billington, G. (2000). Combe Down Greater Horseshoe Bats: Radio Tracking Study.

Figure 9. Location of Total Horseshoe Passes for the Static Detector Study. Blue Circles = Lesser horseshoe, Orange Circles = Greater horseshoe

Table 6. Total Lesser Horseshoe Passes by Detector by Month

Detector Location / Month	1	2L	2R	3	4	5	6	7	8	9	10	Total
April	0	361	19	2	0	0	5	19	21	18	182	627
May	0	0	0	0	0	0	0	3	6	0	7	16
June	1	0	0	0	0	1	0	0	0	0	0	2
July	0	0	0	0	0	0	1	0	0	0	0	1
August	0	0	1	0	0	0	1	1	33	86	65	187
September	0	5	0	2	1	1	3	4	3	0	4	23
October	0	4	3	9	1	2	9	2	46	20	6	102
Total per location	1	370	23	13	2	4	19	29	109	124	264	958

Greater Horseshoe Bats

5.2.13 Table 8 shows that greater horseshoe bats were recorded 40 times over the entire study duration. This species was recorded every month apart from in April. Monthly pass totals ranged from two to ten. These numbers suggest that greater horseshoe bats are present in lower numbers than lesser horseshoe bats, although behavioural differences between the species such as different choice of habitat/bank to use for navigation may have reduced detection to a degree; however greater horseshoe bat echolocation is marginally more powerful in this species. Major differences between the amplitude of echolocation between these species is not thought to be an issue.

5.2.14 In keeping with the distribution of lesser horseshoe bats, Table 8 shows that this species was associated with detector locations in the far west and far east of the city, with the closest to the city centre being a single call in August at Location 7, South Quays. Permeation of the city is much more limited for greater horseshoe bats, but the low numbers of passes may limit that ability to show a true pattern. There is also a trend, albeit a weak one, for their presence mainly in the early and later months (June and July are two of the lowest months). The lack of activity in April may be linked to a later emergence from hibernation for this species, or different use of connecting habitat.

5.2.15 The detector location seen to record the most greater horseshoe bat passes was Location 8 which was at the Tramsheds development on the western bank approximately 250m north of Pulteney Bridge. This was within 50m of the nearby Cattle Market Vaults which is a known roost for greater horseshoe bats, therefore this peak is not unexpected. It is interesting to note that while 18 passes were detected at Location 8, only one was recorded at Location 9 which was situated almost directly opposite. This suggests that either greater horseshoe bats enter the roost away from the river or only use the western bank.

5.2.16 Greater horseshoe bats appear to be much more strongly linked with detector Location 1 than lesser horseshoe bats. The breakdown of time-of-night data in Appendix D and Table 7 shows that the majority of sunset and sunrise activity occurs here (the rest occurs near Location 10). This location is at the confluence between the Newton Brook and the Avon close to where a large bridge carrying the Bristol to Bath Railway Path crosses the river. This location is particularly dark, enclosed and vegetated and the Newton Brook occupies a secluded channel with particularly high banks. The watercourse leads to several habitat features and structures within the known summer range of this species around Englishcombe and further south, including farms near the roosts in Newton St. Loe, canal and railway tunnels, disused mineshafts and woodland.

Table 7. Breakdown of Total Greater Horseshoe Passes by Time of Night

Sunset -1hr to +1hr	Sunset +1hr to +3hr	Middle of Night	Sunrise -1hr to +1hr
7	14	19	1

Table 8. Total Greater Horseshoe Passes by Detector by Month

Detector Location / Month	1	2L	2R	3	4	5	6	7	8	9	10	Total
April	0	0	0	0	0	0	0	0	0	0	0	0
May	0	1	0	0	0	0	0	0	6	0	0	7
June	4	0	0	0	0	0	0	0	0	0	0	4
July	2	0	0	0	0	0	0	0	0	0	0	2
August	0	0	0	0	0	0	0	1	3	0	6	10
September	1	0	0	0	0	0	0	0	4	1	2	8
October	4	0	0	0	0	0	0	0	5	0	0	9
Total per location	11	1	0	0	0	0	0	1	18	1	8	40

Other Bat Species

5.2.17 88% of the entire recorded activity came from soprano (71.25%) and common (17%) pipistrelle bats which are two of the commonest and most light-tolerant species in the UK. Soprano pipistrelles made 336,657 recorded passes during the study. These bats also have considerably more powerful echolocation calls than horseshoe bats and tend to be detected over a greater distance. These species were generally evenly distributed across the study site, with several thousand passes collected at each location for each species. Figure 10 shows how the pattern of abundance of these two species changed throughout the study duration, with a clear summer peak of activity and marked decline in April, September and October. This patterns is roughly the inverse of that shown for horseshoe bats and suggests that the river is most important for pipistrelle bats as a foraging resource during the summer breeding season rather than predominantly as a commuting route. Pipistrelle bats also swarm together outside mating and hibernation roosts during the month of August and early September. This is an important part of the breeding cycle and the peaks in call rates at this time of year could suggest that the river is important for providing swarming habitat and access to mating roosts.

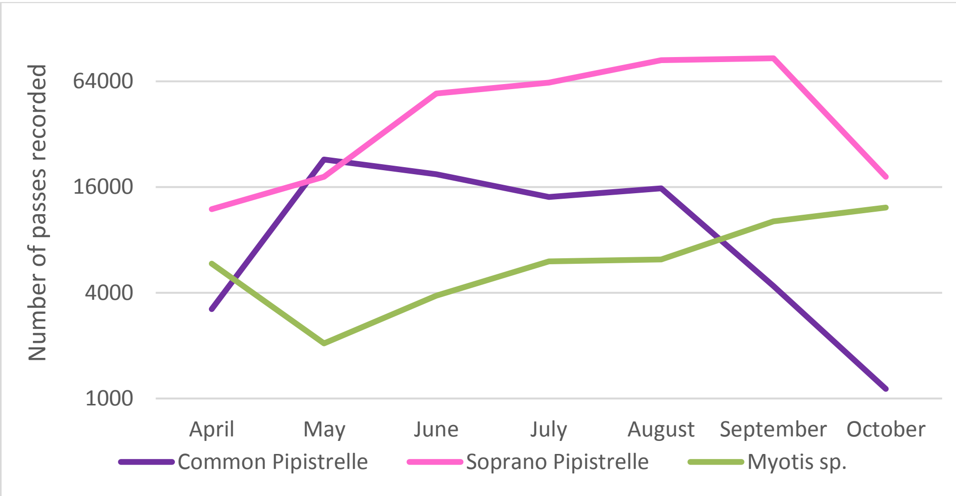


Figure 10. Graph to Show Total Monthly Passes by Pipistrelle and Myotis Bats

5.2.18 Bats of the genus *Myotis* make up the next most abundantly recorded group with 9.83% of the call total and were recorded in every month and detector location. This genus comprises six breeding species and it is believed that Daubenton's bats were the most regularly recorded by the study. Daubenton's bats are closely associated with water and are known to regularly roost in tunnels, bridges and structures within proximity to rivers or still water. Natterer's bats and whiskered bats are anticipated to be the next most abundant species. The presence of April, September and October peaks akin to those of the horseshoe bats may show that these bats use nearby hibernation and swarming sites, with recorded activity resulting from local foraging over the river. In this case, the river corridor is likely to be similarly important for *Myotis* bats as a conduit for dispersal between key roosts. Indeed, it is known that Daubenton's bats regularly occur within the same hibernation roosts as horseshoe bats. Additionally, the river is just as likely to be important for foraging considering how closely associated Daubenton's bats are with water.

5.2.19 The genus *Nyctalus* includes the relatively widespread noctule and the much more uncommon and localised Leisler's bats which are two of our largest species of bats with the most powerful echolocation. These bats generally occupy tree roosts, favouring large rot holes or vacant woodpecker holes and so depend on there being woodland and mature trees. These species are high, fast fliers and are reasonably light-tolerant, being some of the earliest bats to emerge. The results in Table 4 show that more calls were recorded in western and eastern locations, with a particular association with location 1 which is the location perhaps closely linked to woodland and farmland. These species were still recorded in every detector location, owing to their wide-ranging and light-tolerant nature and particular peaks in activity were recorded in June and September. no explanation for this patter could be offered.

5.2.20 Serotine bats are relatively uncommon and restricted to southern Britain. These are large, fast-flying bats and outside of hibernation almost exclusively roost within man-made structures which are thought to have replaced their dependence on caves. Serotine calls were recorded at every location and followed a similar pattern over time as common pipistrelles, with a summer peak and autumn/spring reduction. As serotine bats are largely dependent on pre-war era buildings, it is perhaps not surprising that peaks for this species were both in the far east (close to dark habitats and the housing of the Bathwick area) and also in the centre of the study area at Location 6 (Green Park/North Quays). Therefore, vegetated and dark areas in proximity to historic buildings and houses appear to be favoured by serotine bats.

5.2.21 A total of 35 Nathusius' pipistrelle passes were recorded during the study in very small numbers at all locations except number 1 and 10. Nathusius' pipistrelle are a rare species nationally and are known to migrate across the English Channel, they have also been recorded arriving in the UK in autumn due to the milder climate and food availability compared to other parts of Europe. The spatial spread of recorded passes combined with the fact that this species was only recorded in July, September and October suggests that they are highly mobile and potentially only use the river corridor in the late summer and autumn, potentially to help scope locations and conditions for hibernation or mating.

5.2.22 *Plecotus* refers to the long-eared bats, of which the UK hosts the common and widespread brown long-eared bat, and the much rarer grey long-eared bat. These are medium-sized bats which hunt using both echolocation and their sensitive hearing to listen for the minute sounds made by prey insects. They are extremely quiet bats with very low amplitude echolocation and thought to be highly under-recorded during surveys. Their calls are indistinguishable although it is considered that grey long-eared bats are unlikely to be present in the study area given their principal range within the coastal counties between Devon and Sussex. Long-eared calls were picked up at almost all detector locations, but with a peak count of only three, making any meaningful interpretation difficult. This result highlights the relative difficulty in detecting low-amplitude calls from species such as long-eareds and horseshoe bats, especially as brown long-eared bats are thought to be the second most abundant species in the UK. This species typically flies within and between trees and other vegetation and may not be present within the fringes of the river and space over the water to where the microphones were directed.

5.2.23 Barbastelle bats are another rare species (only five colonies were known in 2001) which have relatively quiet and directional calls making detection difficult. These are small-medium sized bats which have been known to fly significant distances when dispersing and some association with wetland environments has been observed. Nine barbastelle passes were recorded during the months of July to October, mainly at the western and central detector locations. This is a very low rate indicating that few barbastelles use the Avon corridor here and their known roost-switching behaviour would support this. The late season activity may point towards the presence of a small hibernation roost near the study area, typically within a mature tree.

Noise and NoID Files

5.2.24 The numbers of 'Noise' and 'NoID' files across detectors did not seem to fit any strong pattern and were seen to fluctuate widely. As each detector was installed in proximity to at least one of either; running water, leafy vegetation or roads, false triggers can be derived from any of these sources, as well as some weather conditions including high winds affecting vegetation. This is corroborated by the lack of consistency among the detectors indicating that noise files were site/conditions-specific rather than due to a problem with a particular detector. All NoID files were manually reviewed to ensure they did not contain missed horseshoe and other rare bats.

Comparison Between Banks and Detector Types

5.2.25 A basic comparison between the numbers of passes recorded by pairs of detectors on opposite banks was attempted. Paired detectors were placed at 2L & 3, 4 & 5, 6 & 7 and 8 & 9. The monthly detector pass totals are shown in Table 9 below, together with information on detector type (Anabat Express = Red, SM2 = Blue) and bank structure (Bold number = hard edged banks, normal weight = vegetated banks).

Table 9. Breakdown of Passes at Paired Locations with Detector Type, and Bank Structure Shown.

Location / Month	2L	3	4	5	6	7	8	9
April	2058	3081	**2707**	**972**	2165	**2045**	1950	1173
May	1223	6763	**3996**	**1576**	3101	**4687**	5606	4539
June	210	7760	**8626**	**11910**	7590	**7277**	5800	5393
July	3908	7090	**8417**	**8793**	4936	**10087**	7131	6775
August	5908	13696	**14122**	**10892**	7440	**16358**	11494	3919

Location / Month	2L	3	4	5	6	7	8	9
September	9918	7750	**9927**	**10256**	10202	**16596**	6825	1057
October	9614	2673	**782**	**2815**	1154	**2510**	2159	974
Total	32839	48813	**48577**	**47214**	36588	**59560**	40965	23830

5.2.26 It would appear that numbers vary widely between banks suggesting detectors are not able to pick up the majority of calls occurring around the opposite bank. This adds confidence that the horseshoe bat call data accurately records the bank closest to the bat given their relatively low detectability. It can be expected that especially for louder bats, some calls on the bank closest to the bat might also be recorded by the opposite detector, but as this study focusses on horseshoe bats this is not considered a significant problem. During months where trigger rates are similar it is considered that as bat abundance and activity (combining all species) are also high, bats are simply utilising both banks roughly equally.

5.2.27 An accurate comparison of effectiveness and sensitivity of the two detector models used cannot be made as only one model was installed at each location. However, it appears that there is no strong bias to one particular model overall as month totals vary widely between paired detectors. It might be useful for future studies to install the same model of detector where detectors are installed on opposite banks.

5.2.28 Detectors placed at different locations may vary in their ability to detect bats simply by the differences in vegetation, lighting, aspect, microphone location and proximity to preferred flight paths. Therefore recorded activity rates may not be 100% reflective of actual activity rates across the locations. However, as the exact same equipment, locations and deployment specifics were used each month, trends if present would still be expected to be shown in the data.

5.2.29 It is also difficult to look objectively at the differences between hard and soft bank edges as the detectors were spread over such a wide area with differing value for bats owing to connectivity, lighting, adjacent habitat type etc. and only one pair featured different edge types. However, it is interesting to note the consistently higher pass rates at Location 7, South Quays, compared with Location 6 opposite at Green Park. This seems counter-intuitive but may point toward the presence of a dark shadow effect at low levels over the water close to hard banks where there is little or no glare from the opposite bank. The buildings on the southern bank of South Quays, including Angel Place and industrial units further west produce glare and light spill acting mainly on the opposite bank rather than straight down the bank to the water on the south side. Therefore, low light levels may be more important in choosing a commuting route rather than the presence of abundant vegetation, although the importance of the latter is not discounted.

5.3 Activity Survey Findings

5.3.1 At least nine species of bats were recorded during the walked activity transects in total. These included both horseshoe bats as well as the rarer Nathusius' pipistrelle. The collated qualitative summary of bat activity between the five transects is given overleaf in Table 10. Broad activity classes used to describe levels of activity are Constant, Near-Constant, Frequent, Occasional, Rare and Not Present. Due to the near constant activity of several concurrent species for the duration of the three hour transect it was not possible to record absolute numbers of passes. Environmental conditions during the survey were suitable for bat activity and are given in full in Appendix C.

5.3.2 Species recorded during the transect surveys in order of activity were soprano pipistrelle, common pipistrelle, *Myotis sp*., *Nyctalus* sp., serotine, *Plecotus* sp., lesser horseshoe, greater horseshoe and Nathusius' pipistrelle.

5.3.3 Lesser horseshoe bats were recorded on Transects 1, 3 and 5. Lesser horseshoe bats have been relatively consistently recorded on Transect 1 with only June and August recording no passes for this species. Transect 5 recorded one to two lesser horseshoe bats foraging low over the water (<20cm) along the riverbank during September. Most observations of this species came from within the first 2m from the water's edge and the first 4m from the banktop where vegetation was dense ('green lane' effect). Height above water was almost always within 0.5m, though this was increased when encountered at the banktop and inland.

5.3.4 The results for Transect 1 suggest that lesser horseshoe bats continue to commute in and out of the western city limits to the open countryside. The timing of the lesser horseshoe foraging for Transect 5 indicates that there is likely to be a roost for this species in the near vicinity. Figure 11 shows the location of all the recorded passes by lesser horseshoe bats along with the time of year. This shows that this species is encountered throughout the active season in greater numbers in the west and east, while they are rarely picked up in more central, urbanised locations (August and mid-June). One lesser horseshoe bat was also observed light sampling within an arch over the towpath within the structure of the New Bridge on Transect 1, suggesting the presence of a nearby summer roost.

5.3.5 Greater horseshoe bats were only recorded along Transect 1 and 5 (on seven occasions in total), in keeping with the static detector data and the vegetation and lighting assessment (see Figure 12). A greater horseshoe bat was observed perch-hunting from a twig in a tree near Stop point 2 on Transect 5. Each observation of this species was from close to the bank and within or around dense vegetation, especially where there was a closed canopy. The months in which this species was encountered (May-August) seem to suggest usage of the river for foraging by a small number of bats throughout the season, somewhat contrary to research which links this species to cattle-grazed pasture during the summer. It may be that these individuals are juveniles, remaining local to wintering habitat (potentially Brown's Folly or Box Mines), or that these records represent the easterly or westerly limit of bats breeding in roosts located further up and downstream.

5.3.6 An abundance of soprano and common pipistrelle bats and Daubenton's bats which exceeded expectations was recorded during the activity transects. Foraging activity was intense at almost all locations, although somewhat reduced activity rates were observed in central, urban transects (such as 3 and 4) as well as a general decrease as the evening progressed. Activity by these bats was observed at all distances across the river and at varying heights although Daubenton's bats characteristically foraged very low over the water's surface (<50cm). Foraging activity was particularly focussed under unlit bridges and on vegetated banks. The onset of activity was very early on most surveys and on some occasions bats were already active before surveys commenced. This was mainly due to the secluded and overshaded nature of some stretches of the river, including stretches of hard-edged banks in sub-urban locations where lighting was minimal. This pattern indicates the presence of multiple roosts for these species nearby.

Table 10. Qualitative Results of September Survey of Transects

Species / Transect	S. pipistrelle	C. pipistrelle	Nathusius pipistrelle	Daub. / *Myotis*	*Nyctalus*	Serotine	*Plecotus* sp.	Lesser horseshoe	Greater horseshoe
1	Near-Constant	Frequent to Near-Constant	Rare	Frequent	Occasional	Occasional	Rare	Rare	Rare
2	Near-Constant	Frequent to Near-Constant	Not Present	Frequent	Occasional	Rare	Not Present	Not Present	Not Present
3	Near-Constant	Frequent to Near-Constant	Not Present	Frequent	Not Present	Rare	Not Present	Rare	Not Present
4	Frequent to Near-Constant	Frequent to Near-Constant	Not Present	Occasional to Frequent	Not Present	Rare	Rare	Not Present	Not Present
5	Near-Constant	Frequent to Near-Constant	Rare	Frequent	Occasional	Occasional	Not Present	Rare	Rare

Key

Distribution

- April
- May
- Early June
- Mid June
- July
- August
- September
- October

Transect

- 1
- 2
- 3
- 4
- 5

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Project	
River Avon Horseshoe Bat Study	
Title	
Lesser Horseshoe Bat Distribution	
Project **4929**	Figure Number **Figure 11**
Scale **Not to Scale**	Date **13/11/16**

Key

Distribution

- April
- May
- Early June
- Mid June
- July
- August
- September
- October

Transect

- 1
- 2
- 3
- 4
- 5

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Project **River Avon Horseshoe Bat Study**	
Title **Greater Horseshoe Bat Distribution**	
Project Number **4929**	Figure Number **Figure 12**
Scale **Not to Scale**	Date **13/11/16**

6 DISCUSSION AND RECOMMENDATIONS

6.1 Key Findings

6.1.1 The key findings of the study can be summarised as follows.

- Greater and lesser horseshoe bats have been recorded within the Avon corridor in every month of the active season (April – October inclusive) although greater horseshoe bats less frequently.
- Lesser horseshoe bats were observed at every surveyed location along the Avon within the BEZ, although both species favour the western-most and eastern-most locations, tending to venture further into the central urban stretches more during the 'transitional' months when it can be expected that longer-distance movements are more regular, particularly in the early autumn.
- While there are several 'hotspots' for horseshoe bat activity at certain times of the year, the value of these (and in turn the health of the SAC population) depends on the integrity of the riverbanks as a continuous feature for bat movement.
- Horseshoe bat activity peaks in the 'transitional' spring and autumn months (April-May and August-October) which indicates an increased use of the river as a dispersal corridor, most likely between winter hibernation roosts within the SAC sites (probably Bathampton Stone Mines and Brown's Folly due to their proximity to the river east of the city) and summer roosts in the wider landscape (e.g. near Newton St. Loe and Englishcombe south west of the city or the Cattle Market Vaults, Widcombe Hall, South Quays etc.). Horseshoe bats may also use river to access the Linear Park/Two Tunnels features, although this requires further investigation.
- Some bats appear to remain in proximity to the river throughout the active season indicating the presence of small summer and transitional roosts close to the city centre, particularly in the case of lesser horseshoe bats. More survey work is required to complete our understanding of where these are but currently these include those listed as near to the BEZ in Table 1.
- The data supports the classification of the horseshoe bat roost at the Cattle Market as a key transitional roost, as is the known lesser horseshoe roost at South Quays (confirmed by surveys carried out in 2016 to support a planning application) where there are several disused and unlit buildings as well as a 'shadowed' bank owing to its height above the water.
- The location of activity peaks also indicate that other transitional roosts are likely to be present in the vicinity of the Newton Brook (Newton St. Loe – greater horseshoe bats particularly, and New Bridge – lesser horseshoe bats particularly) as well as in proximity to detector 2L (Weston Island, east end) where a large peak of activity was recorded in April.
- The banksides were characterised by natural sloping earth banks with continuous or scattered vegetation apart from city-centre sections (Bath Riverside and Southgate area)

where unvegetated edges formed of concrete up to approximately 2m above average water levels dominated. Lighting was seen to be highly variable, with some light spill present in most locations although a 'shadowed' bank or completely unlit bank was usually present on one side.

- The effects of glare and obtrusive lighting tend to act greatest upon the opposite bank river bank.
- Both species of horseshoe bats were seen to favour the darkest locations along the river and were mostly recorded within 2m from the water's edge, or further inland (up to approx. 5m) where vegetation was particularly dense. It is believed that the absence of lighting or glare has the most influence in predicting horseshoe bank preference, rather than vegetation cover *per se*. This is the case where the most urban settings still create opportunities for dispersal due to the presence of a shadowed bank. However, vegetation cover does have an important role in screening against light spill and dense vegetation was usually present in the darkest locations. Therefore, where appropriate for the setting of development, vegetation should be emphasised as a tool for light mitigation.
- Between 8 and 11 other species of bat were recorded during the study, including the rare species Nathusius' pipistrelle, barbastelle and Leisler's bat and the uncommon serotine bat. Nathusius' pipistrelle and barbastelle bats tend to be associated with wetland habitats and exhibit migratory or roost-switching behaviour, thereby requiring suitable corridors for dispersal.
- Activity patterns close to sunset times indicated that the river corridor is likely to host multiple roosts of Daubenton's bats, soprano pipistrelle and common pipistrelle. Activity patterns also indicate roosts for serotine bat in the east of the city.
- Seasonal patterns of activity show that the river becomes more intensely used by pipistrelle bats during the summer months, reducing during the transitional months, indicating that the river is most valuable to these species in providing a rich foraging resource during the breeding season.
- Static detector surveys were by far the most cost-effective way of gathering large amounts of usage data, although walked transects remain useful in making direct observations of bat behaviour, location and habitat usage.

6.2 Likely Impacts on Bats Arising from Development Within the BEZ

6.2.1 Development within the BEZ can be expected to result in an increase in both the level of human activity (pedestrians, recreational activity, vehicle movements, industrial noise and residential noise) and nocturnal lighting either through external security or public-realm lighting or the trespass of light through windows. Development has the potential to also result in the reduction of vegetation cover as land is cleared to enable construction or is opened up in order to facilitate improved human access to formerly vegetated areas.

6.2.2 Other potential sources of impacts upon bats through a degradation of habitat quality may include increased air pollution, pollution of water-courses and the increased surface water run-off as hard surfaces increase in land cover. These sources are not considered in detail in this report as it is assumed that current planning guidance can sufficiently mitigate for potential adverse effects on bats through measures such as Sustainable Urban Drainage Systems and construction-phase pollution avoidance and containment plans.

6.2.3 The level of human activity along the towpath during the entire survey season during the hours of darkness was noted to be surprisingly low. Numbers of pedestrians or cyclists encountered were highest within the first hour after dusk, but this dropped to negligible levels later on during activity surveys. Only approximately half of the users had torches and these were generally low intensity bulbs. It is therefore not believed that even a moderate increase in this already low level of human activity would result in an adverse impact on bats using the towpath.

6.2.4 Consequently, nocturnal illumination and habitat fragmentation from development are considered the major potential sources of impacts upon bats. As horseshoe bats have been shown to associate with unlit, vegetated routes for movement, with an increase in transitional dispersal activity, any significant degradation in habitat value or lighting barriers to movement has the potential to impact on the favourable conservation status of the SAC.

6.2.5 Horseshoe bats are reliant on dispersal and roost-switching to enable sufficient genetic mixing at different mating sites, for which a proportion of this SAC population uses the river corridor. It is therefore reasonable to assume that an impact on 1% or more of the SAC population of either species annually would lead to a long-term adverse impact on the health of the population as a whole. Activity rates recorded for lesser horseshoe bat are considered likely to indicate a number of individuals using the river over this threshold (5+ bats), and potentially up to 10%. For greater horseshoe bats, the study findings are in line with approximately 1-3% of the population when the SAC was designated (up to 5+ bats), although it is potentially lower if more recent estimates are used. Overall, it is considered that there is sufficient justification for the river corridor within the study area to be designated as supporting habitat for the SAC. Therefore, significant adverse effects on horseshoe bats in terms of lighting and habitat fragmentation in the river corridor must be avoided in the design of new developments in order to preserve the conservation status of the SAC populations.

Specific Lighting Impacts

6.2.6 Insurmountable barrier effects in lesser horseshoe bats have been demonstrated in illuminances as low as 3.6lux in rural environments. Research has also shown that in rural environments, this species favours particularly dark features for navigation, with average illuminances of 0.04 lux being present in one study over eight hedgerow networks in south west England. It is thought that for light-averse species (particularly lesser horseshoe bats), there may be no 'light threshold' below which there is little impact on behaviour[11]. Lighting impacts may also be cumulative; in locations where sources of light disturbance are already present, and so a small

[11] Stone, E. L. (2013) *Bats and Lighting: Overview of current evidence and mitigation guidance*. University of Bristol.

increase in lighting may have a disproportionately greater effect[12]. As such, it is recommended that a highly precautionary approach is adopted, supported by light survey evidence from the flight paths know to be used by horseshoe bats.

6.2.7 Public realm lighting can create illuminance at ground level of 50-100lux or above directly below a typical street lighting column, reducing to around 5-15lux at the edges of an average sub-urban environment. A recent lighting survey by Speirs and Major lighting consultants for B&NES recorded levels of 7.7lux in spill lighting on the towpath under the footbridge at Sainsbury's near Green Park, and 3.7lux at river level in spill light from the handrails and archway bulkhead on Victoria Footbridge (Ruxton, I. pers. comm.). Light meter readings in relatively dark locations experiencing minimal spill lighting at the water's edge ranged between 0.05lux and 0.7lux. Completely unlit and densely vegetated locations can be expected to read zero or negligible levels in the absence of moonlight.

6.2.8 Exterior lighting can be expected to be desirable to designers of new developments for perceived public security and safety reasons. Typical locations would include car parks, footpaths, roads and building exteriors. The effectiveness of new lighting regimes in reducing crime is far from clear. It is known that white lighting increases public perception of safety through good colour rendering and improved facial recognition, with research indicating a decrease or displacement of crime in well-designed schemes. However, there are several studies to suggest that introduction of lighting either has no or even an adverse effect on crime reduction[13]. Lighting can create permanent areas of adjacent shadow as night vision is impaired and so provide cover for criminal activity; conversely lighting can provide visibility for the criminal and aid escape. Clearly an appreciation of pre-development crime situation and the likelihood of an increase in public presence or risk is needed in determining whether lighting is necessary at all. Indeed, as previously stated (6.2.3), the level of use of the towpath at present is very low in the hours of darkness. The introduction of lighting limits in proximity to the river as council policy may also help developers make the decision to reduce external lighting as the perceived liability risk is reduced or shifted onto the local authority.

6.2.9 Light trespass differs from spill light (light present away from its intended location) as it occurs from a building or window into the outside environment. Light trespass contributes to glare and exterior illuminance. It can be expected that, unmitigated, light trespass would occur within new developments, particularly strongly within industrial/office or retail classes but to a lesser extent in residential zones.

6.2.10 The effects of glare on bats is poorly understood. As a nocturnal mammal using eyesight for partial environmental sensing, especially at dusk and dawn, it is reasonable to assume that strong glare (a light source in high contrast with its surroundings) can contribute to dissuasion in bats away from a location or an increased perceived predation risk. Glare can occur

[12] Stone, E. L. (2013) *Bats and Lighting: Overview of current evidence and mitigation guidance.* University of Bristol.
[13] Gaston, K.J., Gaston, S., Bennie, J. & Hopkins, J. (2014) *Benefits and costs of artificial night-time lighting of the environment.* Environmental Review. 23: 14-23.

independently of illuminance barriers, that is, the observer can be in a dark location but still be affected by the glare from a powerful yet distant source such as internal office strip lights or an external security light.

6.2.11 Lastly, artificial lighting has been shown to attract flying invertebrates such as moths away from unlit areas within which bats would forage[14]. This effect favours bat species which are less light averse and have habituated to hunting around luminaires, putting other species potentially at a competitive disadvantage. Light averse species also suffer from a reduced prey abundance in unlit areas due to the shift towards nearby illumination, thereby impacting the fitness and foraging success of affected bats. In one study, invertebrate traps illuminated by high-pressure sodium lights (the most widespread lamp type in Europe) captured 27 times more invertebrates than unlit traps and the effect extends to 40m from the light source[15].

Specific Habitat Fragmentation Impacts

6.2.12 Studies show that horseshoe bats do not cross open, featureless ground except in circumstances where the benefit of doing so outweighs perceived risks or where they are particularly familiar with a certain location. For example, greater horseshoe bats have been radio-tracked crossing a 150m width of the River Severn but only to migrate from winter habitat in the Forest of Dean Bats SAC to breeding roosts in Gloucestershire. This is reflected by the increased permeation into the central river stretches with higher light spill and harder edges by lesser horseshoes during key transitional migration periods. However, in an urban environment with an abundance of lighting and open space (increasing predation risk), it is considered that the distance over which horseshoe bats could cross with no clear linear feature would reduce. Radio-tracking studies of greater horseshoe bats from the Combe Down stone mines shows that the maximum breaks in navigation features crossed was around 10-12m in an unlit rural environment[16]. It is arguable that this figure would reduce in an urban environment. Consequently, the need to preserve dark linear features, ideally well vegetated, along the length of the river corridor is imperative as it is the river banks, rather than the open water, which are key to the viability of the river as a habitat for horseshoe bats. Fragmentation should be avoided wherever possible, tying in with central and local planning policy to deliver interconnected 'green infrastructure' in the suburban landscape.

6.2.13 Trees, hedgerows, ornamental shrubs and scrub are regularly cleared to generate more useful land for development, especially where riverside land is of increased value. It can be expected that increased pedestrian permeability of the riverside zone and towpath is desired in new development to add value, as would unbroken views to the river from development sites. Insurmountable fragmentation of navigation and/or light screening habitat can then occur in all such cases. Similarly, connectivity between the river banks and other linear features leading

[14] Arlettaz, R., Godat, S. & Meyer, H. (2000) *Competition for food by expanding pipistrelle bat populations might contribute to the decline of lesser horseshoe bats.* Biological Conservation. 93, 55-60.
[15] Perkin, E.K., Holcker, F., Tockner, K. (2014) *The effects of artificial lighting on adult aquatic and terrestrial insects.* Freshwater Biology. 59, 368-377.
[16] Billington, G. (2000). Combe Down Greater Horseshoe Bats: Radio Tracking Study.

away from the river are important in allowing bats movement to and from the river corridor and this green infrastructure can be eroded by improperly planned development.

6.2.14 Regeneration developments typically use previously-developed, brownfield land with little loss of habitat, however these developments usually have the greatest potential for opportunities for habitat creation, particularly at the development periphery.

6.3 Recommendations for Avoidance and Mitigation of Effects

6.3.1 Both the value of the riverside habitats for horseshoe bats and the functional link between the river corridor and the SAC sites have been highlighted by the findings of this study. In light of this and the potential for erosion of the conservation status of the SAC, it is considered that the Avon and its bankside habitats should be considered supporting habitat for the SAC, extending its current designation as a Site of Nature Conservation Interest. This should extend at least as far as the study area, although there is a good likelihood of this being valid for the entirety of the SNCI.

6.3.2 As a consequence of this, the need to consider the potential effect of new development upon the integrity of the SAC would fall on any development in close proximity to the river in Bath. Under the Conservation of Habitats and Species Regulations 2010, a test of likely significant effect (TOSLE) would be required to be carried out by the competent authority (B&NES in this case) to determine this. Should an effect be determined likely, a Habitats Regulations Assessment should be undertaken, to include findings of detailed surveys.

6.3.3 The gathering of sufficient data to underpin such an assessment can be a lengthy and costly process, requiring up to an entire year's worth of survey data to be collected and analysed in advance of firm designs being prepared. Given the extent of the BEZ and the river's focal position within it, the number of developments with potential to cause likely effects could be high. In order to simplify this process, the preparation of the Design Guidance is proposed to provide targets and guidelines for the ecologically sensitive design of new schemes on land within approximately the first 50m from the water's edge. This should provide clarity and equality of opportunity for prospective developers within the BEZ as well as avoiding the time costs and uncertainty associated with extensive ecological survey. It would also enable effective consideration of the potential for cumulative impacts which can be difficult to evaluate within individual applications. Consequently it is recommended that all future planning applications within or potentially affecting the BEZ should be compliant with the measures within the Design Guidance.

6.3.4 It is recommended that the Design Guidance is based on the following principles derived from the findings of this study, to be further elaborated during the consultation and refinement process.

Suggested River Corridor Lighting Zones

6.3.5 It is suggested that land extending inland from the water's edge on a development site should be divided into discrete zones according to their intended land use. These zones can then be used to determine the boundaries of different surface illuminance limits to be imposed at the outset of scheme design. The lighting limits have been chosen according to current research findings, the current light readings within known dark flight paths in the study area and the need to adopt a precautionary approach. A description of the land use and light limits is given Table 11 and represented in Figure 13 below. Suggested distances would be proposed, although these would differ according the adjoining land uses and river edge condition, in all cases distances are indicative and advice should be taken from a Suitably Qualified Ecologist on a case by case basis. The notional zones should take into account the particular bank structure, vegetation cover, habitat connectivity for bats and presence of the towpath among other factors. Each zone would roughly accord with one of the Environmental Lighting Zones as outlined by the Institute of Lighting Professionals Guidance Note GN01:2011 where E1 is an 'intrinsically dark area' and E4 is an urban zone with high district brightness[17].

6.3.6 The aim of introducing River Corridor Lighting Zones is to maintain a continuous dark corridor along the river bank suitable for bats to use for navigation year-round and thereby preserve the value of the river as a key component of the SAC. An absence of lighting (taking into account the potential for sources of illumination from both banks) is the priority in Zones A and B. It should be emphasised that sensitive planting schemes as well as other physical barriers like fences and walls, or the adoption of 'smart' glass or low transmittance glass treatments will aid achieving these targets.

6.3.7 The aforementioned Design Guidance document should be developed to elaborate on this concept of zonation, recommended notional distances and different treatment options available to reduce the impacts of lighting and glare would be included. This will take into account the different bank structures and land-use types that are typical of the River Corridor through Bath.

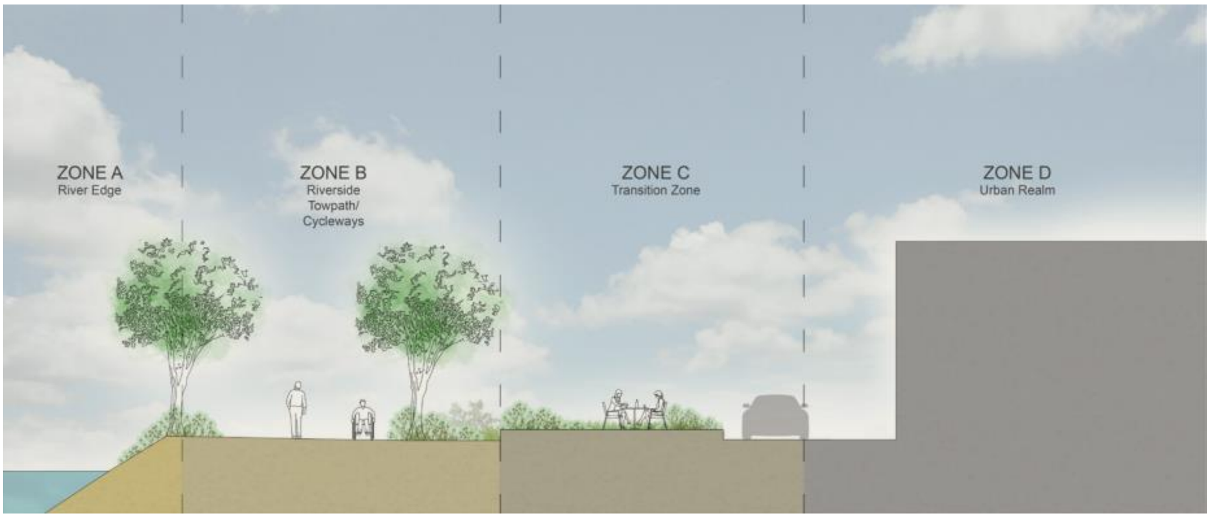

Figure 13. Sketch Concept of River Corridor Lighting Zones which could be adapted for use in Bath's River Corridor (Extract from Draft WaterSpace Study, 2017: 77).

[17] Institute of Lighting Professionals (2011). *Guidance notes for the reduction of obtrusive light. GN01:2011.*

6.3.8 Conformity to these limits should be demonstrated within a planning application via a lux contour plan of the proposed development prepared by a qualified lighting engineer. Sufficient information must be provided in order to demonstrate that these limits have been met, including information on the contribution of light trespass from windows and glare from more distant, intense sources. The following should be observed when producing a lighting plan.

- A qualified lighting engineer should be involved at an early stage in the design process in order to establish lighting principles before conflicts arise.
- The lighting design plan should include the specification, number, orientation, dimming and control (timing, sensing) arrangement for each luminaire.
- The lighting plan should include the anticipated horizontal illuminance at ground level within all areas of the site, with actual lux figures or contours displayed, 'heat map' style colour scales should be avoided.
- Lighting plans must provide a 'worst case scenario' plot, whereby light from all proposed sources, including through windows, should be modelled at a 100% illumination state (i.e. all curtains/blinds opened, all internal lights on and undimmed, all external lights on and at operational dimming levels). This will be the key lighting plan for examination of whether proposals meet prescribed lux maxima by zone. This will also allow an assessment of the likely impact of soft and hard landscaping attenuation. This 100% lighting state will be necessary in order to allow for any unforeseen future loss of soft landscaping or alterations to the external layout of the site which may remove screening features.
- Lux limits for each zone apply to the horizontal plane from ground level up to 3m above ground level. It is recommended that plans showing light levels at 0m, 1m and 2m are given.
- Upwards lighting will not be permitted in zones A-C.
- Where necessary, vertical lighting plots can be given to demonstrate lux levels on features such as walls, hedgerows or tree-lines at or close to the boundary of Zone B and C.
- Light trespass from windows should also be modelled, making assumptions where necessary as to the location, specification, intensity and recessing of bulbs as well as the attenuation caused by balconies and walls etc.
- Key habitats suitable for bats immediately adjacent to the site which may be impacted must also be taken into consideration.
- Lux contour plans should include an output with no Maintenance Factor applied, i.e. full ('Day 1') lighting efficiency and this should be clearly stated.
- 'Warm white' LED luminaires with colour temperatures of 3000K or less should be used wherever possible due to their reduced UV spectrum component.

  The presence of glare acting upon Zones A and B should be considered within the design process and will be considered by the local authority in assessing the plans. A direct line of sight between a relatively intense light source (or group of light sources) to the flight corridors within Zones A and B should be avoided through changing the luminaire type, location, angle/direction or use of blinds and cowls.

- Part-night lighting (PNL) regimes should not be employed as mitigation against impacts on horseshoe bats. Recent research indicates that light-averse bat species are similarly impacted by part-night lighting scheme as they are by full-night lighting schemes[18] and that PNL does not remove the lighting conflict at key post-emergence activity windows[19]. Such activity peaks in horseshoe bats have been demonstrated in this study by the presence of post-sunset and pre-sunrise peaks in the transition months August to October and are deemed key to the function of the river as supporting habitat to the SAC.
- Research is being undertaken to determine the use of the river corridor during the winter months and will be used to inform policy on sensing and management regimes at these times.

6.3.9 As the effects of artificial lighting on the bank of the river often have the greatest impact on the opposite bank, this highlights the importance of considering this effect when designing and assessing new proposals.

[18] Azam, C. *et. al.,* (2016) *Is part-night lighting an effective measure to limit the impacts of artificial lighting on bats?* Global Change Biology. 21, 4333-4341.
[19] Day, J. *et. al.,* (2015) *Part-night lighting: Implications for bat conservation.* Animal Conservation. 18, 512-516.

Table 11: Example description and features of suggested BEZ Bat Zones A-E (NB Any distances and descriptions would need to be refined to relate to the Bath River Corridor and its characteristics, these zones are indicative only and do not yet relate specifically to Bath)

Zone	A (River Channel)	B (Banktop and Towpath)	C (Lighting Transition Zone)	D (Core Development Zone)	E (City/Urban Zone)
Indicative distance from water's edge	e.g. 0-~4m to be defined	e.g ~4m+ to be defined	To be defined	To de defined	To be defined
Description	River channel and banksides,. includes natural and engineered banks, moorings etc. Highest sensitivity zone for bats.	Bank top, which incorporates the towpath on northern bank or riverside walkways elsewhere. In other locations this may include flat ground with habitat continuation of bank vegetation, although may be more scattered. Highly sensitive zone for bats.	Transition zone between undisturbed river corridor and built development. Includes variety of uses and conditions including leisure and recreational amenity areas, linear natural features which run along the river towards Zone D, i.e. hedgerows running away from the river edge towards city and existing built development and walls etc Moderate sensitivity for bats.	Development Zone – Includes illuminated parking and the first buildings in from the water's edge. Characterised by a dominance of hard standing and built structures. Low sensitivity for bats.	Development Zone – High human activity. Dominated by roads and buildings. Low sensitivity for bats.
Development	No development. Habitat to be retained. No/limited human access.	No development, although permeable access for cyclists and pedestrians. Habitat to be retained and reinstated.	Edge of development, mostly comprising communal areas, fencing, unlit parking and landscaping.	Buildings and Hardstanding.	Buildings and Hardstanding in an urban setting.
Lighting **(including corresponding ILP Environmental Lighting Zone (ELZ)**	Lux contours <0.5lux from development. **Must remain unlit with no glare impact.** ILP ELZ – E1	Lux contours <1lux from development. **Must remain unlit with no glare impact.** ILP ELZ – E1	Lux contours <3.5lux from development. Lighting scheme to incorporate innovative lighting solutions – e.g. bollards, cowls, automation, recessed bulbs, walls/screens, smart glazing. Warm white lighting used exclusively (3000K or less). ILP ELZ – E2	No lux limits. Restrictions on potential sources of glare (e.g. exterior security/flood lighting, trespass from windows) through sensitive lighting design. Lighting on building elevations fronting Zones A-C to receive particular focus. ILP ELZ – E3	No lux limits. Restrictions on potential sources of glare (e.g. exterior security/flood lighting, trespass from windows) which could affect the river corridor through sensitive lighting design. ILP ELZ – E3+
Landscaping	Green infrastructure and landscaping actively encouraged to increase value for foraging and commuting bats. Maintenance access only.	Green infrastructure and landscaping actively encouraged to increase value for foraging and commuting bats. High potential for light attenuation through soft landscaping in this zone.	Potential for appropriate landscaping and planting of benefit to bats. Landscaping (soft and hard) can be used to screen the river corridor from lighting and activity	Hard landscaping and buildings dominant.	Hard landscaping and buildings dominant.

	Fencing may be appropriate.		associated with the development.		

Landscaping Design

6.3.10 The advice of a landscape architect and ecologist should be sought at an early stage in the design of new development schemes in order to provide an ecologically sensitive landscaping design. The role of soft landscaping may be crucial for the attenuation of light levels in Zones A-C and in screening from glare. Where soft landscaping plays a key role in providing the dark corridor, the landscape architect can advise on the best species to choose, planting methods and aftercare through a Landscape and Ecological Management Plan (LEMP). A LEMP should be valid for the life of a scheme with commitments to ensure landscaping remains in place to perform its function and in favourable condition. The LEMP should quantify the extent of habitat retention and habitat creation as well as management and enhancement measures.

6.3.11 The principle of No Net Loss should be followed within the design process, in accordance with central (National Planning Policy Framework) and local planning policy. Existing habitat within Zones A-C should be retained wherever possible, especially given the inherent light attenuation properties. Connectivity with habitats leading laterally off-site (Zone C) from the river corridor should be retained and/or strengthened through supplementary planting. Unavoidable clearance of habitats should be compensated by the planting of an equivalent area or length elsewhere on site, with consideration to the opportunity for creation of green infrastructure.

6.3.12 It is anticipated that in some cases, newly planted features will have a reduced screening impact which will improve over time as the feature establishes. This factor needs to be taken into account when assessing the effectiveness of mitigation. The size and depth of the habitat will need to vary according to the distance from light sources, light intensities, spread and luminaire specification.

6.3.13 Species planted should ideally be native, of local provenance or at least known to be of value to invertebrates through providing nectar or other food sources.

6.3.14 Hard landscaping can also contribute to bat navigation and light attenuation. The observed use of the 'bank shadow' effect arising from steep, tall man-made banks by bats indicates that where already dark and free of glare, this feature may be acceptable over short distances. Planting should still be encouraged to ensure no light spill on the water and the presence of lighting and glare from the opposite bank may preclude the use of this feature entirely.

6.3.15 The installation of green walls whereby facades are softened by the installation of vertical vegetation and substrates can also be considered.

Survey Requirements Where Targets Cannot be Met

6.3.16 In cases where development proposals cannot achieve the above lighting limits and No Net Loss landscaping requirements, or where impacts on bats remain uncertain, the developer will need to support their planning application with comprehensive bat survey information and a reasoned assessment in order to justify their design.

6.3.17 It is proposed that a survey scheme based upon the methodology used during this study is adopted, taking into consideration the extent of bankside habitats within the development boundary. Building upon the findings from this study that the static detectors provide a more reliable mechanism by which to record horseshoe bats a greater reliance upon the use of static detectors rather than manned transects is to be promoted.

6.3.18 Therefore, static detector data obtained from each of the months April, May, June, July, August, September and October would be required. One static detector per 50-75m of river bank should be installed at appropriate points. Coverage within Zones B and C at the same rate as Zone A should be obtained at the same time should habitat or lighting conditions on site prove suitable.

6.3.19 Walked transects are less cost-effective than static detectors but still enable an assessment of the behaviour and flightpaths used by bats. Therefore it is recommended that a minimum of three monthly transects should be carried out. These should be spaced through the survey seasons so that one manned transect is undertaken in Spring, Summer and Autumn.

6.4 Recommendations for Further Study

Winter Season Static Detector Survey

6.4.1 Horseshoe bats are known to become active sporadically during the winter hibernation season. Most activity is restricted to small movements for exercise and excretion but foraging bouts and roost-switching also occur in times of mild weather.

6.4.2 It would be useful to extend the static detector element of this study into the winter months November – March in order to obtain a full baseline of activity year-round and establish whether usage occurs in the winter was well ass the active season. This information could be used to inform and further justify the implementation of various mitigation measures, including seasonal/variable lighting regimes.

Remediation of Existing Problematic Lighting

6.4.3 The rapid assessment of the lighting and vegetation cover of the river corridor highlighted several potentially problematic sources of glare and illumination already in place within the BEZ. These arose from both recent and historic developments although were nearly always retail or industrial in use. This information could form the basis of an effort to make contact with landowners at the identified sites (or any riverside business owners) to discuss the potential for reducing their impact on lighting within the river corridor. The lighting zonation proposed above should be used as a target, which would encourage a consistent approach to all riverside landowners.

6.4.4 It may be possible to employ a legal or policy mechanism (such as a Section 106 agreement or Community Infrastructure Levy) supported by new development to subsidise the costs associated with making retrospective remedial measures. It is important to note that reducing light spill is desirable for many other reasons, including reducing energy wastage and carbon emissions, reducing light pollution and obtrusive light and reducing impacts on bird, mammal and invertebrate life which have also been widely documented[20][21].

Baseline Lighting Survey

6.4.5 While spot light meter survey readings have been taken by Speirs and Major in the past, it would be useful to have a comprehensive baseline of lighting conditions around 1hr after sunset (with no full moon, clear skies) when the initial nightly peak of bat activity can be expected. This would enable key locations for mitigation effort to be developed and a context for new lighting design to be set.

6.4.6 This information could also be used in identifying existing sources of obtrusive lighting and glare which could currently be causing barrier or dissuasive effects within the river corridor with a view to targeting remedial action.

Long Term Monitoring Surveys

6.4.7 Although bats are long-lived, populations are dynamic and would react to environmental changes such as climate, food availability and loss of habitat. Furthermore, our understanding of bats and their use of rivers and urban landscapes is likely to evolve over time. Periodic monitoring of the status of the river corridor for bats and any impact new development and mitigation has had should be carried out. Monitoring results would be used to refine the Design Guidance document, mitigation measures and would target conservation or remediation effort.

6.4.8 Monitoring post-development would most likely be become a requirement as part of the emerging Design Guidance, or could be enforced through planning conditions. Such monitoring may not be required in the case of every development, particularly those with little or no lighting or riverside component. It may be possible to focus the requirement of monitoring according to the area of development within a subset of the River Corridor Lighting Zones. Monitoring enforced through conditions would most likely be required in special circumstances not specifically dealt with in the Design Guidance, potentially temporary works, night-time lighting during construction or illuminated bridges. Monitoring could also be part-funded by contributions from any associated CIL or Section 106 agreement for development within the BEZ.

6.4.9 A standardised approach should be adopted so that repeated surveys can be accurately compared. Due to their relatively low cost to operate and analyse, static detectors should form the bulk of the monitoring while a lower effort of walked transects can supplement this through observing bat behaviour. Lighting survey information can also be obtained to measure any changes in lighting. It is recommended that monitoring follows a monthly approach and may need to be repeated for at least two years post-development. This can be expected to be further clarified by the Design Guidance.

[20] Bruce-White, C. & Shardlow, M. (2011) *A Review of the Impact of Artificial Light on Invertebrates.* Buglife
[21] Voight, C.C & Kingston, T. (eds.). (2016). *Bats in the Anthropocene: Conservation of Bats in a Changing World*.

6.4.10 There is the opportunity to involve the public to some extent in this work, particularly as the towpath in the study area extends some 6km and distributed effort would be most cost-effective. A qualified ecologist could take the lead on each transect, supported by a small number of volunteers. Volunteers could also help deploy and retrieve static bat detectors.

Further Investigation of Roosts

6.4.11 Relatively few roosts are known within a short distance of the water's edge considering the presence of multiple unlit and historic buildings in the city. The Cattle Market Vaults located close to detector location 8 is the closest such roost but recent survey information is apparently lacking. The study indicated that this roost is used year-round and plays a role in the transition of horseshoe bats between winter and summer roosts. It would be useful to conduct monthly colony counts either by emergence survey or internal investigation to clarify this status and potentially aid future conservation efforts.

6.4.12 The study data also suggests that other roosts capable of being of value during transitional months are present near to Bath Quays South where several disused buildings are present, as well as near the Newton Brook/Avon confluence and the structure of New Bridge. Additionally, the Linear Park/Two Tunnels underground features and structures within Sydney/Henrietta Gardens may prove productive locations for further study into their relationship with the SAC population and the river. Further investigation may prove useful here as well as potentially increased scrutiny or survey effort within ecological surveys associated with proposed development at these locations.

APPENDIX A: PHOTOGRAPHS OF STATIC DETECTOR LOCATIONS

Photograph 1. Location 1 at Newton Brook/Avon confluence and Cyclepath bridge.

Photograph 2. Location of microphone at 2L – also indicative of vegetation cover at 2R.

Photograph 3. Location 3 – Weston Lock Riverside.

Photograph 4. Location 4 under disused pedestrian bridge.

Photograph 5. Location of detector 5 opposite 4 to rear of Hertz.

Photograph 6. Location of detector 6 at Green Park.

Photograph 7. Location of Detector 7 at South Quays.

Photograph 8. Location of Detector 8 at the Tramsheds

Photograph 9. Location of Detector 9 at Bethel Chapel Gardens.

Photograph 10. Location of Detector 10 at Cleveland Pools.

Appendix B: Weather Details for Static Detector and Transect Studies

Static Detector Deployment Weather Details

Date (evening of)	Min/Max Temperature °C	Rain?	Avg. Wind Speed (Km/h)	Suitable?	Detector Fault?
21/04/15	15-5	No	23	yes	No
22/04/15	9-5	No	22	yes	No
23/04/15	11-3	No	16	yes	No
24/04/15	11-5	No	13	yes	No
25/04/15	13-2	No	7	yes	No
26/04/15	9-2	Some light rain	13	yes	No
10/05/16	15-13	Occasional moderate rain	1	Yes	5
11/05/16	17-13	Some light rain	9	Yes	5
12/05/16	21-12	Some fog	16	Yes	No
13/05/16	17-8	No	21	Yes	No
14/05/16	14-5	No	15	Yes	No
15/05/16	14-6	No	9	Yes	2 and 10
07/06/16	13-20	Fog	9	Yes	2 and 10
08/06/16	13-22	Fog	7	Yes	2 and 10
09/06/16	12-21	Fog	8	Yes	2 and 10
10/06/16	13-20	Light Rain	7	Yes	2 and 10
11/06/16	14-18	Light Rain	5	Yes	2 and 10
12/06/16	13-18	Light Rain	14	Yes	2 and 10
13/06/16	13-18	Light Rain	18	Yes	2 and 10
14/06/16	13-15	Light Rain	20	Yes	2 and 10
15/06/16	11-16	Fog, Light Rain	10	Yes	2 and 10
June Re-deployment of Static Detectors in Locations 2 and 10 only:					
17/06/16	12-18	Rain / Thunderstorm	11	No	No
18/06/16	10-16	No	13	Yes	No
19/06/16	11-16	Light Rain	13	Yes	No
20/06/16	13-18	Light Rain	18	Yes	No
21/06/16	13-18	No	11	Yes	No
22/06/16	13-19	Light Rain	9	Yes	No
23/06/16	12-18	No	10	Yes	No
24/06/16	12-16	Light Rain	14	Yes	No
25/06/16	11-16	Light Rain	15	Yes	No
26/06/16	11-16	Fog, Light Rain	16	Yes	No
08/07/16	14-18	No	17	Yes	No
09/07/16	14-21	No	14	Yes	No
End of June Re-deployment of Static Detectors in Locations 2 and 10 only					
10/07/16	15-19	No	16	Yes	No
11/07/16	12-17	No	22	Yes	No

Date (evening of)	Min/Max Temperature °C	Rain?	Avg. Wind Speed (Km/h)	Suitable?	Detector Fault?
12/07/16	10-17	No	16	Yes	No
13/07/16	10-17	No	13	Yes	No
14/07/16	9-18	No	14	Yes	No
15/07/16	11-16	No	15	Yes	No
09/08/16	10 / 18	No	12	Yes	No
10/08/16	11 / 17	No	12	Yes	No
11/08/16	13 / 17	No	22	Yes	No
12/08/16	15 / 18	No	19	Yes	No
13/08/16	13 / 19	No	17	Yes	No
14/08/16	12 / 19	No	7	Yes	No
15/08/16	10 / 23	No	12	Yes	No
06/09/16	16 / 21	No	7	Yes	No
07/09/16	16 / 23	No	9	Yes	No
08/09/16	14 / 19	No	18	Yes	No
09/09/16	15 / 20	No	20	Yes	No
10/09/16	12 / 17	No	16	Yes	No
11/09/16	10 / 18	No	10	Yes	No
12/09/16	14 / 20	No	19	Yes	No
13/09/16	15 / 20	No	12	Yes	No
03/10/2016	5 / 18	yes	5	Yes	No
04/10/16	6 / 17	yes	11	Yes	No
05/10/16	10 / 17	no	15	Yes	No
06/10/16	6 / 15	no	13	Yes	No
07/10/16	7 / 14	no	9	Yes	No
08/10/16	11 / 15	yes	10	Yes	No
09/10/16	8 / 14	no	10	Yes	No
10/10/16	6 / 14	no	7	Yes	No
11/10/16	5 / 14	no	10	Yes	No

WALKED ACTIVITY TRANSECT WEATHER DETAILS (AVERAGE (MEAN) GIVEN IN BRACKETS)

Survey	Temp at start	Temp at end	wind at start	wind at end	clouds at start	clouds at end	rain?
April	6-10 (8)	2.5-4 (3.25)	0-2 (1)	0-2 (1)	0-2 (1)	0-2 (1)	none
May	15-20 (17)	10-13 (11.5)	0-2 (1)	0-0.5 (0.17)	0-5 (2.75)	0-4 (1.7)	none
June dawn	8-11 (9.3)	9	0-3 (1.4)	1-2 (1.5)	0-7 (2.8)	2-8 (4)	none
June dusk	15-17 (16)	15	0-1 (0.4)	0	6-8 (7.6)	8	none but a recent heavy shower
July	15-16 (15.5)	11	0-1 (0.75)	0-2 (1)	1-8 (5)	1-8 (4)	none
August	19-20 (19.55)	16	0-1 (0.25)	0	6-7 (6.5)	6	none
September	20-23 (21.67)	18	0-0.5 (0.125)	0	1-2 (1.25)	1	none
October	10-14 (11.5)	7-8 (7.5)	0-1 (0.75)	0-1 (0.67)	1-4 (2.9)	2-4 (3.17)	none

Appendix C: Details of Detector Faults During Deployments

Location (Detector)	April	May	June	July	August	September	October
1 (Anabat E)	None	None	None	None	None	None	None
2 (SM2C)	None	Ran out of memory on the 4th night	Faulty microphone - redeployed	None	None	None	None
3 (Anabat D)	None	None	None	None	None	None	None
4 (Anabat C)	None	None	None	None	None	None	None
5 (SM2F)	Ran out of battery after 2 nights	Started recording 2 days late (on the 12th instead of the 10th)	None	None	None	None	None
6 (Anabat B)	None	None	None	None	None	None	None
7 (SM2G)	None	None	None	None	None	None	None
8 (SM2E)	None	None	None	Faulty microphone - redeployed	None	None	None
9 (Anabat A)	None	None	None	None	None	None	None
10 (SM2D)	None	Ran out of memory on the 4th night	Faulty microphone - redeployed	None	None	None	None

APPENDIX D: DETAILED TIME-OF-NIGHT DATA FROM STATIC DETECTORS

Lesser Horseshoe Bats

Month	Position	Sunset -1hr to +1hr	Sunset +1hr to +3hr	Night	Sunrise -1hr to +1hr
Apr	2L	0	0	15	346
Apr	2R	0	0	1	10
Apr	3	0	0	0	2
Apr	6	1	0	1	3
Apr	7	3	2	1	13
Apr	8	0	3	5	13
Apr	9	0	4	1	13
Apr	10	14	1	82	85
May	7	0	0	0	3
May	8	0	4	7	1
May	10	0	1	10	0
Jun	1	0	0	1	0
Jun	5	1	0	0	0
Jul	6	0	0	1	0
Aug	2R	0	0	1	0
Aug	6	0	0	1	0
Aug	7	0	0	1	0
Aug	8	0	1	19	12
Aug	9	1	1	117	8
Aug	10	1	25	40	0
Sep	2L	0	0	5	0
Sep	3	0	0	2	0
Sep	4	1	0	0	0
Sep		0	0	1	0
Sep	6	2	0	1	0
Sep	7	0	2	2	0
Sep	8	0	0	3	0
Sep	10	0	1	3	0
Oct	2L	0	0	4	0
Oct	2R	0	0	3	0
Oct	3	0	0	2	0
Oct	4	0	1	0	0
Oct	5	0	0	2	0
Oct	6	4	2	3	0
Oct	7	0	0	2	0
Oct	8	6	28	12	0

Oct	9	0	16	3	1
Oct	10	3	1	2	0
Total		**37**	**93**	**354**	**510**

Greater Horseshoe Bats

Month	**Position**	**Sunset -1hr to +1hr**	**Sunset +1hr to +3hr**	**Night**	**Sunrise -1hr to +1hr**
May	2L	0	0	1	0
May	8	0	2	4	0
May	10	0	1	0	0
June	1	1	1	2	0
July	1	0	0	1	1
Aug	7	0	0	1	0
Aug	8	0	0	3	0
Aug	10	2	4	0	0
Sep	1	0	0	1	0
Sep	8	0	2	2	0
Sep	9	0	0	1	0
Sep	10	0	1	1	0
Oct	1	4	0	0	0
Oct	8	0	3	2	0
Total		**7**	**14**	**19**	**1**

APPENDIX E: DETAILS OF SETTINGS USED WITH STATIC DETECTORS

Bat Detector	Microphone	Settings	
SM2BAT+	SMX-U1	Trigger Window	1.0s
		Trigger Max.	30s
		High Pass Filter	12,000kHz (fs/32)
		Trigger level Left	15 SNR
		Bits	16
		Division Ratio	16
		File Format	.WAV
		Gain (digital)	0.0dB
		Gain (hardware)	12dB
Anabat Express	Anabat Express	Sensitivity	8
		File length max.	15.0s

APPENDIX F: WORKSHOP PRESENTATION

A River Avon/Enterprise Zone Workshop - Bat Survey Results and Impact on Design/Lighting was held with attendees from Environment & Design, Planning Policy, Development Management, Major Projects, Regeneration and Highways and Public Realm teams on 7th November 2016. The presentation from Clarkson & Woods at this event can be found attached as Appendix F and is available from the B&NES website.

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