Calculate percentages for each crossing behaviour for all bat activity and for individual species (see below).

Examples:

To calculate the percentage of all crossing bats that used the crossing structure:

$$\left(\frac{Total\ of\ 'using'\ column}{Total\ of\ 'total'\ column}\right) \times 100$$

e.g. $(1/34) \times 100 = 3\%$

To calculate the percentage of all crossing bats that crossed the road unsafely:

$$\left(\frac{Total\ of\ 'unsafe'\ column}{Total\ of\ 'total'\ column}\right) \times 100$$

e.g. $(29/34) \times 100 = 85\%$

To calculate the percentage of *P. pipistrellus* bats that used the crossing structure:

$$\left(\frac{Total\ no.\ Ppip\ in\ 'using'\ column}{Total\ no.\ Ppip\ in\ 'total'\ column}\right) \times 100$$

e.g. $(1/7) \times 100 = 14\%$

To calculate the percentage of *P. pipistrellus* bats that crossed the road unsafely:

$$\left(\frac{Total\ no.\ Ppip\ in\ 'unsafe'\ column}{Total\ no.\ Ppip\ in\ 'total'\ column}\right) \times 100$$

e.g. $(5/7) \times 100 = 71\%$

Optional method: Kernel Density Estimation

To produce a cross-sectional plot of your survey area showing the position of the mitigation structure and the density of crossing bats at different heights across the site.

Open R and install/load the following package:

```
Install.packages("spatstat")
library(spatstat)
```

Load and attach your original data file in R as above and give it a name, e.g. site1:

```
site1<-read.csv("C:\\Mitigation\\Site1.csv", header=T)
attach(site1)
```

Replace highlighted text with the file location in your computer directory and the file name of your spreadsheet.

Make a subset of the data for the construction stage of interest e.g.

```
#Subset for first year post-construction
post1<-droplevels(site1[which(site1$stage == "post1"), ] )
```

Replace highlighted text as required e.g. use post2 for two years after construction etc..

Create a new variable which assigns the distances of crossing bats on one side of the mitigation structure as negative values, and the distances of crossing bats on the opposite side as positive values:

```
post1$new_dist <- with(post1, ifelse(side == "W", -distance, distance))
```

This allows crossing bats to be plotted on either side of the structure.

For example, if bats are crossing the road in a North to South direction and you want to provide a cross-sectional view of the crossing structure from the South, assign negative values to the distance of crossing bats on the West side of the structure and keep distances of crossing bats on the east side as positive values.

Create a point pattern of the data:

```
x1<-ppp(post1$new_dist, post1$height,c(-10,10),c(0,15))
summary(x1)
x2<-as.ppp(x1)
summary(x2)
```

The code above specifies the distance and height variables so that crossing bats can be represented as spatial points, and also specifies the extent of the survey area to be included in the plot.

In our example above, we specify the survey area as being 10 m either side of the mitigation structure and a height of 0 to 15 m above the road (code highlighted in blue).

N.B. You may receive some warning messages. These can be ignored. They simply tell you that some of your points (crossing bats) fall outside of the area specified, and/or that there are duplicate points (more than one bat crossing at the same height and distance).

Compute kernel density estimates:

```
den<-density(x2,1)
```

Create a greyscale colour scheme for you plot:

```
greyscale <- colourmap(grey(seq(1, 0, length = 17)), range = c(0,+ 17))
```

Generate the Kernel Density Estimation plot:

```
par(mar=c(1,3,1,3))
plot(den,col=greyscale,box=FALSE,main=NULL,xlab="",
   ylab="",ribsep=0.025,ribscale=1,cex.rib=1)
axis(1,at=c(-10+0:4*5),tck=0.01,pos=0,lwd=2,cex.axis=1.2)
axis(2,at=c(0+0:3*5),tck=0.01,pos=-10,lwd=2,cex.axis=1.2,las=2)
title(ylab="Height (m)", mgp=c(2,1,0),cex.lab=1.2)
title(xlab="Distance (m)", mgp=c(-4,1,0),cex.lab=1.2)
legtitle<-bquote('Density'~'(bats'~'per'~'m'^'2'*')')
mtext(legtitle, side=4,line=1.5,cex=1.2)
```

The appearance of the plot will vary depending on the number of crossing bats or 'points'. You may need to alter the number of grey shades used (code highlighted in yellow above) and/or the scale of the legend (code highlighted in blue).

Annotate the plot, for example:

```
#Add a line to indicate safe/unsafe crossing height:
lines(x=c(-10,10),y=c(5,5),lty=2,lwd=2)

#Draw the position of the mitigation structure on the plot (this is done
#manually by drawing lines with x and y coordinates, modify accordingly):
lines(x=c(-3,3),y=c(6,6),lty=1,lwd=2)
lines(x=c(-3,-3),y=c(6,9),lty=1,lwd=2)
lines(x=c(3,3),y=c(9,6),lty=1,lwd=2)

#Label the crossing structure (modify the text and the x and y coordinates
#for position as required:
text(-3,10,"Overbridge",font=3,cex=1.2)
```

Save the plot by clicking on the plot window and selecting ‘File’, ‘Save as’ on the R menu and choosing the file type. We advise saving as a Jpeg for use in reports.

To finish your session, remove the dataset from R and clear the console:

```
detach(site1)
rm(list = ls())
```

R CODE – copy and paste into R console

```
# To compare the no. of bats using commuting route before and after construction

# Load data
site1<-read.csv("C:\\Mitigation\\Site1.csv", header=T)
attach(site1)

# Make subsets of the data for pre- and post-construction
# Subset of pre-construction data for all bat activity
pre<-droplevels(site1[which(site1$stage == "pre"), ])
# OR subset of pre-construction data for a specific species
pre<-droplevels(site1[which(site1$stage == "pre" $species=="Ppip"), ])
# Subset of post-construction data for all bat activity
post1<-droplevels(site1[which(site1$stage == "post1"), ])
# OR subset of post-construction data for a specific species
post1<-droplevels(site1[which(site1$stage == "post1" $species=="Ppip"), ])

# Extract total numbers of bats crossing per survey
pre_total<-unlist(table(pre$survey_no))
post1_total<-unlist(table(post1$survey_no))
table<-data.frame(t(rbind(pre_total,post1_total)))
# Export as csv file
write.csv(table, "C:\\Mitigation\\Site1_totals.csv")

# To add other construction stages
# Subset of during construction data for all bat activity
during<-droplevels(site1[which(site1$stage == "during"), ])
# OR subset of during construction data for a specific species
during<-droplevels(site1[which(site1$stage == "during" $species=="Ppip"), ])
# Extract number of bats crossing per survey during construction
during_total<-unlist(table(during$survey_no))
# Include additional stages when combining totals in table:
table<-data.frame(t(rbind(pre_total,during_total,post1_total)))
write.csv(table, "C:\\Mitigation\\Site1_totals.csv")

# Detach data and clear console
detach(site1)
rm(list = ls())

# Load csv file created above
totals<-read.csv("C:\\Mitigation\\Site1_totals.csv",header=T)
attach(totals)
# Install and load the 'coin' package
install.packages("coin")
library(coin)
# Run the Wilcoxon signed rank test
wilcoxsign_test(pre_total~post1_total, distribution="exact")

# Draw boxplot
totals$X<-NULL
 boxplot(totals, las=2, par(mar = c(6, 6, 1, 1), par(mgp=c(4,1,0))),
    at=c(1:2), col=c("white","grey"), ylab = "Bats crossing per survey",
    xlab="Stage of construction", pch=19, cex.lab=1.5, cex=2,frame.plot=FALSE,
    xaxt="n", yaxt="n", medlwd=1, whisklty=1, staplewex=0.2, outcex=0.5,
    boxwex=0.4)
 xax<-c("Before","After")
 axis(1, labels=xax, at=c(1:2), las=1, tck=0.01, cex.axis=2, font.axis=1)
 axis(2, cex.axis=2, tck=0.01, font.axis=1, las=2)
box(which="plot", bty="l")

# Detach data and clear console
detach(totals)
```

```
rm(list = ls())
# To compare number of bats using structure and crossing unsafely

# Load data
site1<-read.csv("C:\\Mitigation\\Site1.csv", header=T)
attach(site1)

# Make subset of data for construction stage of interest
# Subset of post-construction data for all bat activity
post1<-droplevels(site1[which(site1$stage == "post1"), ])
# OR subset of post-construction data for a specific species
post1<-droplevels(site1[which(site1$stage == "post1" &site1$species=="Ppip"), ])
# Extract the total number of bats crossing per survey
total<-unlist(table(post1$survey_no))

# Extract the total number of bats 'using' the structure per survey
# For bat gantries/overpasses/overbridges:
using<-with(post1[post1$height>5&post1$dist<=5,],table(survey_no))
# For underpasses:
using<-with(post1[post1$location=="under",],table(survey_no))

# Extract the total number of bats crossing unsafely per survey
unsafe<-with(post1[post1$location=="road"&post1$height<=5,],table(survey_no))

# Combine totals in a table and export as CSV file
table<-data.frame(t(rbind(total,using,unsafe)))
write.csv(table, "C:\\Mitigation\\Site1_post1_crossing_totals.csv")

# Detach data and clear console
detach(site1)
rm(list = ls())

# Load csv file created above
totals<-read.csv("C:\\Mitigation\\Site1_post1_crossing_totals.csv",header=T)
attach(totals)

# Draw boxplot
totals$X<-NULL
boxplot(totals, las=2, par(mar = c(5, 6, 1, 1), par(mgp=c(4,1,0))), at=c(1:3),
    col=c("white","grey","red"), ylab = "Bats crossing per survey", pch=19,
    cex.lab=2, cex=2, frame.plot=FALSE, xaxt="n", yaxt="n", medlwd=1, whisklty=1,
    staplewex=0.2, outcex=0.5, boxwex=0.4)
xax<-c("Total\n","Using\nstructure","Below 5 m\n")
axis(1, labels=xax, at=c(1:3), las=1, tck=0.01, cex.axis=2, font.axis=1,
mgp=c(0,3,0))
axis(2, cex.axis=2, tck=0.01, font.axis=1, las=2)
box(which="plot", bty="l")

# Detach data and clear console
detach(totals)
rm(list = ls())

# Calculate overall percentages for crossing behaviours and individual species

# Load original data
site1<-read.csv("C:\\Mitigation\\Site1.csv", header=T)
attach(site1)

# Make a subset for construction stage of interest
# Subset of the first year of post-construction data
post1<-droplevels(site1[which(site1$stage == "post1"), ] )

# Extract the total number of each bat species crossing
```

```
total<-unlist(table(post1$species))

# Extract the total number of each bat species 'using' the structure
# For bat gantries/overpasses/overbridges
using<-with(post1[post1$height>5&post1$dist<=5,],table(species))
# For underpasses
using<-with(post1[post1$location=="under",],table(species))

# Extract the total number of bat species crossing unsafely
unsafe<-with(post1[post1$location=="road"&post1$height<=5,],table(species))

# Combine totals in a table, add grand total row
table<-data.frame(t(rbind(total,using,unsafe)))
table["Total" ,] <- colSums(table)
# Export as csv file to continue analysis in Excel
write.csv(table, "C:\\Mitigation\\Site1_post1_species_totals.csv")

# Detach data and clear console
detach(site1)
rm(list = ls())

# Kernel Density Estimation

# Install package
Install.packages("spatstat")
library(spatstat)

# Load data
site1<-read.csv("C:\\Mitigation\\Site1.csv", header=T)
attach(site1)

# Make a subset of the data for construction stage of interest
# Subset for first year post-construction
post1<-droplevels(site1[which(site1$stage == "post1"), ] )

# Create new variable to assign spatial distances to crossing bats
post1$new_dist <- with(post1, ifelse(side == "W", -distance, distance))

# Create point pattern
x1<-ppp(post1$new_dist, post1$height,c(-10,10),c(0,15))
summary(x1)
x2<-as.ppp(x1)
summary(x2)

# Compute kernel density estimates
den<-density(x2,1)

# Generate Kernel Density Estimation plot
greyscale <- colourmap(grey(seq(1, 0, length = 17)), range = c(0,+ 17))
par(mar=c(1,3,1,3))
plot(den,col=greyscale,box=FALSE,main=NULL,xlab="",
   ylab="",ribsep=0.025,ribscale=1,cex.rib=1)
axis(1,at=c(-10+0:4*5),tck=0.01,pos=0,lwd=2,cex.axis=1.2)
axis(2,at=c(0+0:3*5),tck=0.01,pos=-10,lwd=2,cex.axis=1.2,las=2)
title(ylab="Height (m)", mgp=c(2,1,0),cex.lab=1.2)
title(xlab="Distance (m)", mgp=c(-5,1,0),cex.lab=1.2)
legtitle<-bquote('Density'~'(bats'~'per'~'m'^'2'*')')
mtext(legtitle, side=4,line=1.5,cex=1.2)

# Annotate plot (optional)
# Add a line to indicate safe/unsafe crossing height:
lines(x=c(-10,10),y=c(5,5),lty=2,lwd=2)
```

```
# Draw the position of the mitigation structure on the plot (this is done
#manually by drawing lines with x and y coordinates, modify accordingly):
lines(x=c(-3,3),y=c(6,6),lty=1,lwd=2)
lines(x=c(-3,-3),y=c(6,9),lty=1,lwd=2)
lines(x=c(3,3),y=c(9,6),lty=1,lwd=2)
# Label the crossing structure (modify the text and the x and y coordinates #for
position as required:
text(-3,10,"Overbridge",font=3,cex=1.2)

# Detach data and clear console
detach(site1)
rm(list = ls())
```