Description R script

Project title	Potential collision risk of a threatened wader with wind turbines - an analysis based on high-resolution flight behaviour data

Structure — The script is structured in three chapters:

1. Data input & selection
2. Data processing
3. Calculation of results

(Details see below)

Raw data — The raw data contains:

- .shp-files (Curlew tracks, study area, wind turbine sites)
- .csv/.xlsx-files (Curlew nesting sites)
- .tif-files (digital elevation models)

Memory — Large data objects had to be removed from R Workspace due to limited storage capacity. Required information of the Curlew tracks were previously converted into data frames. For the three chapters, the respective Workspace can be loaded into the R environment. The content refers to the process that has progressed up to that point. The files of stored Workspaces are:

- R_script_chapter_1_envi
- R_script_chapter_2_envi
- R_script_chapter_3_envi

Packages — raster, rgdal, dplyr, ggplot2, sp, sf, writexl, tidyr, geosphere, reshape2, lme4, MuMIn, ggeffects, multcomp,

Most of the packages are listed at the beginning of the script. However, some specific packages are loaded at relevant positions in the script.

Labelling — All processing steps are labelled in the script.

Running the code

1. Data input & selection
   1.1 Curlew
       Input of nesting sites and tracks of Curlews
       Selection by time (breeding season) & buffers (10 km around nests)
   1.2 DEM
       Input of DEM (Lower Saxony, Bremen, NRW)
       Allocation of elevation information to each GPS fix of the birds
       Calculation of birds' flight altitude above ground by subtracting ground level from the flight altitude above sea level
   1.3 Wind turbines
       Input of wind turbine sites (Lower Saxony, Bremen, NRW)
       Demarcation of study area
       Selection by construction type, location and operational status
       Definition of rotor height range (RHR)

2. Data processing
   2.1 Adaptation of data formats
       Division of data with high & low recording rates
       ID for each flight track
       Sequential number for each GPS position of a flight track
   2.2 Selection of high-resolution data (high recording rate)

2.3 Arrivals and departures of the birds in the breeding sites
Check of first & last transmission of data in the nest buffers

2.4 Detection and exclusion of outliers
On basis of sudden flight altitude differences & flight duration (>10 seconds)

2.5 Calculation of accuracy in recorded fixes
Calculation of precise vertical precision
Calculation of inaccuracy in horizontal dilution of precision (HDOP)

2.6 Battery charge level

2.7 Preparation of further evaluation steps

3. Calculation of results

3.1 General flight information
Number of flight fixes and flight tracks
Flight speed
Distribution of flight altitudes
Residence time of the birds in their breeding sites
Duration of breeding season
Track length

3.2 Wind turbine information (plot)

3.3 Flight activity
Activity per day
Activity throughout the day (plot)

3.4 Dependency of flight distance and flight altitude
Calculation of Euclidean distance between take-off and landing
GLMM (plot)
Flight distances throughout the day (plot)

3.5 Flight duration

3.6 Number of flights
Number of flights per day
Number of flights throughout the day (plot)

3.7 Vertical overlap
Flight altitude per bird
Flight altitude throughout the day (plot)
Proportion of fixes in the rotor height range (plot)

3.8 Horizontal overlap
Intersection of flights and wind turbine buffers (200 m)
Distribution of the number of flight fixes for each bird
Special calculation of bird breeding in a buffer
Proportion of flight fixes of individual birds within the buffer

3.9 Vertical avoidance behaviour
GLMM (plot)

Export   csv-files, commands are set passive in the script, using comment function #