Argos-Links: a potential habitat distribution model for woodland species in Cornwall.

Technical summary

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Argos-Links is a framework for deriving potential habitat models for a range of different terrestrial woodland species for Cornwall. The name Argos-links was chosen because the model works by calculating the relative distances/links between woodland (**Argos in Cornish**) patches.

The model is a generalised solution for estimating potential habitat areas, producing two spatial polygon layers for a given species, the viable habitat in the zone and the area that contains this viable habitat, limited by road boundaries.

One of the key factors influencing terrestrial mammal mobility in a contemporary landscape is the road network. Roads are by no means a permanent barrier to animals but they are a significant cause of mortality and do exert and strong control over animal migration and movement (Glista, et al., 2009). Therefore, in this work we make the simplified assumption that A and B roads are a barrier to the movement of the considered species. This simplification means that the model cannot be used for certain applications. For example it would not be suitable for predicting the movement of animals between different viable habitat zones.

However, The primary intention of this model is to identify viable habitat areas with sufficient woodland extent that is not intersected by A or B roads. This provides a useful indicator of which regions offer the best opportunities for releasing a given species. Those zones that contain a greater woodland area should be considered to have a greater potential for species recovery/release success.

The only habitat type considered in this model is woodland. We define woodland habitat as continuous woody cover with a minimum area of 0.1 ha and a minimum canopy cover of 25%.

There were four key variables considered in this model and are described in the following tables:

Habitat/Woodland preference

This may be Either Deciduous, or coniferous in the model. A mixed category is included in Table 1 for clarity. However, it is clear that all species can establish in either woodland type.

Table 1

Species	Habitat Preference
Boar	Deciduous (1), Mixed (2), Coniferous (3) (Leaper et al. 1999; Labudzki et al. 2009)
Squirrel	Coniferous, Mixed, Deciduous (Lurz et al. 1995; Cagnin et al. 2000;Hämäläinen et al. 2018) but preference isn't particularly strong. However if considered in context of martens, coniferous habitat likely less preferable when the latter present (Twining et al. 2022).
Marten	No clear preference (Balharry et al. 2008), however broadleaved woodland likely offers greater dietary breadth (Twining et al. 2022).
Wildcat	Deciduous, Mixed, Coniferous (Sarmento et al. 2006; Oliveria et al. 2018)

Minimum Total Woodland Area

The minimum total accessible woodland area required for a given species. This measure includes all woodland patches that are within the specified gap distance (Table 4) of one another.

Table 2

Species	tot. woodland area (ha)	info
Boar	100	Mean home range size 4.9km2/2.5km2 for males/females in Belgium (Prévot & Licoppe 2013), minimum size 1.06km2 in Romania with mean daily home range between 0.6 – 1.25km2 (Fodor et al. 2018). An adult female social unit of 6-30 individuals may cover a range of 2-5km2 expanding to 10-40km2 in winter while adult male range can be 50km2. (Spitz 1992). Density in mosaic landscape of France of 1-3 animals per km2. Suggested home min home range 1km2.
Squirrel	1	Min home range 1.52ha in large Belgian forests (Wauters & Dhondt 1990), densities of 0.5-1.5 per ha with large fluctuations recorded (Lurz et al. 2005). Suggested min home range 1 ha.
Marten	20	Mean home range in Bialoweiza Forest 2.23 km2 for males and 1.49km2 for females (Zalewski et al. 2004), in more fragmented habitat in the French Ardennes Minimum home range 0.25km2/0.10km2 (mean 1.90/0.49) for males/females in fragmented habitat and 3.45km2/1.21km2 (mean 3.45/1.21) in forest (Mergey et al. 2011), translocated martens in Wales mean 9.5km2 (range 0.2 -65.6km2) (McNichol 2020). Mostly coniferous forest in Wales and mixed woodland with agriculture in Ardennes, food availability likely greatest influence over smaller home ranges sizes here and especially within fragmented landscapes. Suggested min home range 0.2km2.
Wildcat	100	In wet woodlands in Germany minimum home ranges of 8ha for females and 30 ha for males, in Swiss mixed woodland surrounded by pasture and woodland patches 70 ha for females and 150 ha for males (Walsh 2019). German woodlands surrounded by cultural landscape host home ranges averaging 285 ha for females and 1189 ha for males (Jerosch et al. 2017). Suggested min home range 100ha.

Minimum Patch Area

The minimum woodland patch size that might contribute to the habitat of a given species.

Table 3

Species	min. patch area (ha)	info
Boar	25.0	Estimated 1km2 of woodland can sustainably support 4 boar in context of Scottish reintroduction (Howells & Edward-Jones 1997) while taking a less conservative estimate Leaper et al. (1999) suggested based on various European populations an expected density of 3-5 boar per km2. Suggested minimum patch size 0.25km2.
Squirrel	0.5	Minimum patch size on Isle of Wight 0.25 ha (Rushton et al. 1999). Suggested minimum patch size 0.5ha
Marten	20.0	In lowland linear riparian woods in Italy (similar habitat to Cornwall – wooded river valleys below agri landscapes) estimated density of pine martens is 0.8 - 2 per km2 (Pereboom et al 2008). Suggested minimum patch size 0.2km2.
Wildcat	7.0	Minimum individual core range within wider home range 7ha for females and 215ha for males (433/770 max) in woodland/cultural landscape in Germany (Jerosch et al. 2017).

Gap distance

The distance between individual woodland patches that is likely to be travelled by a species within its home range.

Table 4

Species	max. gap distance (m)	info
Boar	2980	Mean dispersal distance 2.98km in Belguim (Prévot & Licoppe 2013), direct distance between resting places varies between 0-7km (Spitz 1986).
Squirrel	51	Minimum dispersal distance 51m in Belgium in fragmented habitats (mean 1,014m) (Wauters et al 2010)
Marten	1100	Minimum dispersal distance of translocated martens in Wales was 1.1km (mean 8.7km) (McNichol et al. 2020).
Wildcat	1430	Unknown. Maximum mean distance moved by wildcats in a Portugese study was 1.43km (Matias et al. 2021).

Methods

The Argos-Links models is written using the R programming language and is dependent on the following packages: "sf", "plyr", "tidyverse", "purrr", "furrr", "curl", "zip", "terra", "raster", "fasterize", "gdalio", "rmapshaper", "stars", "tmap".

The model is written as a reproducible {targets} workflow. The source code for the model can be found at: https://github.com/h-a-graham/argoslinks

Input Data

The following input datasets are used for this model and should be additionally sited when referring to this model. See table X for the dataset names and references.

Full Name	Short Name	source location
Centre for Ecology and Hydrology, Land Cover Map 2019	LCM 2019	https://catalogue.ceh.ac.uk/documents/643eb5a9-9707-4fbb-ae76-e8e53271d1a0
Copernicus Tree Cover Density, 2018	TCD 2018	https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density/status-maps/tree-cover-density-2018
Ordnance Survey Boundary Line	OS Boundary-Line	https://www.ordnancesurvey.co.uk/business-government/products/boundaryline
Ordnance Survey Open Roads	OS open-roads	https://www.ordnancesurvey.co.uk/business-government/products/open-map-roads

Data Preparation:

- Cornwall county region from the Ordnance Survey Boundary-Lines dataset Extracted as a spatal polygon feature.
- CEH Land Cover Map and Copernicus Tree Cover were Reprojected to 10 m resolution, with equivalent extents and grid alignment, contrained by the cornwall county bounding extent. The LCM was resampled using the "nearest" resampling method and the TCD is resampled using the "cubic-spline" method. This operation is handled using the gdal-warp utility.
- A new raster is reated from the LCM and TCD maps. Regions where the TCD value is >25 were given a value of 1. Regions where the LCM is classed as Broadleaf woodland were given a value of 1. Regions where the LCM is classed as coniferous were given a value of 2 (overriding a value of 1 if previously assigned.) Values not considered woodland were set to 0. Offshore regions were set as NA. We refer to this raster as the Woodland Type Raster (WTR)
- All Roads that intersect the Area of Interest (AOI), in this case the Cornwall county boundary, were extracted from the OS open-roads dataset.

Creating woodland spatial vector

- WTR values that equaled zero were converted to NA. The WTR is then converted to a spatial vector where broadleafed and coniferous were each classified with a unique integer ID (either 1 or 2). The features that fall within 1 km of the county boundary were retained.
- Woodland polygons with an area < 0.1 ha were removed, as these were not considered to reliably contribute valuable woodland habitat.
- The feature geometries were then simplified, retaining 25% of vertices. This improves the performance of spatial operation whilst retaining accuracy.

splitting woodland spatial vector by road network.

- The cornish road network was filtered, selecting only A and B roads. The network was then unionised into a single MULTILINESTRING geometry. Herein referred to as minimal road network.
- A negative buffer of 500 m was applied to the county area and was then split into discrete polygons using minimal road network. The - 500 m buffer is used so that small gaps between road dead-ends and the coastline were not considered as viable connectivity routes. This simplification is required in order to avoid the assumption that viable corridors can form along these areas. In reality, they typically comprise steep cliffs/rocky areas/beaches which were less likely to afford a viable route between woodland patches. The polygon areas created in this step are referred to as road patches.
- Woodland areas that intersect the road patches were retained and a spatial intersection of the road patches and woodland areas is carried out, resluting in a woodland area polygon split by the minimal road network. These features are referred to herein as in-patch woodland.
- The previous intersection step excludes woodland that falls within 500 m of the coastline. These woodlands may provide important habitat. Therefore, woodland polygons that either overlap or do not intersect the road patches were located and subset. Features of this subset that overlap the road pataches are intersected (removing the part of the polygon that is already considered). These features are then then spatially joined to the nearest road patch using a k-nearest neighbours algorithm with a maximum search distance of 750 m. These features are referred to herein as out-patch woodland.
- The in-patch and out-patch woodland features are joined resulting in a woodland area polygon with unique ID attributes, a road patch attribute which denotes the inter-road zone that each woodland polygon belongs to and a woodland type classifier.
- This spatial polygon layer is provided as a layer in the provided dataset (Named: MW_InterRoadCover). This dataset is not species specific but is general and provides a useful overview as to which regions of the county contain woodland (not) intersected by main roads.

Species-level models.

- At this stage, the rules described in Tables 2-4 are used to determine which inter-road zones provide suitable habitat.
- Woodland features are grouped by the road patch ID. For each road patch the following steps are carried out:
  - The area of each invidual woodland patch is calculated. All features with an area less than the minimum patch size (Table 3) are removed.
  - The total area of remaining woodland within the road patch is calculated. If this is less than the minimum Total Woodland Area (Table 2) for the species, all woodland within the roach patch is removed and no features are returned.

- Remaining feature are all buffered by the gap distance (Table 4) divided by 2. The distance is halved because other woodlands are also buffered and this therefore marks the halfway point between woodland areas. Where these buffers intersect, the gap distance is less than the maximum allowed.
- These buffered areas are then intersected by remaining woodland greater than the minimum patch size. Those intersectng areas are retained as viable habitat.
- The Total habitat area is once again checked and if less than the minimum total area, no features are returned.

- Returned woodland features and and buffered areas were retained and spatially joined with the road patches to assign a unique road patch ID for each zone and the patches within the zones.
- These features were then saved in the GeoPackage format.

Output Data

The model results are provided in the directory ArgosLinks/Data/. Data is provided in the GeoPackage format which supports multiple layers and can be read my the majority of GIS software. Two files are provided: *ArgosLinks.gpkg* and *MW_InterRoadCover.gpkg*.

ArgosLinks.gpkg The file contains 8 layers with the one of the follwoing naming conventions: *ArgosLinks_SPECIES_patches* or *ArgosLinks_SPECIES_chunks* .

layers ending with *patches* display the woodland area suitable for a given species. Those ending in *chunks* display the area accessible by the species based on range and road obstructions. Both patch and chunk laers have corresponding **species_region** and **inter_road_zone** attributes that identify habitat regions.

MW_InterRoadCover.gpkg This file comprises a single layer displaying all woodland zones. All zones have a **inter_road_zone** attribute that corresponds with the ArgosLinks dataset. The woodland type - either Broadleaf or Confier is also given as **wood_class**.

Output Interactive Maps

interactive leafleat maps were produced to display the general datasets and individual species level models. And can be found in the following directory: ArgosLinks/Data/LeafMaps. These html files can be viewed in any web browser.

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