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DISTRIBUTION MODELLING OF THE EURASIAN OTTER (*Lutra lutra)* ON THE ISLE OF ANGLESEY, WALES

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Abstract

*The Eurasian otter (*Lutra lutra*) remains a high priority conservation species despite recent increases in UK populations. Specifically, a marked increase in surveyed site occupancy (50%) was observed on the Isle of Anglesey (North Wales) between 2002 and 2009. Understanding the drivers that act upon the distribution of* L. lutra *will allow for more targeted conservation efforts. In this study, species distribution modelling (MaxEnt) was applied to predict the potential distribution of* L. lutra *across Anglesey. Elevation and, distance to roads and water (m) were found to be the most influential factors in determining the distribution of individuals across all models. The generated models performed better than random and were capable of identifying areas where* L. lutra *could potentially occur across Anglesey (AUC = 0.818). Locations for concentrating future research efforts are suggested through analysis of spatial variation, human disturbance effects and population analysis across the study region. This study provides a baseline of* L. lutra *habitation possibility across Anglesey and exposes areas for future conservation in habitat management and research efforts.*

Keywords: *habitat suitability; conservation; management; human impact*

INTRODUCTION

Lutra lutra (Eurasian otter) is a key biological indicator species **(Delibes et al., 2009)** that has experienced a continued population decline during the 1900s **(Conroy and Chanin, 2000)**. Since the 1970s surveys have been conducted across the British Isles to monitor their presence **(Strachan, 2010)** and these have shown a continued expansion and consolidation of their range. However, there are still regions where *L. lutra* previously inhabited which continue to show no presence. In surveys on Anglesey, North Wales, that were conducted prior to 2002 no positive sites were reported. However, after 2002 the island recorded an increase in positive observations (17.9% to 67.5%) between 2002 and 2009 **(Strachan, 2010)**. Little or no formal research has been conducted to quantify the population status on Anglesey, most likely due to evidence from previous surveys suggesting there was possibly no population to monitor (**Strachan, 2010**). The cause of this marked population increase in recent years has yet to be ascertained.

Population and distribution monitoring efforts have been carried out for several decades throughout the UK, commonly through the analysis of spraint distribution **(Macdonald and Mason, 1983)**. Recently, Species Distribution Modelling (SDM) has been used to analyse their distribution **(Jo et al., 2017)**. Field observations of organism presence are coupled with environmental data to determine the niche of a species and this can be used to determine the likelihood of an organism occurring in unsurveyed areas (**Phillips et al., 2018**). One popular technique is known as MaxEnt, which has been found generally to outperform other SDM techniques **(Elith et al., 2006)**. MaxEnt shows robustness to irregular data samples and minor location errors and has been shown to predict accurate models from relatively small sample sizes (n = 25; **van Proosdij et al., 2016)**.

Several studies have assessed the factors that control *L. lutra* distribution **(Ross, 1985; Kruuk, 1995). Jo et al. (2017)** used MaxEnt to identify environmental variables affecting distribution across South Korea and aimed to determine potential distribution and identify regions for focused management and recovery projects. Elevation, land use and human disturbance were identified as key limiting factors. The results were different than those previously conducted within smaller regions of South Korea, suggesting that the results were spatially dependent. The influence of human disturbance on the distribution was also observed to be minimal, concluding that the two species can co-exist. This suggests that individual responses of *L. lutra* to human disturbance may vary **(Strachan, 2010; Jo et al., 2017)**.

Whilst the population of *L. lutra* has increased within the UK, this species remains a high conservation priority **(Roos et al., 2015)**. Specifically, on Anglesey, a population increase of 50% was observed between 2002 and 2009 **(Strachan, 2010)**. However, no specific studies have been conducted regarding the distribution of this species within the area. This study conducted species distribution modelling to help identify potentially suitable habitat on Anglesey. The relevance of findings are discussed by exploring the most important environmental drivers that influence distribution and identifying areas of high habitat suitability future studies and conservation efforts.

METHODS

Study Area

This study was conducted on the Isle of Anglesey in North Wales, which is isolated from the Welsh mainland by the Menai Strait (Figure 1a). The island is predominantly low-lying (<100 m) with its highest peak just 220m above sea level and additional hills/cliffs in the Northeast. Across the island, agricultural pastures account for 80% of total land use, with water bodies accounting for just 0.75% **(Rae, 2017)**. No rivers exceed 25km in length and they are generally narrow. Their gradient, low energy and bankside cover provide prime conditions for *L. lutra* habitation **(Strachan, 2010).**

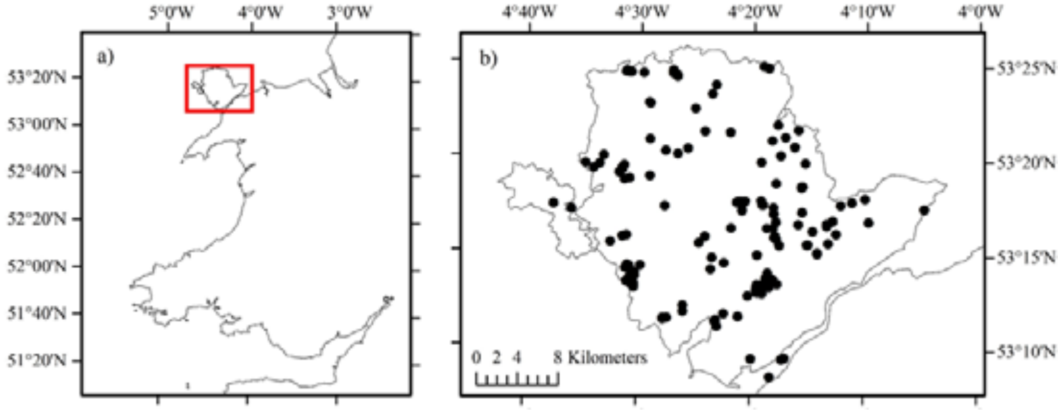

Figure 1. Distribution (2011 – 2016) of* Lutra lutra *across Anglesey from the Cofnod compiled database in WGS 1984 UTM 30°N for a) location of study site, b) sightings.

Presence Data

Cofnod, (North Wales Environmental Information Service) a Welsh organisation that compiles large data sets of species observation records to produce one centralised database, provided presence data for *L. lutra* across Anglesey (Figure 1b). Records between 2011 and 2016 were selected as the most current for distribution analysis. The record type (categories: live sighting, spraint and road casualties) were assessed to determine their suitability for distribution modelling. Road casualties were further omitted from analysis due to these not being a true representation of habitat utilisation. A total of 243 presence records were used for analysis.

Environmental Variables

A total of four environmental layers (distance to coastline, railway, roads and freshwater), elevation and a land cover map were compiled from three data sources and used in analysis (Table 1).

Table 1. Environmental data sources and original resolution used in this study.

Variable	Native Resolution (m)	Categories	Source
Distance to coastline (m)	200	1	*Open Street Map Contributors (2018)*
Distance to railway (m)	200	1	*Open Street Map Contributors (2018)*
Distance to roads (m)	200	1	*Open Street Map Contributors (2018)*
Distance to freshwater (m)	200	1	*Open Street Map Contributors (2018)*
Elevation	1000	1	*OS Terrain 5 (2018)*
Land cover	1000	10	*Jackson (2000)*

The 2015 land cover map of Anglesey (**Land Cover Map 2015, 2018**) provided information on the ten land use categories across the island in 1km squares. Elevation data was provided in 5km grid squares (**OS Terrain 5, 2018**) and these were stitched together in ArcGIS using the 'Mosaic to New Raster' tool providing a range of 0 – 220m. The environmental data layers were imported from Open Street Map in vector form **(Open Street Map Contributors, 2018)**. As the statistical model used in predictive distribution (MaxEnt) cannot read vector data these were converted to Raster form using 'Euclidean Distance' analysis in ArcGIS. The maximum distance (m) used in transformation was dependent on the feature being analysed (coastline = 11,000m, railway = 11,000m, road = 2,500m and water = 4,000m).

Statistical Data Analysis

Presence data of *L. lutra* was partitioned randomly generating 90% training and 10% test data (used to test produced models). These were then cross-validated using 100 random partitions comparison of fit to test presence data using AUC (Area Under Curve). Models with an AUC of 0.5 represent a no better than random prediction, whilst an AUC of 1.0 denotes a perfect fit (**Baldwin, 2009**). Raw output of MaxEnt is the importance of each layer and estimate of relative suitability of one location compared to another **(Ward et al., 2016)**.

RESULTS

The distribution model produced performed well across validation metrics with a mean AUC value of 0.818 (Table 2) and was significantly different from that of a random prediction (AUC = 0.5; Wilcoxon rank-sum test, $p < 0.01$). The omission rate observed (12%) indicates that only few presences were misclassified and that the predictions were more probable than that of a random background pixel (Table 2).

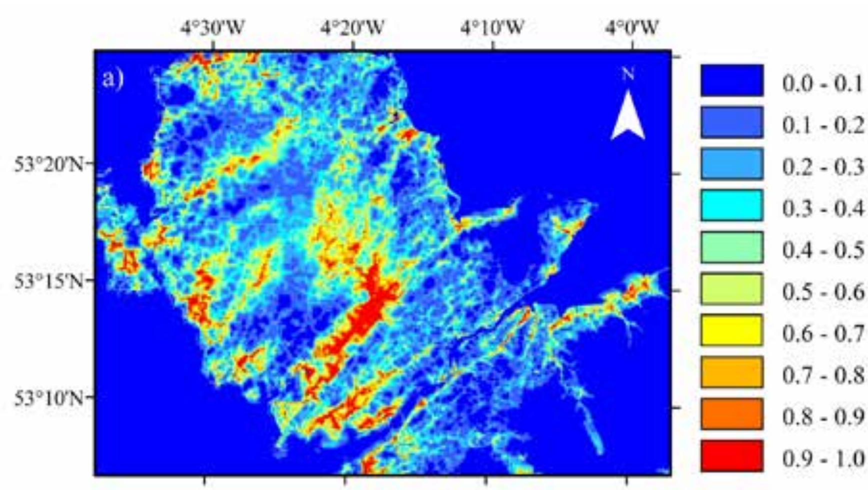

Figure 2. Pointwise mean* Lutra lutra *potential distribution (habitat suitability) across Anglesey from 100 cross validation runs of MaxEnt, based on six environmental factors (elevation, land use and distance to coastline, railway, road and water (AUC = 0.818) in a WGS 1984 UTM 30N map scale. Map cropped to the extent of the data.

The MaxEnt models identified suitable habitat for *L. lutra* across Anglesey (Figure 2) and the majority was around Malltraeth Marsh, Rhosneigr and, Afon Cefni, Braint and Alaw. The land South of Red Wharf Bay had predictable low probability of *L. lutra* habitation (Figure 2).

Table 2. Analysis of statistics and jack-knife variable contributions to the models produced by MaxEnt.

Variable	
Validation Statistics	
Test AUC	0.818
Test gain	0.822
10th percentile training presence	0.472
Omission rate (threshold 10)	12%
Jack-knife of variable importance	
Distance to coastline (m)	0.017
Elevation (m)	0.503
Land use	0.065
Distance to railway (m)	0.054
Distance to roads (m)	0.246
Distance to water (m)	0.222
Test AUC for a single variable	
Distance to coastline (m)	0.554
Elevation	0.761
Land use	0.587
Distance to railway (m)	0.586
Distance to roads (m)	0.678
Distance to water (m)	0.681

MaxEnt identified the variables most likely to influence the probability of species presence (Table 2). Jack-knife analysis of variable contribution and test AUC scores for single variable models showed that the highest contributions to habitat suitability were elevation, and distance to roads and water (Table 2).

DISCUSSION

Habitat Suitability

This study found elevation to be the most influential environmental variable affecting *L. lutra* distribution on Anglesey. The combination of two aspects creates the limiting effect of elevation: the availability of food and air/water temperatures. Elevation has been observed to influence the distribution of *L. lutra* in previous studies **(Macdonald and Mason, 1983; Kruuk, 1995; Jo et al., 2017)** with only one record of the species in a highly elevated region (Tibet, 4120 m; **Macdonald and Mason, 1983**). The effect of increased elevation on the physiological requirements of individuals is threefold: drop in atmospheric pressure, drop in temperature and reduction of oxygen concentration. The key limiting factor most influential in semi-aquatic mammals is that they do not possess thick layers of fat or blubber to protect themselves as the temperature decreases with increased elevation **(Crait et al., 2012)**. **Kruuk (1995)** observed that with decreasing temperature, foraging time increased as a result of significant heat loss. The increase in thermoregulatory energy requirements means an increased need for food, thus increasing foraging time. The limitation of prey availability with increased elevation **(Ruiz-Olmo, 2007)** is an additional factor imposing increased foraging times upon individuals. The regions observed in this model with a suitability of <20% were all locations above 75m and this demonstrates a clear avoidance of highly elevated regions by *L. lutra* on the island. The region South of Red Wharf Bay for example, showed the greatest area with low suitability (elevation height of 175m).

Distance to water (m) was also found to influence *L. lutra* distribution across Anglesey. However, this was for freshwater with distance to coastline (m) and therefore saltwater was found to have little influence on the distribution. This infers that at present the population may not be exploiting the coastal marine habitat and are purely freshwater, although this could be confirmed by more detailed study. The generally narrow and short rivers across Anglesey lead to a high fish carrying capacity **(Rae, 2017),** thus increasing prey capture success rates, with brown trout and eels widespread in the island's waterways **(Hunt and Jones, 1972)**. In this study, all *L. lutra* reports were found within 400m of freshwater. The closeness to water, along with improved waterways and availability of fish in rivers could explain the increase in positive survey sites throughout the UK as a correlation has been noted between breeding success and prey availability **(Kruuk and Moorhouse, 1991)**.

Whilst *L. lutra* are known to be highly affected by human disturbance, recent research has shown the scale of tolerance to be dependent upon individual variation **(Strachan, 2010)**. This was echoed in our study, with the distance to roads (m) found to be a limiting factor in the habitat suitability models. Therefore, tolerance to disturbance is higher than previously thought with individuals, on average, being found closer to roads than waterways (100m and 400m, respectively). The construction of new roads in particular has the greatest impact as they use traditional paths, which often cross such developments **(Macdonald and Mason, 1983)**. Whilst land use, particularly agricultural pastures has been found to impact habitation, in this study it was found not to be a limiting factor.

The increase in *L. lutra* populations between 2002 and 2009 does suggest that individuals on the island may be consolidating their territories and breeding **(Strachan, 2010)**. However, such increases need to be treated with caution, as they do not necessarily infer a population increase. This study identified three key rivers that had the highest habitat suitability and are therefore most likely to be exploited by *L. lutra* across the island: Afon Alaw, Braint and Cefni. The areas of Malltraeth Marsh and Rhosneigr are wetland regions on the island that also had high habitat suitability. These regions are most valuable for future protection. In general, almost all waterways on the island show high habitat suitability for otters with only regions more than 75m above sea level found to have the lowest suitability.

STUDY LIMITATIONS

Whilst this study has produced some significant findings there are still some factors that should be considered when interpreting the results. Firstly, the variety of sampling methods **(Cofnod, 2018)** used in this compiled data set, allows for the possibility of sampling bias and therefore, all results should be taken with care and as indicative. The output and weakness of the MaxEnt algorithm has the possibility for significant over-prediction of habitat suitability, and this has been mostly noted in small presence data sets which were not analysed in this study **(Papes and Gaubert, 2007)**. The data analysis was conducted based on the presence of spraint and this has been shown not to be an extensive representation of habitat use by *L, lutra* as spraint deposits are subject to seasonal changes. It has also been found that spraints are left in some vegetation types, banks or areas, but not in all habitats **(Conroy and French, 1987)**. Several variables that may influence distribution (e.g. water quality and human disturbance; **Jo et al., 2017**) could not be included in the analysis either due to insufficient resolution available or such data not being available. The use of the term habitat preference should also be taken with care as it does not always infer habitat usage **(Kruuk et al., 1998)**.

CONCLUSIONS

This study provides a baseline for future research efforts of *Lutra lutra* on Anglesey with results being indicative and not conclusive. Whilst the output models do not pinpoint specific areas of habitation it is useful for directing future research efforts and indicates highly probable regions of suitability. This study found elevation to be a key limiting factor on presence and this greatly influences food availability and air/water temperatures. An analysis of Anglesey fish populations and resultant availability, along with specific *L. lutra* population analysis is further required to infer the potential causal factor of the increase in positive survey sites observed between 2002 and 2009. This study has been key in providing a baseline of *L. lutra* habitation probability across Anglesey and denoting areas for future conservation and research efforts. Areas of research concentration pointed out by this study include, spatial variation, effects of human disturbance, and specific population analysis.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

Author Biographies

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