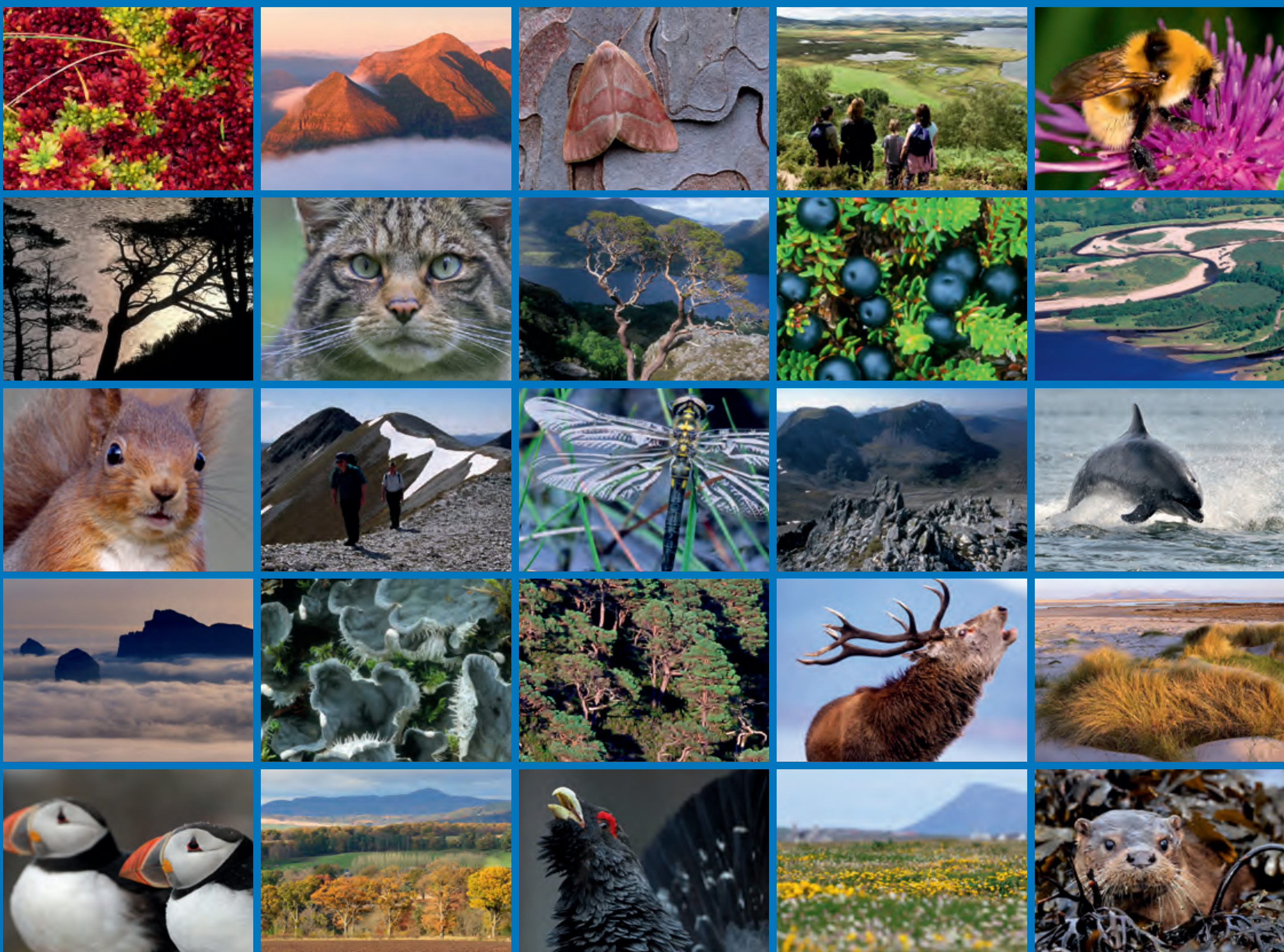
Scottish Natural Heritage
Commissioned Report No. 452

Simulation model for the management of American mink, *Neovison vison*, on Harris and Lewis



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COMMISSIONED REPORT

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Simulation model for the management of American mink, *Neovison vison*, on Harris and Lewis

For further information on this report please contact:

Iain MacLeod
Scottish Natural Heritage
32 Francis Street
STORNOWAY
Isle of Lewis
HS1 2ND
Telephone: 01851 705258
E-mail: iain.macleod@snh.gov.uk

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COMMISSIONED REPORT

Summary

Simulation model for the management of American mink, *Neovison vison*, on Harris and Lewis

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Keywords

American Mink; *Neovison vison*; Simulation model; Outer Hebrides, Hebridean Mink Project; spatially explicit; eradication.

Background

An individual-based computer simulation model was commissioned by Scottish Natural Heritage (SNH) to assess efficacy of the control strategy for the removal of the Outer Hebrides mink population. Mink were introduced to Lewis and Harris in the late 1950s (Cuthbert 1973), as a result of escapes from fur farms. They have spread throughout Lewis and Harris with significant detrimental impacts on breeding birds, populations, aquaculture, fisheries and poultry (e.g. Rae 1999, Roy 2006).

Specific objectives of the work were to:

1. develop an individual-based mink model suitable for the Outer Hebrides.
2. parameterise the model using local and published data from the literature.
3. use the model to predict future population trajectories under agreed control scenarios.

Main findings

1. An individual-based simulation model of mink populations was developed to investigate the predicted effect of methods to eradicate this invasive mammal species. The spatially-explicit approach simulated the spread of mink through Lewis and Harris based on two introduction nuclei (I. Macleod pers. comm.).
2. The model was spatially explicit in that landcover data of Lewis and Harris were used to define potential mink habitats. In collaboration with the Hebridean Mink Project (HMP), these were defined as: crofting, Uist farming, machair, boggy moorland, knock and lochan, rock and lochan and mountain massif.
3. The model integrated this spatial information with mink life history data and spatially and temporally explicit HMP control efforts.
4. The model simulated HMP trap locations and trap zones based on a temporal sequence provided by the project. Future trapping scenarios relied on information by HMP on the scale and timing of likely control operations.
5. Three main scenarios were simulated. These included: (i) population expansion with no trapping; (ii) trapping from 2007 until 2012 and (iii) trapping from 2007 to 2011 followed by two years of no trapping. The latter scenario was extended to illustrate the likely population decline to 2013 if trapping effort continued, for a minimum (HMP

estimate) and a maximum (model estimate) mink carrying capacity of Lewis and Harris.

6. Model predictions suggest that following a release of 30 animals in two locations, carrying capacity was reached after approximately 20 years of population expansion (Mean: 1605; range: 1461-1787).
7. An analysis of HMP trap data showed that the average mink trap had a 60% chance of catching a mink with no significant seasonal changes across the year.
8. Traps in waterside habitats and moorland were significantly more likely to catch mink than those in mountain habitats.
9. The analysis also indicated that there were significant differences in the probability of a trap catching a mink between years (2001-2009). There was an observed increase in 2008 with traps in that year being 1.33 times more likely to catch a mink than traps in 2007. The probability of a trap catching a mink declined in 2009. This may reflect the history of the HMP with an increase in trapping effort from 2007 to 2008.The decline in trap hazard in 2009 suggests that the mink control strategy was effective. The mink population was declining which resulted in a lower probability of captures with similar or increased trap effort.
10. Modelled control scenarios based on HMP trap locations and effort over time predict that, if trapping effort is continued in 2011 and 2012, there will be approximately 329-599 mink remaining across Lewis and Harris. The model suggests that the probability of an individual mink being present would be highest in the north and north-west of the island.
11. Model predictions simulating a stop to control efforts indicate a clear population recovery with a doubling of the above predicted remaining population of 329-599 within two years. Probabilities of mink being present would again be highest in the north and north-west of the island.
12. Two scenarios were investigated if current control efforts were to continue until 2013. One based on a minimum carrying capacity (HMP estimate) and one on a maximum carrying capacity (model predictions). The model suggests that mink may be extinct by 2013 in the lower carrying capacity scenario or reduced to a small remnant population (250±70) for the maximum carrying capacity scenario.

The true remaining population of mink is likely to lie somewhere between the conservative HMP mink population estimate and the maximum predicted by the model. Whilst eradication by 2013 appears achievable with current trapping effort, the likely error associated with predictions as well as potential changes in mink behaviour (not included in model predictions) once population levels drop to small numbers, would make monitoring efforts post 2013 strongly advisable.

For further information on this project contact:
Iain MacLeod, Scottish Natural Heritage, 32 Francis Street, Stornoway, Isle of Lewis, HS1 2ND.
Tel: 01851 705258 or iain.macleod@snh.gov.uk
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research@snh.gov.uk

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1. METHODS

The model employed in this project is an individual-based, spatially-explicit model. It falls under the general category of process-based models. These model the underlying processes at the level of the individual but lead to population level outputs. By modelling processes at the level below that of the desired output, the model accounts for emerging behaviour such as density dependence, heterogeneous movement patterns, dynamic carrying capacity, and greater importance of stochastic events at low population densities.

The model used here is a variation on published individual-based models of mammals (Rushton et al. 1997, Rushton et al. 2000, Lurz et al. 2001, Shirley et al. 2003, Rushton et al. 2006, Shirley et al. 2009). A full description of the model with its variations will soon be available in the scientific literature; in the meantime, the description of the UWP model of hedgehog populations (Shirley et al. 2007, Shirley and Lurz 2010) is the most complete description of the structure of this model available.

1.1 Model landscape

The model relies on a raster map of habitats of relevance to mink (Figure 1). In common with Ratcliffe *et al*. (2008), islands over 2 km from the mainland or a shoreward island chain are excluded from the habitat map. Habitats of relevance to mink on the Outer Hebrides include the shoreline, riverbanks, and the edges of lochs. The preliminary map for this model was taken from the UK 2000 Landcover data set. The inland water and estuary habitat types were extracted, and a 100 m buffer put around the landward side of these linear features. The Bartholomew Maps dataset provided the location of rivers. A 100 m buffer was placed either side of each river. These buffered maps were added together to provide the available habitat for mink to utilise.

Following discussion with the HMP, the project supplied a new map in which habitats such as boggy moorland or mountain massif (Table 1) were considered unsuitable or only occupied by itinerant individuals rather than breeding populations. The map also refined habitat types along some coastal areas where higher quality crofting areas alternated with boggy moorland.

Table 1. Main habitat types on Lewis & Harris

Habitat type	SNH map code
Crofting	295-298
Uist farming	299
Machair	300
Boggy moorland	301-302
Knock & Lochan	303
Rock and Lochan	304
Mountain massif	305-306

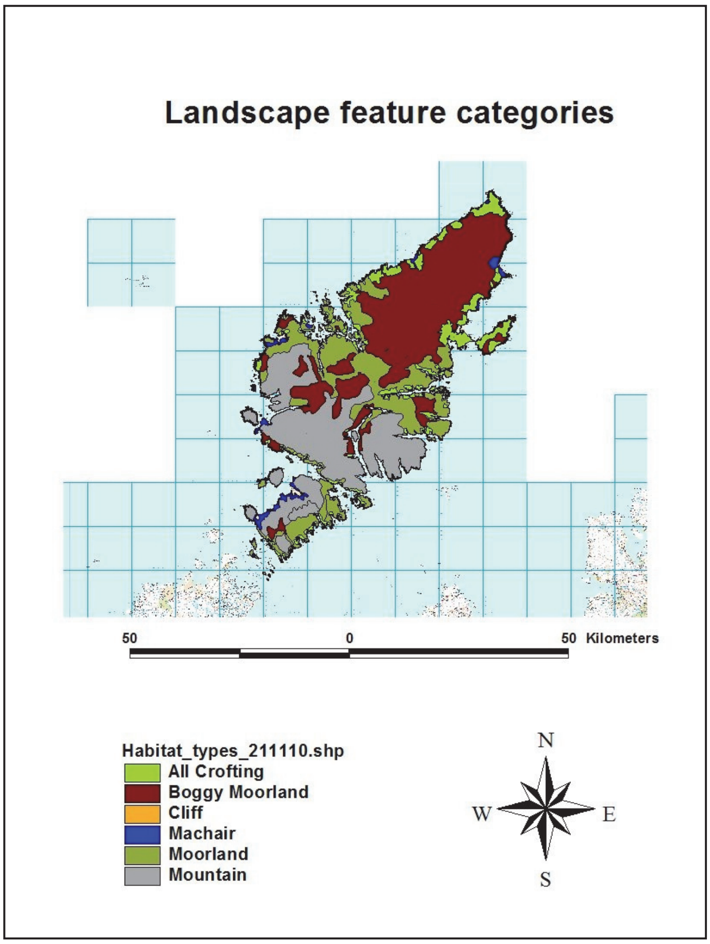

Figure 1. Broad habitat map of Lewis and Harris. (Map provided by HMP)

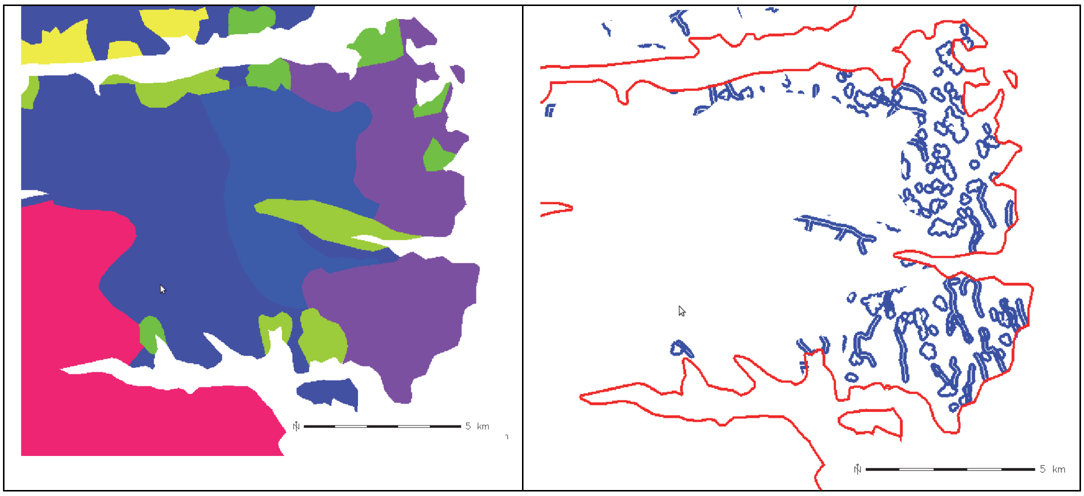

Figure 2. Zoomed in habitat map (left) of crofting habitats (yellow and green), moorland (shades of blue), knock & lochan (purple) and mountain massif (red) and how this was translated into available mink habitat along e.g. stream sites, lochs (right map in blue) and coastline (right map in red).

Figure 1 and Figure 2 illustrate how available habitat types supporting different observed densities of mink, such as stream and lochside habitat or coastal shore (Table 2) were simulated within the model. Note that on advice from HMP, the simulations presume mink are absent from boggy moorland and mountain massif. Whilst these habitats may not support breeding populations, the presence of itinerant mink cannot be completely excluded. The fact that this represented an error in terms of predictions was discussed with HMP together with a need for monitoring. Initial simulations that allowed breeding populations in these areas led to significant over-prediction of resident mink. In the absence of data that would allow a finer differentiation of the habitat map with respect to boggy moorland, model predictions are therefore a potential but slight under-prediction.

1.2 Model description

The model integrates spatial information on landcover types, mink life history data and known interactions with trapping effort (Figure 3).

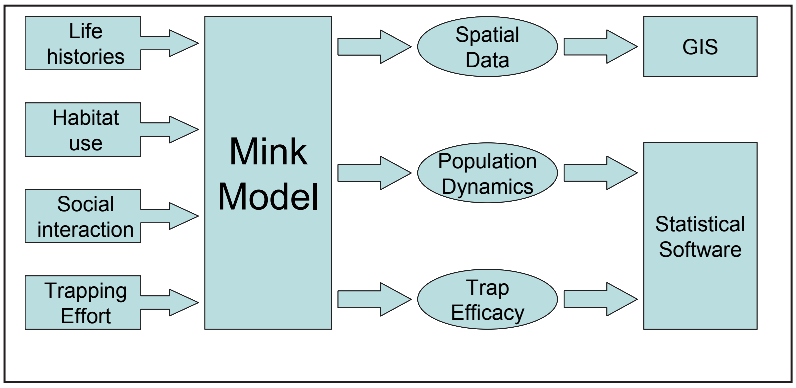

Figure 3. Diagram illustrating the spatially explicit modelling approach

1.2.1 Individual-based modelling approaches

Individual-based models simulate the dynamics of a species in terms of the life histories and dispersal movements of individuals rather than operating on a life stage or a population as a whole. The current model has a monthly time step, and at each time step each individual experiences up to six life history processes, depending on the month and the location of the mink (Figure 4). These are ageing, mating, birth, death, dispersal, and control.

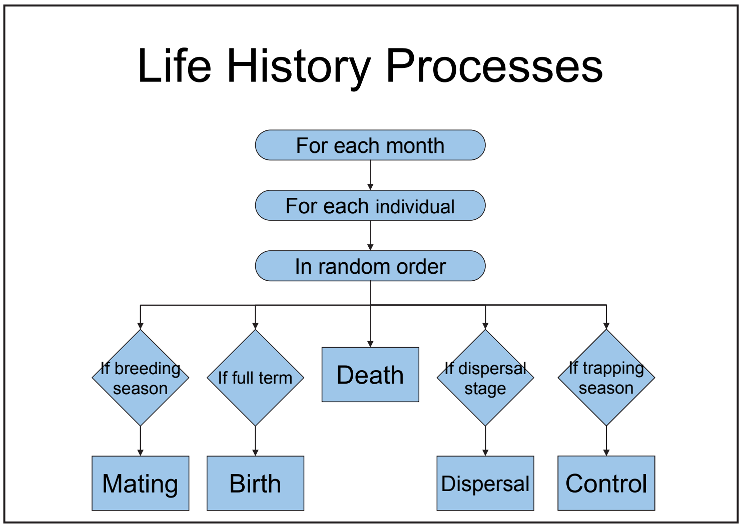

Figure 4. Overview of modelled life history processes in the mink model. Note that ageing is subsumed within the time step.

Ageing occurs first at every time step. The other processes occur in a random order, but all individuals in the population experience the same order of events each month. This minimises any dependence on event order in the model. Models that are explicit in terms of space also hold information regarding the location of the simulated population, and apply habitat-specific constraints on the processes that affect changes in population size and location.

1.2.2 Ageing

During the ageing process, all individuals were advanced in age, and their life stage (young or adult) was determined from their new age. Young mink were defined as not yet having had a breeding season; adult mink had had one or more breeding seasons.

1.2.3 Mating

The mating process only occurred in a month designated as a breeding month, and there was one breeding month in each year (Table 2). In a breeding month, each female of breeding age had a probability that she would attempt a mating. A female attempting to mate interrogated her immediate environment for a suitable mate. All adult males found at a distance from the female which was within the maximum nightly ranging distance of a male mink (which was varied as a model input) were considered to be suitable mates, although males who were fathers, sons or siblings of the female in question were rejected. Less than 0.01% of all possible matings in the model were rejected due to inbreeding avoidance. Of the remaining males whose home range fell within the radius of the female's position, a mate was chosen at random. It was assumed that all meetings between suitable mates resulted in a pregnancy (i.e. copulation success equals one). Note that the result of this process - a female mink impregnated by a random, non-related, neighbouring male mink - is the same if instead the males interrogate the landscape for females. The proportion of females who successfully found a mate at each time step (i.e. breeding success) was recorded as an output of the model.

1.2.4 Birth

The birth process occurred only to those females who had successfully mated, and only after the requisite gestation period had elapsed. The litter size for each birth was determined by sampling deviates from a triangular distribution using known minima, maxima and peak litter sizes and these were varied as model inputs. Young were assigned a sex based on the primary sex ratio of the population, which was also a model input.

1.2.5 Mortality

The probability of death for each individual was determined by sampling deviates from a uniform distribution in the range 0 to 1, with mortality occurring if the deviate was in the range of the mortality for the relevant factor. All mortality rates were dependent on stage, and were varied as model inputs. For simplicity, no seasonal variation in mortality rates was included, instead temporal trends in mortality were averaged throughout the year.

1.2.6 Dispersal

In a spatially-explicit model, dispersal and the establishment of new home ranges by successful dispersers is a key stage in predicting the spread of an invasive species. The model allows mink to move up to their dispersal distance in an attempt to find a home range, although they search close to their natal home range before looking further afield. This ensures that space left vacant by mortality is filled (Figure 5).

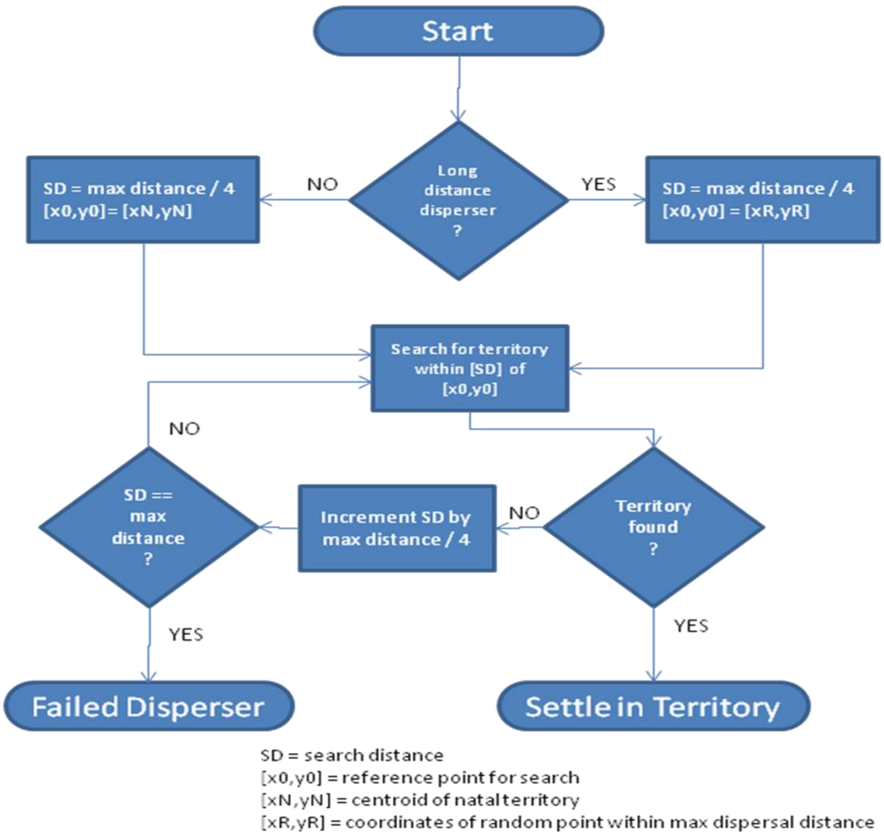

Figure 5. Flow diagram explaining the process of mink dispersal

Lacking specific information on mink dispersal on the Outer Hebrides, the dispersal behaviour was modelled in a generic fashion. A given proportion of animals (arbitrarily set at 10%) was randomly assigned as long distance dispersers which migrated to a start point distant from their natal group. Other animals used their natal territory as a start point. Potential territories were examined within four circles of this start point with radii (search distances, or SD) of a quarter, a half, three quarters, and the full maximum dispersal distance. Space for territories was assessed for suitability based on the presence nearby of conspecifics.

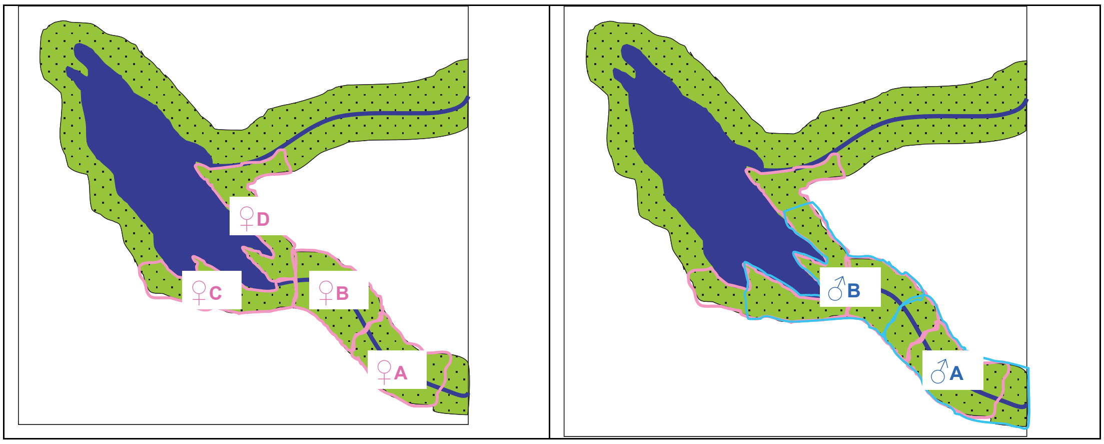

Figure 7. Illustration of female home ranges coloured pink (left) and overlapping female and male ranges in blue (right). Dark blue represents water, green represents usable habitat in proximity to water.

Male mink could not establish a home range within a critical distance of a resident male home range; and females likewise avoided settling too close to an existing female home range. Males ignored females when settling, and vice versa (Figure 6). The critical distance is calculated based on the ideal inter-point distance for a non-aggregated, non-uniform dispersion.

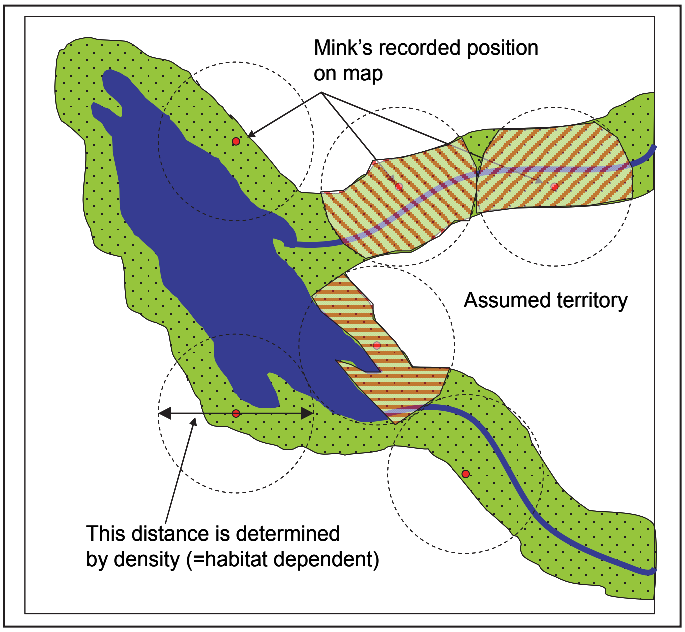

Figure 8. Simplified illustration of mink territories in different habitat types (loch and stream territories).

Density estimates given in Table 3 were converted from numbers per kilometre to numbers per kilometre squared, based on a 100 m buffer zone from the linear feature. For example, 1.01 mink per km of shoreline was equivalent to 1.01 mink in 0.1 km^2 of shoreline, or 10.1 mink km^{-2}. Likewise, 0.209 mink per km of river was equivalent to 0.209 mink in 0.2 km^2 (because both banks were utilised), which resulted in a density of 1.05 mink km^{-2} (see also Figure 8). The result of this process was a dynamic population density based on the current availability of spaces and the suitability of that space to the current list of dispersers. This was deemed more realistic than an artificial notion of 'carrying capacity' of the habitat.

1.2.7 Control

Control in the model was applied using the HMP trapzones (Figure 9) and the model simulated the actual spatial and temporal trap sequence as supplied by HMP (I. Macleod pers. comm.).

Exact trap locations used in the HMP were used to apply simulated control to the same locations in the model. Trapping regimes were followed as closely as possible to actual practice, activating traps in the same temporal and spatial patterns as in the HMP. Control was simulated by applying mortality for each trap that fell within each individual's territory. Trap mortality was calculated from the output of the survival analysis (Section 2.1), adjusted for habitat. Neither age nor sex of the mink, nor season of the year, were significant predictors of trap mortality.

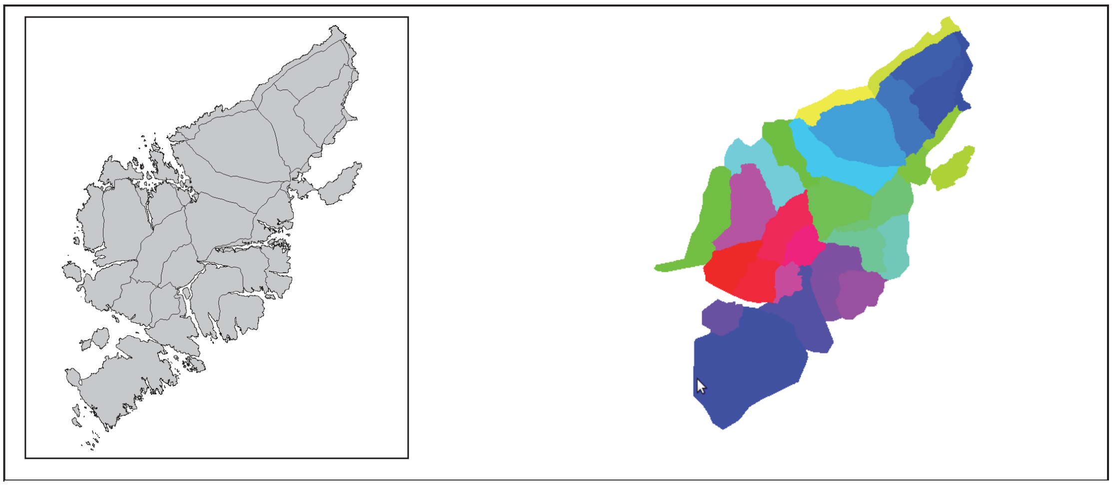

Figure 9 Division of Lewis and Harris into trap zones as used by the HMP

1.2.8 Starting conditions

Following consultation with HMP (I. Macleod), the model simulated an initial starting condition of 30 individuals in two separate locations at Dalmore and Steinish. The release of mink would have led to the islands being colonised and reaching carrying capacity after approximately 20 years (Figure 10).

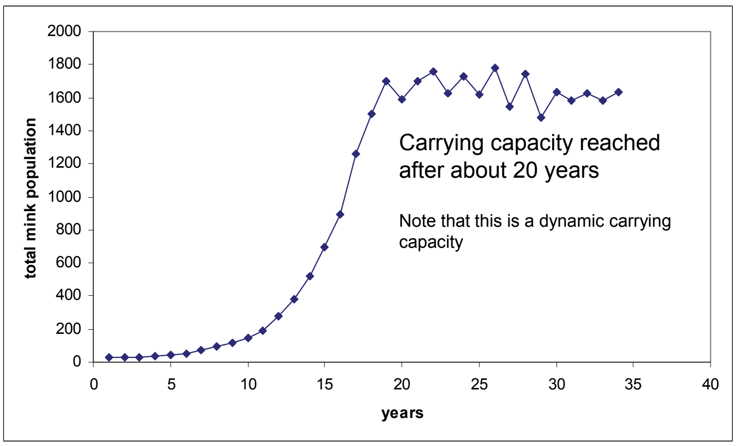

Figure 10. Simulated mink population growth on Lewis and Harris. Carrying capacity is reached after approximately 20 years.

1.2.9 Parameter values

The parameter values currently employed in the model are derived from the available literature (Table 2 and Table 3). We have followed standard practice for spatially-explicit individual-based models (e.g. Łomnicki 1999, Grimm et al. 2006, Rushton et al. 2006) in using probabilities of events occurring as our prime driving variables. The value of the probability is compared with a random deviate drawn from a uniform distribution to determine whether the event occurs or does not. Where driving variables take the form of random whole numbers (e.g. litter size), then the distribution used (usually a triangular distribution) is given in Table 2 and Table 3. Some variables have no stochastic variation; these are typically variables which limit the upper or lower bounds of a modelled process; in these cases stochasticity is realised by other parameters or processes in the model.

Table 2. Llife-history and ranging parameters for mink,and their values

Variable name	Explanation	Value	Sources
Adult Age	age (months) at which animal can first breed	9	(Birks and Dunstone 1991)
Breeding Month	Time steps in which a female looks for mates	3	(Birks and Dunstone 1991, Dunstone and Macdonald 2008)
Mating Success	proportion of females attempting to breed	1.0	(Birks and Dunstone 1991)
Gestation Period	months	2	(Birks and Dunstone 1991, Dunstone and Macdonald 2008)
Litter Size, Min Litter Size, Peak Litter Size, Max	parameters of a triangular distribution	2 5 7	(Gerell 1971)
Sex Ratio	primary sex ratio: (number of females born) / (number of males born)	0.5	(Dunstone and Macdonald 2008)
Adult Mortality	Monthly individual probability of death	0.03	(Gerell 1971)
Juvenile Mortality	Monthly individual probability of death	0.19	(Gerell 1971, Bonesi et al. 2006)
Dispersal Age	age (months) at which the individual disperses	3–5	(Birks and Dunstone 1991)
Dispersal Distance	Maximum dispersal distance	50 km	(Mitchell 1961, Gerell 1971)
Ranging Distance	maximum distance moved to find mate	14 km	(Dunstone 1993)

Table 3. Habitat-specific parameters and their values and extra habitats. The values for stream/river and loch were averaged

Variable	Explanation	Value	Sources	Hebrides
Density	Mink numbers per kilometre of shoreline	1.01	(Moore et al. 2003)	Yes
Density	Mink numbers per kilometre of stream/river and loch	0.194	(Moore et al. 2003)	Yes

2. RESULTS

2.1 Analysis of mink capture data

Trap data from the mink project (2007-2009) were analysed using a Cox proportional hazards model (following Therneau and Grambsch 2000) to derive a model parameter value regarding the probability of a trap catching a mink. For the purpose of the analysis the time of year, together with habitat information abstracted from the GIS and classed into: mountain, moorland, grass, machair and water-side. Both single event and multiple event analyses were undertaken (Therneau and Grambsch 2000).

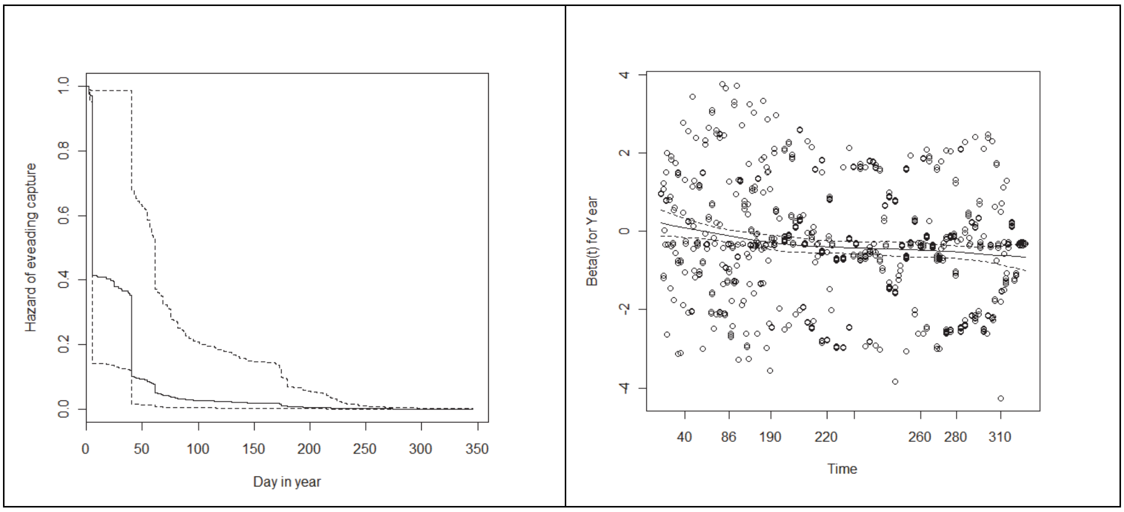

Figure 11. Graph indicating the chances of an individual mink evading a trap (40% at time 0; left) indicating that on average a trap had a 60% chance of catching a mink within the first 10 days. There was no change in capture risk over time (see right).

Results showed that on average a trap had a 60% chance of catching a mink within the first 10 days (Figure 11). An analysis to determine whether there was a seasonal change to the probability of catching a mink indicated that there was no change across the year (Figure 11). In other words, the parameter value could be kept constant in the model and there was no need to change it seasonally for the different periods when trapping occurred.

Table 4. Cox proportional hazards analysis results. Note: Mountain habitat is used as baseline (lowest N of captures). Asterisks represent the degree of significance: '' indicates the [0.05, 0.001) range, '**' the [0.001, 0.0001) range, and '***' the [0.0001, 0] range.*

Variables	Coefficient	Exp(coef)	Se(coef)	z-value	Pr(>|z|)	
Year	-0.33366	0.171630	0.05003	-6.670	2.56e-11	***
Moorland	0.29916	1.34872	0.13220	2.263	0.0236	*
Machair	-0.24729	0.78092	0.21206	-1.166	0.2436	
Grassland	-0.30057	0.74040	0.28107	-1.069	0.2849	
Water-side	0.96509	2.62503	0.13280	7.267	3.67e-13	***

The findings indicate that traps set in moorland and water-side habitats are significantly more likely to catch mink than those in mountain (the comparator). For example, a trap in a watery habitat (Table 4) is 2.6 times more likely to catch a mink as one in a mountainous area. The hazard (or probability) of catching a mink in mountain, machair and grassland habitats are broadly similar.

In addition, there were also significant differences in the 'hazard of catch' between years (Table 5).

Table 5. Hazard analysis of any year effects comparing the years 2008 and 2009 to 2007. Asterisks as in Table 4.

	Coefficient	Exp(coef)	Se(coef)	z-value	Pr(>|z|)	
Year 2008	0.29108	1.33787	0.09438	3.084	0.00204	**
Year 2009	-0.66675	0.51337	0.11016	-6.053	1.43e-9	***

Taking 2007 as the comparator year, the data in Table 5 clearly show that traps in 2008 were 1.33 times more likely to catch mink than in 2007, whilst the hazard for a catch in 2009 was only half that of 2007.

The results of the analysis were used as an estimate of the likely effectiveness of the traps, based on the year of trapping and the habitats in which they are found. They also reflect the history of the HMP with an increase in trapping effort from 2007 to 2008, since the new traps were put into previously untrapped areas where mink populations had not yet been subject to direct control. The following decline in trap hazard in 2009 suggests that the control strategy was working and the mink population was declining, resulting in fewer captures with similar or increased trap effort.

2.2 Model scenarios

Following discussions with HMP project staff at the end of 2010, the following scenarios were agreed and investigated using the model:

1. Population expansion with no trapping
2. Trapping from 2007 until 2012
3. Trapping from 2007 to 2011 followed by two years of no trapping

Table 6. Detailed overview of presented scenarios with no trapping (1), trapping 2007-2012 (2), and trapping until 2011 followed by 2 years of no trapping (3).

Year	Scenario 1	Scenario 2	Scenario 3
2006	NT	NT	NT
2007	NT	T	T
2008	NT	T	T
2009	NT	T	T
2010	NT	T	T
2011	NT	T	T
2012	NT	T	NT
2013	NT	stop	NT

In addition, scenario 3 (Table 6) was extended to illustrate the likely population decline to 2013 if trapping effort continues (similar effort to previous years) for a minimum (HMP estimate) and maximum (model estimate) carrying capacity.

2.2.1 No control scenario

Population estimates were based on an initial introduction event of 30 animals in two locations (see section 1.2.8) and subsequent simulations of a 40 year expansion period. Carrying capacity was reached after approx. 40 years and Figure 10 illustrates population growth from

2007 to 2013 in the absence of trapping. Population estimates suggest a total carrying capacity of Lewis and Harris of about 1600 animals (average 1606) with a lowest estimate of 1461 mink (Figure 12). However, life history parameters used in the model are a combination of local data and data derived from the literature from other regions. Predictions are probably based on a maximum estimate of carrying capacity (Macleod, pers. comm.) and results using a lower value based on HMP estimates are also presented (see section 2.2.4).

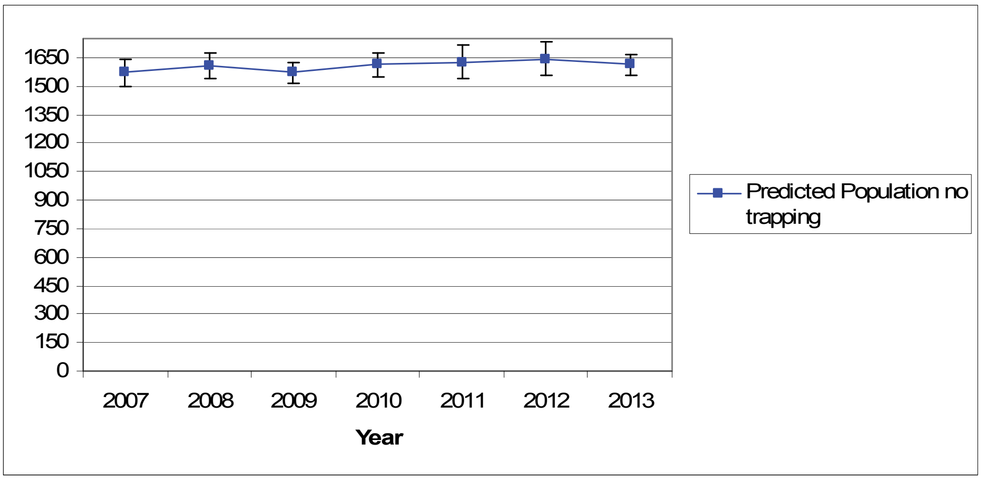

Figure 12. Predicted mink population for Lewis and Harris in the absence of trapping. Points and error bars represent the mean and standard deviation of 100 replicate runs of the model.

2.2.2 Trapping from 2007 until 2012

Model predictions based on the actual trap locations and calculated trapping effort until 2011 (project data base) plus likely trapping effort for 2012 suggest that the sustained control programme would reduce the mink population to approximately 329-599 animals across Lewis and Harris (see Figure 13 and Figure 14).

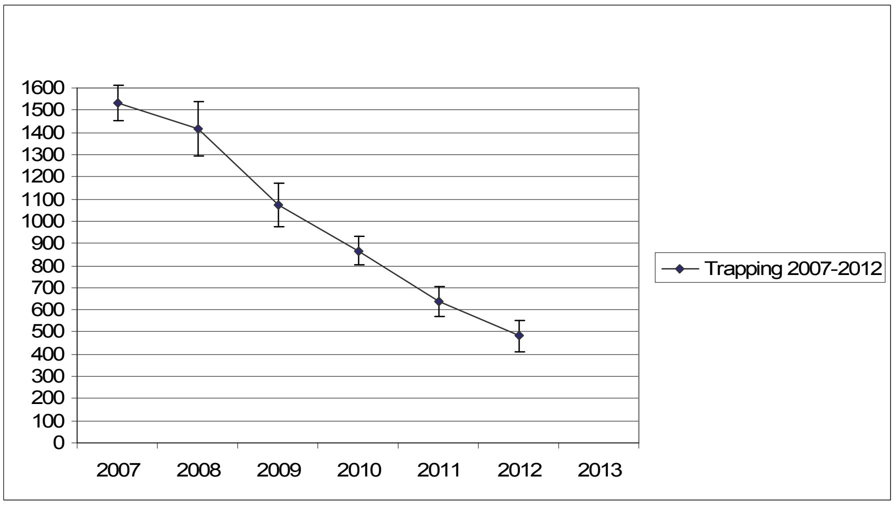

Figure 13 Predicted mink population trend following actual and proposed trapping from 2007 to 2012. Points and error bars represent the mean and standard deviation of 100 replicate runs of the model.

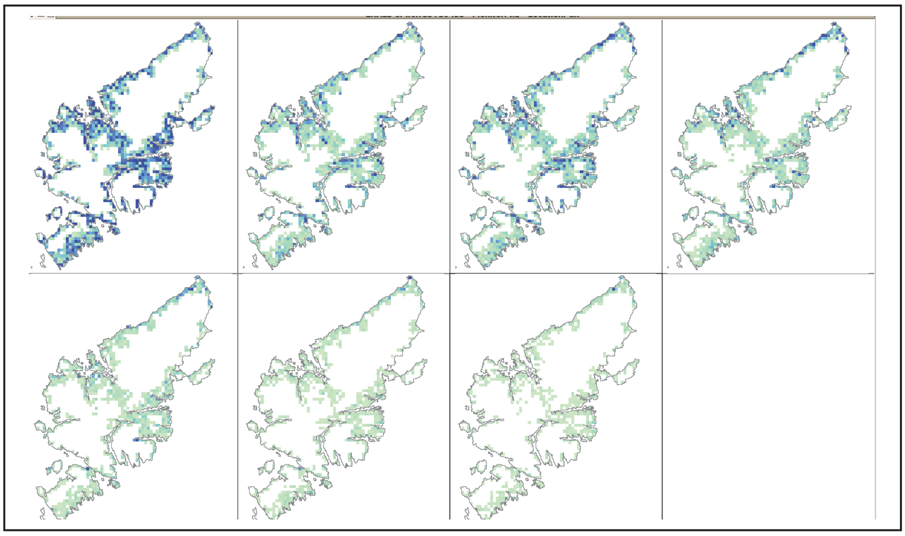

Figure 14. Probability density map illustrating predicted spatial distribution of mink in 2006 (top left) to 2012 (bottom right). Dark blue represents 100% probability, cyan 50%, green 30% and light green 10%.

Figure 14 illustrates the likely spatial distribution and relative probabilities of mink presence. Probabilities are predicted to be very low for most areas with a possible highest predicted remnant at the north-west of the island.

2.2.3 Trapping 2007 until 2011; followed by two years of no trapping

Model predictions for this scenario show a clear and immediate increase in population numbers should trapping effort stop in 2011. A cessation of efforts would lead to a mink population recovery (Figure 15 and Figure 16).

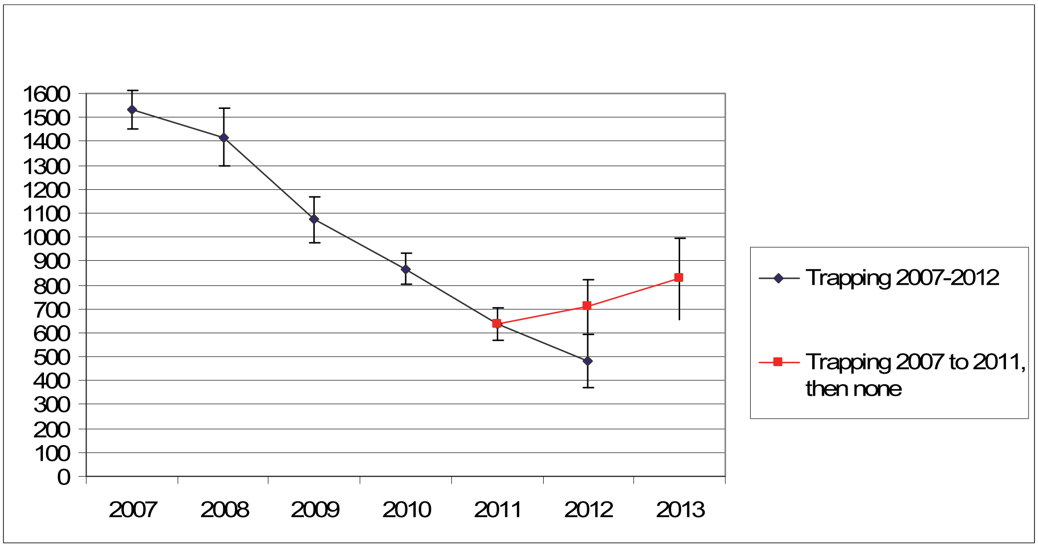

Figure 15. Illustration of two trapping scenarios: trapping 2007 until 2012 and trapping 2007 until 2011 followed by two years of no trapping. Points and error bars represent the mean and standard deviation of 100 replicate runs of the model.

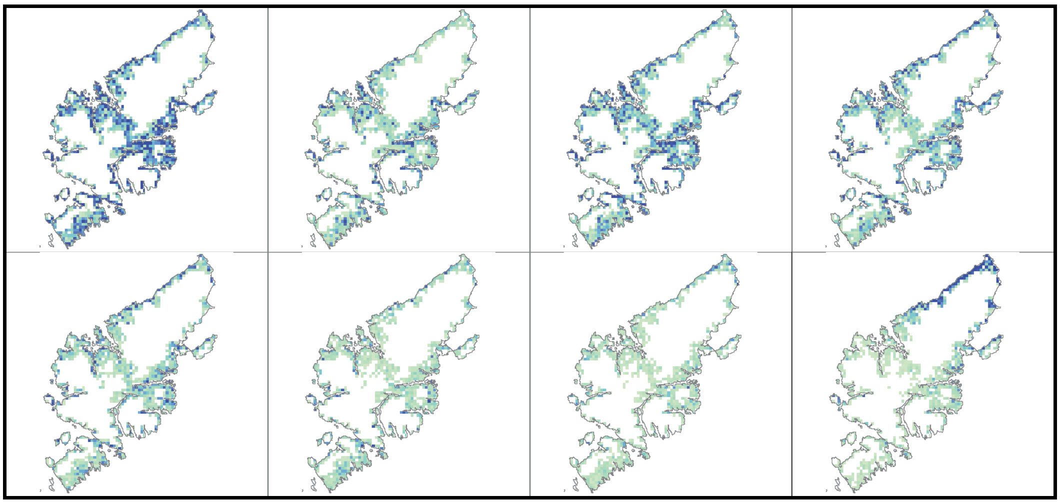

Figure 16. Probability density map illustrating predicted spatial distribution of mink in 2006 (top left) to 2013 (bottom right). Dark blue represents 100% probability, cyan 50%, green 30% and light green 10%.

Figure 16Figure 16 clearly shows that a cessation in trapping in 2012 and 2013 (bottom right) leads to population recoveries with highest predicted probabilities of mink presence in the north and north-west of Lewis.

2.2.4 Continuing efforts to 2013

Depending on overall carrying capacity and the initial population of mink on Lewis and Harris and if control can be sustained at current levels until 2013, then eradication could be achieved by 2013 (Figure 17).

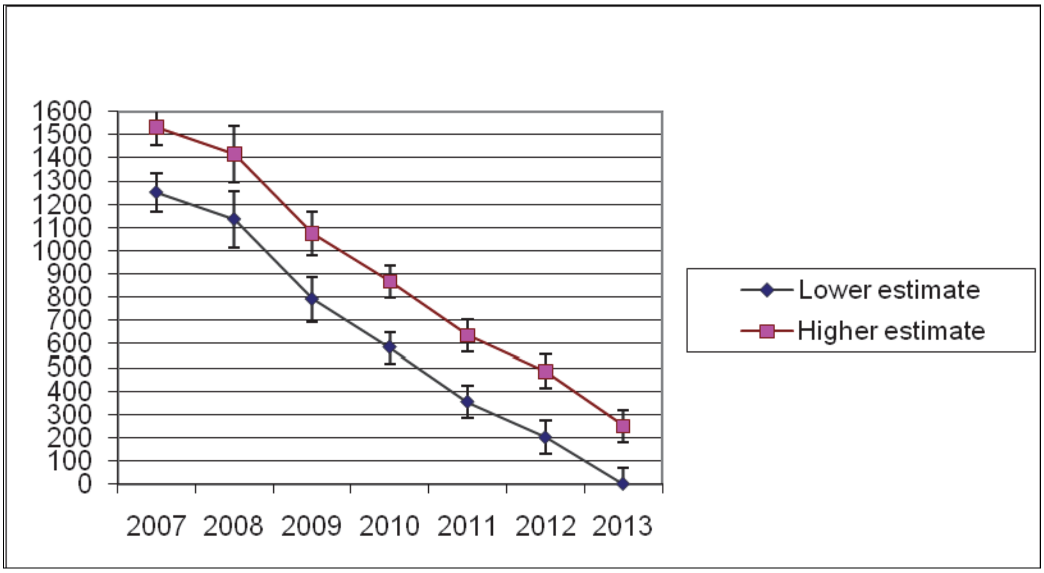

Figure 17. Illustration of predicted mink population decline based on a minimum (HMP estimate) and a maximum carrying capacity and sustained control until 2013. Points and error bars represent the mean and standard deviation of 100 replicate runs of the model.

3. DISCUSSION

An analysis of the project trap data indicates observed differences in the likelihood of trapping mink in relation to different habitat types with mountain areas showing the lowest probability of catching a mink. Furthermore, there are also clear differences in trapping success reflecting the history of the HMP. The analysis of HMP trapping data indicates an increase in trapping effort from 2007 to 2008. This is followed by a decline in trapping success in 2009 despite similar or increased trap effort, suggesting that the control strategy employed by HMP was working.

One of the key challenges of the mink model development was to simulate mink population dynamics within the different habitat types available on Harris and Lewis and a fine tuning of the habitat mosaic in relation to potential carrying capacity. This was particularly true for mountain and boggy moorland as well as some stretches of coastal habitat. On advice and observations from HMP no resident populations were therefore modelled in mountain massif and boggy moorland habitats and several attempts were made to improve the GIS habitat map used for the remaining landcover types. Nevertheless it is important to note that current predictions therefore ignore mountain massif and boggy moorland areas and the potential presence of itinerant individuals or a small refugium of breeding animals cannot be excluded in the absence of data from field surveys.

Model predictions based on the HMP project trapping effort and proposed trapping for 2012 clearly show that there has been a significant population decline with a possible 80% reduction in the overall population (best case scenario of an extant population of 326 and an average total population of 1606). Furthermore, if current efforts were to continue, the model suggests that mink may be extinct by 2013 (best case scenario assuming a lower than predicted carrying capacity, HMP pers. comm.) or reduced to a small remnant population (worst case scenario based on predicted carrying capacity) with the highest probabilities for animals remaining to the north and north-west of Lewis.

The true remaining mink number is likely to lie somewhere between the conservative HMP mink population estimate and the maximum predicted by the model. Whilst eradication by 2013 therefore appears achievable with current trapping effort, the likely error associated with predictions due to problems simulating very low densities or itinerant individuals in boggy moorland or mountain massif habitats. In addition, there may also be potential changes in mink behaviour once population levels drop to small numbers. Current model predictions are based on established mink populations with concomitant field and trap data. The behaviour of very few remaining mink may not reflect this in terms of their spatial distribution, ranging or mating behaviour and monitoring efforts post 2013 are strongly advisable.

Model predictions of current and future mink population levels in the scenario where efforts to control the population cease in 2011, show a certain population recovery with a likely doubling of currently remaining numbers (326 predicted) within two years. The simulation model has demonstrated the potential for mink populations to grow quickly, and thus it is important to develop strategies for control which take into account the creation of potential refugia in areas where control is difficult.

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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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