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Habitat Preferences of Capercaillie in Scotland: Modelling Functional Responses to Climate Change

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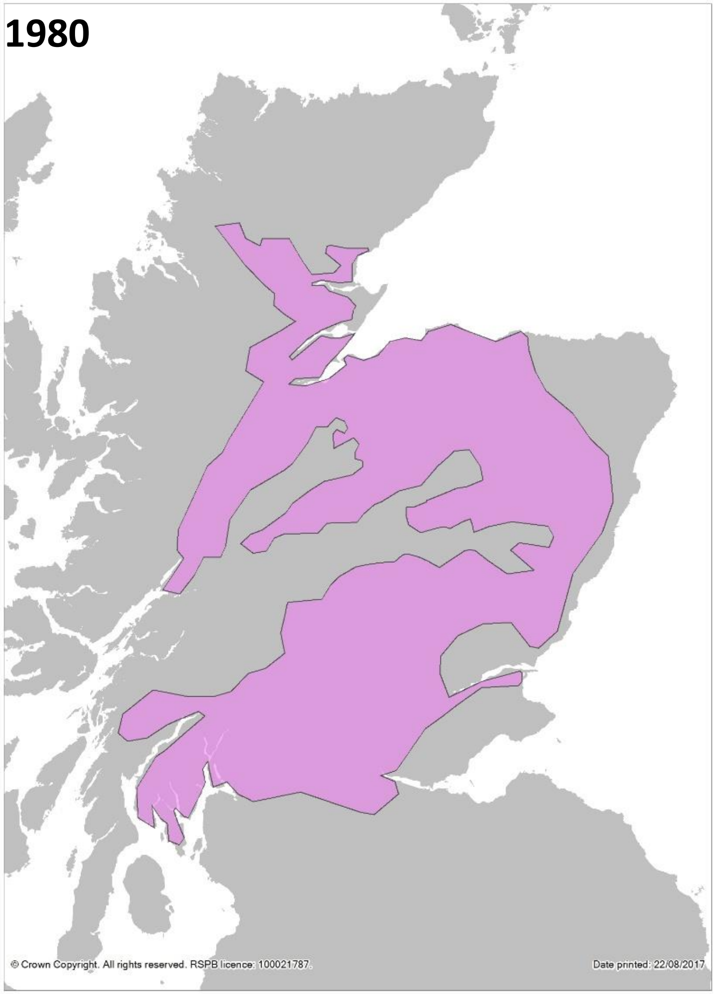

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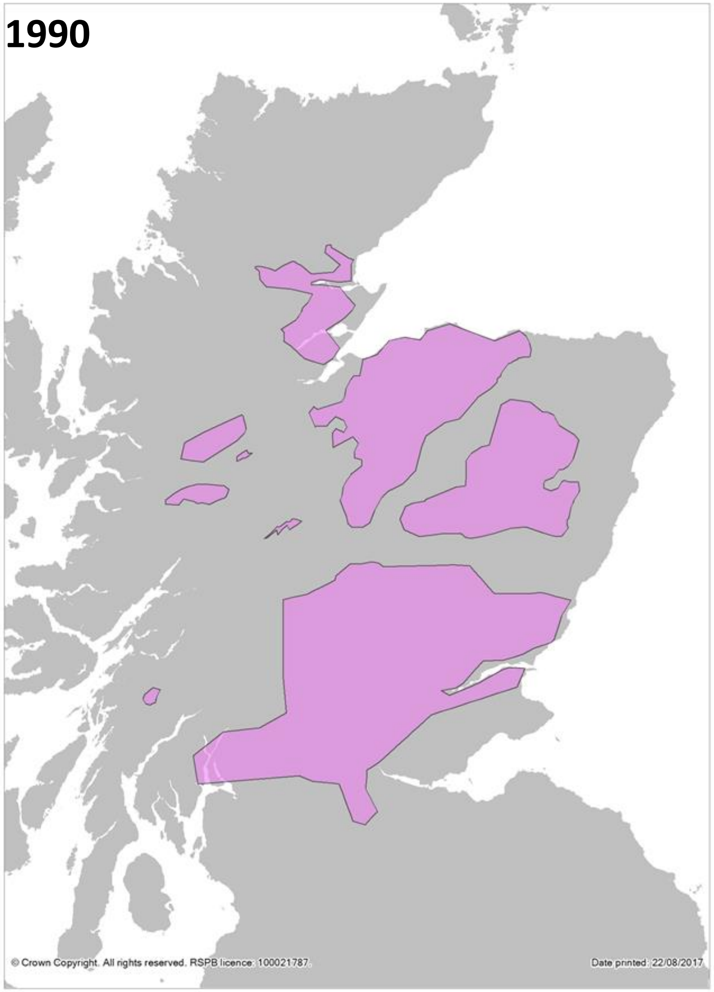

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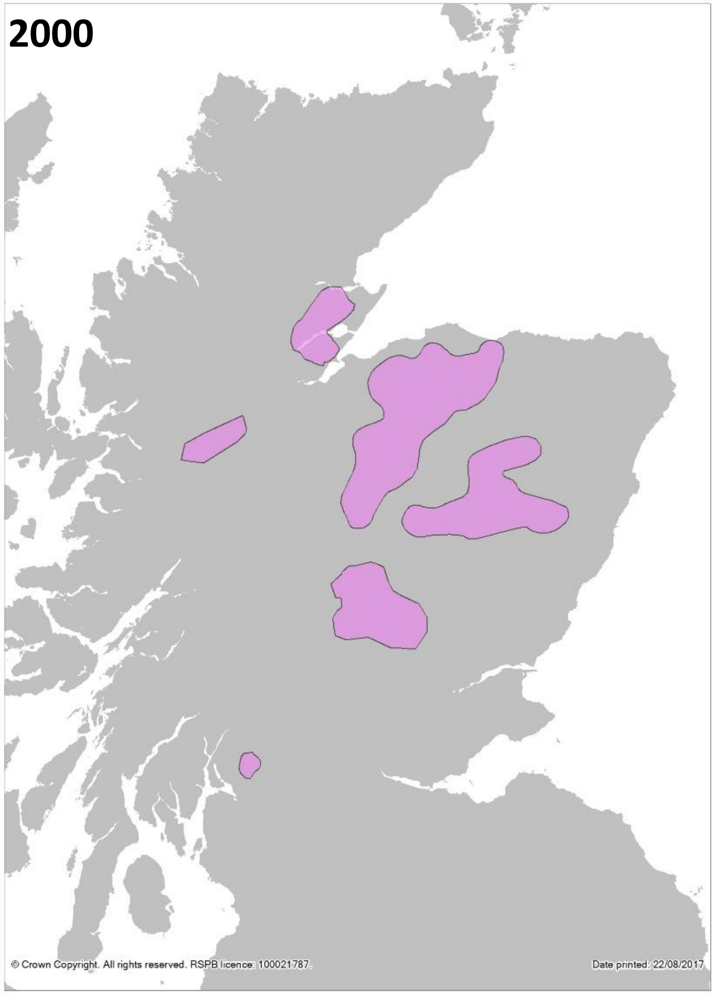

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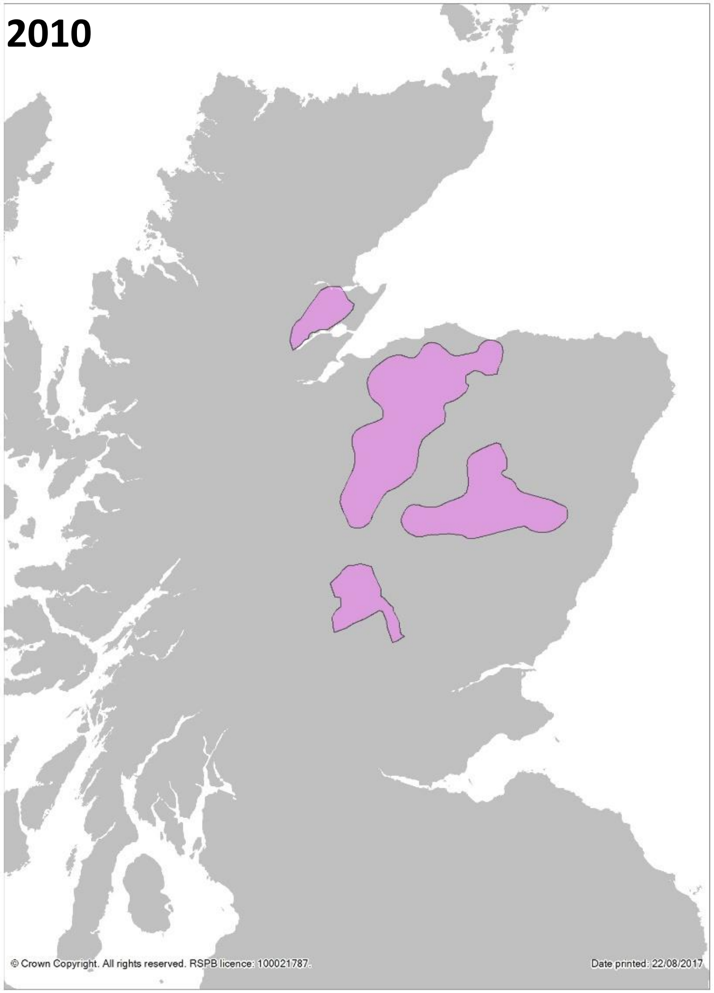

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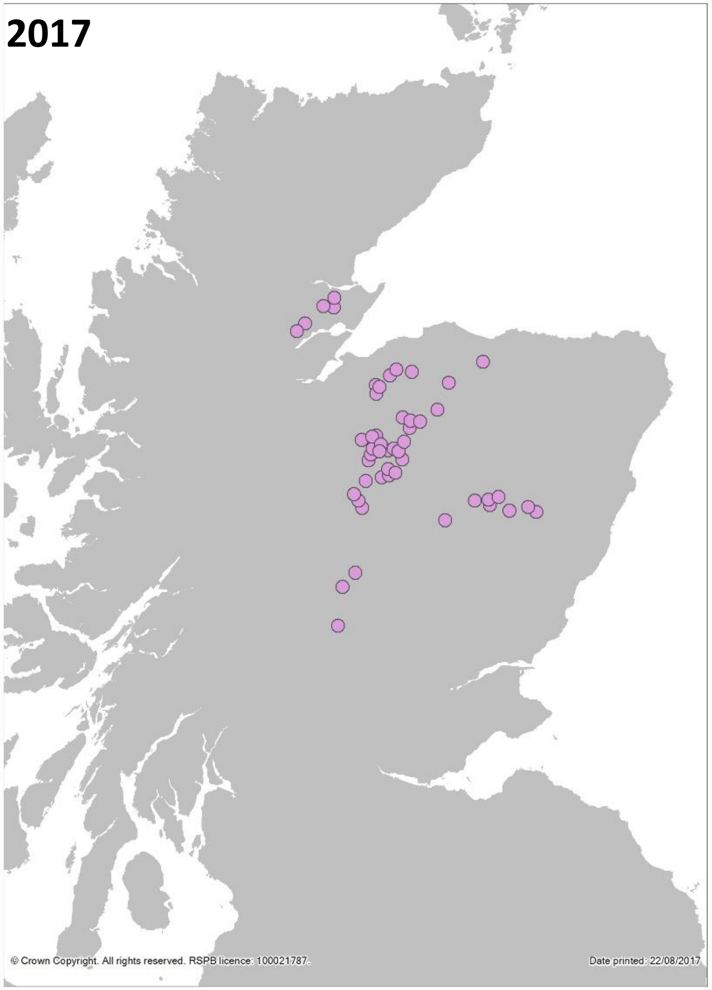
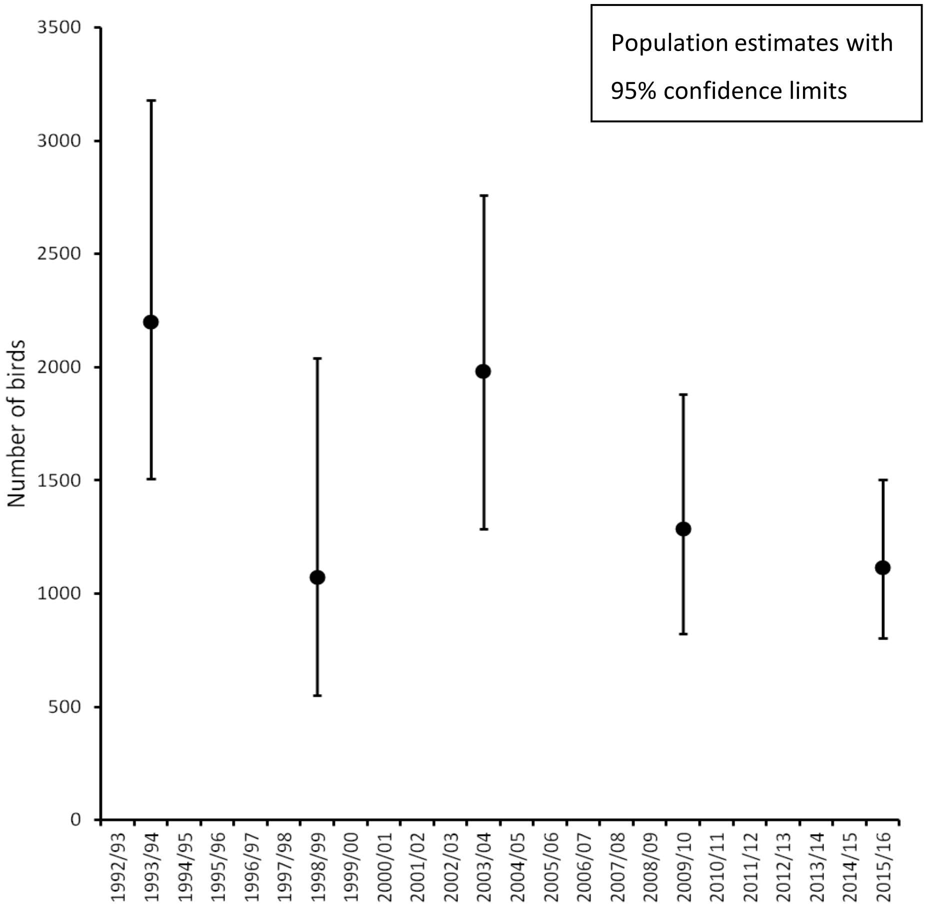



Population estimates with 95% confidence limits
Number of birds
3500
3000
2500
2000
1500
1000
500
0
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
1998/99
1999/00
2000/01
2001/02
2002/03
2003/04
2004/05
2005/06
2006/07
2007/08
2008/09
2009/10
2010/11
2011/12
2012/13
2013/14
2014/15
2015/16

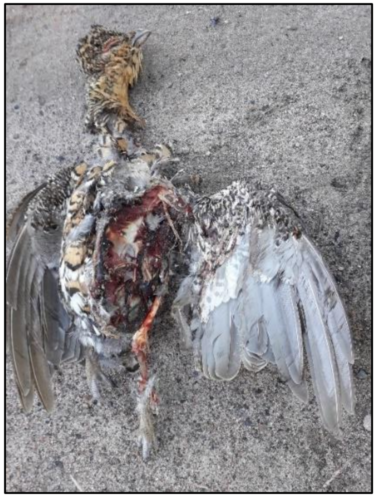
Reasons for decline

Proximate

- Fence collisions
- Disturbance
- Predation

Ultimate?

- Climate impacts on productivity:
  - Rapid warming in April (-)
  - Warmer Aprils in Norway (+)
  - Warm temperatures in May and June (+)
  - Precipitation in June (-)
  - Trends in some of these climatic variables



MONARCH (Modelling Natural Resource to Climate change)

- Walmsley *et al.* 2007
- Modelled future climate space
- Predicted 100% loss of climate space for capercaillie by 2080

- Generic model
- Artificial neural network
- Applied to suite of species
- Only included climate variables
- Some variables possibly not relevant to capercaillie

- Is it worth continuing with conservation action for capercaillie given the climate is changing?

Modelling functional responses of capercaillie to climate change

Two-stage approach

- Model current habitat preferences of hens (including climatic)
- Use model to predict how future changes in habitat preferences affect capercaillie distribution

Modelling functional responses of capercaillie to climate change

Data

- Brood survey sites across Scotland (n=31)
- 2003 to 2011
- 97 surveys
- Locations of 727 hens = use points
- 30km buffer around survey sites = extended count area (ECA)
- Availability points placed randomly within ECA @ $10km^{-2}$

- Forest, track and deer fence data from Scottish Forestry
- Used 3 forest habitat scenarios: no change, 5km buffer, full expansion within CPZ

- Climate change scenarios from WorldClim database (www.worldclim.org)
- Based on IPCC Fifth Assessment climate projections
- Used 4 climate scenarios to 2070

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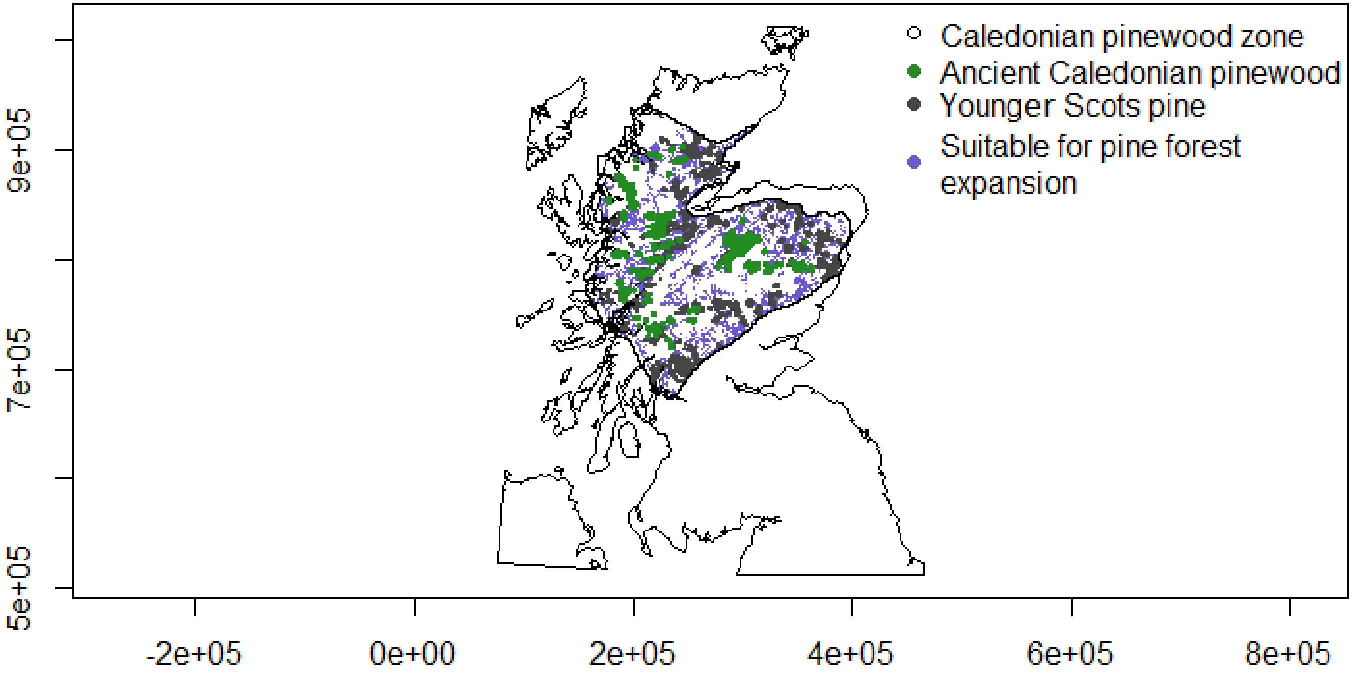
Modelling functional responses of capercaillie to climate change

Data – forest expansion scenarios



Modelling functional responses of capercaillie to climate change

Data – climate change scenarios

Scenario	June precipitation (mm)	April (°C)	May (°C)	June (°C)
Current climate	78.6	7.0	10.0	11.9
2.6	71.7	7.2	10.4	14.3
4.5	66.3	7.9	11.1	15.0
6.0	73.2	7.7	11.1	14.8
8.5	69.0	8.6	11.9	15.7

Modelling functional responses of capercaillie to climate change

VARIABLE	JUSTIFICATION
April mean temperature	Cooler temperatures in April associated with increased breeding success (Moss et al. 2001).
May mean temperature	Warmer temperatures at the end of May associated with increased breeding success (Moss et al 2001).
June mean temperature	Warmer temperatures at the start of June associated with increased breeding success (Moss et al. 2001).
June precipitation	June rainfall inversely related to breeding success (Moss 1985).
Pinus sylvestris	Presence/absence. Caledonian pine is ideal habitat, but many capercaillie are found in younger pine.
Distance to deer fences	Fence collisions are a major source of mortality (Moss et al. 2000).
Distance to bogs	Bogs are a source of invertebrate food to chicks (Stuen and Spidsø 1988).
Distance to recreation routes	Avoided by capercaillie (Moss et al. 2014).
Distance to forest roads	Avoided by capercaillie (Summers et al. 2007).

Modelling functional responses of capercaillie to climate change

Method

- Resource Selection Function (RSF) are snapshot in time
- RSF with extended structure to model functional responses to habitat change
- Generalised Functional Response (Matthiopolous *et al*. 2011)
- Model fitted as a binomial Generalised Linear Model
- 'Use' as response variable
- AIC used for model selection
- R package: *HATOPO* (HAbitats-TO-POpulations; available from J Matthiopolous)

- *Assesses response of hens to variable X given changes in other variables*

Modelling functional responses of capercaillie to climate change

Results

Current habitat preference

- Final model explained 82.2% of deviance
- June precipitation (-): Use points 60.4mm / availability points 70.8mm
- Presence of Scots pine (+)
- April temperature (-)
- May temperature (+): Use points mean 9.9°C / availability points 8.3°C
- Distance to bog (-)
- Distance to tracks (+)

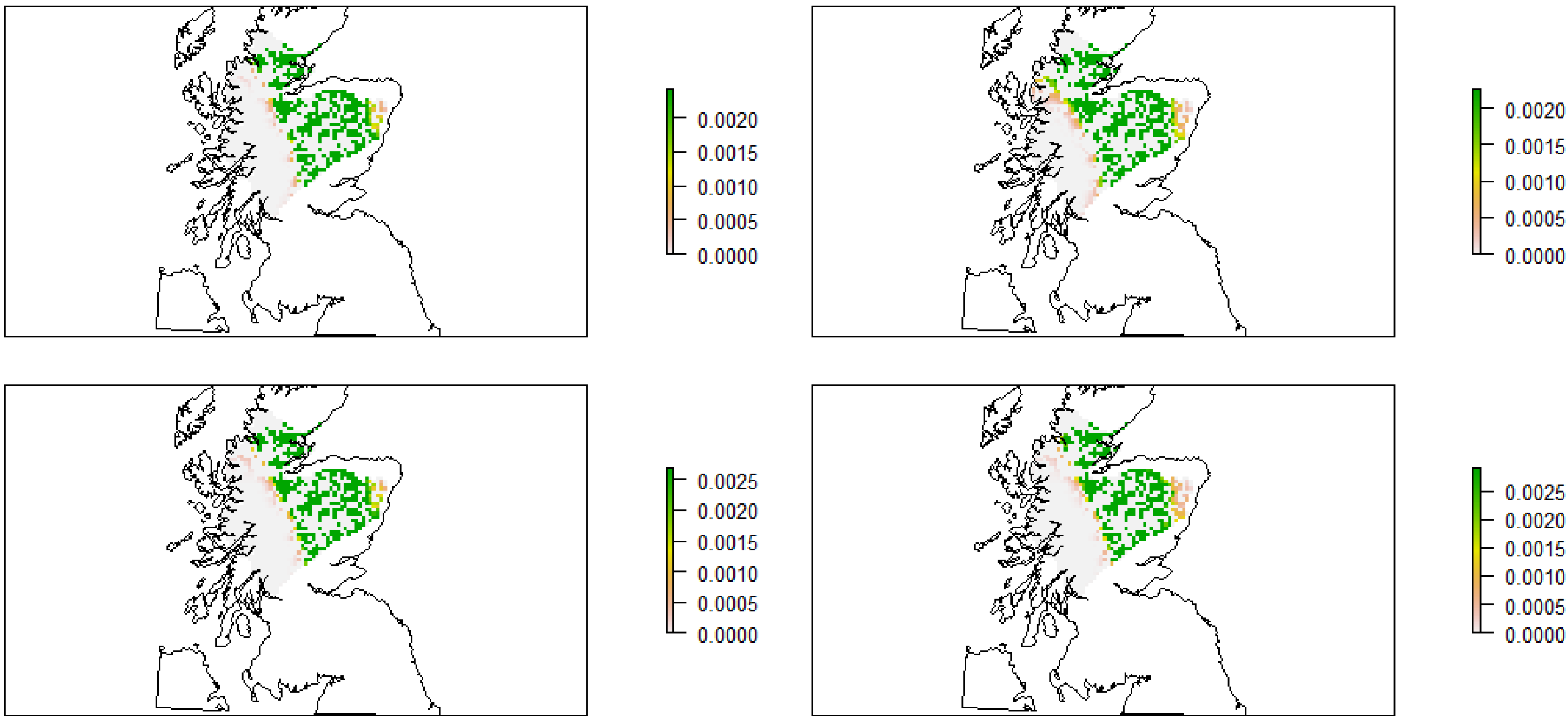
Modelling functional responses of capercaillie to climate change

Results

Future habitat preference

- Final model explained 78.4% of deviance
- June precipitation (-)
- Under **all** climate x forest expansion scenarios habitat increased:
  - CPZ remained suitable – except western part
  - 5km expansion within CPZ increased suitable habitat
  - Full expansion within CPZ increased suitable habitat vastly

Modelling functional responses of capercaillie to climate change



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Modelling functional responses of capercaillie to climate change

Key findings

- Significant climate envelope will remain for capercaillie
- Capercaillie make fine-scale choices about climate suitability
- June precipitation is particularly important
- Bogs are important

Conclusions

- Extirpation of capercaillie in Scotland is **not** inevitable – even under most extreme climate scenarios
- Forest expansion will increase area of suitable habitat
- Bog reinstatement important

Jason Matthiopoulus

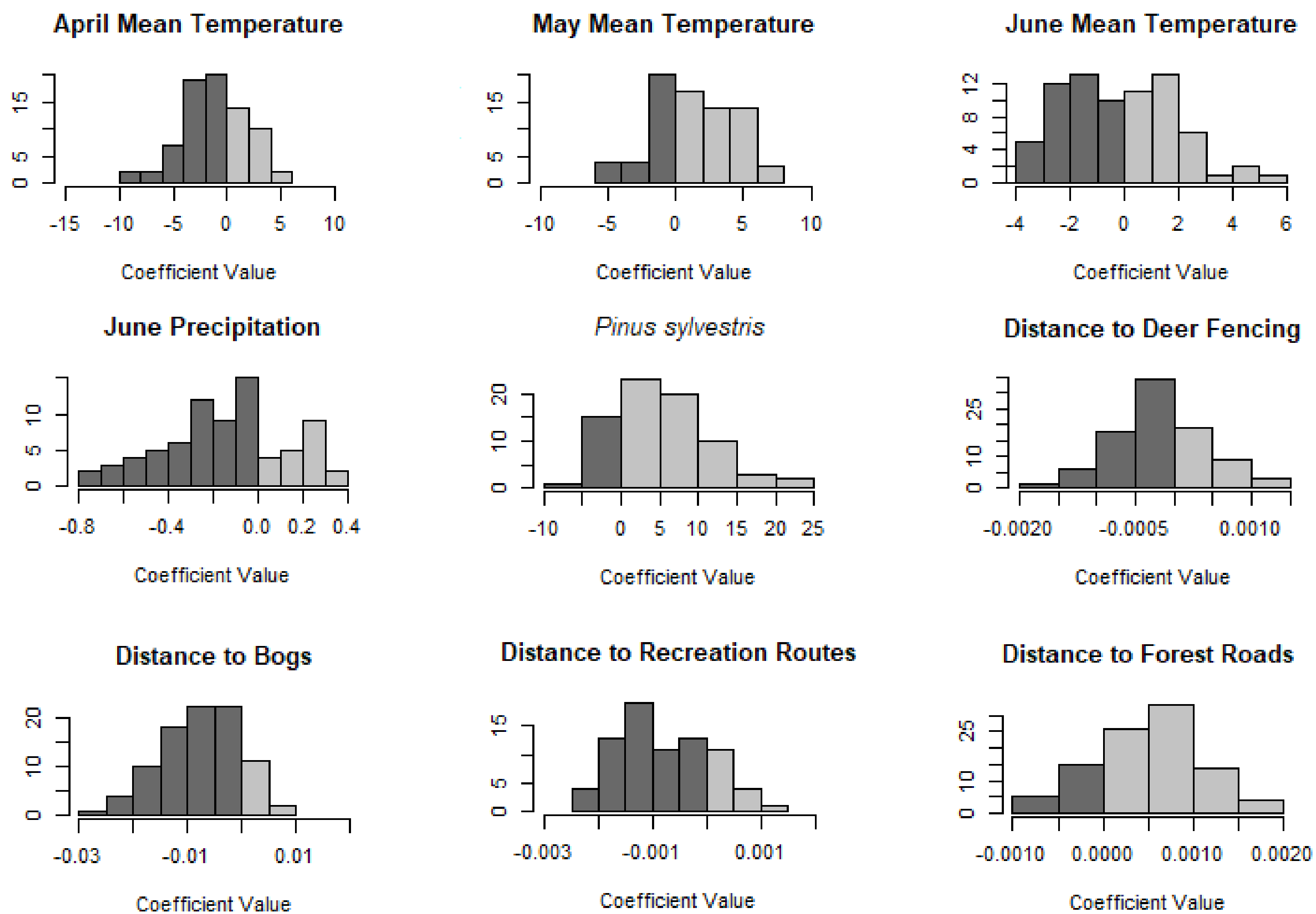
Mairi Hilton

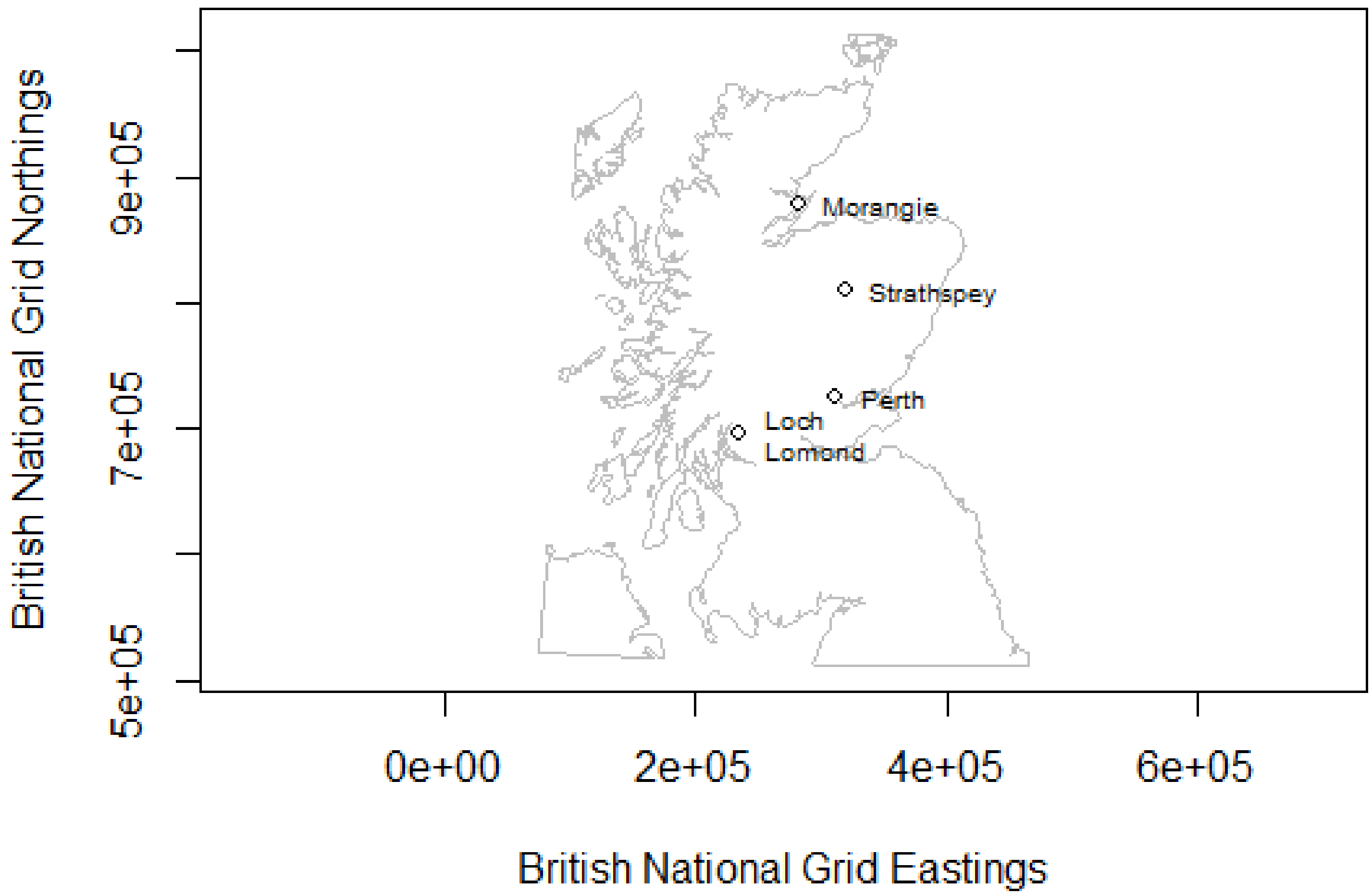
Robert Moss

Kenny Kortland

Thank you

$$
\begin{aligned}
\beta_{i,k} &= \gamma_{i,0} + \int\limits_{R^I} \left\{ \sum_{j=1}^{I} \sum_{m=0}^{M_j} \delta_{i,j}^{(m)} x_j^m \right\} f_k(\mathbf{x})\, d\mathbf{x} + \varepsilon_{i,k} \\
&= \gamma_{i,0} + \sum_{j=1}^{I} \sum_{m=0}^{M_j} \delta_{i,j}^{(m)} \int\limits_{R^I} x_j^m f_k(\mathbf{x}) d\mathbf{x} + \varepsilon_{i,k} \\
&= \gamma_{i,0} + \sum_{j=1}^{I} \sum_{m=0}^{M_j} \delta_{i,j}^{(m)} E[X_j^m]_k + \varepsilon_{i,k}
\end{aligned}
$$


April Mean Temperature
0 5 15
-15 -10 -5 0 5 10
Coefficient Value
May Mean Temperature
0 5 15
-10 -5 0 5 10
Coefficient Value
June Mean Temperature
0 4 8 12
-4 -2 0 2 4 6
Coefficient Value
June Precipitation
0 5 10
-0.8 -0.4 0.0 0.2 0.4
Coefficient Value
Pinus sylvestris
0 10 20
-10 0 5 10 15 20 25
Coefficient Value
Distance to Deer Fencing
0 10 20 25
-0.0020 -0.0005 0.0010
Coefficient Value
Distance to Bogs
0 10 20
-0.03 -0.01 0.01
Coefficient Value
Distance to Recreation Routes
0 5 15
-0.003 -0.001 0.001
Coefficient Value
Distance to Forest Roads
0 10 25
-0.0010 0.0000 0.0010 0.0020
Coefficient Value



British National Grid Northings
9e+05
7e+05
5e+05
0e+00
2e+05
4e+05
6e+05
British National Grid Eastings
Morangie
Strathspey
Perth
Loch
Lomond