

CoFoRD

Final Report

'The spread of grey squirrels to the west of Ireland (WIGS)'

DAFM Project Reference No: 10/RD/WIGS/NUIG/719

Start date: 01/11/2011

End Date: 30/04/2015

Principal Coordinator and Institution: Dr Colin Lawton, NUI Galway
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Collaborating Research Institutions and Researchers:

Dr Emily Goldstein, UCC

Dr Michael Carey, Forestry Consultant

Please place one "x" below in the appropriate area on the research continuum where you feel this project fits

Basic/Fundamental	→	Applied/Pre Commercial				
			X			

Please specify priority area(s) of research this project relates to from the National Prioritisation Research Exercise* (NRPE) report:

Priority Area (s)	N/A
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Key words: (max 4) *Biodiversity, conservation, invasive species, forestry damage*

1. Rationale for Undertaking the Research

This section should outline the rationale for carrying out the research and identify the need / problem to be addressed

The grey squirrel, a non-native and invasive forest mammal, has caused problems in Ireland on two fronts since its introduction in 1911. It has had a negative impact on the native red squirrel through competition and possibly disease, and has caused considerable damage to Irish woodland through its habitat of bark stripping trees. The grey squirrel has spread from its original point of introduction to cover much of the eastern half of the island of Ireland. The grey squirrel has not however established itself in the west of Ireland, with the river Shannon marking the western boundary of its range. This region offers the best chance for the continued existence of the red squirrel in Ireland.

This project set out to update the distribution of both squirrel species in Ireland, and to further investigate the status of grey squirrels in the west of Ireland/Shannon region. The project aimed to model future grey squirrel spread in Ireland, and to determine likely routes of invasion. There was also the need to identify key areas where future management programmes could be focused. This management would involve both monitoring and controlling grey squirrel populations, with the aim of preventing the grey squirrel from becoming established in the west and other regions. Current levels of bark stripping damage were to be assessed, and potential future damage considered in relation to likely paths of invasion.

2. Research Approach

Specify the research methodologies employed, emphasising novel techniques and also outline any modifications from the original approved project proposal

The distribution of both squirrel species and the pine marten (which has been linked with the regional demise of the grey squirrel, and return of the red squirrel) were investigated using a 'citizen science' approach. A survey was conducted which invited input from members of the public as well as professionals working in the wildlife and forestry sectors. Considerable exposure of the project was gained using various media (including radio interviews and newspaper articles) which stimulated much interest in the survey. Further information on the distribution and broader ecology of squirrels was gained from hair tube and live trapping studies. On-site inspections for squirrel damage were systematically carried out in a selection of broadleaf plantations of a damage-prone age and species.

A variety of modelling approaches were taken to answer different questions relating to grey squirrels in Ireland. The potential distribution of grey squirrels, based on habitat, was examined using a species distribution model (using MaxEnt), which could be directly compared with the actual distribution shown from the public survey. The MaxEnt output was subsequently used to derive the 'least cost pathway' model (using modelling software UNICOR), which showed the most likely routes of invasion of the grey squirrel based on the permeability of the landscape. RAMAS 6.0 software was used as a spatially explicit population model to examine predicted future spread of the grey squirrel into the southwest of Ireland (an area where the species is continuing to spread, and containing a large amount of damage-prone woodland). The impact of different management regimes on this future spread was also modelled, feeding into the management plan for the overall project. Finally discriminant function analysis was used to examine factors distinguishing regions where the grey squirrel has disappeared and where they are still problematic, allowing us to consider possible causes of the regional decline in the midlands of Ireland.

3. Research Achievements/Results

Outline main results achieved

New distribution maps of the grey squirrel, red squirrel and pine marten were produced, based on 2851 animal records received in 2012. These are the most up-to-date distribution maps for the three species currently available. They show that the grey squirrel has continued to spread at the edges of its previous range, pushing further into the northwest, southwest and southern parts of the country. In other regions however, the grey squirrel has gone into decline, most markedly in the Irish midlands, in counties to the east of the river Shannon. This area corresponds to part of the core range of the pine marten, which was further shown to be an important factor in determining the likelihood of grey squirrel presence in an area. There was a significant increase in the number of sightings of red squirrels compared to recent squirrel distribution surveys, in particular in the areas where the grey squirrel had disappeared. This shows a capability of the native species to recover if grey squirrels are removed from a region.

The absence, or very low densities, of grey squirrels in the midlands of Ireland corroborates other recent research on Irish squirrels, and was linked to the high densities of pine marten in the region and some habitat characteristics, through the discriminant function analyses. Bark stripping damage levels were also found to be lower than expected, however it was possible to highlight areas of concern in relation to future spread, in particular in Co Cork where a lot of damage-prone plantations are found.

Over the three year course of the study 1776 records were received for the Shannon region. These were combined with the hair tube and live trapping results to establish the current squirrel distribution in the region. A species distribution model was used to create a habitat suitability map for the island of Ireland. Ten woods were identified that lie on or near to the river Shannon, which could support large grey squirrel populations and should be monitored as part of the species management plan. The habitat suitability map and current grey squirrel distribution were used to derive a least cost pathway model showing the most likely routes of invasion into the west of Ireland. 'Pinch points' were highlighted for future monitoring and control of grey squirrels. The potential impact of control regimes on the spread of grey squirrel was also examined, and further informs future management.

4. Impact of the Research

A summary of the impact of the research should be provided through the project outputs and outcomes however please provide a synopsis of the benefits / improvements the research has made to the area under investigation. Outline the benefits of the research to end users, e.g. industry, consumers, regulatory authorities, and scientific community etc

This project has furthered the understanding of squirrel ecology in Ireland, and provided up to date distribution data for the entire island on three key mammal species. The various modelling approaches used in the study have allowed us to predict future grey squirrel distributions and greatly informs management programmes for the invasive species, allowing a proactive, rather than reactive approach. This is of benefit to regulatory authorities (e.g. National parks and Wildlife Service; Department of Environment Northern Ireland), wildlife conservation bodies (e.g. Irish Wildlife Trust; Vincent Wildlife Trust), and forestry and silviculture in Ireland (e.g. Forest Service, Coillte, Teagasc and private foresters). The project also provides a template for managing other invasive species in Ireland and other countries. The silviculture industry further benefited from the

damage survey work conducted as part of this project, both from the information provided during the course of the work, and from the outputs of the survey. Research that can help contain and manage grey squirrel bark stripping damage will increase profitability of the sector, and help to maintain lower prices for consumers.

The project has stimulated links with other squirrel ecology researchers in Ireland, in particular with University College Cork. There was a significant amount of media coverage of the project, which helped to highlight the threat to the native red squirrel and educate the general public on the importance of Irish forests for biodiversity and conservation. The work has been presented at international conferences in the United Kingdom, Portugal and Finland, increasing the profile of Irish mammal biologists to their peers. The work was used as part of a successful bid to host the next International Colloquium on Arboreal Squirrels, which will be held in NUI Galway in 2018. Further research opportunities can build on the work carried out in this project, and can allow collaborations with other squirrel biologists in Ireland, the United Kingdom and Italy. As an example, the project team will take part in a new Ulster Wildlife Trust EU Life+ project, by conducting similar models piloted in this work for the Northern Ireland landscape. Researchers in Queen's University Belfast will form another branch of this collaborative effort.

4(a) Summary of Research Outcomes

(i) Collaborative and Industry links developed during this research

Links were developed with several governmental, NGO and public groups in promoting and carrying out the citizen science study that led to the production of the squirrel and pine marten distribution maps. Links with Coillte, the Forest Service, Teagasc, NI Forestry Service, NPWS and the National Association of Regional Game Councils were initiated or significantly enhanced during the project. Collaborations with researchers in Queen's University Belfast and through the Northern Ireland Squirrel Forum allowed the work to be conducted on an all-island basis.

An existing collaboration with Dr Fidelma Butler's research group in University College Cork was significantly enhanced through the work modelling the spread of grey squirrels into the southwest of Ireland by Dr Emily Goldstein. Other researchers/research groups in the UK, Italy and USA advised on the study and discussed the outcomes, enhancing the international reputation of the research team.

(ii) Outcomes where new products, technologies and processes were developed and/or adopted

For the most part, the outcomes in this study inform management and environmental policy and improve academic understanding, however the models used have broader applications and can help inform conservation work and management programmes on other invasive species or in different ecosystems.

(iii) Outcomes with economic potential

The grey squirrel has had an environmental impact in Ireland, by threatening the existence of a native species through competition and disease. It also has an impact on silviculture through bark stripping damage and this is of economic concern to all those involved in the industry. Damage levels were lower than previously reported, linked to the general trend of lower grey squirrel densities reported in the study. However, the work allows the prediction of future grey squirrel ranges, and the monitoring of the progress of grey squirrel spread. This can permit the forestry

industry to be proactive in managing at-risk plantations, by predicting time of arrival and likelihood of occurrence of grey squirrels in the area.

(iv) Outcomes with national/ policy/social/environmental potential

This project allows informed management decisions to be made on an invasive species that has an impact on an important native species, as well as on the broader ecosystem. The decisions can be based on up-to-date distribution maps, as well as predicting the future distribution of the species, and the most likely routes through which future spread will take place. This is particularly important in protecting the west of Ireland, which has as yet not been invaded by the grey squirrel and is recognised as the long term refuge for red squirrels in Ireland given previous distribution trends. The importance of the pine marten for the future of both species was further highlighted during this study, and this informs the need for continued protection of this native carnivore.

4 (b) Summary of Research Outputs

(i) Peer-reviewed publications, International Journal/Book chapters.

Goldstein, E.A., Butler, F. & Lawton, C. (under review). Modeling future range expansion and alternative management strategies for an invasive squirrel species. Submitted to *Biological Invasions*, 21st May, 2015.

Flaherty, M. & Lawton, C. (in prep). The regional demise of a non-native invasive species – To be submitted as a journal article to *Ecography*.

Flaherty, M., Goldstein, E.A. & Lawton, C. (in prep). Predicting grey squirrel spread in Ireland for future management – Invited by editors to submit as a book chapter in “The Grey Squirrel: Ecology & Management of an Invasive Species in Europe”.

Flaherty, M. & Lawton C. (in prep). Investigation into the status of a red squirrel population in Continuous Cover Forest (CCF) in Ireland – To be submitted as a journal article to *Irish Forestry*.

Flaherty, M. & Lawton, C. (in prep). Conservation strategy for reds squirrels in the west of Ireland – To be submitted as a journal article to *European Journal of Forestry Research*.

(ii) Popular non-scientific publications and abstracts including those presented at conferences

Flaherty, M., Carey, M., Goldstein, E.A., Sheehy, E. & Lawton, C., 2013. Demise of the previously invasive grey squirrel (*Sciurus carolinensis*) in the Shannon Region, Ireland. *Poster presentation* at the 11th International Mammalogical Congress, Queens University Belfast, Northern Ireland, 11th – 16th August 2013.

Flaherty, M. & Lawton, C., 2014. An investigation into the potential dispersal and future distribution of an invasive rodent species. *Oral presentation* at the 14th *Rodens et Spatium* – International Conference on Rodent Biology, University of Lisbon, Portugal, 28th July – 2nd August, 2014

Flaherty, M. & Lawton, C., 2015. An investigation into the potential dispersal and future distribution of the invasive grey squirrel (*Sciurus carolinensis*) in Ireland. *Oral presentation* at The Mammal Society Spring Conference, Lancaster University, England, 27th – 29th March, 2015

Lawton, C., Flaherty, M., Goldstein, E.A., Sheehy, E. & Carey, M., 2015. The 2012 Irish Squirrel Survey. *Poster presentation* at The Mammal Society Spring Conference, Lancaster University, England, 27th – 29th March, 2015

Flaherty, M. & Lawton, C., 2015. Using species distribution models and landscape connectivity analysis to develop management strategies for squirrel conservation. *Oral presentation* at the 7th International Colloquium on Arboreal Squirrels in University of Helsinki, Finland, June 1st – 5th, 2015

Lawton, C., Flaherty, M., Goldstein, E.A., Sheehy, E. & Carey, M., 2015. The 2012 Irish Squirrel Survey. *Poster presentation* at the 7th International Colloquium on Arboreal Squirrels in University of Helsinki, Finland, June 1st – 5th, 2015

(iii) National Report

Flaherty, M., Carey, M., Goldstein, E. A. & Lawton, C. (2015). West of Ireland Grey Squirrel (WIGS) project. Final report, prepared for the Dept. of Agriculture, Food and the Marine, April 2015. NUI Galway.

Lawton C., Flaherty M., Goldstein E.A., Sheehy, E. and Carey M. (2015) Irish Squirrel Survey 2012. *Irish Wildlife Manuals* No. 89. National Parks and Wildlife Service, Department of the Arts, Heritage and the Gaeltacht, Ireland.

(iv) Workshops/seminars at which results were presented

Information on the project and results from our research were presented at a number of workshops/seminars including:

- Galway Irish Wildlife Trust, February 2012
- Galway and Roscommon Game and Hunting Associations, March 2012
- Northern Ireland Squirrel Forum, April 2012
- Connemara National Park Summer Lecture Series, Letterfrack, Co. Galway – July 2012
- Annual Zoology Colloquium at NUI Galway – 2012, 2013, 2014 & 2015
- CELT Symposium, NUI Galway – June 2012
- Ryan Institute Research Day, NUI Galway - September 2013
- Zoology Lunchtime Seminar, NUI Galway – November, 2014
- Queen’s University, Belfast – November 2014
- Teagasc field day for private woodland owners – October 2014
- ProSilva Ireland field day, Coole Park, Gort, Co. Galway - May 2015
- Seminar for Biodiversity & Land-Use Planning (MSc Class), NUI Galway – May 2015

(v) Intellectual Property applications/licences/patents

N/A

(vi) Other

Media and newsletter articles on the project and advertising the citizen science survey appeared in the Irish Times (14/02/2012), Irish Independent (27/03/2012) and Irish Examiner (02/05/2012), and in several local newspapers (e.g. Donegal Daily (01/05/2012); Bray People (09/05/2012); Leinster Leader (10/05/2012); Tipperary Star (13/05/2012); Offaly Express (21/05/2012)). Information on the project also appeared in the newsletters of Irish Timber Growers Association (spring 2012), Society of Irish Foresters (summer 2012), Birdwatch Ireland (autumn 2012), Forest Service news (winter 2012), UK red squirrel group (spring 2013), and the Fermanagh red squirrel group (summer 2013).

5. Scientists trained by Project

Total Number of PhD theses: 2*

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date

M. Flaherty (to be submitted in September 2015). An investigation into landscape connectivity and the invasive grey squirrel (*Sciurus carolinensis*). PhD Thesis, NUI Galway.

E.A. Goldstein (2014). Ecology of frontier populations of the invasive grey squirrel (*Sciurus carolinensis*) in Ireland. PhD Thesis, University College Cork

*Emily Goldstein was funded by a stipend from the Irish Research Council, however part of her project was supported by this DAFM funded project, with one chapter of her PhD thesis in particular contributing to the overall project.

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
NUI Galway	3	0.6

Total

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers		
PhD students	2	3.6
Masters students		
Temporary researchers		
Other		

Total

8. Involvement in Agri Food Graduate Development Programme

Name of Postgraduate / contract researcher	Names and Dates of modules attended
N/A	N/A

9. Project Expenditure

Total expenditure of the project: €127,744.01

Total Award by DAFM: €127,744.01

Other sources of funding including benefit in kind and/or cash contribution (specify): €0.00

Breakdown of Total Expenditure

Category	NUI Galway	Name Institution 2	Name Institution 3	Name Institution 4	Total
Contract staff	0.00				0.00
Temporary staff	0.00				0.00
Post doctorates	0.00				0.00
Post graduates	61586.88				61586.88
Consumables	2385.19				2385.19
Travel and subsistence	11580.05				11580.05

Sub total	75552.12	75552.12
Durable equipment	1937.87	1937.87
Other (Sub-contracting costs)	27588.38	27588.38
Overheads	22665.64	22665.64
Total	127744.01	127744.01

10. Leveraging

Summarise any additional resources'/funding leveraged by this award from other sources i.e. Additional Staff, National/EU funding secured, EI Commercialisation Fund

Salaries for time contribution for permanent researchers, funded by NUI Galway, were €38,352.15.

The British Ecological Training and Travel Grant (£500) and Ryan Institute Travel Award (NUI Galway) (~ €500) were received and facilitated travel to the 7th International Colloquium on Arboreal Squirrels, held in Helsinki in June 2015.

Funds to cover final year tuition fees for PhD student M. Flaherty (€4529) were secured by C. Lawton.

11. Future Strategies

Outline development plans for the results of the research.

Future strategies arising from this research fall under two categories: (i) future management recommendations and (ii) future research requirements.

(i) Recommendations for squirrel management include:

- Appointment of two squirrel conservation officers with responsibilities for carrying out targeted control of grey squirrels, a point of contact for landowners, and provision of information to the public on grey squirrel control and red squirrel conservation.
- Establishment of red squirrel conservation groups across the Republic of Ireland tasked with conducting regular monitoring of squirrel populations, to act as an early warning system for changes to grey squirrel status in an area.
- Creation of a network of red squirrel reserves, particularly in the west of Ireland, managed to include continuous cover forestry. This network should include sites potentially suitable for red squirrel translocations.
- Co-ordination of future grey squirrel control efforts is necessary. The efficacy of different control regimes should be monitored and analysed. Researchers (and Squirrel Conservation Officers) should work closely with stakeholders in this regard.
- Strategic tree planting regimes are required in light of planned increases for forest cover in Ireland. This should be conducted with reference to routes of grey squirrel invasion, and avoid habitat facilitating dispersal. Planting of damage prone trees needs to be avoided in areas of high grey squirrel density.

(ii) Requirements for future research include:

- Monitor any changes to the status of pine martens in the Shannon region and west of Ireland, along with regional investigations on the ecology of the species. Further work is required on the mechanism by which the pine marten impacts on grey squirrel populations.
- Examine the status and ecology of naturally established red squirrel populations in coniferous forestry in the west of Ireland. The lack of landscape connectivity potentially restricts red squirrel dispersal. An effective management plan is required to maintain and promote connectivity between the most important woodlands for red squirrels.
- Monitoring of the translocated squirrel populations in West of Ireland needs to be continued with the populations being supplemented by extra individuals if required.
- Examination of grey squirrel genetics in Ireland is required which will contribute to understanding the relatedness of different populations and their connectivity, and further validate dispersal corridors identified in this research.
- Research on the status of squirrelpox virus (SQPV) is lacking, particularly in the Republic of Ireland. SQPV greatly amplifies the impact of grey squirrels on red squirrel populations.

12. Consent to Publish Final Report on the DAFM Website and/or Through Other Dissemination channels

I consent to this report being made available to the public, through the Department's website and other dissemination channels. *

Yes No

13. Declaration

I declare that the information contained in this final report is complete and true to the best of my knowledge and belief.

Signed:  Project Coordinator

Date: 18/08/2015

*IPR sensitive information that the coordinator does not wish to make public should be highlighted in red font. All text in red font in this report will not be made publicly available by DAFM.

Guidelines for the Completion of Final Report

The attached Final Report Template should be completed for DAFM projects funded under the 2006, 2007, 2008, 2010 and 2011 Calls.

The aim of the final report is to provide a summary of all aspects of the research project. A final report is required for all projects and a percentage of the grant award will be withheld until it is submitted and deemed satisfactory.

Please note that the Department of Agriculture, Fisheries and the Marine may publicise information included in the Final Report. **All sections of the report must be completed.** Incomplete reports will not be accepted by DAFM and will be returned to the project coordinator for completion.

Two copies of the final report are required, 1) a signed hard copy and 2) an electronic copy.

A guideline of up to 400 words per relevant section is recommended.

Project Details

The project title, project reference number and actual start and actual finish date should be noted. Indicate on the research continuum from basic/fundamental research to applied/pre-commercial research where you feel the research project fits by placing 'x' in the most appropriate box. Indicate in the section provided **the priority area of research this project relates to from the National Prioritisation Research Exercise* (NRPE) report**, There are 14 priority areas of Research as follows;

A Future Networks & Communications	H Food for Health
B Data Analytics Management, Security & Privacy	I Sustainable Food Production and Processing
C Digital Platforms, Content & Applications	J Marine Renewable Energy
D Connected Health & Independent Living	K Smart Grids & Smart Cities
E Medical Devices	L Manufacturing Competitiveness
F Diagnostics	M Processing Technologies and Novel Materials

In addition, key words relating to the project should be included in this section.

***<http://www.agriculture.gov.ie/research/14researchprioritisationactionplans>**

1. Rationale for Undertaking the Research

This section of the final report should provide background information on why the research was needed. It should clearly outline the reason for carrying out the research and identify the problem / knowledge gap that needed to be addressed. It should address the question **'why was this research needed?'**

2. Research Approach

Information provided on research approach should address the questions **'how the research was carried out?'** Details should include work carried out and research methodologies used to address the issues identified in the 'rationale for undertaking the research'. Emphasis should be placed on novel techniques, materials, technology and equipment used. Scientific or technical difficulties encountered in the research and any significant modifications from the original proposal must be noted. Please note that this section does not require fine scientific detail, but is designed to give the reader an overall view of the research methods employed.

3. Research Achievements/Results

This section is simply designed to address the question **'what are the results of the research'**. Emphasis should be placed on novelty and innovation. Tabulated scientific results are not required but a succinct summary of results obtained from each task should be illustrated.

4. Impact of the Research

A summary of the impact of the research should be provided through the project outputs and outcomes. The benefits / improvements the research has made to the area under investigation should be elucidated. Specifically, describe how the outcomes of the research have benefited the end users such as industry, consumers, regulatory authorities, policy makers and the scientific community.

4(a). Summary of Research Outcomes

The outcomes reported must detail the wider effect of the project from a sectoral or national perspective; these may be in the medium or long term. The summary of research outcomes is a critical component of the final report. It is imperative that this section is completed fully and precisely, as DAFM is required to report on the outcomes of all research projects. In addition, this data is essential to DAFM in justifying value for money of its research programmes and in securing future funding. Therefore, please ensure that information in this section is accurately reported.

4(b). Summary of Research Outputs

Research Outputs are what are produced by the project in terms of activities, events, services that reach people. The summary of research outputs is a critical component of the final report as it provides quantitative data on the research. It is imperative that this section is completed fully and precisely, as DAFM is required to report on the

outputs of all research projects. In addition, this data is essential to DAFM in justifying value for money of its research programmes and in securing future funding. Therefore, please ensure that information in this section is accurately reported.

5. Scientists trained by the project

The total number of PhD and MSc theses produced as a direct result of work carried out on this DAFM project should be noted. In addition, the authors, institutions and titles of the theses and submission dates should be specified. If theses have not been submitted before completion of the final report, please give details including the anticipated submission date.

6. Permanent Researchers

The number of permanent research staff who contributed to the project (on a cost neutral basis) per institution and associated time contribution must be captured.

7. Researchers Funded by DAFM

Details of numbers, total time contribution (in months) and of all, post doctorates (PD) & contract researchers; PhD students; Masters students; temporary researchers and other staff funded by DAFM should be included.

8. Involvement in Agri Food Graduate Development Programme

The names of students / researchers that participated in the Agri Food Graduate Development Programme should be included in addition to the names and dates of modules undertaken.

9. Project Expenditure

The aim of this section is to provide a summary of expenditure during the lifetime of the project. Please note that it is imperative that all figures included in this section correspond to figures included in the last progress report submitted and evaluated by DAFM. The names of the institutions involved must be included in the tables provided.

10. Leveraging

The aim of this section is to summarise any additional resources'/funding leveraged from this award from other sources e.g. Additional Staff (type of staff, value of staff secured), National/EU funding secured, EI Commercialisation Fund

11. Future Strategies

Future strategies to further develop the outputs of the research should be indicated. If the outputs of the research have not been taken up by end users, explain why this is the case. What further advances / work is required in your area of research in order for the outputs to be taken up by industry / consumers / end users? What follow-on research is required in this area to realise an end product? If further funding is

required for research in this area, where do you intend to apply for funding e.g. Enterprise Ireland?