Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

CoFoRD

Final Report

Impacts of forest clear-felling on Kerry Slug (*Geomalacus maculosus*) populations with the development of mitigation measures based on preferred diet of the species *(GEOFOREST)*

DAFM Project Reference No: 13/C/474

Start date: 01/02/2014

End Date:31/03/2016

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Collaborating Research Institutions and Researchers: Dr Aileen O Sullivan (Coillte); Professor Rory Mc Donnell (University of California Riverside – now based in Oregon State University)

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)	I

Key words: *(max 4)*
Kerry Slug, Forest Management

1. Rationale for Undertaking the Research

The Kerry Slug (*Geomalacus maculosus*) was discovered in County Kerry in 1842 and subsequently described as a new species. Until recently its distribution was believed to be limited to northern Iberia and south-west Ireland, where it was known to inhabit oak-dominated or mixed deciduous woodland as well as open moor/ blanket bog. However, recent surveys have shown that the species is found in *Picea sitchensis* / *Pinus contorta* conifer plantations in counties Kerry and Cork and one in Oughterard, Co. Galway, the latter more than 200km north of its previously known range. Given that the species has not yet been recorded in counties between Kerry and the Co. Galway site it is believed that the Kerry Slug was introduced to Co. Galway through anthropogenic sources. Due to its restricted distribution worldwide, the Kerry Slug is listed as a protected species in Annex II and IV (irrespective of natural range) of the EU Habitats Directive 92/43/EC and by the Wildlife Act 1976 under Statutory Instrument No. 112 of 1990 and Wildlife (Amendment Act) 2000.

Given the confirmed presence of the protected Kerry Slug in commercial conifer plantations in Ireland, the interaction of forest management with the species urgently needs to be addressed There are, however, a number of gaps in the knowledge which need to be filled to better inform management practices in forests where the Kerry Slug is present. These include assessing the effects of using different sampling methodologies on capture rates across the seasons in clear-felled, mature conifer plantations and adjacent unplanted peatland; quantifying catch size and estimating population sizes of the Kerry Slug using mark-recapture techniques before and after clear-felling; and determining food preferences of the species in relation to forest stands to develop practical mitigation strategies for the species in commercial forests. The filling of these gaps will contribute to our understanding of the ecological requirements for the species in actively managed conifer plantations.

2. Research Approach

There were three elements to this study:

1. *Comparison of capture rates for the Kerry Slug (using different methodologies and across the seasons) for the Kerry Slug in clear-felled and mature compartments of conifer plantations and adjacent unplanted peatland*

This element of the study (additional to the original proposal) was undertaken to determine, for the first time, optimum sampling protocols for the Kerry Slug, particularly important for any future monitoring of the species. The impact of De Sangosse refuge trap position in forested and open habitats on *G. maculosus* catches was assessed and compared with hand searching. The effects of seasonal variation on catches were also quantified to determine the optimum sampling season for site assessment. In addition, the influence of temperature and rainfall in forested and open habitats on catches was determined to inform optimum weather conditions during which to undertake sampling.

2. *Assessing the impacts of commercial forestry practices on Kerry Slug populations*

This element of the study was undertaken to determine (for the first time) the impacts of clear-felling using Before-After-Control-Impact (BACIP) analysis. Models for estimating Kerry Slug population sizes using capture-mark-recapture were also assessed in addition to which Kerry Slug catches in planted, clear-felled and unplanted habitats were compared. The latter was particularly important as it formed part of the risk management plan for the project where, in the event, Coillte scheduled clear-felling activities were severely disrupted by Storm Darwin permitting only one BACIP analysis rather than the four originally planned in the proposal.

3. *Feeding preferences and mobility studies of the Kerry Slug*

This element of the study was undertaken to establish ranked feeding preferences for the Kerry Slug with a view to helping inform potential mitigation options for the species within the context of commercial conifer plantation forestry practices. This is the first time Kerry Slug feeding behaviour has been analysed under darkened conditions using Ethovision XT software. An experimental procedure first had to be set up, *de novo*, to undertake the above experimental procedure. In addition, the mobility of the Kerry Slug was recorded for the first time in the laboratory thereby informing potential dispersal rates which is of critical importance to commercial forest managers. The results for the latter represent additional data to the original proposal.

3. Research Achievements/Results

1. *Comparison of capture rates for the Kerry Slug (using different methodologies and across the seasons) for the Kerry Slug in clear-felled, mature conifer plantations and adjacent unplanted peatland*

Results indicate that autumn is the optimal time for sampling the Kerry Slug but avoiding extremes of hot or cold weather. While refuge traps placed at 1.5m on trees in mature conifer plantations and directly on exposed rock in blanket peatlands result in significantly greater catches, hand searching is the most successful approach for clear-fell areas. Hand searches in clear-fell preceded by rain are likely to result in greater numbers caught. The results of this study form, for the first time, the basis for *G. maculosus* monitoring guidelines for forestry managers.

2. *Assessing the impacts of commercial forestry practices on Kerry Slug populations*

Mean catches of Kerry Slug were greatest in mature coniferous forest compartments consisting predominantly of *Picea sitchensis*. The Schnabel model for estimating population size was most suited for mature forest stands but could not be utilised for other habitats. BACIP analysis showed a 95% reduction in Kerry Slug mean catches post-felling where no individuals marked prior to felling were recaptured compared to 21% recapture rates at the control site. Greater tree circumference and yield class correlated with greater catches.

3. Feeding preferences and mobility studies of the Kerry Slug

Given that automated behavioural analysis has never been undertaken for the Kerry Slug, a number of barriers for laboratory trials were first tested resulting in salt impregnated paper being selected as the most appropriate. Observational trials indicated that when the Kerry Slug was in contact with food, it was actively feeding for 95% (median) of the time. Using Ethovision XT10 software to record contact time with a range of lichens, mosses and liverworts, Kerry Slug behaviour was recorded and analysed for the first time under darkened conditions. While preferences for some bryophytes and lichens were observed, overall results indicate that the Kerry Slug is a generalist lichen and bryophyte herbivore with no differences in feeding preferences shown by the two colour morphs, associated with forested and open habitats respectively. Maximum mean distance moved in the laboratory over two hours by The Kerry Slug was 6.7m (± 2.9 SE) with mean meander by colour morphs of open habitats being significantly greater (P = 0.008) than that of colour morphs of forested habitats. The results of this study, based on Kerry Slug food preferences, suggest that the retention of deadwood and an increase in light availability within mature conifer plantations are likely to support those lichen and bryophyte species ranked top in the food preference trials.

4. Impact of the Research

4(a) Summary of Research Outcomes

(i) Collaborative and Industry links developed during this research

During this research, collaborative links were developed with Coillte (both research and technical staff) which facilitated the site selection process. In addition, links were developed with a slug specialist at the University of California Riverside and with an invertebrate biologist at Liverpool John Moores University.

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

The outcomes of this research include proposed survey and monitoring protocols for the Kerry Slug which can be used by forest managers to determine the presence and monitor the longterm impacts of forestry practices on the Kerry Slug. This protocol can be used to determine the success or otherwise of mitigation measures for the species. In addition, the identification of key food plants for the species can be used to inform potential, future mitigation measures.

(iii) Outcomes with economic potential

Research outputs from this project will support forest certification schemes including the Forest Stewardship Council (FSC) certification and the Programme for the Endorsement of Forest Certification (PEFC) schemes further assuring buyers of forest products that the timber products purchased come from sustainably managed forests. The results of this study provide, in support of the above schemes, guidelines for the detection and monitoring of the Kerry Slug in commercial conifer plantations which is the first step to incorporating the protection of the species within forest practices. In addition, potential mitigation measures for the protection of the Kerry Slug in commercial forestry are suggested. However, it is recommended that further research is undertaken to test the effectiveness of a range of mitigation options thereby further strengthening adherence to the forest certification schemes.

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

This research supports our obligations under the European Habitats Directive and Irish Wildlife Act to protect the Kerry Slug in addition to informing policy and practice for the sector (FS-DAFM & NPWS) with environmental benefits arising. The impacts of this research will also give Irish citizens a sense of pride in Ireland's endeavours to protect rare species. This is even more important in the context of the Kerry Slug in that it indicates that biodiversity is not just about the better known 'iconic species' such as mammals and birds. This study will impact on people's consciousness that less known but important invertebrate species also play an important role in ecosystem function. The results of this work also provide quantitative data which will contribute to Coillte's Framework Document to Sustainable Forest Management. In particular, the work contributes to Criterion 4 of that document (Biodiversity & Nature Conservation) where alignment of Standard Operating Procedures (SOPs) takes greater account of biodiversity and nature conservation potential in day-to-day forestry operations. The benefits of this work will be the provision of practical guidelines for forest practitioners on how best to monitor the Kerry Slug while informing the development of potential mitigation measures to protect the species. This research will also contribute to scientific knowledge regarding protected mollusc species in commercial forestry plantations through publications which in turn will inform the relevant policy makers. In addition, the results of this study will aid foresters in their compliance with national and European legislation.

4 (b) Summary of Research Outputs

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

Johnston,E., Kindermann,G., O'Callaghan, J., Burke, D., McLaughlin, C., Horgan, S., Mc Donnell, R., Williams C., Gormally, M . (*in press*) Monitoring the EU protected *Geomalacus maculosus* (Kerry Slug): what are the factors affecting catch returns in open and forested habitats? *Ecological Research*.

Johnston,E., Kindermann,G., O'Callaghan, J., Burke, D., McLaughlin, C., Horgan, S., Reich, I., Mc Donnell, R., Williams C., Gormally, M. ***Geomalacus maculosus*** (Kerry Slug): implications of commercial forestry practices on an EU protected species. *Annals of Forest Science* (under review – submitted 28.07.2016)

Johnston,E., Kindermann,G., O'Callaghan, J., Emmett, L., Moura, K., Mc Donnell, R., Gormally, M. Feeding preferences and mobility studies of the EU protected Kerry Slug, *Geomalacus maculosus*: automated behavioural analysis and barrier assessment for laboratory trials. *Journal of Molluscan Studies* (under review – submitted 12.09.2016).

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

Johnston, E., Kindermann, G., Mc Donnell, R., Williams, C., Burke, D., Gormally, M. The impact of forest clear-felling on Kerry Slug (*Geomalacus maculosus*) populations. *Environ, 2015, April 8th, 9th and 10th, Sligo, Ireland*

Johnston, E., Kindermann G., O'Callaghan, J., Mc Donnell, R., Gormally, M. Are they lichen it? An assessment of the feeding behaviour of *Geomalacus maculosus* to inform conservation management practices. *Post-Graduate Colloquium of Animal and Plant Ecological Research, 2015, December 4th, Galway, Ireland (poster)*

Johnston, E., Kindermann, G., Mc Donnell, R., Williams, C., Burke, D., Gormally, M. Impact of clear-felling on the Kerry Slug (*Geomalacus maculosus*). *Post-Graduate Colloquium of Animal and Plant Ecological Research, 2015, December 4th, Galway, Ireland (presentation).*

Johnston, E, Kindermann, G, O'Callaghan, J, Burke D, McLaughlin C, Horgan S, Mc Donnell R, Williams C, Gormally M. The implications of forestry practices in Ireland on the EU protected *Geomalacus maculosus* (Kerry Slug). *Ecology and Evolution Ireland conference, 2016, November 24th, 25th and 26th, Sligo, Ireland (presentation)*

(iii) National Report
-None

(iv) Workshops/seminars at which results were presented

Seminars presented to students taking the MSc Sustainable Resource Management: Policy & Practice (NUIG / UL) and the MSc in Biodiversity & Land-use Planning (NUIG)

(v) Intellectual Property applications/licences/patents
-n/a

(vi) Other
Based on the results of this study, an updated version of the Forest and Kerry Slug Guidelines (Forest Service) is presented

5. Scientists trained by Project

Total Number of PhD theses: __1__

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

Johnston, E. (2016) *Geomalacus maculosus:* An assessment of trapping methods, forestry management impacts and feeding preferences. PhD thesis submitted 02.09.2016.

Total Number of Masters theses: ___0_

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

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
NUI Galway	1	0.140

Total	**1**	**0.140**

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	0	0
PhD students	1	2.161
Masters students		
Temporary researchers	3	0.922
Other (Advisors)	2	0.080
Total	**6**	**3.163**

8. Involvement in Agri Food Graduate Development Programme

Name of Postgraduate / contract researcher	Names and Dates of modules attended
n/a	

9. Project Expenditure

Total expenditure of the project: €132,583.63

Total Award by DAFM: €139,724.00

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

NUI Galway bestowed €3,000 to provide additional support to the PhD student: €3,000.00

Breakdown of Total Expenditure

Category	NUI Galway	Name Institution 2	Name Institution 3	Name Institution 4	Total
Contract staff					
Temporary staff					
Post doctorates	26,435.77				26,435.77
Post graduates	43,631.51				43,631.51
Consumables	7,901.01				7,901.01
Travel and subsistence	14,113.07				14,113.07
Sub total	92,081.36				92,081.36
Durable equipment	1,397.96				1,397.96
Other: Rory McDonnell	2,258.17				2,258.17
Other: Software & Training	9,221.73				9,221.73
Overheads	27,624.41				27,624.41
Total	**132,583.63**				**132,583.63**

10. Leveraging

n/a

11. Future Strategies

This research provides, for the first time, a baseline for the development of a national survey and monitoring protocol for the Kerry Slug in commercial forest areas (mature forest, clearfell areas and unplanted areas). The implementation of the proposed monitoring protocol using trained personnel would be a major improvement on the current situation where any monitoring of the Kerry Slug, where it takes place, is generally undertaken on an *ad hoc* basis. Nevertheless, additional research is required to further refine a Kerry Slug monitoring protocol. This includes an assessment of the use by the Kerry Slug of the upper reaches of mature conifers to determine what proportion of the total population on a tree is represented by slugs captured using traps placed at 1.5m. The influence of humidity levels beneath traps on Kerry Slug capture success also needs to be assessed to determine the value of wetting traps prior to and during monitoring. Hand-searches in clear-fell areas undertaken at different times of the day

(including night-time) and under different weather conditions is required to finalize optimum times for hand-searching.

While the results of this study strongly suggest that clear-felling has negative impacts on Kerry Slug capture rates, replicated trials using BACIP at different locations are required to substantiate this. Hurricane Darwin at the start of this project permitted access to only one site where a BACIP could be undertaken during the timeframe of this study. In addition, the success or otherwise of potential mitigation measures needs to be investigated thoroughly so that the impact of forestry practices on the Kerry Slug can be reduced as much as possible. Possible mitigation measures the success of which requires further exploration include: a comparison of the effects of felling during the four seasons; the value of translocating the Kerry Slug to other suitable habitats prior to felling and the possible impact of this on other invertebrate species; the use of deadwood with suitable lichen cover after felling; the value of continuous cover and low impact forestry cover etc. Likely sources of funding to~~p~~ pursue the above research goals are The Department of Agriculture, Food and the Marine and / or The National Parks & Wildlife Service.