An assessment of the use of conifer plantations by the Kerry Slug *Geomalacus maculosus* with reference to the potential impacts of forestry operations

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Executive Summary

The Kerry Slug, *Geomalacus maculosus* is listed on Annex II and IV of the EU Habitats Directive 92/43/EC. The slug is also protected under the Wildlife Act 1976 (as amended) having been added under Statutory Instrument No. 112 of 1990. Historically, within Ireland, *G. maculosus* was thought to be restricted to the Devonian Old Red Sandstone strata of West Cork and Kerry. However, during July 2010, the species was collected on granite outcrops and on the trunks of conifer trees in Cloosh Forest, a conifer plantation near Oughterard, Co. Galway (Kearney, 2010). The widespread planting of commercial conifer forestry was originally thought to have had a detrimental effect on populations of *G. maculosus* (NPWS, 2010) but results from McDonnell and Gormally (2011a) indicate otherwise.

The discovery of the protected slug in Cloosh Forest provided the incentive to survey possible habitats of *G. maculosus* in the counties which lie between the known populations in Kerry and Cork and the newly discovered population in Co. Galway, to determine the possibility of an existing corridor through which the slug might have migrated. A presence / absence survey of *G. maculosus* at a total of 42 sites within 15 hectads in counties Galway, Clare, Limerick and Kerry was undertaken between 10/10/2011 and 22/11/2011 but no *G. maculosus* were found.

Given that the Kerry Slug was not found at the above sites, research focused on the recently discovered Kerry Slug population in the conifer plantation in Cloosh Forest, Co. Galway. In order to establish if and how habitat factors affect the occurrence of *G. maculosus* within Cloosh, hand searches and live trapping were undertaken from November 2011 to April 2012 to determine the outer extremities of the distribution of the slug at the site. Results found a localized population of the Kerry Slug at Cloosh and it is, therefore, likely that the species was introduced through anthropogenic sources possibly stemming from activities associated with commercial forestry operations.

Transects were utilized from October 24, 2011 to January 23, 2012 to determine the distance from the main public road (along a selected forest road) the slug was found in addition to the distance (up to 90m) the slug had penetrated into dense forestry plantations from the edge of the forest road. Throughout the 13 week survey, a total of 1009 slugs (7 species) were trapped of which 27% were *G. maculosus*. While the species was trapped in dense forest up to 90m from the forest road edge, it was only trapped up to 1.2km from the main public road although suitable habitat exists for a further ~2km.

An investigation of environmental parameters and food sources available to the Kerry Slug in Cloosh Forest took place between December 2011 and April 2012 to address the paucity of information regarding the ecology of the species. A weak positive correlation between Kerry Slug abundance and bryophyte cover and Kerry Slug abundance and the circumference of the trunk at breast height (CBH) was found. It was also found that lichens were the preferred food source with preliminary studies on lichens taken from conifers in Cloosh showing that the foliose lichen *Platismatia glauca* is the most favoured species while *Lepraria incana* is the least favoured species. Six crustose lichen species taken from granite rock outcrops around the conifer plantation at Cloosh were also consumed by the Kerry Slug during our experiments.

The creation of buffer zones to ensure the protection of the endangered Freshwater Pearl Mussel (*Margaritifera margaritifera*), has resulted in the felling of conifers along water bodies within plantations. In the case of Cloosh forest, tree stumps (about 3m high) were left in place in buffer zones as a possible mitigation measure for the protection of *G. maculosus* (Nelson, pers. comm.). The success of the remaining tree stumps and clearfell in supporting *G. maculosus* by comparison with an adjacent mature plantation was investigated from October 24, 2011 to April 30, 2012. While numbers of Kerry Slugs in the mature plantation were significantly higher throughout the sampling period, the tree stumps left in situ at the clearfell site also provided a habitat for the slugs. No correlation was found between temperature and slug abundance in the clearfell or mature plantation, neither on the day of sampling nor on the day prior to sampling.

Acknowledgements

Sincerest thanks to Paul Whelan for his time, effort and advice with lichen identification and to Eamonn O'Sullivan for his assistance with bryophyte identification. We are grateful to Dr Brian Nelson for useful discussions on all aspects of this report and also to Dr Roy Anderson for advice on slug ecology and identification. Thanks to Barry Rintoul of Coillte for providing information on the management practices at Cloosh Forest and to Eugene Cush, Fiachra Tierney and Maxime Poissonneau for their assistance with field work and experiments in the laboratory. We also thank Prof. Martin Feely and Paul Murray for providing us with valuable advice and assistance in obtaining rock samples.

Introduction

Background information on *Geomalacus maculosus*

The Kerry Slug, *Geomalacus maculosus*, was first discovered in Co. Kerry, Ireland in 1842 and described as a new species in 1843 (Allman, 1843, 1844, 1846). In 1868 the species was discovered in northern Spain and five years later it was collected in northern Portugal. Although it has been reported from Brittany in France (Desmars, 1873), the absence of museum specimens means that the French record is now widely regarded as being erroneous (Platts & Speight, 1988; Falkner et al., 2002). While three other species of *Geomalacus* are recognized i.e. *G. anguiformis*, *G. malagensis* and *G. oliveirae* (Castillejo *et al.*, 1994), these are not known, nor is there any evidence to suggest that they exist in Ireland (Platts & Speight, 1988).

Although, in recent times, *G. maculosus* has been repeatedly collected in south-west Ireland and northern Spain, it is listed as 'vulnerable' in Spain by Verdu & Galante (2005) and in Ireland there is a lack of quantitative data on favourable management practices, the habitat size required to sustain populations and genetic variation across its home range (NPWS 2008). For these reasons and because of its narrow global distribution, *G. maculosus* is listed on Appendix II of the Bern Convention and subsequently on Annex II and Annex IV of the EU Habitats Directive 92/43/EC. Annex II lists fauna and flora species that require the designation of Special Areas of Conservation for habitats that contribute to conserving these species. In Ireland, seven Special Areas of Conservation (SACs) have been designated for *Geomalacus maculosus* (NPWS, 2010).

Annex IV lists fauna and flora species of community interest that require strict protection. In addition, under Irish legislation the slug is protected by the Wildlife Act 1976 under Statutory Instrument No. 112 of 1990. The main threats to *G. maculosus* in Ireland were considered to be afforestation and forestry management, invasion of woodland by *Rhododendron ponticum*, agricultural reclamation and infrastructure development (NPWS, 2010).

A recent conservation assessment of the species in Ireland (NPWS, 2008) concluded that it was in Favourable Conservation Status and that there was no evidence of any recent range reduction. However, this assessment was based on limited data on populations, distribution and habitat condition, particularly outside SACs (NPWS, 2008). In addition, Byrne *et al.* (2009) concluded that Irish populations of *G. maculosus* were strong, globally important, could expand with global warming and the species was assessed as of least concern under IUCN red list criteria.

Historically, within Ireland, *G. maculosus* was thought to be restricted to the Devonian Old Red Sandstone strata of West Cork and Kerry. However, in July 2010, the species was collected on granite outcrops and on the trunks of trees in Cloosh Forest, a conifer plantation near Oughterard, Co. Galway (Kearney, 2010). The widespread planting of commercial conifer forestry was originally thought to have had a detrimental effect on populations of *G. maculosus* (NPWS, 2010) but Mc Donnell & Gormally (2011a) demonstrated that the species does occur on conifer trunks in commercial forestry plantations in the south-west of Ireland. Nevertheless, throughout the rest of its Irish range (West Cork and Kerry) *G. maculosus* occurs in three general habitat types. These are deciduous woodland (usually *Quercus* dominated), blanket bog or unimproved oligotrophic open moor and lake shores

(Platts & Speight, 1988; NPWS, 2010). Mc Donnell *et al*. (in press) also cited wet grassland as a potentially suitable habitat for the species. Within these habitats, *G. maculosus* tends only be present if there is outcropping of Devonian Old Red Sandstone (NPWS, 2010), humid conditions and lichen, liverworts and/or mosses in which the species can shelter and on which it can feed (Platts & Speight, 1988). While Platts & Speight (1988) and Boycott & Oldham (1930) reported the species disappearing in limestone areas and reappearing with the occurrence of sandstone, a recent laboratory investigation by Barrett (2011) did not find that the Kerry Slug had a significant preference for either sandstone, granite or limestone.

Individuals that occur in woodlands tend to be brown with yellow spots whereas in more open situations specimens are grey/black with white spots. Juveniles, on the other hand, usually have two dark lateral stripes which become less obvious with age. *G. maculosus* is also capable of rolling into a ball (Plate 1) when it is disturbed (Platts & Speight, 1988) and this is a useful identification character for the species.

Plate 1: Specimen of *Geomalacus maculosus* collected in a woodland (© Eugene Cush).

Like many slugs, *G. maculosus* is a crepuscular animal and it takes refuge in crevices in rocks or under the bark of trees during the day. However, Platts & Speight (1988) and Taylor (1907) recorded diurnal activity during or after rain. In terms of life history, the species is hermaphroditic and can self-fertilise. Eggs are deposited between July and October in batches of 18-30 with hatching taking place after 6-8 weeks (Rogers, 1900). Juveniles usually reach maturity after two years and specimens can live for more than 6 years (Oldham, 1942).

Research Objectives

1. To provide data on the range of the species by investigating potentially suitable habitat in unsurveyed areas of counties Clare, Galway, Limerick and Kerry through presence/absence surveys.
2. To provide detailed information on the spatial distribution of the species in a conifer plantation at Cloosh Forest, Co. Galway.
3. To provide information on the habitat requirements of the species in conifer plantations.
4. To provide information on the potential impact of forestry operations on the distribution and abundance of the species.

Investigation of potentially suitable *Geomalacus maculosus* habitats in previously unsurveyed hectads in Ireland

Rationale

The range of *G. maculosus* in the south-west of Ireland was updated during 2009 and 2010 by Mc Donnell *et al*. (in press) and at the same time, the species was discovered in Cloosh Forest, Connemara, Co. Galway (Kearney, 2010). This provided the incentive to survey suitable habitats in the counties which lie between the known populations in SW Ireland and the newly discovered population in Co. Galway, with a view to determining the presence of a corridor through which the slug may have migrated.

Materials and methods

The presence or absence survey for *G. maculosus* in a total of 42 sites within 15 hectads in counties Galway, Clare, Limerick and Kerry (Figures 2.1, 2.2, Appendices 1 & 2) took place between October 10, 2011 and November 22, 2011 was initiated by a hand search, which took place in damp weather and lasted for about 45 minutes at each site. Searching for the species in woodlands involved checking under carpets of epiphytic bryophytes and lichens growing on tree trunks while on blanket bogs and heaths, specimens were often found between the vegetation and the base of rock outcrops Each of the 15 hectads had a maximum of 3 different survey sites and if no Kerry Slugs were found by hand searching, up to two metric traps were placed on tree trunks (Mc Donnell & Gormally, 2011b) within the forests at each site (Plate 2). Traps were baited with carrot and checked after three weeks. A licence under section 23 of the Wildlife Act was acquired from NPWS before commencing the study.

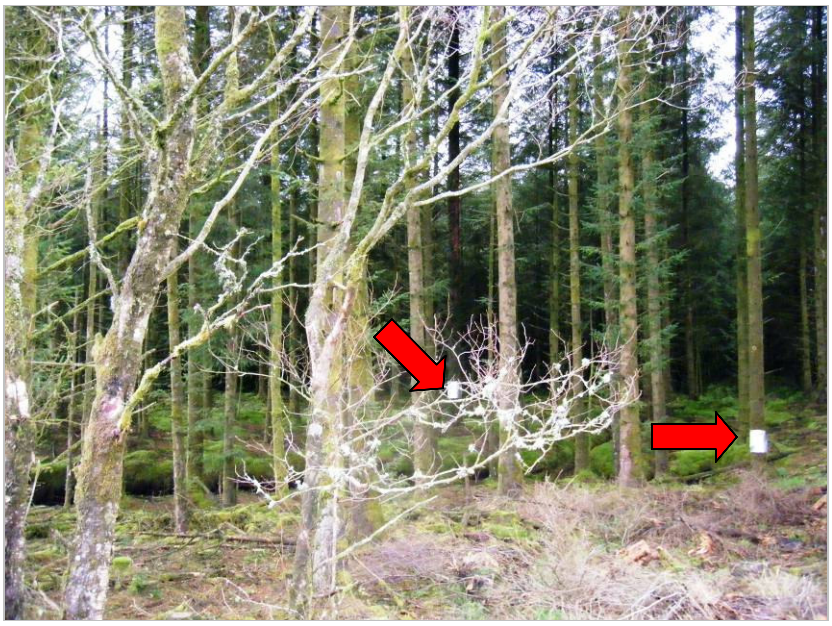

Plate 2: Metric traps (arrows) set up at a site in a conifer plantation in Hectad R21 (© Inga Reich).

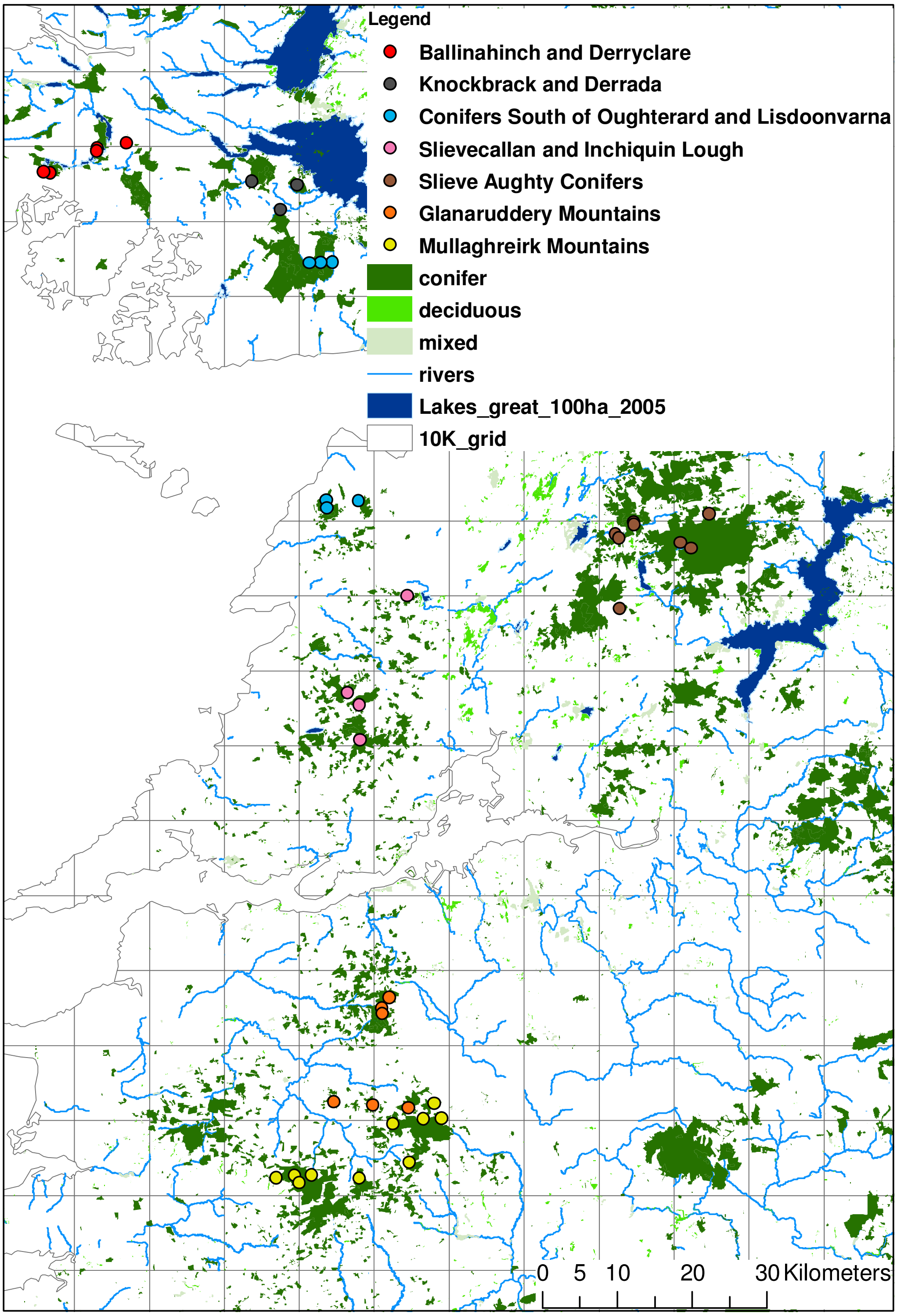

Figure 1: Location of study sites in counties Galway, Clare, Limerick and Kerry used for the *G. maculosus* presence/absence survey between October 10, 2011 and November 22, 2011.

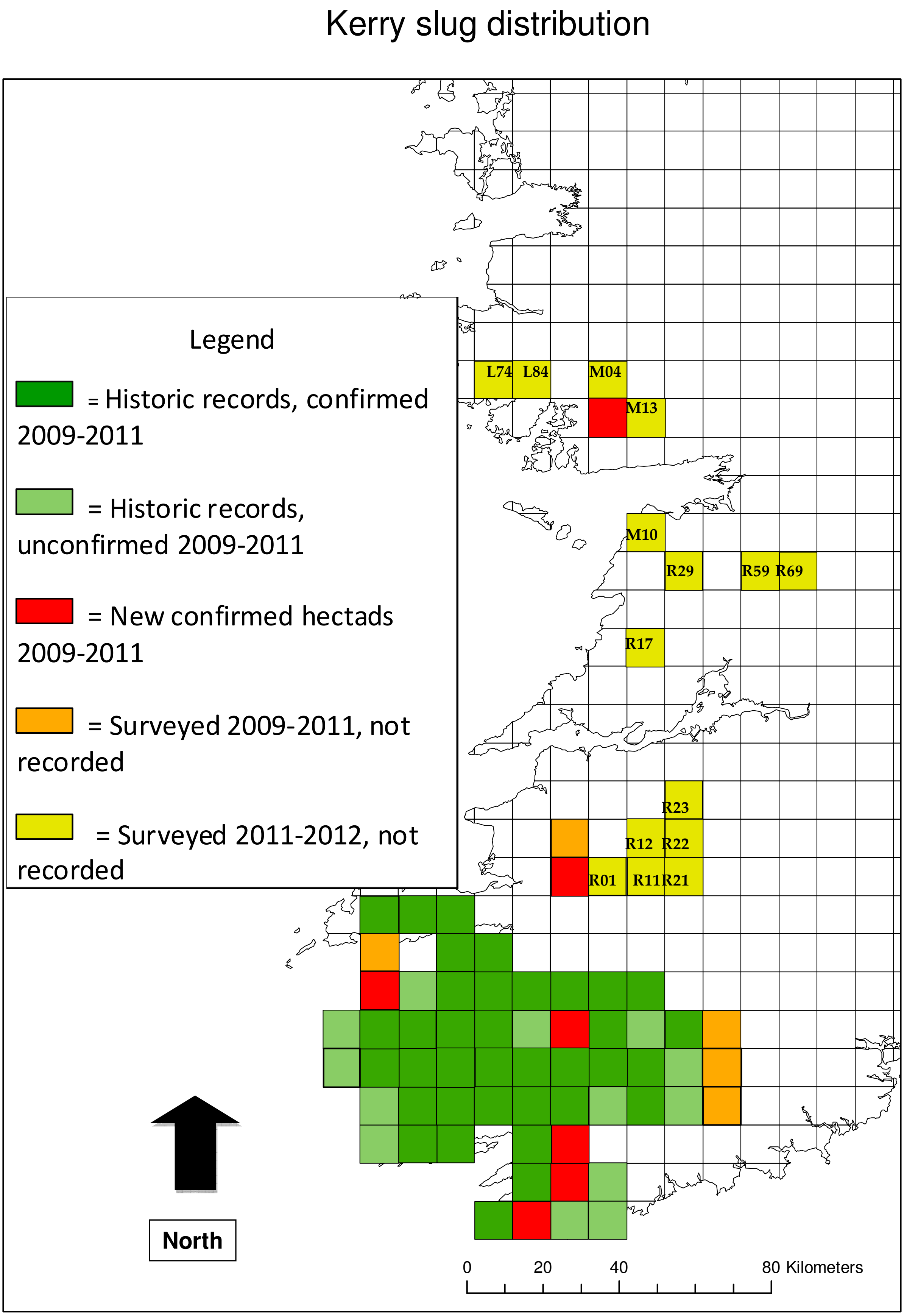

Figure 2: Partial map of Ireland showing hectads (10km grid-squares) surveyed for *G. maculosus* (source of data pre-2011: Mc Donnell *et. al.*, in press)

Results and discussion

No *G. maculosus* were recorded from any of the surveyed sites. The habitats searched included low and medium density conifer plantations, mixed deciduous/coniferous stands and adjacent clearfells as well as open areas with heather dominated vegetation which were deemed suitable for the species.

Eleven other slug species were trapped during the survey: *Lehmannia marginata* (Plate 3) was found in all hectads and was the most abundant species, comprising 50% of the overall catch. *Arion subfuscus* (20%), *Arion ater* agg. (9%) and *Deroceras laeve* (8%) were trapped at a number of sites and only a few specimens of *Deroceras reticulatum* (5%), *Arion flagellus* (2%, Plate 4), *Arion distinctus* (1%), *Arion circumscriptus* (2%), *Arion fasciatius* (1%), *Arion intermedius* (1%) and *Arion hortensis* (1%) were recorded (Figures 2.3, 2.4, Appendix 3). All of the above species are considered relatively common in Irish woodlands and have a red list status of least concern (Byrne *et al.*, 2009).

Plate 3: *Lehmannia marginata* in a Kerry Slug-like 'ball'. This behaviour was only observed once by the authors, so appears unusual. This species was found in all sites and is very common in woodlands and on rocks in open areas (© Inga Reich).

Plate 4: Juvenile *Arion flagellus* - easy to distinguish from other arionid slugs due to its continuous band between mantle and body and only 7 rows of tubercles between the bands. It inhabits a range of different habitats and is a common species across Ireland (Anderson, pers. comm.) (© Inga Reich).

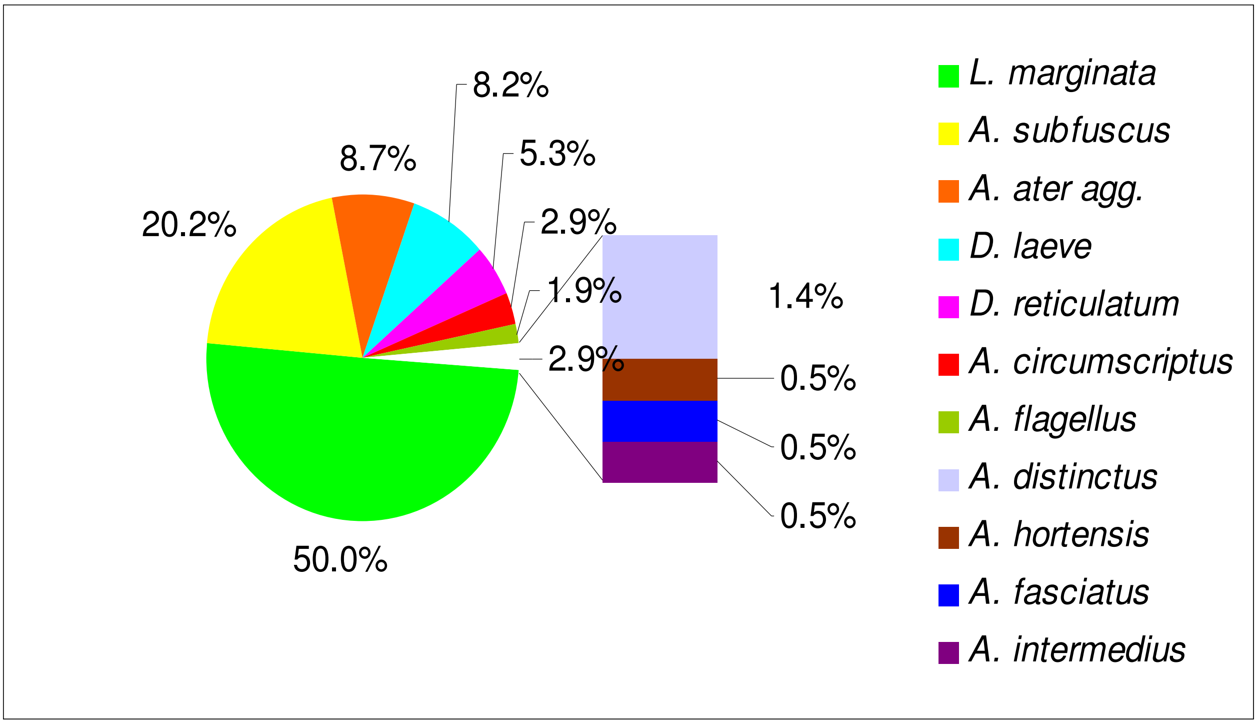

Figure 3: Percentage of all slug species trapped in the 15 hectads surveyed between November 1st and November 25, 2011, total n = 210.

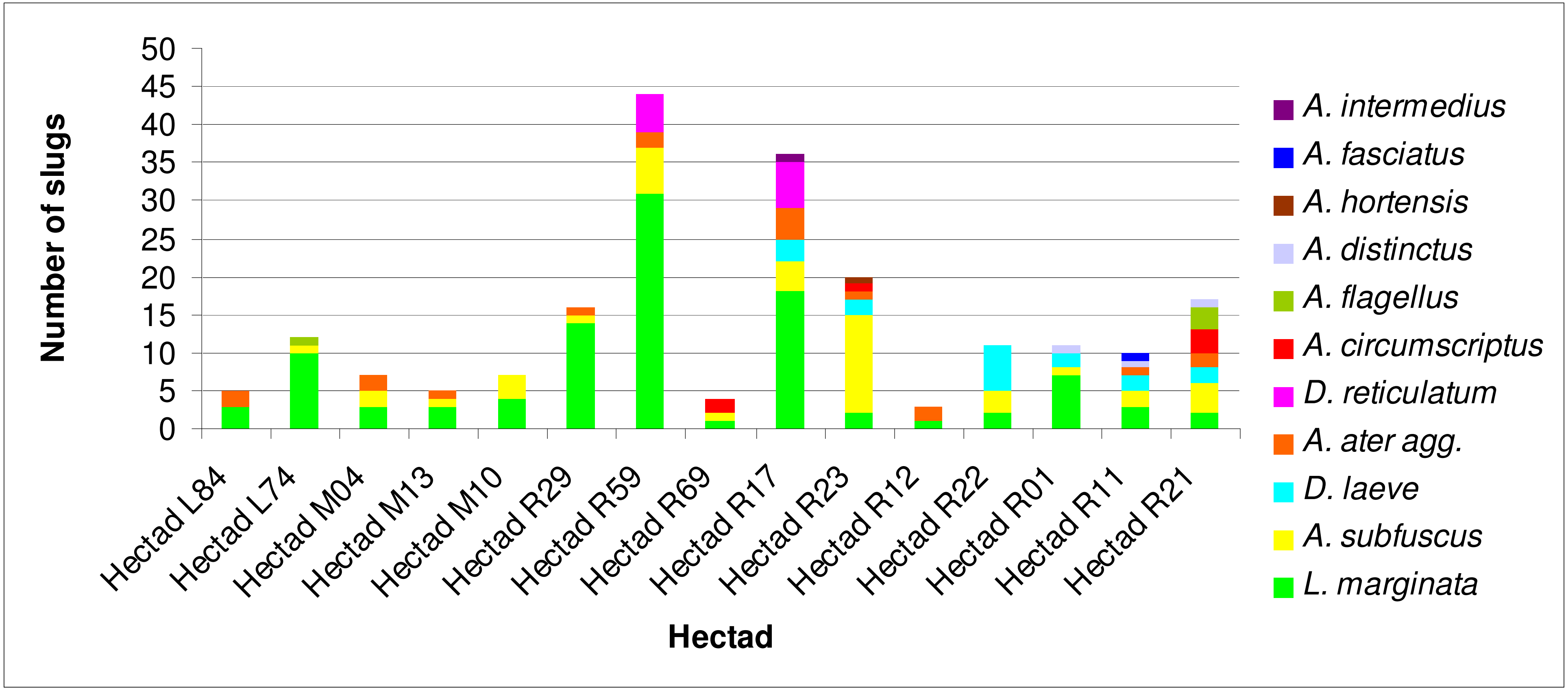

Figure 4: Slug composition in each of the 15 hectads surveyed in counties Galway, Clare, Limerick and Kerry between November 1 and November 25, 2011.

Analysis of the spatial distribution of *Geomalacus maculosus* in Cloosh Forest, Co. Galway

Locations of *Geomalacus maculosus* within Cloosh Forest

Rationale

In Ireland, *G. maculosus* was long believed to be restricted to mixed deciduous woodlands and open moor or blanket bog (Platts & Speight, 1988). However, Mc Donnell & Gormally (2011a) showed that the species occurs on conifer trunks in commercial forestry plantations in the south-west of Ireland. Surprisingly these authors also demonstrated that such areas can support large populations of *G. maculosus* suggesting that relatively open conifer forests with abundant epiphytic bryophytes can be suitable habitats for the species. Such conditions exist in parts of Cloosh Forest, Co. Galway. As *G. maculosus* is a protected species, management practices in forestry plantations in which it is found must take the protection of this species into account. This is particularly important considering that conifer plantations account for over 90% of the forested area of Ireland (www.unece.org).

As the Kerry Slug was not found at any other sites surveyed, our research was focused on the occurrence of the slug in Cloosh Forest, Co. Galway. In order to establish if and how forest structure (age of planted trees, tree species), habitat type (plantation forest or blanket bog) and varying abiotic habitat factors such as light intensity, temperature or humidity affect the occurrence of *G. maculosus* within Cloosh, it was important to determine the extent of its distribution at the site.

Site description

Cloosh Forest is located approximately 7km south of the village of Oughterard in Connemara, Co. Galway and covers an area of approximately 7,000 hectares (Coillte, 2009) (Figure 5) . The forest was planted mainly throughout the 1960s and 1970s on blanket bog (Coillte, 2009) and the soils range from shallow to deep blanket peat. The combination of extreme wind exposures and the poor soil quality makes broadleaf establishment difficult (Coillte, 2009) and therefore, tree species selection was limited mainly to *Picea sitchensis* (Sitka Spruce) and *Pinus contorta* (Lodgepole Pine) with some broadleaves such as *Betula pendula* (Silver Birch) and *Alnus sp*. (Alder). Large areas of the forest are now on their second rotation, i.e. they have been felled and subsequently replanted (Coillte, 2003, 2009). Thinning is not appropriate for this type of forest because, when trees are removed, the bog is not stable enough to support the remaining trees which would be subject to the constant threat of wind blow (Coillte, 2009).

Cloosh Valley is part of the Connemara bog complex which occupies an area north of Clifden in the west to Galway city in the east. The bog complex is protected under NHA (National Heritage Areas) and SAC (Special Areas of Conservation) designations (Coillte, 2009). The natural geology of Connemara, which includes Cloosh, is mainly limited to outcrops of granite (Feely, pers. comm.).

Cloosh forest is made up of a number of properties including Seecon, Letter, Lettermass, Knockalough, Finnaun, Lettercraffroe and Derradda (Coillte, 2009). This report encompasses a number of the above properties and unless otherwise stated the sites are located in Cloosh.

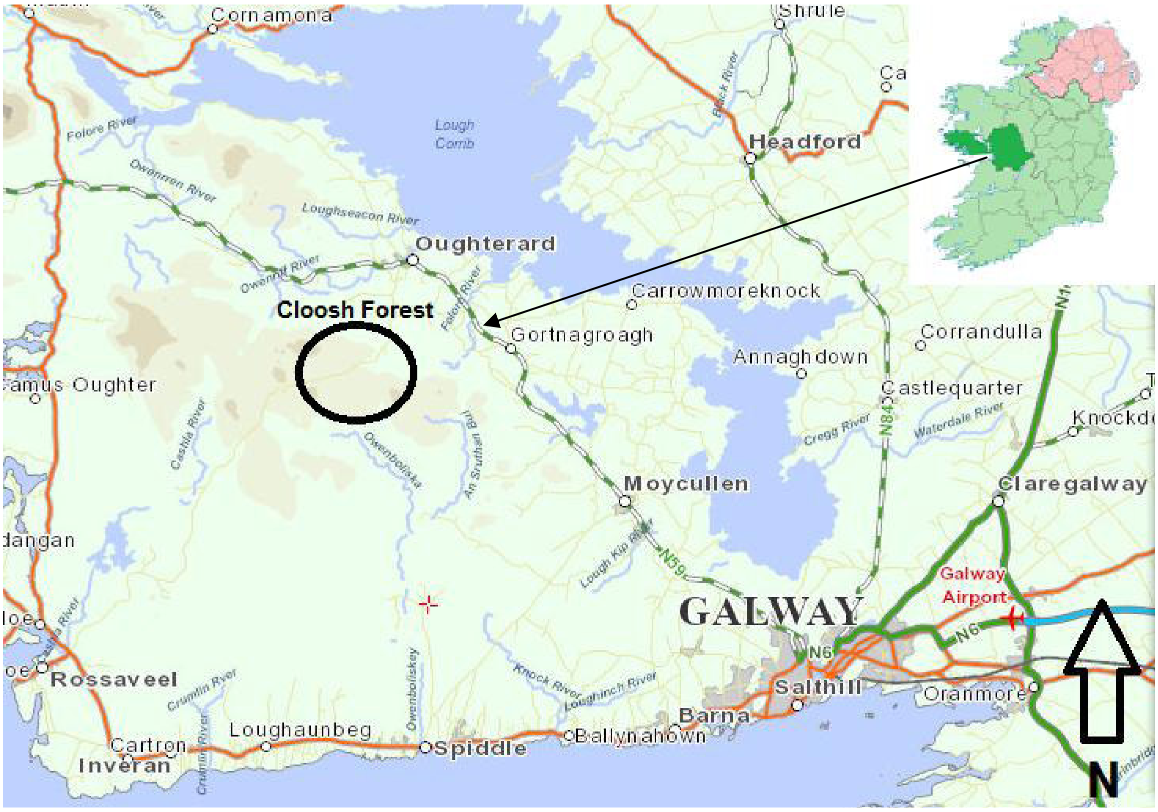

Figure 5: Location of Cloosh Forest in Connemara, Co. Galway (© OSI).

Materials and methods

Hand searching at Cloosh began in November 2011, using existing forestry roads to determine the boundaries between Kerry Slug presence and absence at the forest. If, after a 45 minute hand search no Kerry Slugs were found, a number of metric traps were put in place and checked weekly thereafter for four weeks (trapping method as described in previous chapter). If, during the 45 minute hand search a Kerry Slug was found, then the search moved further through the forest and the procedure was repeated. Searches at Cloosh which depended on appropriate weather conditions (damp weather, according to Platts & Speight, 1988) took place throughout the winter of 2011 until April 2012.

Results and discussion

Since the distribution of the Kerry Slug at Cloosh was found to be localized (Figure 6), it is likely that the species was introduced through anthropogenic sources possibly stemming from activities associated with commercial forestry operations. However, the less likely possibility that they form part of a relic population, undiscovered during ecological surveys of the Connemara Bog Complex should also be considered.

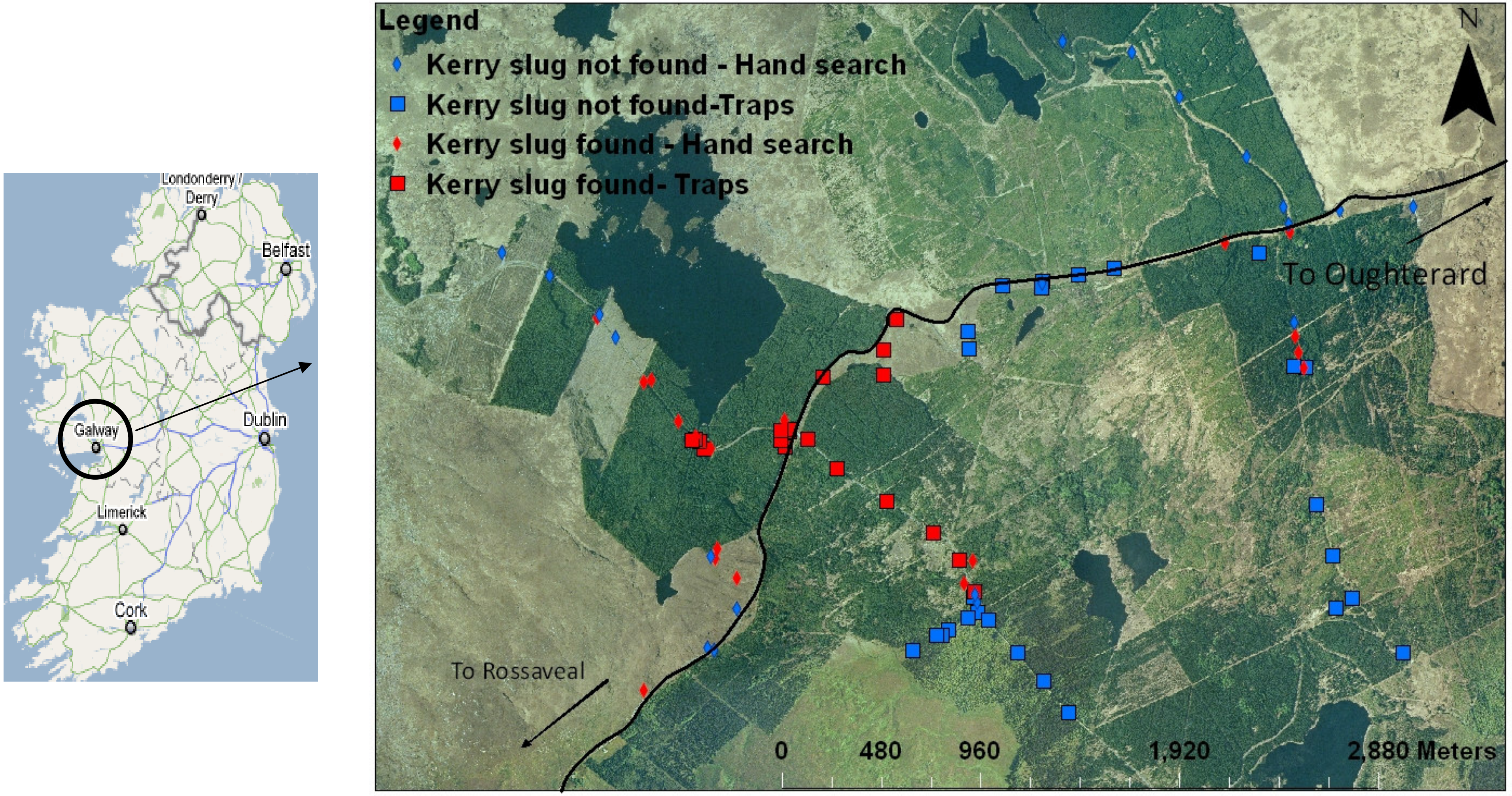

Figure 6: Hand searching and metric trapping points at Cloosh Forest, Co. Galway, carried out between November 2011 and April 2012.

Detailed investigation of *Geomalacus maculosus* distribution at Seecon

Rationale

Knowledge of the distribution of *G. maculosus* in Cloosh Forest could provide a valuable insight into factors limiting its occurrence. As previously mentioned, Cloosh Forest contains a number of properties and the area of focus for this study is herein referred to as Seecon. Seecon was selected for a detailed investigation, the aim of which was to determine the distance along a forest road connected to the main public road that the Kerry Slug was found. In addition, the distance at which the Kerry Slug occurred (up to 90m) into the dense forest from the edge of the forest road was also determined.

Site description

Seecon was planted in the early 1970s and is dominated by a non-native conifer plantation (WD4) of mixed tree ages (Fossitt, 2000). The dominant tree species are *P. sitchensis* and *P. contorta*. The conifers were planted on an upland blanket bog (PB2) habitat and the ground vegetation reflects this type of habitat (Fossitt, 2000). While the majority of the under-storey is covered by pine needles, some species of ground flora, which are typical of blanket bogs, are visible e.g. *Schoenus nigricans* (Black Bog-rush), *Sphagnum* spp. and *Molinia caerulea* (Purple Moor-grass). Small areas of Scrub (WS1) comprising *Rubus fruticosus agg*. (Bramble) and *Ulex europaeus* (Gorse) were also found although the closed canopy of the mature conifers limited the diversity of vegetation at most of the site by reducing the level of light available to ground flora.

Materials and methods

Ten transects (each with ten sampling points) were set up along the main forest road, east of the main Oughterard to Rossaveel road (Figure 7). The transects were 200m apart from each other and each consisted of ten trees located approximately 0, 10, 20, 30, 40, 50, 60, 70, 80, and 90 metres into the forest on the northern side of the forest road (Figure 8). On each tree a single metric trap was nailed at breast height onto the north side of the trunks. All traps were soaked in water from a local water source before they were put up and baited with a piece of organic carrot (Mc Donnell & Gormally, 2011b). The traps were checked on a weekly basis, during which time their underside was sprayed with a mist gun to keep them moist and baited with a fresh piece of carrot. To avoid counting the same individual twice, Kerry Slugs found under the traps were removed under licence and brought back to the laboratory where they were kept in a plastic container filled with moss and fed on a diet of carrots until the end of the survey at which stage all Kerry Slugs were released at the location from where they were removed. All other species of slugs captured were preserved for identification. Sampling took place mid-morning and was carried out on a weekly basis from October 24, 2011 until January 23, 2012 with the exception of December 26, 2011 when no sampling was undertaken.

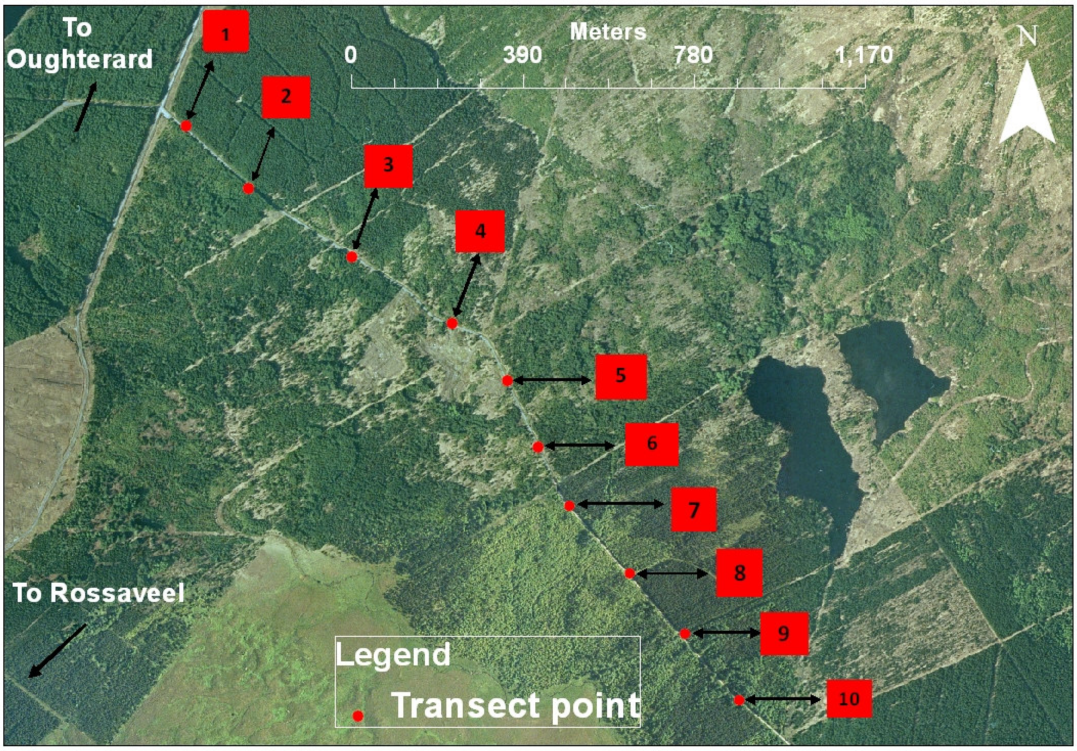

Figure 7: Seecon area of Cloosh Forest, Co Galway showing locations of the transects for the detailed Kerry Slug distribution investigation.

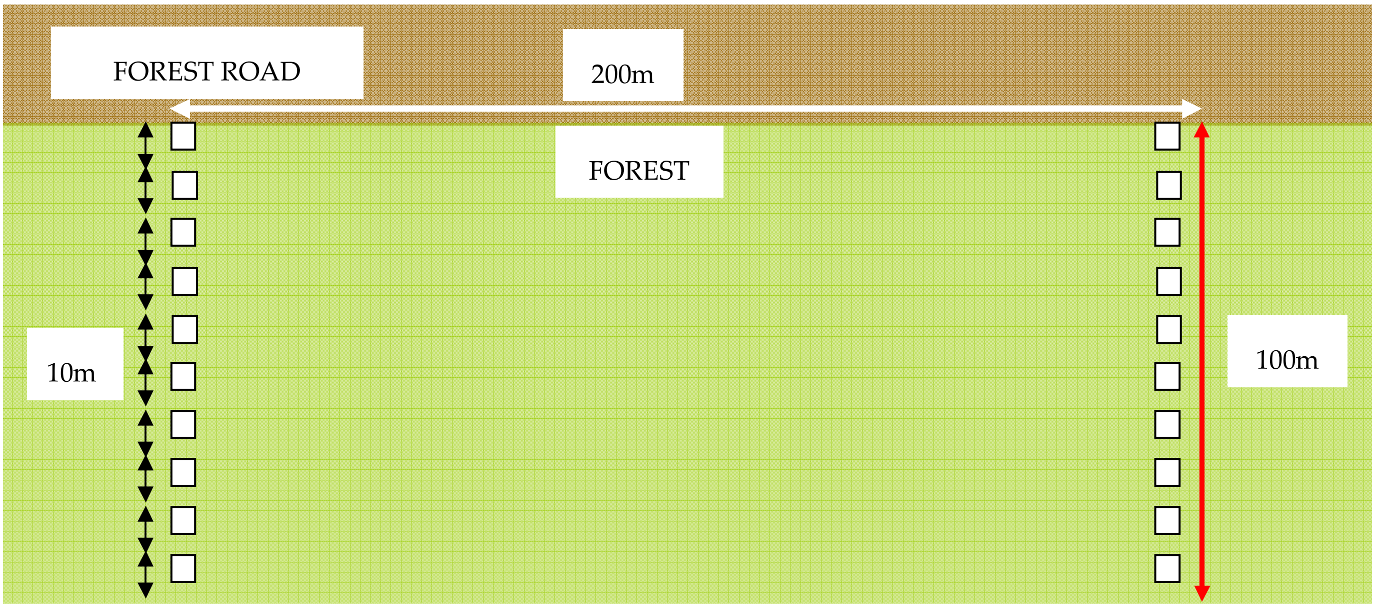

Figure 8: Schematic showing the arrangement of traps and transects in Seecon.

Results and discussion

A total of 1009 slugs (7 species) were trapped in the transects during the 13 week survey. *Lehmannia marginata* was the most abundant species with 517 specimens (38%) trapped in transects 1-10 followed by *G. maculosus* with 373 individuals (27%) trapped in transects 1-6 only (Appendix 4). *Arion subfuscus* and species of the *A. ater* agg. complex were also found in comparably high numbers, with total catches of 269 (19%) and 194 (14%) specimens respectively. Both of these species were found throughout transects 1-10. Less than 5% of the slugs trapped were *A. circumscriptus* (22 specimens), *Limax cinereoniger* (6 specimens) and *A. flagellus* (1 specimen) (Figure 9, Appendix 5). The discovery of *L. cinereoniger* (Plate 5) in the plantation is surprising in that it is classed as Vulnerable on the latest Irish Red List (Byrne *et al.*, 2009) and is a species of high conservation interest due to its restricted distribution. It is also believed to be a biological indicator of high quality woodlands (Byrne *et al.*, 2009) but this may now have to be revised due to its presence in a commercial forestry plantation.

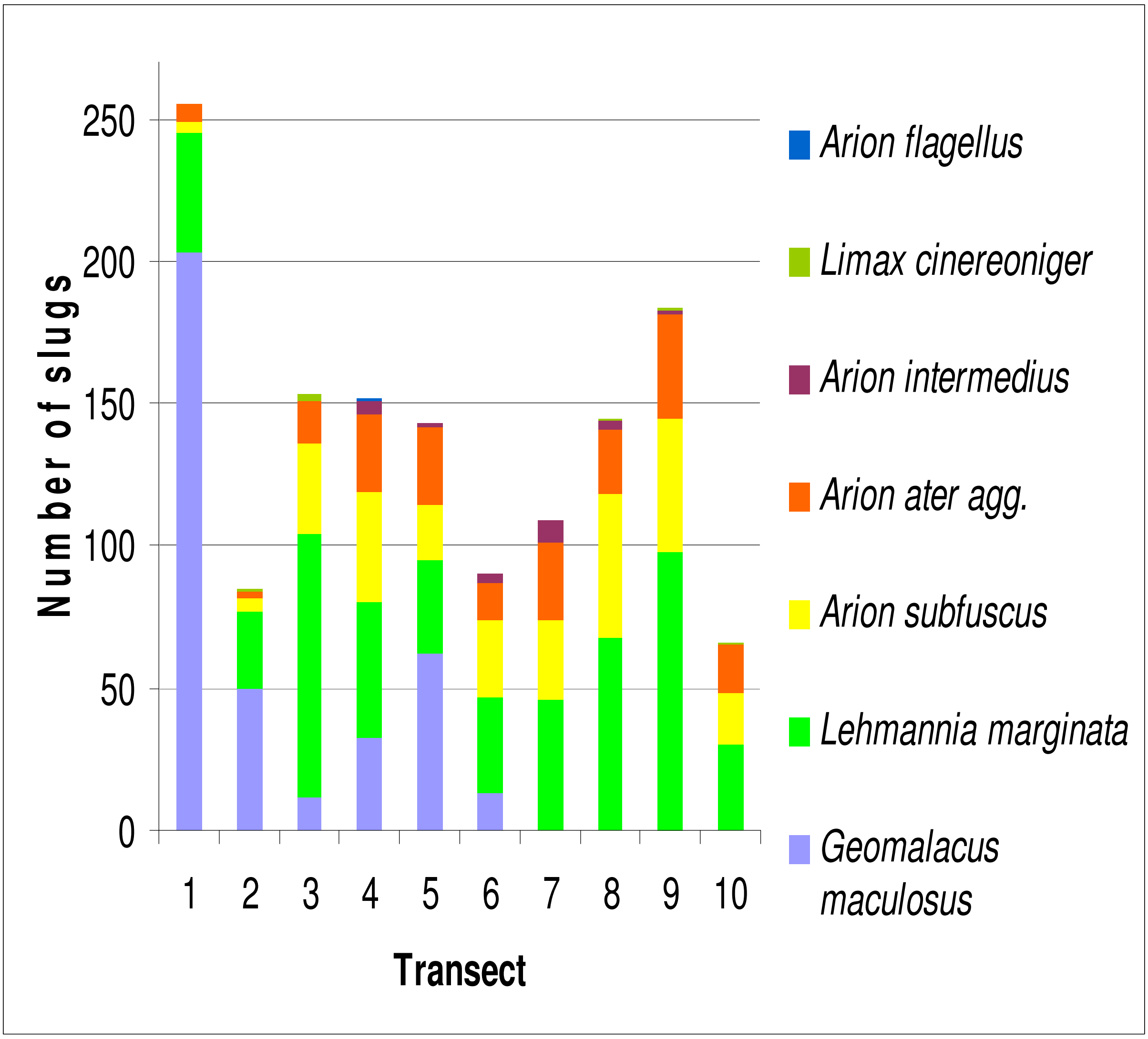

Figure 9: Abundances of slug species found at each transect in Seecon, Cloosh Forest (October 24, 2011 to January 23, 2012).

Plate 5: *Limax cinereoniger*, a species with a red list status of Vulnerable. Finding this species in a commercial forestry plantation sheds a different light on the value and importance of this habitat for slugs (© Inga Reich).

The median number (14) of *G. maculosus* trapped at Transect 1 i.e. the transect nearest the main public road (Table 1) is significantly greater than the median numbers caught at any of the other transects (Kruskal Wallis Test, H = 36.36 (adjusted for ties), $p < 0.01$). The species was trapped at all distances into the forest on this transect and despite the slight variations in slug numbers between the different distances (Figure 10), the differences between the medians were not significant (Kruskal Wallis Test, H = 8.54 (adjusted for ties), $p > 0.05$). The results might suggest that the distribution of *G. maculosus* in Seecon is either due to a dramatic change in habitat conditions between transects 6 and 7, which is not the case at Seecon, or due to the slug having been introduced (accidentally or otherwise) to the site possibly near the main public road and that it simply has not yet spread throughout the whole surveyed area. The correlation of habitat factors with the abundance of *G. maculosus* will be discussed later in this report.

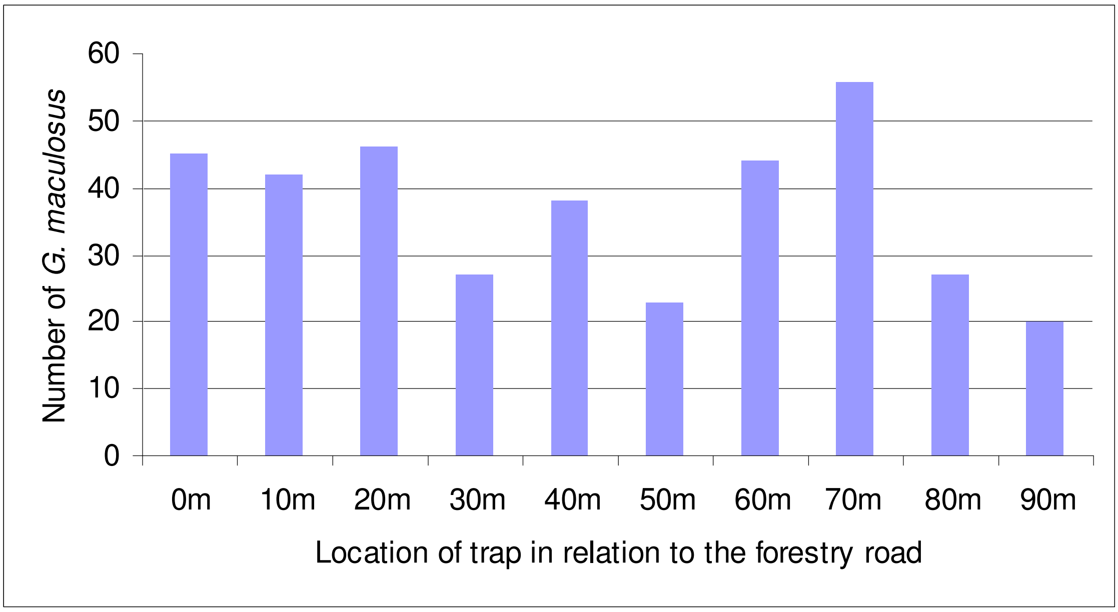

Figure 10: Total number of *G. maculosus* found under the traps in transects 1-6 at different distances into the forest (October 24, 2011 to January 23, 2012) in Seecon, Cloosh Forest.

Table 1: Total catch, mean ± SD and median numbers of slugs per transect for the four dominant slug species (October 24, 2011 to January23, 2012) in Seecon, Cloosh Forest.

		G. maculosus	*L. marginata*	*A. subfuscus*	*A. ater* agg.
Transect 1	n	203	42	4	6
	Mean ± SD	15.62 ± 9.61	3.23 ± 2.39	0.31 ± 0.48	0.46 ± 0.88
	Median	14	3	0	0
Transect 2	n	50	27	5	2
	Mean ± SD	3.85 ± 3.65	2.08 ± 1.75	0.38 ± 0.51	0.15 ± 0.38
	Median	4	2	0	0
Transect 3	n	12	92	32	15
	Mean ± SD	0.92 ± 0.95	7.08 ± 6.05	2.46 ± 1.94	1.15 ± 0.90
	Median	1	7	2	1
Transect 4	n	33	47	39	27
	Mean ± SD	2.54 ± 2.22	3.62 ± 2.14	3.00 ± 3.42	2.08 ± 3.50
	Median	3	3	2	1
Transect 5	N	62	33	19	28
	Mean ± SD	4.77 ± 3.65	2.54 ± 2.15	1.46 ± 0.88	2.15 ± 1.52
	Median	4	2	1	2
Transect 6	N	13	34	27	13
	Mean ± SD	1.0±1.29	2.62 ± 1.85	2.08 ± 1.93	1.0±1.68
	Median	0	3	1	0
Transect 7	n	0	46	28	27
	Mean ± SD	0	3.54 ± 2.15	2.15 ± 1.52	2.08 ± 2.25
	Median	0	3	2	1
Transect 8	n	0	68	50	23
	Mean ± SD	0	5.23 ± 4.38	3.85 ± 2.88	1.77 ± 2.28
	Median	0	4	3	1
Transect 9	n	0	98	47	36
	Mean ± SD	0	7.54 ± 6.39	3.62 ± 3.50	2.77 ± 3.14
	Median	0	7	3	2
Transect 10	n	0	30	18	17
	Mean ± SD	0	2.31 ± 1.97	1.38 ± 1.45	1.31 ± 1.25
	Median	0	1	1	1

Also of interest is, that the number of the other dominant slug species *A. subfuscus*, *A. ater* agg. and *L. marginata* caught per trap is significantly higher in transects 7-10, where G. *maculosus* is absent (Figure 11). In addition, there is a significant (Spearman's Rank Test, r = -0.263, p <0.05) negative correlation between the number of *G. maculosus* and *A. subfuscus* trapped per week during the sampling period (Table 2, Figure 12). No correlation could be found between the number of *G. maculosus* and *A. ater* and *L. marginata* (Table 2, Figures 13, 14). It is possible therefore that the Kerry Slug out competes *A. subfuscus* where they co-occur but replicated studies in multiple forest are required to substantiate this.

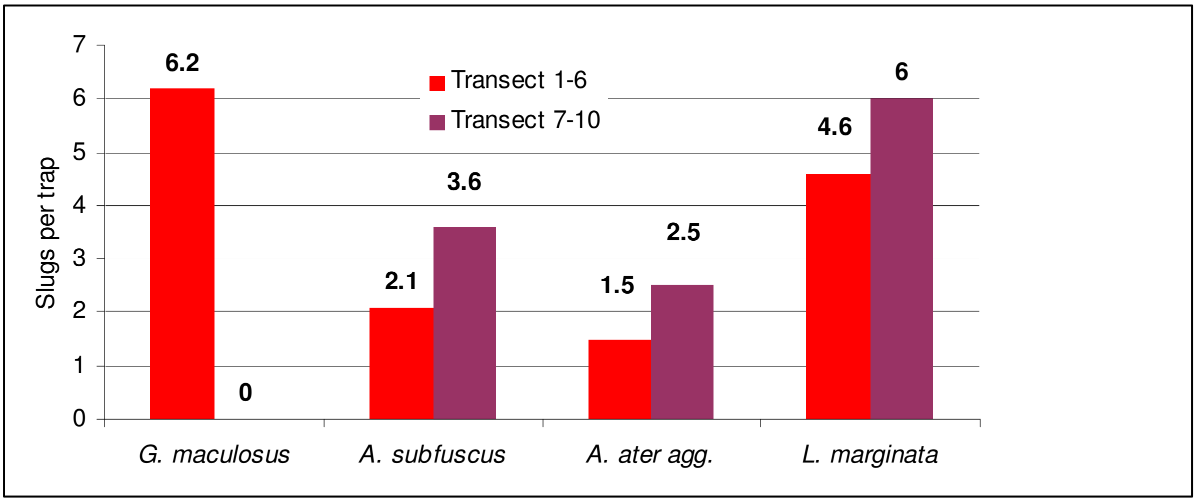

Figure 11: Number of slugs divided by the number of traps for the four dominant species in transects 1-6 and transects 7-10 during the 13 week sampling period between October 24, 2011 and January 23, 2012 in Seecon, Cloosh Forest.

Table 2: Spearman's Rank Test performed on the weekly abundance of *G. maculosus* and the three other dominant slug species found during the 13 week sampling period between October 24, 2011 and January 23, 2012 in Seecon, Cloosh Forest.

	L. marginata	*A. subfuscus*	*A. ater* agg.
Spearman's r	-0.076	-0.263	-0.144
p	0.388	0.002	0.103

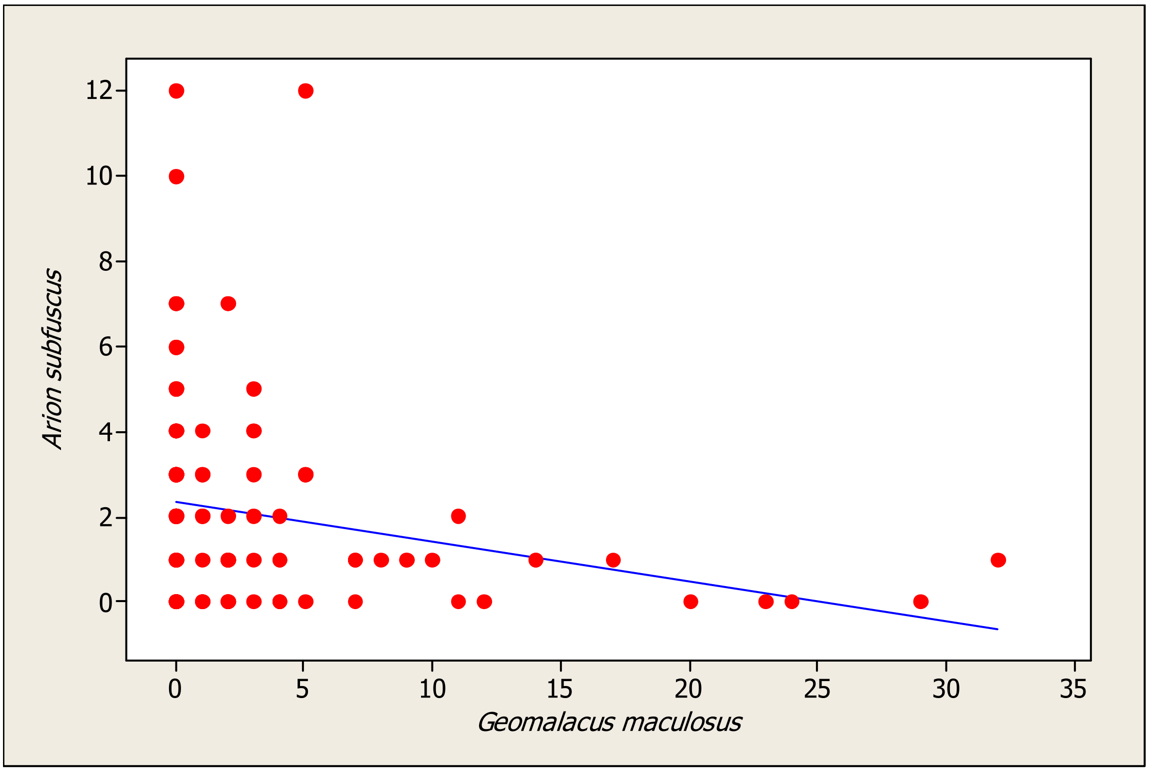

Figure 12: Scatterplot showing numbers of *Geomalacus maculosus* and *Arion subfuscus* trapped per week at Seecon, Cloosh Forest (October 24, 2011 – January 23, 2012) and regression curve.

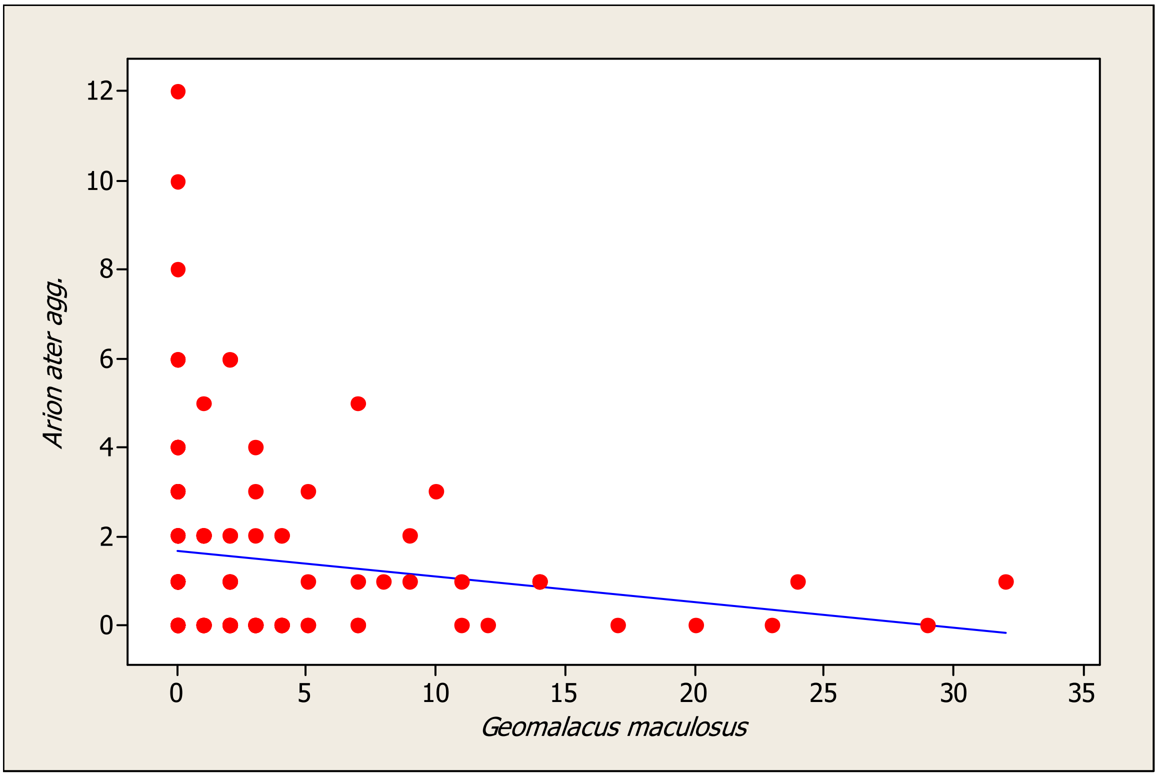

Figure 13: Scatterplot showing numbers of *Geomalacus maculosus* and *Arion ater* agg. trapped per week at Seecon, Cloosh Forest (October 24, 2011 – January 23, 2012) and regression curve.

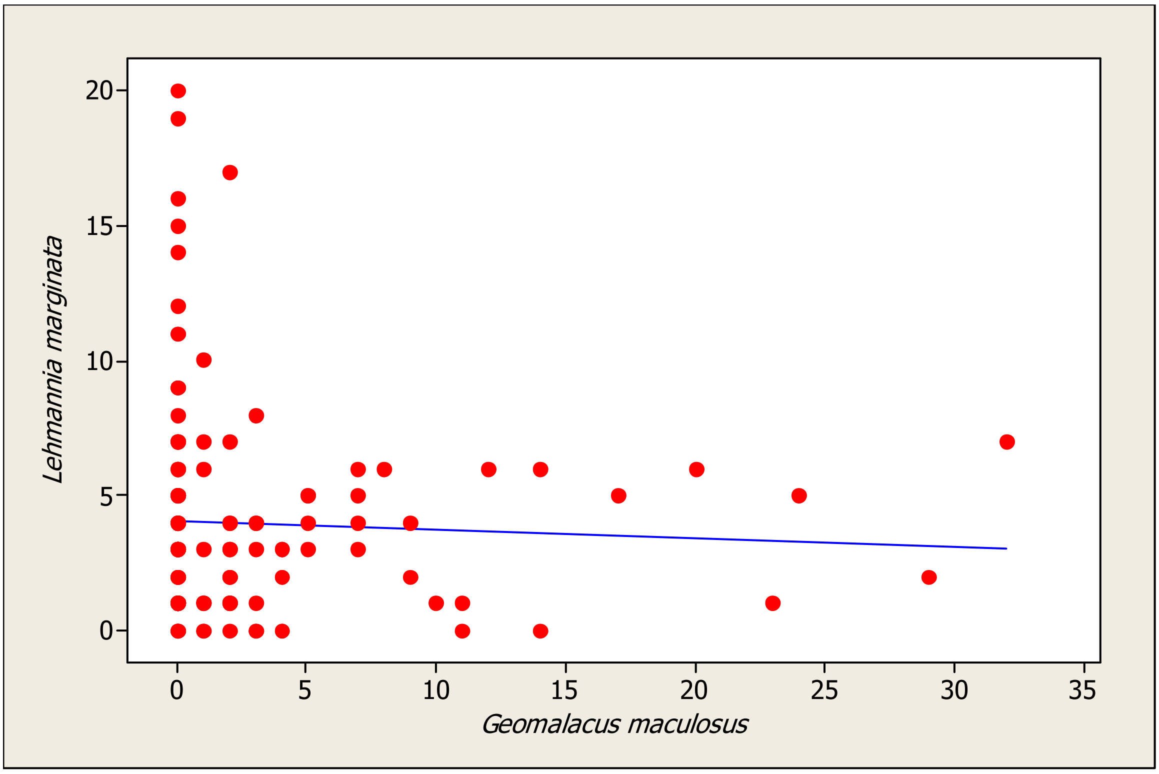

Figure 14: Scatterplot showing numbers of *Geomalacus maculosus* and *Lehmannia marginata* trapped per week at Seecon, Cloosh Forest (October 24, 2011 – January 23, 2012) and regression curve.

Habitat requirements of *G. maculosus* at Cloosh Forest

Rationale

A key deficiency regarding Kerry Slug studies to date has been the paucity of information regarding the ecological requirements of the species, an issue discussed by Mc Donnell & Gormally (2011a), who suggest that this area requires urgent investigation to ensure the successful conservation of the species. To address this issue, a study of the environmental conditions in areas where the Kerry Slug is found, in addition to food sources available to the species was undertaken at Cloosh Forest between December 2011 and April 2012.

Environmental parameters

Materials and methods

Tree CBH (circumference at breast height), tree species, bark structure (smooth, flaky, cracked), bryophyte cover (%) and light intensity were recorded for all traps in Seecon from transects 1-6 where *G. maculosus* was found (Appendix 6). The temperature was recorded at traps 1 and 10 in transects 5 and 7 using a Tinytag data logger and a Hanna Lux meter (HI 97500) was used to record the light intensity at each of the 100 trapping points.

Results and discussion

A significant positive correlation (Table 3) was found between Kerry Slug abundance and both CBH (Spearman's Rank Test, $r = 0.336$, $p < 0.01$) and bryophyte/lichen cover (Spearman's Rank Test, $r = 0.338$, $p < 0.01$) was found in transects 1-6. Bryophyte and lichen cover is likely to be beneficial to *G. maculosus* as it provides shelter and food for the species (Platts & Speight, 1988). The CBH is most likely linked to the bryophyte/lichen cover, as the trunks of more mature trees which have a greater CBH usually have more lichen and bryophyte cover than the younger trees with a smaller CBH.

Table 3: The correlation of CBH (circumference at breast height), light intensity, bryophyte/lichen cover, bark structure and tree species to the abundance of *G. maculosus* found in transects 1-6, measured in April 2012 in Seecon, Cloosh Forest.

	CBH (cm)	**Light intensity (klux)**	**Bryophyte/lichen cover (%)**	**Bark structure**	**Tree species**
Spearman's r	0.336	-0.015	0.338	0.238	-0.067
p	0.009	0.911	0.008	0.066	0.613

Interestingly, median percentage cover of bryophytes and lichens was significantly lower (Mann-Whitney U Test, W = 3473.5, $p < 0.01$) at transects 7-10 where the Kerry Slug was absent than at transects 1-6 where it was present (Table 4). This adds weight to our hypothesis that bryophyte/lichen cover is a key microhabitat requirement for the species in conifer plantations. However, no significant difference in median CBH was detected in the two sets of transects (i.e. 1-6 and 7-10).

Table 4: Mean ± SD, median and W-value of CBH and bryophyte/lichen cover measured in April 2012 in Seecon, Cloosh Forest, between the transects where *G. maculosus* has been found (transects 1-6) and where it is absent (transects 7-10).

	CBH (cm)		**Bryophyte/lichen cover (%)**	
	Transect 1-6	Transect 7-10	Transect 1-6	Transect 7-10
Mean ± SD	72.43 ± 20.79	77.1 ± 30.2	2.05 ± 0.77	1.53 ± 0.68
Median	73.5	75.5	2	1
W	2963.0		3473.5	
P	0.6398 (adjusted for ties)		0.0009 (adjusted for ties)	

* The mean and median values shown for bryophyte cover (%) are derived from categorical values. 0-30% bryophyte cover was referred to as '1', 30-60% cover as '2' and >60% cover as '3'.

The temperatures that were recorded with the Tiny Tags between February 14 and May 24, 2012 are not significantly different in transects 5 and 7 (Table 5), so it is not likely that the absence of *G. maculosus* from transect 7 to 10 is due to a change in temperature.

Table 5: Mean ± SD, median and W-value for the minimum, maximum and average temperatures measured between February 14 and May 24, 2012 in transects 5 and 7 in Seecon, Cloosh Forest.

	Minimum		**Maximum**		**Average**	
	Transect 5	Transect 7	Transect 5	Transect 7	Transect 5	Transect 7
Mean ± SD	4.3°C ± 3.82	4.9°C ± 3.43	11.4°C ± 4.67	12.0°C ± 4.95	7.8°C ± 3.89	8.5°C ± 3.86
Median	3.7°C	4.3°C	10.1°C	10.4°C	7.1°C	7.7°C
W	10378.0		10501.5		10228.0	
p	0.1124		0.1912 (adjusted for ties)		0.0538	

Geomalacus maculosus feeding trials

Materials and methods

According to Platts & Speight (1988) *G. maculosus* feeds on or takes shelter under lichens, liverworts and/or mosses. With regard to this, samples of bryophytes and lichens were collected from granite rock outcrops and conifer trees in Cloosh and offered to Kerry Slugs under laboratory conditions. Throughout the experiments, only slugs collected from forested areas were used.

A number of preliminary feeding trials were carried out to assess the lichen species for which G. *maculosus* had the greatest affinity. Prior to experimentation, individuals were starved for 24 hours. The slugs were then placed in Petri dishes with moist filter paper and a lichen sample. Ten individual slugs were each presented one of the following lichen species: *Cladonia ramulosa*, *Cladonia portentosa*, *Cladonia uncialis* ssp. *biuncialis*, *Cladonia squamosa*, *Parmotrema perlatum* and *Cladonia coniocrea*. Individuals were observed for one hour and the time spent feeding on the individual lichen species was noted. The same procedure was followed for 10 moss, 3 liverwort, 2 heather or 1 fern species. According to Simroth (1891), a *G. maculosus* specimen is feeding when they take up a hunched position with the head and eyes protruding only very slightly from under the mantle.

As the results from the preliminary tests showed that lichens were the most palatable to *G. maculosus*, they were used for the following experiments:

1. Experiment 1: focused solely on lichens that were collected from tree bark. Six different species were tested (2 fruticose, squamulose, cup lichens, 2 foliose lichens, 1 crustose, leprose lichen and 1 fruticose lichen). One sample of each lichen species was randomly placed in a plastic container (32cm x 42cm) and sprayed with water using a mist gun. Slugs were starved for 24 hours prior to being placed in the container to encourage feeding during the 2 hour experiment. Thirty-two Kerry Slugs, both juveniles and adults, were put into the container at the same time and observed: Every ten minutes, it was noted how many slugs were feeding on each lichen species. A total of ten experiments were carried out using the same individuals, although numbers declined due to mortality and suspected cannibalism (no slug carcasses were found and it was not possible for the slugs to escape out of their container) among specimens. By experiment number 10, 25 slugs were alive.
2. Experiment 2: focused solely on crustose lichens taken from granite rock outcrops on blanket bog surrounding Cloosh Forest. Slices of the rock, which were cut using a con saw, were placed in a large plastic container which was filled with ~2cm of water to prevent the slugs from moving between rocks (Plate 6). Five slugs were placed on each rock sample and were observed every five minutes for a period of one hour. The slugs were moistened every 15 minutes with water using a mist gun to prevent desiccation. At each observation the number of slugs that were feeding and the lichens on which they fed were noted.

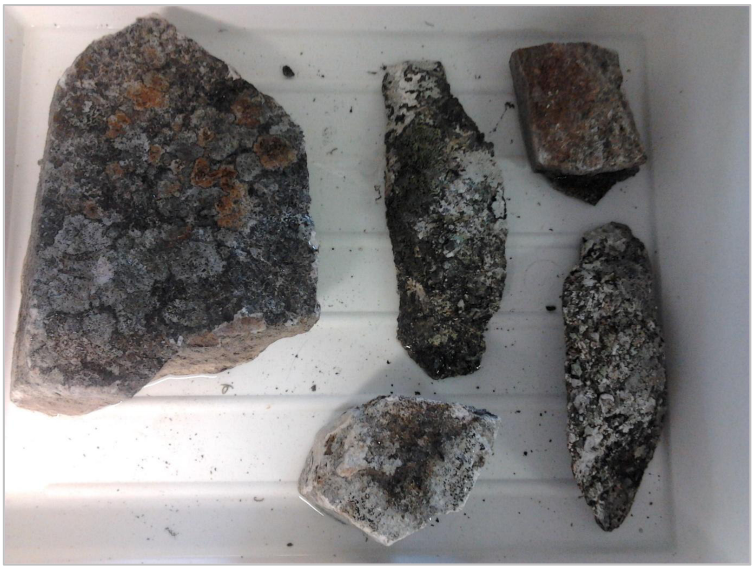

Plate 6: Rock samples in water-filled (~ 2cm) plastic container as used in experiment 2 (© Kim O'Meara).

Results and discussion

During preliminary experiments, *G. maculosus* was observed feeding on all the species of fruticose and foliose lichen they were offered (Table 6), suggesting that the majority of lichen species growing on granite taken from Cloosh are palatable to *G. maculosus*. In contrast, the slugs were only observed feeding on 2 of the 8 moss species offered (i.e. *Campylopus introflexus* and *Pleurozium schreberi*), indicating that mosses are not as important a food source for *G. maculosus*. This is unsurprising as mosses are known to be unpalatable to most slugs due to the large amount of phenolic compounds they produce (Davidson & Longton, 1987; Davidson *et al.*, 1989). *P. schreberi*, a moss on which the slugs were observed feeding has been shown to contain relatively low concentrations of phenolics which may explain its palatability. The unpalatability of most moss species does not necessarily mean their presence is not important for *G. maculosus* as they appear to be used for shelter. This is supported by the fact that a significant positive correlation was found between *G. maculosus* abundance and bryophyte/lichen cover (see above). During sampling, comparably larger numbers of slugs (Kerry Slugs as well as other species) were observed on trees with bryophyte cover. The liverworts tested were the thallose species *Metzgeria furcata* and the leafy species *Saccogyna viticulos* and *Frullania dilatata,* all of which were consumed. The slugs were not observed feeding on the heather or fern species tested (Table 6), indicating that lichens, liverworts and some mosses are their most important food sources.

Table 6: Preliminary results of feeding trials showing species of lichens, mosses, liverworts, heathers and fern consumed/not consumed by *G. maculosus*.

Vegetation type	**Consumed species**	**Species which were not consumed**
Lichen	*Cladonia cariosa*	
	Cladonia coniocrea	
	Cladonia fimbriata	
	Cladonia portentosa	
	Cladonia ramulosa	
	Cladonia rangiferina	
	Cladonia squamosa	
	Cladonia uncialis ssp. *buncialis*	
	Parmelia saxatilis	
	Parmotrema perlatum	
	Sphaerophorus globosus	
	Stereocaulon vesuvianum	
Moss	*Campylopus introflexus*	*Sciuro-hypnum populeum*
	Pleurozium schreberi	*Hylocomiastrum umbratum*
		Hypnum cupressiforme
		Isothecium myosuroides
		Polytrichum commune
		Racomitrium heterostichum
		Sphagnum sp.
		Trichostomum crispulum
Liverwort	*Frullania dilatata*	
	Metzgeria furcata	
	Saccogyna viticulosa	
Heather		*Calluna vulgaris*
		Erica cinerea
Fern		*Blechnum spicant*

Experiment one – Lichens collected from trees

Throughout the ten feeding trials, feeding behaviour was determined using 1,517 observations. Figure 15 shows the percentage of each tested lichen species that *G. maculosus* was observed to be feeding on. The foliose lichen *Platismatia glauca* was the most favoured species (487 observed feedings), followed by the fruticose species *Usnea cornuta* (358 observed feedings) (Plate 7), the fruticose squamulose *Cladonia uncialis* (260 observed feedings), the foliose *Paromtrema perlatum* (246 observed feedings) (Plate 8) and the fruticose squamulose *Cladonia coniocraea* (125 observed feedings). The leprose *Lepraria incana* (41 observed feedings) (Plate 9) was the least favoured lichen species (Figure 15), which might be due to its crustose growth form, which is comparably hard to graze for slugs (Whelan, pers. com.).

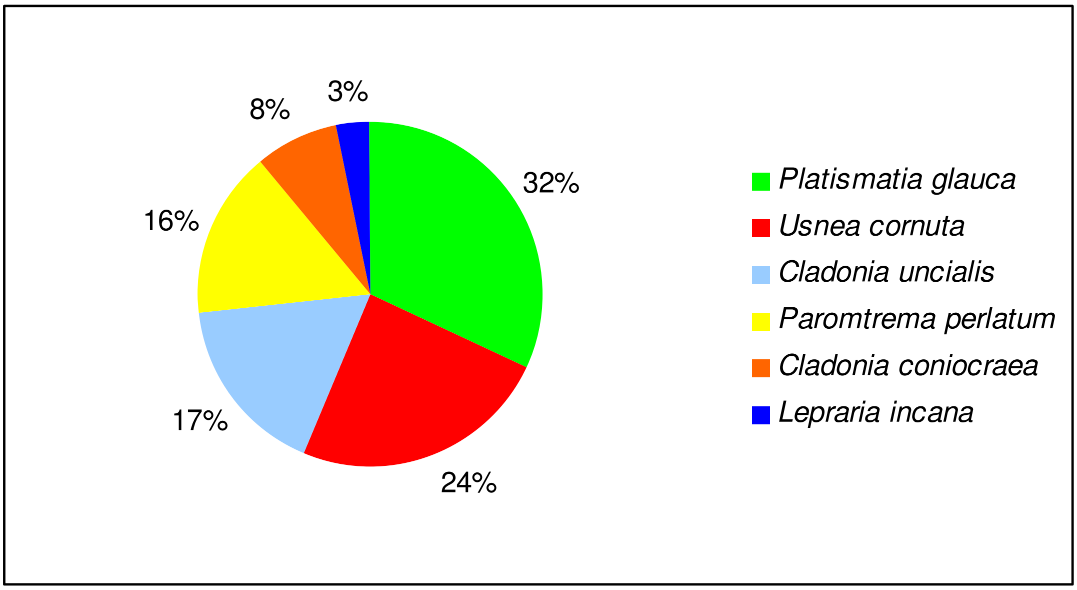

Figure 15: Percentage of observed feedings of *G. maculosus* on each tested lichen species (total n = 1517).

The differences in the preferences were highly significant (χ^2 Test for the Goodness of Fit, $p < 0.01$) for five out of the six tested lichen species (Table 7). Future research should establish if the preferences are due to the nutrient values of the lichens, secondary compounds deterring or favouring consumption of the lichen species or if they are simply due to the growth form of the lichen.

Table 7: χ^2- Values indicating the preferences (based on the 1517 feeding observations) of *G. maculosus* for the lichen species offered to the species during 10 feeding trials.

	P. glauca	*L. incana*	*P. perlatum*	*U. cornuta*	*C. coniocraea*
C. uncialis	91.514[1]	176.886[1]	0.2914	19.516[1]	54.218[1]
P. glauca		456.110[1]	104.480[1]	27.296[1]	268.230[1]
L. incana			161.726[1]	289.988[1]	44.966[1]
P. perlatum				25.930[1]	44.962[1]
U. cornuta					133.682[1]

* [1] indicates a significant preference with p <0.01

Plate 7: *Usnea cornuta* lichen at Cloosh Forest, Connemara, Co. Galway (© Inga Reich).

Plate 8: *Paromtrema perlatum* lichen at Cloosh Forest, Connemara, Co. Galway (© Inga Reich).

Plate 9: *Lepraria incana* lichen at Cloosh Forest, Connemara, Co. Galway (© Inga Reich).

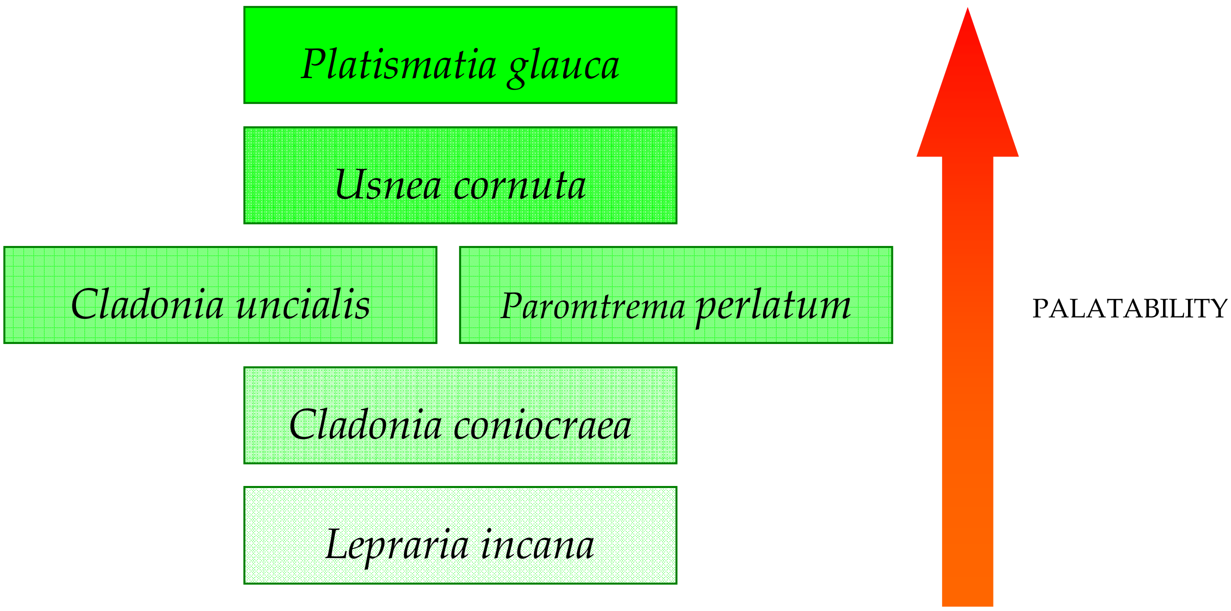

Figure 16: Schematic showing the preferred lichen species of *G. maculosus* as established in the ten feeding trials.

Experiment two – Lichens collected from granite rock outcrops

Lichens are known to absorb compounds such as atranorin, salazinic and lobaric from their environment which form crystals within their structure. It has been shown that the presence of such secondary compounds reduces herbivory, meaning that they play an important role in protecting lichens from grazing pressures (Gauslaa, 2005). It is therefore likely that the species of lichens on which *G. maculosus* were observed feeding did not contain significant quantities of these secondary compounds or that *G. maculosus* has evolved mechanisms to cope with the chemicals (Table 8).

Porpidia flavocruenta is known to accumulate large quantities of iron, which often causes it to become orange in colour (Fryday, 2005), as was the case with the *P. flavocruenta* tested in this study. It is likely that this high concentration of iron is a defence against grazing pressures and causes this particular species to be unpalatable to *G. maculosus*. Crustose lichens including other *Porpidia* species collected from Burren limestone were not eaten by *G. maculosus*. This might be due different secondary compounds accumulating in lichens growing on limestone and that these compounds may influence the palatability of a species to *G. maculosus*. This may help explain why *G. maculosus* is not known to inhabit limestone areas. The apparent unpalatability of the *Verucaria* species on the rock samples tested may be due to *G. maculosus* experiencing difficulty in scraping the very thin, tar like layers that this species forms on the substrate (Whelan, pers. comm.). As the other lichen species on the rock samples grew in much thicker formations this would make them less labour intensive for *G. maculosus* to remove from the substrate and therefore easier to feed upon.

Table 8: Crustose lichens from Connemara offered to *G. maculosus*

Consumed species	**Species which were not consumed**
Pertusaria lactescens	*Porpidia flavocruenta*
Porpidia tuberculosa	*Verucaria* sp.
Porpidia crustulata	
Porpidia cinereoatra	
Lecanora sulphurea	
Rhizocarpon geographicum	

The potential impact of forestry operations on the distribution and abundance of *G. maculosus* at Cloosh Forest

Rationale

As *G. maculosus* is a protected species, management practices in forestry plantations in which it is found must take the protection of this species into account. In addition, the creation of buffer zones to ensure the protection of the endangered freshwater pearl mussel (*Margaritifera margaritifera*), has resulted in the felling of conifers along water bodies within plantations. The implications of this practice for *G. maculosus* have yet to be determined and in the case of Cloosh forest and in particular the Lettercraffroe property, tree stumps (approximately 3m high) were left in place in felled areas to mitigate potential negative effects on *G. maculosus* (Nelson, pers. comm.). This section of the project investigates the success of the remaining tree stumps and clearfell in supporting the population of *G. maculosus* by comparison with an adjacent mature plantation.

Site description

This survey was carried out in the most mature forested area in Cloosh Forest, herein referred to as Lettercraffroe which was planted in the late 1950s and early 1960s. Traps were set up in two areas to distinguish between *G. maculosus* use of a clearfell and mature plantation (Figure 17). The plantation consists predominantly of Sitka Spruce and the adjacent site which was clearfelled in September 2011 holds the remains of tree trunks which were left in place to maintain *G. maculosus* populations.

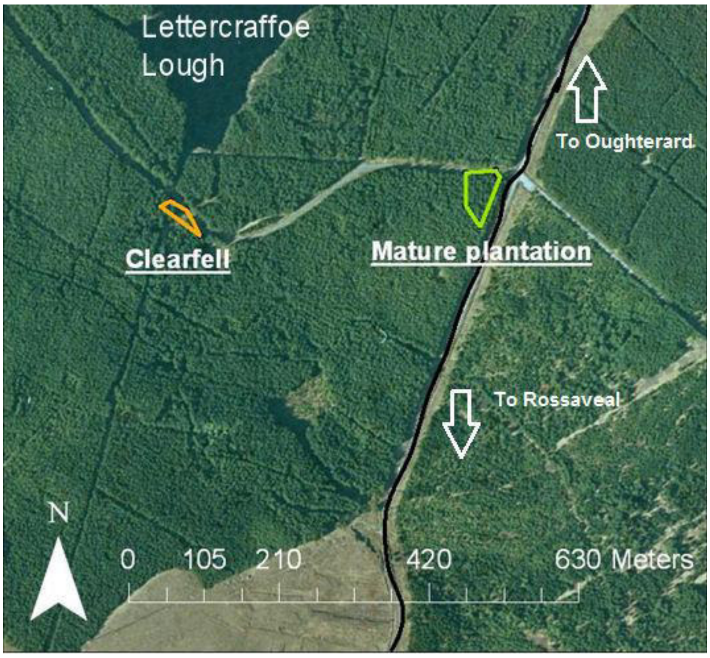

Figure 17: Photograph showing the clearfell and mature plantation study sites at Lettercraffroe, Cloosh Forest.

The mature plantation site which is within the forest department of Lettercraffroe is located 500m to the east of the clearfell site and is adjacent to the main public road running through Cloosh

(Oughterard – Rossaveel). Consisting of a dense stand of mature *P. contorta* and *P. sitchensis* which was planted in the 1950s, it is classified as a conifer plantation (WD4) (Fossitt, 2000). There is a notable amount of brash in this site, and the ground flora is comprised of a carpet of bryophytes (Plate 10).

Plate 10: Mature plantation which was used to assess *G. maculosus* populations in Lettercraffroe, Cloosh Forest (© Eugene Cush).

The forest in the clearfell site was felled in September 2011 to create a buffer zone next to a stream which enters Lettercraffroe Lough. Tree stumps of 2-3 meters in height were left in situ to provide a microhabitat for *G. maculosus* in the area. The site is classified as recently felled woodland (WS5) (Fossitt, 2000). It contains numerous stumps of *Pinus contorta* and *Picea sitchensis* (Plate 11), upon which bryophytes and lichens grow. Brash covers the ground throughout the site leading to a scarcity of ground flora although some lichens and bryophytes are present. The study area is divided by a small stream running through the centre towards Lettercraffroe Lough.

Materials and Methods

Fifteen metric traps were set up on randomly spaced trees or stumps on October 17, 2011 in each of the sites described above with both trapping areas measuring approximately 50m^2. Traps were soaked with water from a local water source, baited with a piece of organic carrot and nailed onto the north side of the trunks. The traps were checked on a weekly basis, the underside sprayed with water using a mist gun to keep them moist and re-baited with a fresh piece of carrot. To avoid counting the same individuals twice, all Kerry Slugs found under the traps are removed and brought back to the laboratory. They will be released at the location from which they were removed at the end of the study. All other species of slugs captured are preserved for identification.

Plate 11 Tree stumps on a clearfell in Lettercraffroe, Cloosh Forest, which

were left in place for *Geomalacus maculosus* (left © Eugene Cush; right © Kim O'Meara).

Results and discussion

Throughout the 14 week sampling period from October 24, 2011 to April 30, 2012 at Cloosh Forest, Kerry Slugs were collected on all but one sampling date (January 2, 2012) (Figure 18, Appendix 7). This day saw minimum temperatures of below 1°C, which is the most likely explanation for the absence of *G. maculosus* under the traps. Hand searching for Kerry Slugs in cold weather was predominantly unsuccessful at Cloosh and it is therefore suspected that under such conditions the species take refuge inside cracks in bark and below the soil/ tree root or rock outcrop interface. Simroth (1891) also observed Kerry Slugs showing a worm-like ability to vanish into the narrowest of fissures.

The median number of Kerry Slugs was significantly higher in the mature plantation than in the clearfell throughout the sample period (Mann-Whitney U Test, $W = 557.0$, $p < 0.05$, Table 9), although on six out of 14 sampling dates, more Kerrys Slugs were captured in the clearfell than the forested area. The fact that the traps on the tree stumps in the clearfell are more exposed than traps in the mature plantation could mean that the clearfell traps dry out more quickly between sampling dates thereby making these traps less attractive to the slugs. Future studies at Cloosh will investigate this possibility by visiting traps daily and ensuring that the traps are re-wetted on a daily rather than weekly basis.

Table 9: Total abundance, mean ± SD, median and W-value of *G. maculosus* trapped in a recent clearfell and adjacent conifer plantation at Lettercraffroe, Cloosh Forest from October 24, 2011 to April 30, 2012.

	Clearfell	**Forest**
Total number of *G. maculosus* trapped	320	522
Mean ± SD	12.26 ± 16.62	19.33 ± 15.13
Median	4	15.5
W	557.0	
p	0.0158 (adjusted for ties)	

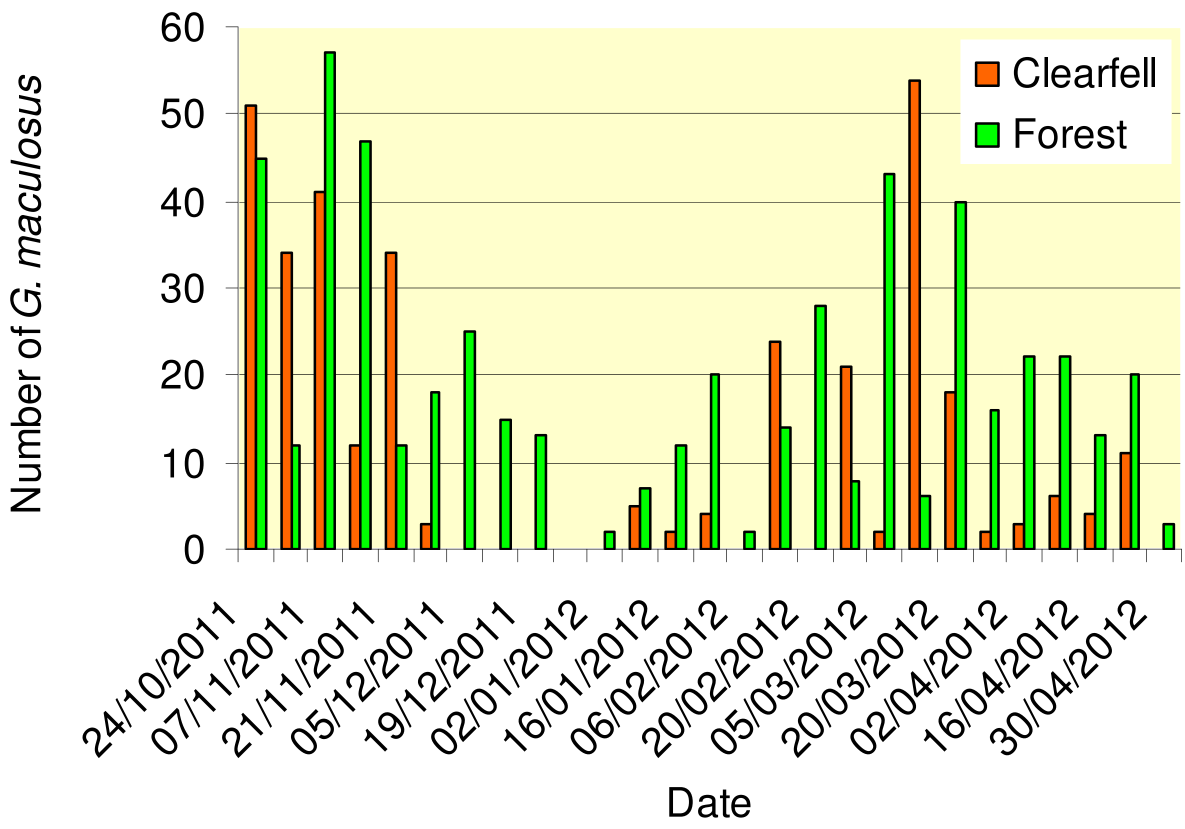

Figure 18: The abundance of *G. maculosus* in a recent clearfell and adjacent conifer plantation at Lettercraffroe, Cloosh Forest from October 24, 2011 to April 30, 2012.

Figure 19 shows the average daily temperatures recorded (Appendix 8) using Tiny Tag data loggers for the clearfell and the mature plantation. The daily minimum, maximum and average temperatures in the clearfell and plantation are significantly different (Table 10). The clearfell experienced significantly higher temperatures (Mann-Whitney U Test, W = 23038.5, p <0.00), which when coupled with increased wind exposure is likley to dry out the traps more rapidly.

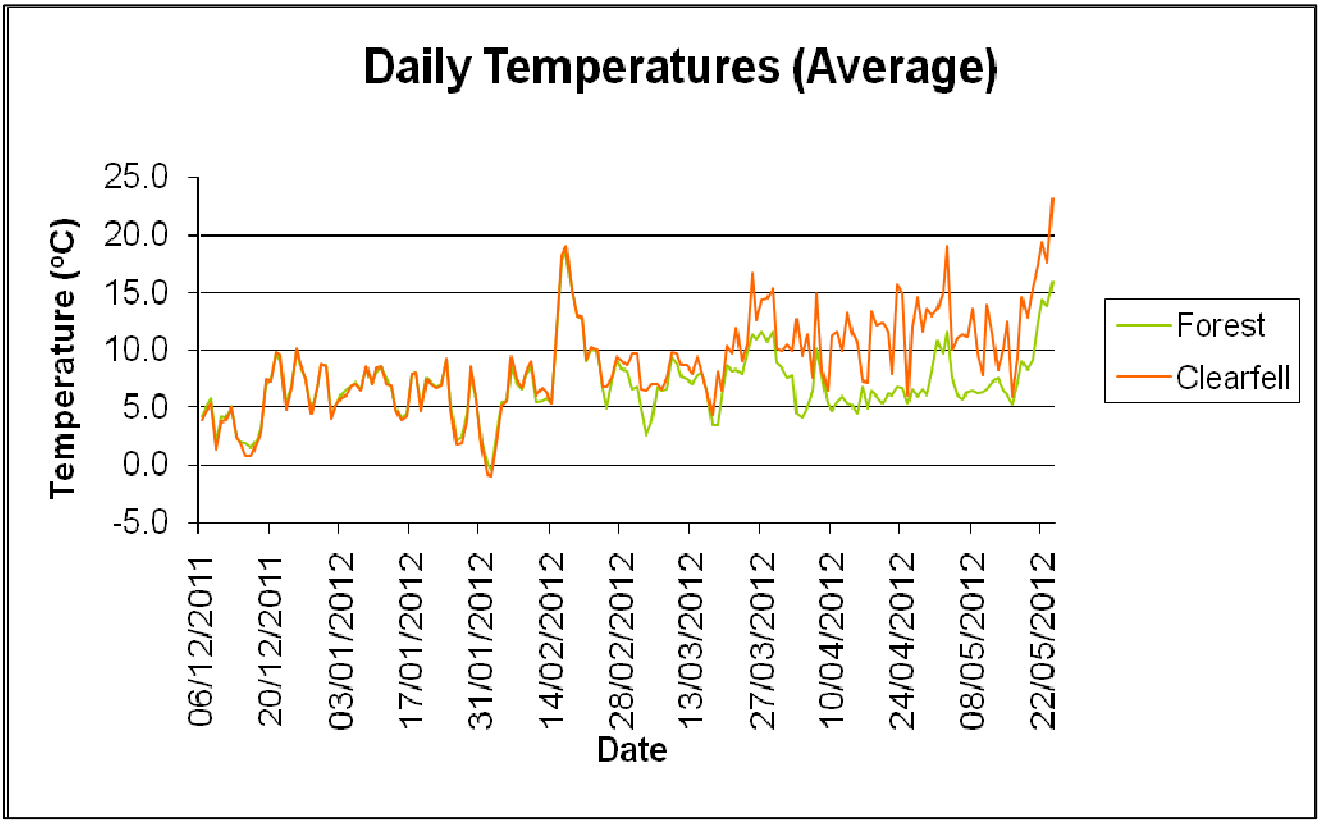

Figure 19: Average daily temperatures (°C) for the mature plantation and clearfell areas surveyed at Lettercraffroe, Cloosh Forest, from December 6, 2011 to May 24, 2012.

Table 10: Mean SD, median, W- value for the daily minimum, maximum and average temperatures measured in a recent clearfell and adjacent conifer plantation at Lettercraffroe, Cloosh Forest from December 6, 2011 to May 24, 2012.

	Minimum		**Maximum**		**Average**	
	Clearfell	Plantation	Clearfell	Plantation	Clearfell	Plantation
Mean ± SD	3.7°C ± 3.14	4.4°C ± 2.66	13.6°C ±7.14	9.0°C ± 2.86	8.6°C ± 4.01	6.7°C ± 2.54
Median	3.5°C	4.3°C	10.5°C	9.0°C	8.4°C	6.6°C
W	31006.0		23038.5		23024.5	
p	0.0258 (adjusted for ties)		0.00 (adjusted for ties)		0.00 (adjusted for ties)	

No significant correlation was found between temperature and slug abundance in the clearfell or plantation, neither on the day of sampling nor on the day before sampling. Factors such as humidity might play a bigger role in trapping success, but more research is needed to prove this.

A study by Barrett (2011) observed a lower abundance of *G. maculosus* in an area which had been clearfelled for five years than on surrounding blanket bog at Glanteenassig, Co. Kerry suggesting that suitable habitat around a clearfell may in time support slugs from the clearfell itself. Further studies by means of slug tagging would provide more accurate information in this instance.

Management Recommendations

1. While no *G. maculosus* specimens were found or trapped in commercial forests situated between counties Cork and Galway, the presence of the species at a conifer plantation in Oughterard, Co. Galway suggests that it could be present in forests in other parts of Ireland. It is recommended that a simple information leaflet be developed to increase awareness of the possible presence of the species in forestry plantations outside its currently known range.
2. *G. maculosus* was found in various locations throughout Cloosh Forest i.e. mature plantation, clearfell and open areas. No individuals were found in very young plantations (plant year 2005). These observations should be taken into account when management plans are made and mitigation measures might have to be installed to accommodate slug populations in newly planted areas.
3. In this short term study, average *G. maculosus* abundances were lower in the selected clearfelled area (with retained stumps) than in the nearby mature plantation. Nevertheless, Kerry Slugs were still trapped in the clearfell site almost one year after the felling occurred. The retained tree stumps in the clearfell site were being used by *G. maculosus* up to the end of this study and it is likely that they offer the species both shelter under the moss and in the cracks of the tree bark as well as food in form of lichens growing on the trunks. However, given that the longevity of the stumps is limited the site should be revisited on an annual basis to check for the presence of *G. maculosus*.
4. Laboratory trials have indicated those lichen species associated with conifer plantations which are preferred by *G. maculosus*. It is recommended that a simple guide to these lichens be produced for forest managers to inform commercial forestry practices for those sites in which *G. maculosus* is found. Selected stands of trees on which the preferred lichens grow could be maintained within sheltered clearfelled areas if necessary.

Future Research

1. The effects of clearfelling and re-planting on populations sizes of *G. maculosus* should be investigated using the capture-mark-recapture procedure described in Mc Donnell & Gormally (2011a).
2. Our results show a correlation between the presence of *G. maculosus* and bryophyte and lichen cover. However, replicated trapping needs to be carried out in areas with Kerry Slug populations other than Cloosh Forest to investigate whether this could be a critical factor in determining the presence or absence of the species in woodlands and conifer plantations nationwide.
3. A genetic analysis of the population at Cloosh Forest and the populations of *G. maculosus* in counties Kerry and Cork will help to determine whether the Connemara population has been introduced to the area. If the population proves to be unique, it will be critical to conserve this

population to ensure the preservation of genetic diversity of the species in Ireland. If the species was introduced, then the vector of introduction needs to be identified, as it may provide information on where other potentially undiscovered populations exist within Ireland.

4. The extent of competition between *G. maculosus* and other slug species such as *A. ater*, *A. subfuscus*, or *L. marginata* needs further investigation. If our preliminary observations of a decline in abundance of other slug species where *G. maculosus* is present is substantiated, the implications of the spread of the Kerry Slug for other rare slug species i.e. *L. cinereoniger* needs to be determined.
5. This study showed that lichens are a primary food source for *G. maculosus*. Future research should focus on why certain species of lichens are preferred over other ones. This could be either due to their nutrient value, their growth form, or the secondary compounds within the lichens which might deter or favour their consumption.

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Websites

www.habitas.org.uk/molluscireland (April 2012)

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Appendix 1: Results of hand search and trapping for the presence/absence survey

Hectad	County	No of sites	Date hand search	Date trapping
L84 – Derryclare Nature Reserve	Galway	3	10/10/2011	01/11/2011
L74 – Conifers at Ballynahinch	Galway	2	10/10/2011	01/11/2011
R59 – Extensive conifer plantations	Clare/Galway	3	18/10/2011	08/11/2011
R69 – Extensive conifers around Slieve Aughty	Galway	3	18/10/2011	08/11/2011
R23 – Conifer plantations west of Newcastle West	Limerick	3	19/10/2011	09/11/2011
R12 – Glanaruddery Mountains	Kerry	2	19/10/2011	09/11/2011
R22 – Conifer plantations on Mullaghareirk Mountains	Kerry	3	19/10/2011	09/11/2011
R01 – Conifers east of Castleisland	Kerry	3	20/10/2011	09/11/2011
R11 – Conifers	Kerry	2	20/10/2011	10/11/2011
R21 – Conifer plantations on Mullaghareirk Mountains	Limerick/Kerry	3	20/10/2011	10/11/2011
R17 – Conifer plantations on Slievecallans	Clare	3	21/10/2011	10/11/2011
M13 – Conifer plantations south of Oughterard	Galway	3	25/10//2011	14/11/2011
M10 – Conifer plantations north of Lisdoonvarna	Clare	3	26/10/2011	15/11/2011
R29 – Conifers at Inchiquin Lough	Clare	2	26/10/2011	15/11/2011
M04 – Conifer plantations at Knockbrack and Derradda	Galway	3	27/10/2011	17/11/2011

Appendix 2: Detailed description of the sites visited for the presence/absence survey

Grid reference	Site description	Elevation (m)
L 83030 49806	Medium density Sitka Spruce plantation, trees covered in beard lichen	63
L 82965 49450	Derryclare Nature Reserve, native oak forest surrounded by Lodgepole Pine	25
L 86906 50510 *	Medium density Sitka Spruce plantation	67
L 76766 46508	Low density plantation of Sitka Spruce and Lodgepole Pine with a slight undergrowth of *Rhododendron ponticum*	54
L75832 46651	Low density plantation of Sitka Spruce with a few Grand Fir, close to lake	34
R 52604 97779	Medium density Sitka Spruce plantation in boggy area surrounded by birch	64
R 54621 99571	Low density Sitka Spruce plantation with birch and holly trees next to creek	87
R 52703 88328 *	Medium density Sitka Spruce plantation at a hiking trail	221
M 64638 00942 *	Low density Sitka Spruce plantation next to a clearfell fringed by birch	124
R 60843 97158	Low density plantation of Sitka Spruce and Lodgepole Pine with some birch close to a creek	130
R 62216 96407	Medium density Sitka Spruce plantation next to a lake	138
R 20998 35032	Medium density Sitka Spruce plantation next to a clearfell	173
R 21079 34257	Medium density Sitka Spruce plantation at a forestry road	256
R 21985 36454	Sitka Spruces and willows in a wet area	280
R 14602 22470	Medium density Sitka Spruce plantation surrounded by wet grassy area full of brambles	240
R 19757 22094	Low density Sitka Spruce plantation with undergrowth of *Rhododendron ponticum*, brambles and heather in open patches	282
R 24498 21680	Low density Sitka Spruce plantation at forestry road with brambles in open patches	297

Grid reference	Site description	Elevation (m)
R 28952 **2**0302	Medium density Sitka Spruce plantation close to windturbines	316
R 27980 **2**2298	Low density Sitka Spruce plantation on steep hill	325
R 06857 **1**2347	Medium density Sitka Spruce plantation	287
R 09341 **1**2678	Low density Sitka Spruce plantation in boggy area	347
R 17987 **1**2281	Low density Sitka Spruce plantation at forestry road	268 meters
R 11610 **1**2754	Low density Sitka Spruce plantation in swampy area close to river; fringed by laurel, *Rhododendron ponticum* and sycamore	213 meters
R 09962 **1**1648 *	Low density plantation of Sitka Spruce and Lodgepole Pine on steep hill fringed by heather and brambles	336 meters
R 22453 **1**9536	Low density Sitka Spruce plantation with many small creeks	290 meters
R 26493 **2**0248 *	Low density Sitka Spruce plantation at forestry road fringed by birch	360 meters
R 24672 **1**4386	Low density Sitka Spruce plantation at forestry road	309 meters
R 17975 **7**5515	Medium density Sitka Spruce plantation at forestry road, close to house	141 meters
R 18106 **7**0802	Medium density Sitka Spruce plantation at water reservoir	177 meters
R 16427 **7**7091	Very low density plantation of Sitka Spruce, with laurel and *Rhododendron ponticum* growing in many areas, close to a small river	115 meters
M 14385 **3**4572	Medium density Sitka Spruce plantation next to a clearfell	147 meters
M 12785 **3**4534	Low density Sitka Spruce plantation with small creeks	93 meters
M 11359 **3**4477	Medium density Sitka Spruce plantation close to river	76 meters
M 17859 **0**2690	Medium density Sitka Spruce plantation fringed by birch next to a clearfell	226 meters
M 13553 **0**2803	Low density plantation of Sitka Spruce and Lodgepole Pine	218 meters
M 13662 **0**1785	Medium density Sitka Spruce plantation at creek fringed with rushes	233 meters
R 24371 **9**0066	Medium density, very dark Sitka Spruce plantation with some gorse and brambles at the fringes	102 meters
R 22919 **9**0242	Very low density Sitka Spruces and deciduous shrubs	83

Grid reference	Site description	Elevation (m)
M 07526 **4**0540	Low density Sitka Spruce and Lodgepole Pine plantation	113
M 07109 **4**1199	Low density Lodgepole Pine plantation	47
M 04333 **4**5316	Medium density Sitka Spruce plantation with creeks	80

Note: for those marked * the grid references for these samples were just outside the hectad we were surveying at the time but belonged to the same forested area. So L 86906 50510 was treated as belonging to hectad L84, site R 52703 88328 to hectad R59; site M 64638 00942 to hectad R69, site R 09962 11648 to hectad R11 and site R 26493 20248 to hectad R21.

Appendix 3: Number of slugs of each species found under the traps in each hectad

Species/Hectad	L84	L74	R59	R69	R23	R12	R22	R01	R11	R21	R17	M13	M10	R29	M04	Total
Lehmannia marginata	3	10	31	1	2	1	2	7	3	2	18	3	4	14	3	104
Arion subfuscus	/	1	6	1	13	/	3	1	2	4	4	1	3	1	2	42
Arion ater agg	2	/	2	/	1	2	/	/	1	2	4	1	/	1	2	18
Deroceras laeve	/	/	/	/	2	/	6	2	2	2	3	/	/	/	/	17
Deroceras reticulatum	/	/	5	/	/	/	/	/	/	/	6	/	/	/	/	11
Arion flagellus	/	1	/	/	1	/	/	/	/	3	/	/	/	/	/	5
Arion circumscriptus	/	/	/	2	/	/	/	/	/	3	/	/	/	/	/	5
Arion distinctus	/	/	/	/	/	/	/	1	1	1	/	/	/	/	/	3
Arion fasciatus	/	/	/	/	1	/	/	/	/	/	/	/	/	/	/	1
Arion hortensis	/	/	/	/	/	/	/	/	1	/	/	/	/	/	/	1
Arion intermedius	/	/	/	/	/	/	/	/	/	/	1	/	/	/	/	1
Total	5	12	44	4	20	3	11	11	10	17	36	5	7	16	7	210

Appendix 4: Number of *G. maculosus* found under traps during sampling at Seecon, Cloosh Forest

Date	Transect	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5	Trap 6	Trap 7	Trap 8	Trap 9	Trap 10
24/10/2011	1	5	2	0	0	1	1	1	0	1	1
31/10/2011	1	0	0	0	0	0	0	0	2	0	0
07/11/2011	1	4	0	2	3	1	3	0	3	1	1
14/11/2011	1	4	2	2	4	3	1	2	1	1	1
21/11/2011	1	6	3	1	1	1	0	1	0	0	0
28/11/2011	1	3	3	4	1	4	0	1	9	5	5
05/12/2011	1	0	6	2	3	2	3	0	1	4	4
12/12/2011	1	1	1	7	0	6	0	5	4	0	0
19/12/2011	1	1	0	0	0	0	0	0	0	1	1
02/01/2012	1	0	1	2	1	1	1	0	0	0	0
09/01/2012	1	3	0	1	2	0	0	2	0	1	1
16/01/2012	1	0	1	1	0	3	0	4	2	0	0
23/01/2012	1	1	8	2	1	4	0	2	5	1	1
24/10/2011	2	0	0	0	0	1	0	3	0	0	0
31/10/2011	2	1	0	1	2	0	0	0	0	0	0
07/11/2011	2	1	3	2	0	0	3	2	0	3	0
14/11/2011	2	0	0	0	0	0	2	0	0	0	0
21/11/2011	2	0	0	0	1	0	0	0	0	0	0

28/11/2011	2	0	0	0	0	0	0	0	0	0	2
05/12/2011	2	0	0	0	0	0	0	0	0	0	0
12/12/2011	2	0	0	0	0	0	1	0	2	0	2
19/12/2011	2	0	0	0	0	0	0	0	0	0	0
02/01/2012	2	0	0	1	0	0	0	0	0	1	1
09/01/2012	2	0	0	0	1	2	0	0	0	1	0
16/01/2012	2	0	0	1	0	0	0	0	2	0	1
23/01/2012	2	0	0	3	0	0	0	0	1	1	2
24/10/2011	3	1	0	0	0	0	0	0	0	0	0
31/10/2011	3	0	0	0	0	0	0	0	0	0	0
07/11/2011	3	0	0	0	0	0	0	0	0	0	0
14/11/2011	3	1	0	0	0	0	1	0	0	0	0
21/11/2011	3	0	0	1	0	0	0	0	0	0	0
28/11/2011	3	0	1	0	0	1	0	0	0	0	0
05/12/2011	3	0	0	0	0	0	1	0	0	0	0
12/12/2011	3	0	0	0	0	0	1	0	0	0	0
19/12/2011	3	0	0	0	0	0	0	0	0	0	0
02/01/2012	3	0	0	0	0	0	1	0	0	0	0
09/01/2012	3	0	0	0	0	0	0	0	0	0	0
16/01/2012	3	0	0	0	0	0	0	0	0	0	0
23/01/2012	3	0	0	0	0	0	0	2	1	0	0
24/10/2011	4	2	1	0	0	0	0	1	0	0	1

31/10/2011	4	2	0	1	0	0	0	0	0	0	0
07/11/2011	4	1	0	3	1	0	0	0	0	0	0
14/11/2011	4	0	1	0	1	0	0	1	0	0	0
21/11/2011	4	5	0	0	1	0	0	1	0	0	0
28/11/2011	4	1	1	1	0	0	0	0	0	0	0
05/12/2011	4	0	0	0	0	0	0	0	0	0	0
12/12/2011	4	0	0	1	0	0	1	0	0	0	0
19/12/2011	4	0	0	0	0	0	0	0	0	0	0
02/01/2012	4	0	0	0	0	0	0	0	0	0	0
09/01/2012	4	0	1	0	0	0	0	0	0	1	1
16/01/2012	4	2	0	0	0	0	0	0	0	0	0
23/01/2012	4	0	0	0	0	0	0	0	0	0	0
24/10/2011	5	0	0	1	1	0	0	4	1	1	0
31/10/2011	5	0	2	0	0	3	0	0	3	1	0
07/11/2011	5	0	2	0	1	2	0	0	2	0	2
14/11/2011	5	0	0	0	0	1	0	1	9	0	0
21/11/2011	5	0	1	0	0	0	0	1	0	0	0
28/11/2011	5	0	0	0	1	1	1	0	2	0	0
05/12/2011	5	0	0	1	0	0	0	0	0	0	0
12/12/2011	5	0	0	0	0	0	0	1	0	0	0
19/12/2011	5	0	0	0	0	0	0	0	0	0	0
02/01/2012	5	0	0	0	0	0	0	2	0	0	0

09/01/2012	5	0	2	0	0	0	0	0	1	0	0
16/01/2012	5	0	0	2	0	0	0	3	2	0	0
23/01/2012	5	0	0	2	0	0	0	1	0	1	0
24/10/2011	6	0	0	0	0	0	0	0	0	0	0
31/10/2011	6	0	0	0	0	0	0	0	0	0	0
07/11/2011	6	0	0	0	0	0	0	0	0	0	0
14/11/2011	6	0	0	0	0	0	0	1	0	1	0
21/11/2011	6	0	0	0	0	0	0	0	0	0	0
28/11/2011	6	0	0	0	0	0	2	0	0	0	0
05/12/2011	6	0	0	0	0	0	0	2	1	1	0
12/12/2011	6	0	0	0	0	0	0	0	0	0	0
19/12/2011	6	0	0	0	0	0	0	0	0	0	0
02/01/2012	6	0	0	0	1	0	0	0	1	0	0
09/01/2012	6	0	0	1	0	1	0	0	0	0	0
16/01/2012	6	0	0	0	0	0	0	0	0	0	0
23/01/2012	6	0	0	0	0	0	0	0	1	0	0

Appendix 5: Total number of all species trapped per transect between October 24, 2011 and January 23, 2012 at Seecon, Cloosh Forest

Species/Transect	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Geomalacus maculosus	203	50	12	33	62	13	0	0	0	0	373
Lehmannia marginata	42	27	92	47	33	34	46	68	98	30	517
Arion subfuscus	4	5	32	39	19	27	28	50	47	18	269
Arion ater	6	2	15	27	28	13	27	23	36	17	194
Arion intermedius	0	0	0	5	1	3	8	3	2	0	22
Limax cinereoniger	0	1	2	0	0	0	0	1	1	1	6
Arion flagellus	0	0	0	1	0	0	0	0	0	0	1
Total	52	35	141	119	81	77	109	145	184	66	1009

Appendix 6: Environmental parameters measured for each trapping tree in all transects at Seecon, Cloosh Forest

Transect	Trap no	Bark structure	Tree circumference cm	Bryophyte cover (%)	Tree species	Light Intensity (klux)
1	1	flaky	91	30-60	Lodgepole Pine	0.67
1	2	flaky	86	60-100	Lodgepole Pine	0.56
1	3	flaky	76	60-100	Lodgepole Pine	0.49
1	4	flaky	74	60-100	Lodgepole Pine	0.42
1	5	smooth	99	60-100	Lodgepole Pine	0.29
1	6	flaky	71	30-60	Lodgepole Pine	0.53
1	7	flaky/cracked	90	30-60	Lodgepole Pine	0.23
1	8	flaky/cracked	100	30-60	Lodgepole Pine	0.59
1	9	flaky/cracked	86	30-60	Lodgepole Pine	0.57
1	10	flaky/cracked	83	30-60	Lodgepole Pine	0.21
2	1	smooth	35	0-30	Sitka Spruce	0.21
2	2	smooth	90	30-60	Sitka Spruce	0.15
2	3	flaky/smooth	100	0-30	Sitka Spruce	0.21
2	4	flaky/smooth	69	60-100	Lodgepole Pine	0.5
2	5	flaky	86	0-30	Lodgepole Pine	0.48
2	6	flaky	96	30-60	Lodgepole Pine	0.56
2	7	flaky	49	60-100	Lodgepole Pine	0.2

2	8	flaky/cracked	96	60-100	Lodgepole Pine	0.26
2	9	flaky/cracked	82	60-100	Lodgepole Pine	0.45
2	10	flaky	48	30-60	Lodgepole Pine	0.45
3	1	smooth	61	0-30	Lodgepole Pine	0.34
3	2	cracked	66	0-30	Lodgepole Pine	1.28
3	3	flaky	77	30-60	Lodgepole Pine	0.44
3	4	smooth/flaky	56	30-60	Lodgepole Pine	0.44
3	5	cracked/flaky	81	60-100	Lodgepole Pine	0.2
3	6	smooth	73	30-60	Lodgepole Pine	0.43
3	7	flaky/cracked	100	60-100	Lodgepole Pine	0.38
3	8	flaky	76	30-60	Lodgepole Pine	0.41
3	9	flaky/smooth	94	30-60	Lodgepole Pine	0.28
3	10	flaky	73	30-60	Lodgepole Pine	0.27
4	1	smooth	70	60-100	Sitka Spruce	0.56
4	2	smooth	57	60-100	Sitka Spruce	0.29
4	3	flaky	75	60-100	Sitka Spruce	0.07
4	4	smooth	58	30-60	Sitka Spruce	0.1
4	5	smooth	58	0-30	Sitka Spruce	0.2
4	6	smooth/flaky	82	0-30	Sitka Spruce	0.09
4	7	smooth/flaky	113	0-30	Sitka Spruce	0.04
4	8	smooth	70	0-30	Sitka Spruce	0.04
4	9	smooth	49	0-30	Sitka Spruce	0.05

4	10	cracked/flaky	83	0-30	Lodgepole Pine	0.54
5	1	smooth	45	30-60	Sitka Spruce	1.01
5	2	flaky	61	30-60	Sitka Spruce	0.23
5	3	smooth	72	60-100	Lodgepole Pine	0.33
5	4	smooth	57	30-60	Lodgepole Pine	0.24
5	5	smooth	60	30-60	Sitka Spruce	0.11
5	6	flaky/smooth	118	60-100	Sitka Spruce	0.08
5	7	flaky	86	60-100	Sitka Spruce	0.17
5	8	smooth	66	30-60	Sitka Spruce	0.11
5	9	flaky	106	60-100	Lodgepole Pine	0.31
5	10	smooth/cracked	50	0-30	Lodgepole Pine	0.72
6	1	flaky	80	30-60	Lodgepole Pine	0.68
6	2	flaky	30	60-100	Lodgepole Pine	0.65
6	3	smooth	32	60-100	Lodgepole Pine	1.03
6	4	cracked	86	30-60	Lodgepole Pine	0.48
6	5	smooth	49	30-60	Lodgepole Pine	0.79
6	6	smooth/cracked	72	30-60	Lodgepole Pine	0.35
6	7	cracked	75	0-30	Lodgepole Pine	0.61
6	8	cracked	59	0-30	Lodgepole Pine	0.38
6	9	smooth	26	0-30	Lodgepole Pine	2.04
6	10	smooth	37	0-30	Sitka Spruce	0.39
7	1	flaky/cracked	107	0-30	Lodgepole Pine	0.98

7	2	flaky/cracked	70	0-30	Lodgepole Pine	2.43
7	3	flaky/cracked	75	0-30	Lodgepole Pine	1.92
7	4	flaky/cracked	58	0-30	Lodgepole Pine	3.05
7	5	flaky/cracked	82	0-30	Lodgepole Pine	1.64
7	6	flaky	70	0-30	Lodgepole Pine	2.15
7	7	flaky/cracked	82	60-100	Lodgepole Pine	2.42
7	8	flaky/cracked	89	0-30	Lodgepole Pine	1.06
7	9	flaky/cracked	82	0-30	Lodgepole Pine	2.33
7	10	smooth	92	30-60	Lodgepole Pine	0.58
8	1	flaky	78	0-30	Sitka Spruce	0.9
8	2	flaky/cracked	55	30-60	Lodgepole Pine	1.51
8	3	cracked	90	0-30	Lodgepole Pine	3.1
8	4	smooth	31	0-30	Sitka Spruce	0.79
8	5	smooth	44	0-30	Sitka Spruce	0.99
8	6	flaky/cracked	73	0-30	Lodgepole Pine	0.73
8	7	smooth	33	30-60	Sitka Spruce	1.48
8	8	smooth	77	30-60	Sitka Spruce	0.65
8	9	smooth	30	0-30	Sitka Spruce	1.18
8	10	smooth/flaky	54	30-60	Sitka Spruce	1.51
9	1	smooth	81	0-30	Sitka Spruce	0.2
9	2	flaky	107	60-100	Sitka Spruce	0.08
9	3	smooth/flaky	109	60-100	Sitka Spruce	0.32

9	4	smooth	59	30-60	Lodgepole Pine	0.75
9	5	flaky/cracked	96	60-100	Lodgepole Pine	0.57
9	6	flaky	94	30-60	Sitka Spruce	0.59
9	7	flaky	119	30-60	Sitka Spruce	0.28
9	8	smooth	65	30-60	Sitka Spruce	0.42
9	9	cracked	74	30-60	Lodgepole Pine	1.09
9	10	flaky	79	0-30	Lodgepole Pine	2.33
10	1	flaky	172	30-60	Sitka Spruce	2.38
10	2	flaky	146	0-30	Sitka Spruce	0.59
10	3	smooth/flaky	115	0-30	Sitka Spruce	0.37
10	4	flaky/cracked	60	0-30	Lodgepole Pine	0.92
10	5	smooth	76	30-60	Sitka Spruce	0.39
10	6	smooth	74	30-60	Sitka Spruce	0.66
10	7	cracked	55	0-30	Lodgepole Pine	2.01
10	8	smooth	37	0-30	Sitka Spruce	4.31
10	9	cracked	69	0-30	Lodgepole Pine	3.1
10	10	smooth	25	0-30	Sitka Spruce	4.42

Appendix 7: Number of *G. maculosus* found under the traps in the clearfell and in the mature plantation at Lettercraffroe, Cloosh Forest.

Date	Clearfell	Forest
24/10/2011	51	45
31/10/2011	34	12
07/11/2011	41	57
14/11/2011	12	47
21/11/2011	34	12
28/11/2011	3	18
05/12/2011	0	25
12/12/2011	0	15
19/12/2011	0	13
26/12/2011	0	0
02/01/2012	0	2
09/01/2012	5	7
16/01/2012	2	12
23/01/2012	4	20
06/02/2012	0	2
13/02/2012	24	14
20/02/2012	0	28
27/02/2012	21	8
05/03/2012	2	43
12/03/2012	54	6
20/03/2012	18	40
26/03/2012	2	16
02/04/2012	3	22
11/04/2012	6	22
16/04/2012	4	13
23/04/2012	11	20
30/04/2012	0	3

Appendix 8: Minimum, maximum and average temperatures measured in the clearfell and mature plantation at Lettercraffroe, Cloosh Forest

Date	Min Clearfell	Max Clearfell	Average Clearfell	Min Plantation	Max Plantation	Average Plantation
06/12/2011	1.3 °C	6.5 °C	3.9 °C	2.0 °C	6.4 °C	4.2 °C
07/12/2011	2.4 °C	6.9 °C	4.7 °C	3.4 °C	6.6 °C	5.0 °C
08/12/2011	1.0 °C	9.8 °C	5.4 °C	2.2 °C	9.6 °C	5.9 °C
09/12/2011	-1.0 °C	3.8 °C	1.4 °C	0.2 °C	3.5 °C	1.9 °C
10/12/2011	-1.0 °C	8.5 °C	3.8 °C	0.4 °C	8.0 °C	4.2 °C
11/12/2011	1.7 °C	6.0 °C	3.9 °C	2.3 °C	6.0 °C	4.2 °C
12/12/2011	1.4 °C	8.5 °C	5.0 °C	2.4 °C	7.7 °C	5.1 °C
13/12/2011	0.8 °C	4.3 °C	2.6 °C	0.9 °C	3.8 °C	2.4 °C
14/12/2011	0.0 °C	3.7 °C	1.9 °C	0.9 °C	3.2 °C	2.1 °C
15/12/2011	-2.1 °C	3.8 °C	0.9 °C	-0.4 °C	4.1 °C	1.9 °C
16/12/2011	-2.2 °C	3.8 °C	0.8 °C	-0.7 °C	3.8 °C	1.6 °C
17/12/2011	-0.4 °C	4.2 °C	1.9 °C	0.8 °C	3.5 °C	2.2 °C
18/12/2011	0.1 °C	5.5 °C	2.8 °C	1.2 °C	5.1 °C	3.2 °C
19/12/2011	5.4 °C	9.6 °C	7.5 °C	5.1 °C	8.9 °C	7.0 °C
20/12/2011	4.4 °C	10.2 °C	7.3 °C	4.9 °C	10.2 °C	7.6 °C
21/12/2011	9.3 °C	10.3 °C	9.8 °C	9.3 °C	10.2 °C	9.8 °C
22/12/2011	7.9 °C	11.1 °C	9.5 °C	7.9 °C	10.3 °C	9.1 °C
23/12/2011	1.8 °C	7.9 °C	4.9 °C	2.9 °C	7.9 °C	5.4 °C
24/12/2011	4.1 °C	9.4 °C	6.8 °C	4.6 °C	9.3 °C	7.0 °C
25/12/2011	9.4 °C	11.0 °C	10.2 °C	9.3 °C	10.8 °C	10.1 °C
26/12/2011	7.2 °C	10.5 °C	8.9 °C	7.0 °C	10.2 °C	8.6 °C
27/12/2011	6.1 °C	8.8 °C	7.5 °C	6.3 °C	8.5 °C	7.4 °C
28/12/2011	2.8 °C	6.2 °C	4.5 °C	3.3 °C	6.4 °C	4.9 °C
29/12/2011	5.3 °C	8.1 °C	6.7 °C	5.4 °C	8.1 °C	6.8 °C
30/12/2011	7.3 °C	10.3 °C	8.8 °C	7.3 °C	10.1 °C	8.7 °C
31/12/2011	6.6 °C	10.5 °C	8.6 °C	7.1 °C	10.3 °C	8.7 °C
01/01/2012	1.0 °C	7.1 °C	4.1 °C	1.4 °C	7.2 °C	4.3 °C
02/01/2012	0.4 °C	9.8 °C	5.1 °C	0.9 °C	9.2 °C	5.1 °C

03/01/2012	1.6 °C	10.2 °C	5.9 °C	2.3 °C	9.8 °C	6.1 °C
04/01/2012	3.2 °C	9.0 °C	6.1 °C	4.2 °C	8.9 °C	6.6 °C
05/01/2012	4.8 °C	9.0 °C	6.9 °C	5.0 °C	8.9 °C	7.0 °C
06/01/2012	4.6 °C	9.6 °C	7.1 °C	5.0 °C	9.5 °C	7.3 °C
07/01/2012	5.0 °C	7.9 °C	6.5 °C	5.6 °C	7.6 °C	6.6 °C
08/01/2012	7.6 °C	9.6 °C	8.6 °C	7.6 °C	9.3 °C	8.5 °C
09/01/2012	5.1 °C	9.0 °C	7.1 °C	5.2 °C	8.9 °C	7.1 °C
10/01/2012	7.1 °C	9.8 °C	8.5 °C	6.4 °C	9.7 °C	8.1 °C
11/01/2012	7.3 °C	9.8 °C	8.6 °C	7.5 °C	9.7 °C	8.6 °C
12/01/2012	4.9 °C	9.3 °C	7.1 °C	5.9 °C	9.3 °C	7.6 °C
13/01/2012	5.6 °C	8.4 °C	7.0 °C	5.7 °C	7.7 °C	6.7 °C
14/01/2012	3.7 °C	6.0 °C	4.9 °C	4.3 °C	5.7 °C	5.0 °C
15/01/2012	1.5 °C	6.2 °C	3.9 °C	2.5 °C	5.7 °C	4.1 °C
16/01/2012	1.3 °C	7.3 °C	4.3 °C	2.3 °C	6.7 °C	4.5 °C
17/01/2012	6.0 °C	9.9 °C	8.0 °C	6.3 °C	9.7 °C	8.0 °C
18/01/2012	5.8 °C	10.4 °C	8.1 °C	6.1 °C	10.1 °C	8.1 °C
19/01/2012	3.1 °C	6.3 °C	4.7 °C	3.6 °C	6.3 °C	5.0 °C
20/01/2012	5.2 °C	9.7 °C	7.5 °C	5.5 °C	9.6 °C	7.6 °C
21/01/2012	5.3 °C	8.9 °C	7.1 °C	5.6 °C	8.9 °C	7.3 °C
22/01/2012	4.8 °C	8.5 °C	6.7 °C	5.2 °C	8.4 °C	6.8 °C
23/01/2012	4.6 °C	9.2 °C	6.9 °C	5.2 °C	8.9 °C	7.1 °C
24/01/2012	8.5 °C	10.0 °C	9.3 °C	8.5 °C	9.8 °C	9.2 °C
25/01/2012	1.0 °C	8.7 °C	4.9 °C	2.1 °C	8.6 °C	5.4 °C
26/01/2012	0.2 °C	3.4 °C	1.8 °C	0.7 °C	3.5 °C	2.1 °C
27/01/2012	-1.1 °C	4.9 °C	1.9 °C	0.8 °C	4.3 °C	2.6 °C
28/01/2012	-0.5 °C	8.2 °C	3.9 °C	1.2 °C	7.9 °C	4.6 °C
29/01/2012	7.2 °C	9.9 °C	8.6 °C	7.2 °C	8.5 °C	7.9 °C
30/01/2012	4.2 °C	7.4 °C	5.8 °C	4.2 °C	7.2 °C	5.7 °C
31/01/2012	-1.2 °C	4.5 °C	1.7 °C	-0.5 °C	4.2 °C	1.9 °C
01/02/2012	-3.0 °C	1.4 °C	-0.8 °C	-1.4 °C	1.8 °C	0.2 °C
02/02/2012	-3.5 °C	1.6 °C	-1.0 °C	-2.2 °C	1.4 °C	-0.4 °C
03/02/2012	-1.2 °C	4.9 °C	1.9 °C	0.0 °C	5.2 °C	2.6 °C
04/02/2012	1.8 °C	8.4 °C	5.1 °C	2.9 °C	8.0 °C	5.5 °C
05/02/2012	2.3 °C	8.9 °C	5.6 °C	2.9 °C	8.4 °C	5.7 °C
06/02/2012	8.0 °C	10.8 °C	9.4 °C	7.8 °C	9.2 °C	8.5 °C

07/02/2012	6.4 °C	8.5 °C	7.5 °C	6.2 °C	8.0 °C	7.1 °C
08/02/2012	6.4 °C	7.1 °C	6.8 °C	6.2 °C	6.9 °C	6.6 °C
09/02/2012	6.7 °C	9.4 °C	8.1 °C	6.6 °C	9.1 °C	7.9 °C
10/02/2012	7.6 °C	10.5 °C	9.1 °C	7.6 °C	9.5 °C	8.6 °C
11/02/2012	2.2 °C	9.9 °C	6.1 °C	3.4 °C	7.6 °C	5.5 °C
12/02/2012	3.5 °C	10.0 °C	6.8 °C	4.0 °C	7.1 °C	5.6 °C
13/02/2012	3.3 °C	9.4 °C	6.4 °C	4.0 °C	7.6 °C	5.8 °C
14/02/2012	2.5 °C	8.3 °C	5.4 °C	3.6 °C	7.2 °C	5.4 °C
21/02/2012	8.7 °C	9.7 °C	9.2 °C	8.5 °C	9.5 °C	9.0 °C
22/02/2012	9.5 °C	11.2 °C	10.3 °C	9.3 °C	10.9 °C	10.1 °C
23/02/2012	9.5 °C	10.5 °C	10.0 °C	9.5 °C	10.3 °C	9.9 °C
24/02/2012	3.1 °C	10.5 °C	6.8 °C	3.3 °C	10.0 °C	6.6 °C
25/02/2012	1.7 °C	11.9 °C	6.8 °C	2.5 °C	7.4 °C	4.9 °C
26/02/2012	6.1 °C	9.0 °C	7.6 °C	6.0 °C	8.7 °C	7.3 °C
27/02/2012	8.9 °C	10.0 °C	9.4 °C	8.7 °C	9.7 °C	9.2 °C
28/02/2012	7.9 °C	10.5 °C	9.2 °C	7.7 °C	9.2 °C	8.5 °C
29/02/2012	7.5 °C	9.9 °C	8.7 °C	7.3 °C	9.0 °C	8.2 °C
01/03/2012	2.7 °C	16.5 °C	9.6 °C	4.4 °C	8.9 °C	6.6 °C
02/03/2012	3.5 °C	15.8 °C	9.7 °C	4.3 °C	9.4 °C	6.8 °C
03/03/2012	0.5 °C	12.6 °C	6.6 °C	1.4 °C	8.5 °C	4.9 °C
04/03/2012	-1.1 °C	14.0 °C	6.5 °C	0.2 °C	5.0 °C	2.6 °C
05/03/2012	0.0 °C	14.0 °C	7.0 °C	1.3 °C	6.3 °C	3.8 °C
06/03/2012	4.3 °C	10.0 °C	7.1 °C	4.0 °C	9.7 °C	6.9 °C
07/03/2012	3.2 °C	10.0 °C	6.6 °C	3.1 °C	9.7 °C	6.4 °C
08/03/2012	4.8 °C	10.2 °C	7.5 °C	4.6 °C	8.7 °C	6.6 °C
09/03/2012	9.0 °C	10.6 °C	9.8 °C	8.7 °C	10.1 °C	9.4 °C
10/03/2012	7.5 °C	11.8 °C	9.7 °C	7.4 °C	10.1 °C	8.8 °C
11/03/2012	7.0 °C	10.5 °C	8.7 °C	6.8 °C	8.6 °C	7.7 °C
12/03/2012	6.7 °C	10.6 °C	8.6 °C	6.6 °C	8.3 °C	7.5 °C
13/03/2012	6.0 °C	9.8 °C	7.9 °C	5.8 °C	8.3 °C	7.0 °C
14/03/2012	6.1 °C	12.7 °C	9.4 °C	6.1 °C	9.5 °C	7.8 °C
15/03/2012	6.2 °C	10.1 °C	8.2 °C	6.2 °C	10.0 °C	8.1 °C
16/03/2012	2.9 °C	9.9 °C	6.4 °C	3.6 °C	9.7 °C	6.6 °C
17/03/2012	1.2 °C	7.6 °C	4.4 °C	2.2 °C	4.9 °C	3.6 °C
18/03/2012	0.2 °C	16.1 °C	8.2 °C	0.9 °C	6.2 °C	3.5 °C

19/03/2012	2.3 °C	10.6 °C	6.5 °C	3.2 °C	8.8 °C	6.0 °C
20/03/2012	8.3 °C	12.5 °C	10.4 °C	7.9 °C	9.5 °C	8.7 °C
21/03/2012	7.2 °C	12.0 °C	9.6 °C	7.0 °C	9.3 °C	8.1 °C
22/03/2012	1.8 °C	21.9 °C	11.8 °C	3.4 °C	13.2 °C	8.3 °C
23/03/2012	4.7 °C	13.3 °C	9.0 °C	5.6 °C	10.3 °C	8.0 °C
24/03/2012	4.1 °C	16.8 °C	10.5 °C	5.6 °C	14.0 °C	9.8 °C
25/03/2012	6.1 °C	27.3 °C	16.7 °C	7.0 °C	15.7 °C	11.4 °C
26/03/2012	2.9 °C	22.4 °C	12.6 °C	5.2 °C	16.7 °C	10.9 °C
27/03/2012	4.6 °C	24.0 °C	14.3 °C	6.1 °C	17.2 °C	11.7 °C
28/03/2012	2.9 °C	26.1 °C	14.5 °C	6.0 °C	15.4 °C	10.7 °C
29/03/2012	6.6 °C	24.2 °C	15.4 °C	7.7 °C	15.6 °C	11.6 °C
30/03/2012	6.4 °C	13.8 °C	10.1 °C	7.3 °C	10.6 °C	9.0 °C
31/03/2012	5.4 °C	14.3 °C	9.9 °C	6.5 °C	10.3 °C	8.4 °C
01/04/2012	3.5 °C	17.4 °C	10.5 °C	4.6 °C	10.5 °C	7.5 °C
02/04/2012	4.5 °C	15.3 °C	9.9 °C	5.9 °C	9.7 °C	7.8 °C
03/04/2012	0.1 °C	25.4 °C	12.7 °C	2.1 °C	6.9 °C	4.5 °C
04/04/2012	-0.6 °C	19.6 °C	9.5 °C	1.7 °C	6.7 °C	4.2 °C
05/04/2012	-1.0 °C	23.8 °C	11.4 °C	1.6 °C	8.6 °C	5.1 °C
06/04/2012	0.6 °C	14.6 °C	7.6 °C	3.0 °C	9.8 °C	6.4 °C
07/04/2012	6.9 °C	22.9 °C	14.9 °C	7.6 °C	12.6 °C	10.1 °C
08/04/2012	6.0 °C	10.3 °C	8.1 °C	6.4 °C	9.0 °C	7.7 °C
09/04/2012	2.1 °C	10.9 °C	6.5 °C	3.1 °C	7.6 °C	5.3 °C
10/04/2012	1.2 °C	21.2 °C	11.2 °C	2.1 °C	7.4 °C	4.8 °C
11/04/2012	-0.3 °C	23.6 °C	11.6 °C	1.9 °C	9.2 °C	5.5 °C
12/04/2012	1.6 °C	18.3 °C	9.9 °C	3.2 °C	8.8 °C	6.0 °C
13/04/2012	0.0 °C	26.5 °C	13.2 °C	1.8 °C	8.9 °C	5.3 °C
14/04/2012	-0.3 °C	23.6 °C	11.6 °C	1.8 °C	8.6 °C	5.2 °C
15/04/2012	-1.6 °C	22.9 °C	10.6 °C	0.9 °C	8.0 °C	4.4 °C
16/04/2012	4.2 °C	10.4 °C	7.3 °C	4.2 °C	9.5 °C	6.8 °C
17/04/2012	3.3 °C	11.1 °C	7.2 °C	3.5 °C	6.5 °C	5.0 °C
18/04/2012	3.6 °C	23.0 °C	13.3 °C	4.3 °C	8.7 °C	6.5 °C
19/04/2012	1.7 °C	22.5 °C	12.1 °C	2.8 °C	9.1 °C	6.0 °C
20/04/2012	0.1 °C	24.7 °C	12.4 °C	1.4 °C	9.4 °C	5.4 °C
21/04/2012	2.6 °C	20.6 °C	11.6 °C	2.9 °C	9.6 °C	6.3 °C
22/04/2012	2.1 °C	13.6 °C	7.9 °C	3.5 °C	8.7 °C	6.1 °C

23/04/2012	1.6 °C	29.7 °C	15.6 °C	3.2 °C	10.5 °C	6.8 °C
24/04/2012	1.5 °C	28.4 °C	15.0 °C	3.3 °C	10.1 °C	6.7 °C
25/04/2012	2.7 °C	9.5 °C	6.1 °C	3.4 °C	7.2 °C	5.3 °C
26/04/2012	3.6 °C	20.5 °C	12.0 °C	4.6 °C	8.4 °C	6.5 °C
27/04/2012	0.9 °C	28.3 °C	14.6 °C	3.0 °C	8.9 °C	6.0 °C
28/04/2012	1.1 °C	22.1 °C	11.6 °C	3.3 °C	9.8 °C	6.6 °C
29/04/2012	0.2 °C	27.0 °C	13.6 °C	2.6 °C	9.5 °C	6.1 °C
30/04/2012	4.8 °C	21.1 °C	12.9 °C	4.5 °C	11.8 °C	8.2 °C
01/05/2012	6.3 °C	20.9 °C	13.6 °C	7.9 °C	13.8 °C	10.8 °C
02/05/2012	4.7 °C	25.1 °C	14.9 °C	6.3 °C	13.1 °C	9.7 °C
03/05/2012	6.4 °C	31.7 °C	19.0 °C	7.5 °C	15.8 °C	11.7 °C
04/05/2012	3.7 °C	16.4 °C	10.0 °C	4.9 °C	10.2 °C	7.5 °C
05/05/2012	2.1 °C	19.8 °C	11.0 °C	3.3 °C	8.8 °C	6.1 °C
06/05/2012	-0.5 °C	23.3 °C	11.4 °C	1.7 °C	9.8 °C	5.8 °C
07/05/2012	3.8 °C	18.5 °C	11.2 °C	3.7 °C	8.9 °C	6.3 °C
08/05/2012	1.7 °C	25.6 °C	13.6 °C	3.6 °C	9.4 °C	6.5 °C
09/05/2012	0.2 °C	19.0 °C	9.6 °C	2.3 °C	10.2 °C	6.2 °C
10/05/2012	4.1 °C	11.6 °C	7.9 °C	5.0 °C	7.6 °C	6.3 °C
11/05/2012	2.4 °C	25.6 °C	14.0 °C	3.4 °C	9.7 °C	6.6 °C
12/05/2012	1.7 °C	21.5 °C	11.6 °C	3.5 °C	10.8 °C	7.2 °C
13/05/2012	4.8 °C	11.9 °C	8.4 °C	5.5 °C	9.7 °C	7.6 °C
14/05/2012	2.7 °C	17.6 °C	10.2 °C	3.9 °C	9.0 °C	6.5 °C
15/05/2012	1.7 °C	23.2 °C	12.5 °C	3.2 °C	8.9 °C	6.1 °C
16/05/2012	0.4 °C	11.6 °C	6.0 °C	2.3 °C	8.3 °C	5.3 °C
17/05/2012	5.2 °C	13.6 °C	9.4 °C	5.2 °C	9.2 °C	7.2 °C
18/05/2012	6.9 °C	22.2 °C	14.6 °C	6.6 °C	11.4 °C	9.0 °C
19/05/2012	6.7 °C	19.0 °C	12.8 °C	6.4 °C	10.3 °C	8.4 °C
20/05/2012	5.1 °C	25.6 °C	15.4 °C	5.8 °C	12.5 °C	9.1 °C
21/05/2012	9.6 °C	25.2 °C	17.4 °C	9.3 °C	15.5 °C	12.4 °C
22/05/2012	11.2 °C	27.6 °C	19.4 °C	11.7 °C	16.9 °C	14.3 °C
23/05/2012	10.4 °C	25.0 °C	17.7 °C	11.1 °C	16.7 °C	13.9 °C
24/05/2012	11.2 °C	35.2 °C	23.2 °C	11.6 °C	20.4 °C	16.0 °C