NESSA DARCY CREATIVE ENTOMOLOGIST

# Howth Ground Beetle Survey 2019

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# 1. INTRODUCTION

## 1.1. Study Site Background

The ecological, geological and historical significance of Howth Head has long been appreciated and has resulted in it being awarded several designations intended to protect its seabird colonies, scarce plant species, invertebrates and lichens. Howth Head comprises a Special Area of Conservation (SAC), Special Protected Area (SPA) and Natural Heritage Area (pNHA), and is situated within the Dublin Bay Biosphere. Its status is due in part to the presence of habitats of European conservation significance, specifically Vegetated sea cliffs of the Atlantic and Baltic coasts (1230), and European dry heaths (4030), and previous records of protected species.

While areas of the Howth landscape have become built up or converted into golf courses, the SAC designation aims to preserve areas of *Calluna vulgaris* heathland, grassland, woodland and cliffs of conservation significance. In its Biodiversity Action Plan, Fingal County Council (2010) outlines the international responsibility to "make sure that a favourable conservation status is maintained for the habitats and species of these sites, which are rare and threatened throughout Europe. These sites are our critical natural capital and their protection forms the basis of the nature conservation strategy and sustainable planning framework in Fingal."

As part of this effort, Fingal County Council aims to develop site-specific management plans for Howth's important habitats. In recent years, the landscape of Howth is changing due to shifts in land use. 70 years ago, much of the land was grazed by Dexter cattle and goats. Now that the animals are gone, the heathland is becoming overgrown with gorse (*Ulex gallii*) and dense stands of bracken (*Pteridium aquilinum*) are developing. Meanwhile, elsewhere in Ireland, much of the heathland has been damaged by overgrazing as the number of sheep in the state almost trebled between 1980 and 1991 (Lucey and Doris, 2001).

As an area of special amenity, Howth receives high numbers of visitors who walk and ride horses across the landscape, causing erosion. Fire is an important factor in natural heathland regeneration, but unplanned fires can pose a danger to uncommon habitats and species. With increased biomass of gorse, due to lack of grazing, the fires burn hotter than they would on shorter heath vegetation, and scorch the earth.

In short, the protection of these semi-natural habitats requires regular intervention. Controlled burning and grazing are two options which have been shown to benefit the botanical diversity of heathlands. This survey has been commissioned by Fingal County Council to ensure that any vegetation management plans they implement will support and not negatively affect the suitability of these sites for important ground beetle species and ground beetle diversity. Ground beetles are undergoing declines at rates comparable to those reported for butterflies and moths (Brooks, et al., 2012), thus it is essential that they be considered as carefully as other insect and plant species in management plans.

This study aims to assess the ground beetle conservation value of each site; identify significant habitat features for ground beetles; provide recommendations for site-specific management plans to ensure the protection of important beetle species and species richness; and collect baseline data for monitoring the effects of

management measures, using ground beetles as bioindicators. It focuses especially on heathland management.

### 1.2. Ground Beetles as Bioindicators

Studies have shown that communities of invertebrates, such as ground beetles, reflect changes in vegetation structure more strongly than they reflect differences in plant species assemblages (Darcy, 2012; Rushton, et al., 1990; Vessby, et al., 2002). Changes in vegetation structure affect microclimatic conditions by, for example, altering the average temperature or relative humidity within the vegetation layer (Holland, 2002). This alters the habitat in which the invertebrates live, causing them to change behaviour, typically measured as a change in abundance of sensitive species (Luff, 1996). Habitat management plans based on plant species may not always be appropriate for the conservation of ground beetles or other fauna (Gardner, 1991; York, 1999), therefore it is prudent to carry out a survey of invertebrates in conjunction with any botanical survey, and, preferably, multiple taxa of invertebrates (Pedley, et al., 2013).

Baseline information is essential for any long-term monitoring or management programme (Willis, et al., 2007) but resources are limited. Selecting particular taxa to monitor as bioindicators can save valuable time and funds by providing clear and rapid information on the effects of a new management technique (Rainio and Niemalä, 2003). A bioindicator is an organism or group of organisms which can be used to monitor the health of an ecosystem. Beetles—ground beetles in particular—are a suitable candidate for biological assessment of Howth Head as they fit the criteria summarised by Rainio and Niemalä (2003): the group must be well known and its ecology and distribution reasonably well understood; it should have specialist habitat requirements; it should respond rapidly to changes in environmental factors; and it needs to be simple and inexpensive to sample.

Beetles represent the biggest grouping of insects with over 400,000 recorded species worldwide. Of these, at least 2,154 occur in Ireland (Regan, et al., 2009). Beetle species have been known to respond to many different influences, including habitat structure change, disturbance, and invasive species, by decreasing or increasing in abundance or diversity, or by shifting their distribution (New, 2010). Several species in Ireland are recognised as being of high ecological value or in need of special protection. The abundance and relative ease of sampling also contribute to making beetles a highly suitable group to study in order to develop an invertebrate-friendly management plan (Rainio and Niemalä, 2003).

### 1.3. Historical Records

Declan Doogue outlines the rich history of botanical recording at Howth and mentions plant species and habitats of conservation importance in his discussion document *Protecting Howth's Habitats*. More recently, the Red Rock site underwent a thorough botanical survey by Catriona Brady (2018). Four out of six targeted rare species were rediscovered (*Trifolium striatum, Ornithopus perpusillus, Trifolium ornithopodioides*, and *Scilla verna*) within a complex mosaic of habitats, some of significant conservation interest.

The Howth Head SAC Site Synopsis (Department of Arts, Heritage and the Gaeltacht, 2013) mentions the following two rare fly species, along with a ground beetle species listed below:

***Phaonia exoleta*** (Meigen, 1826), a fly, has been recorded nowhere in Ireland apart from the woods at the back of Deerpark.

***Sphaerophoria batava*** (Goeldlin, 1974), a hoverfly, has been recorded from very few sites in Ireland. Here it is found in heathland.

The National Biodiversity Database holds many records from Howth for hoverflies, butterflies, moths, lacewings, ladybirds, water beetles, saproxylic beetles, spiders, true bugs, water beetles, lice, millipedes, molluscs and more. 32 bee species have been recorded at sites along the cliff walk (Ronayne, 2006). Ground beetle records for the area are not as easily found, but a couple of notable species have been recorded:

***Cicindela campestris*** (Linnaeus, 1758), the green tiger beetle, is found in heathland on Howth in early summer. It is a widely distributed species in sandy heathland and similar habitats, but local and uncommon.

***Platyderus depressus*** (Audinet-Serville, 1821), a ground beetle which looks "like a slightly red-brown Calathus" (Anderson, pers. comm., 2019), is found nowhere else in Ireland but on Howth Head. It was recorded there by Halbert in 1924. Roy Anderson also found a specimen in a back garden on the cliff path in recent years. It lives in "short turf on sandy or chalky soils where it occurs among moss, under stones or leaf rosettes… A thermophilic species at the northern limit of its range in the British Isles, and confined to warm, dry, open habitats in Ireland. " (National Museums Northern Ireland, 2006)

***Trechus subnotatus*** (Dejean, 1831), a ground beetle, has only been recorded at three locations in Ireland, all in Dublin. It was introduced from the Mediterranean area, and first recorded from a compost heap in St. Anne's Park, Clontarf (O'Mahony, 1940). It was then found in streamside moss at Whitewater Brook, Howth (Anderson & Bryan, 2013). It is believed to be naturalised in Dublin now, having been recorded by the author at the Dodder wet woodland proposed Natural Heritage Area in Oldbawn (Darcy, et al., 2017).

***Trechus rubens*** (Fabricius, 1792) is a ground beetle found on storm beaches on the eastern cliffs of Howth. Its distribution is widespread in Ireland, but it is rarely encountered.

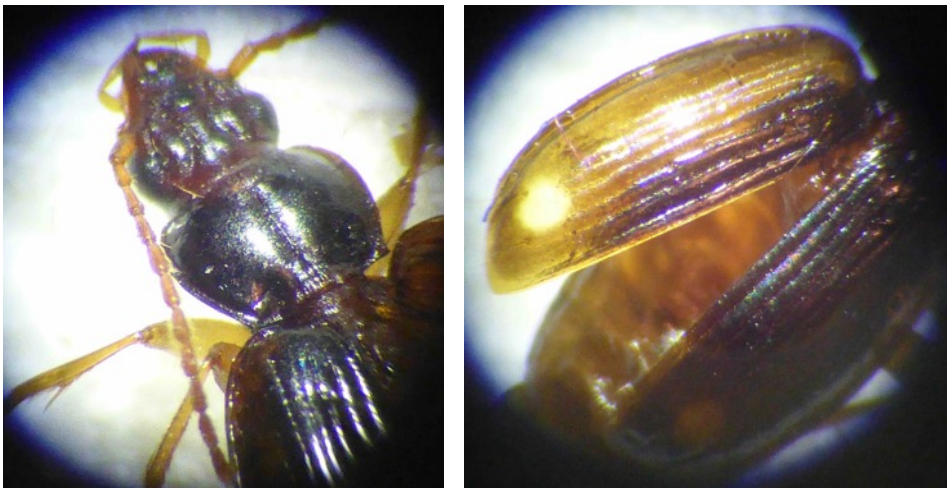

Fig. 1. A *Trechus subnotatus* specimen from the Dodder Wet Woodland pNHA.

### 1.4. Primary Aims

The primary aims of this survey were to:

- Identify any beetle species which might be affected by a change in the vegetation management regime by sampling the beetle fauna in selected sites and assessing their habitat preferences.
- Investigate the presence of any rare or red data listed beetle species which could be affected by changes in vegetation structure.
- Provide baseline data for monitoring the effects of the new management regime, and successional growth after fires, using beetles as bioindicators.
- Provide simple, site-specific recommendations for a management plan, which may include grazing or burning, which would balance the needs of invertebrates with other species.

The fieldwork was undertaken between July and October 2019. This report details the findings of the survey, and suggests management measures for protecting the carabid biodiversity of the surveyed sites.

# 2. METHODOLOGY

### 2.1. Site Selection

The Howth Head SAC encompasses five main sites of ecological interest, covering approximately 200 ha of heathland: Bellingham's Farm, Ben of Howth, East Mountain, Shielmartin and Red Rock. Fingal County Council outlined the precise areas they wished to have surveyed.

### 2.2. Pitfall Traps

Within these sites, 54 pitfall trap locations were chosen to be representative of the main habitat types within the SAC, and roughly proportionate in number to the extent of each habitat type across the SAC. The habitats were chosen with the specific management concerns of Fingal County Council in mind. They are as follows:

- Heather-dominated (*Calluna*) heathland
- Gorse-dominated heathland
- Grassland
- Heath other (a patchy, transitional mosaic of dwarf shrub, grasses and herbs)
- Bracken
- Woodland

For the purposes of this study, classification of the habitat types was based on the plants which visibly make up the majority of their vegetation and most strongly influence the habitat structure. For example, gorse-dominated heathland is where previously heather-dominated heathland has become overgrown with tall, woody, gorse. Heather dominated heathland received the greatest number of traps, to ensure that all of its different growth stages were represented: pioneer (0–5 years), building (6–14 years), and mature (15–23 years), as categorised by Bargmann, et al. (2015).

The traps consisted of opaque plastic 350 ml cups of varying colours (red, yellow, blue, green), 7 cm in diameter at the top, 5 cm at the base. These were set in the ground up to the rim. They were placed at least 50 m apart from each other. A piece of medium gauge chicken wire was placed in the mouth of each cup to prevent small mammals and frogs from becoming trapped. The traps were set at least 10 m away from the edges of each habitat patch, except in the case of a few particularly dense stands of gorse.

To each cup, approximately 100 ml of a mixture of propylene glycol (50%) and water (50%) were added. A 20 cm x 20 cm lid was secured 5 - 10 cm above each trap using bamboo skewers. These lids were cut from old plastic election campaign posters. A notice was written on the back explaining their purpose and providing contact details.

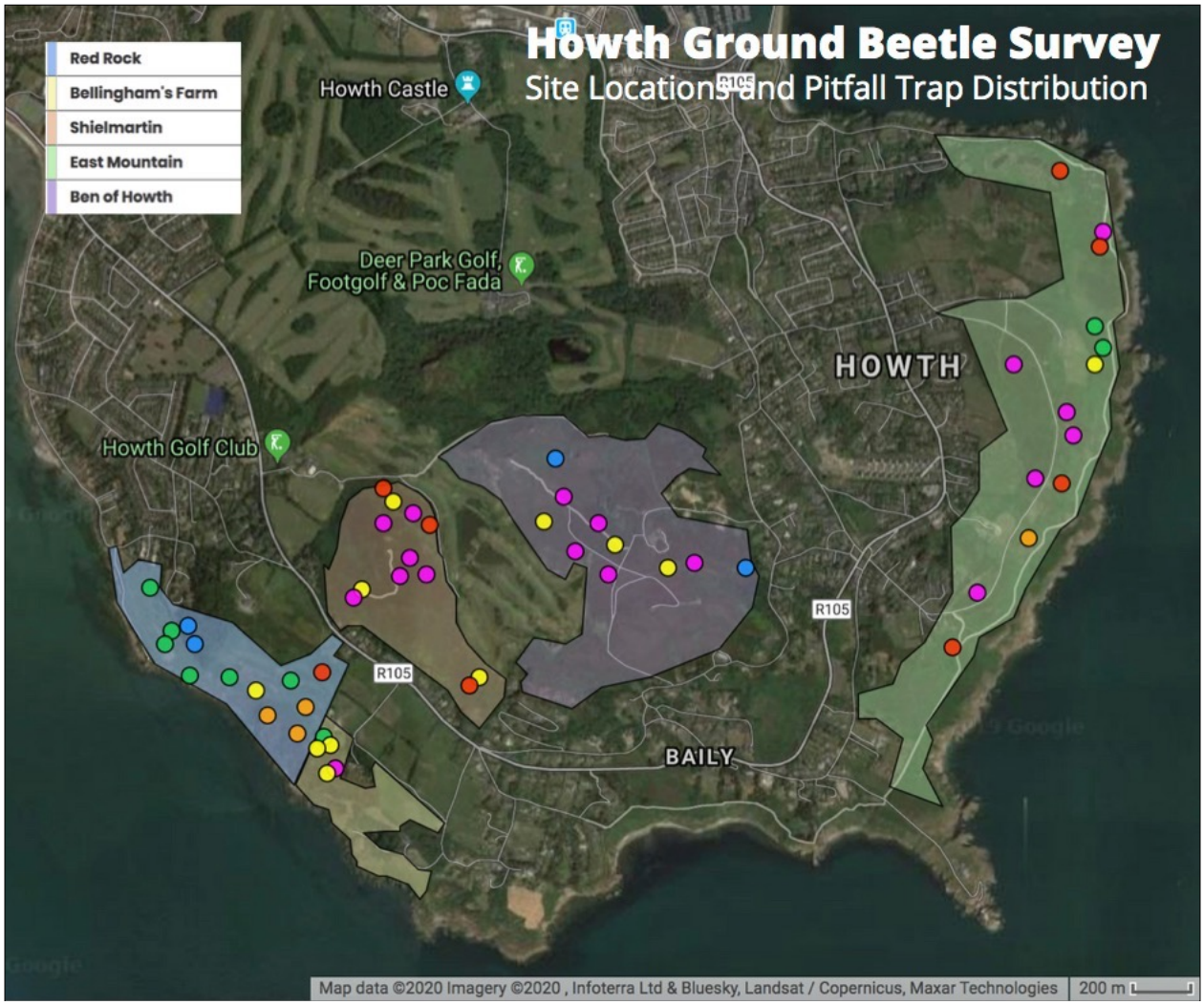


Fig. 2. Map of Howth study sites showing distribution of pitfall traps in different habitat types (red circle = bracken, yellow = gorse dominated heath, green = grassland, orange = heath other, magenta = heather dominated heathland, blue = woodland).

For the first round of sampling, the traps were left open for 14 days each, between the dates of 15th July and 8th August. For the second round, they were set for 17 - 19 days, between the dates of 12th September and 11th October. On collection, a lid was placed on each cup and the contents were stored for several weeks in the cups until sorting. After being sorted into three categories - Coleoptera, Arachnidae and miscellaneous, the contents were transferred to tubes containing 70% ethyl alcohol.

### 2.3. Sweep Netting

A medium sweep net (40 cm at widest point) was used to collect beetles from at least one 1 m x 2 m patch of vegetation in the vicinity of each pitfall trap. This was achieved by sweeping the net back and forth twelve times (in a 1 m span), taking a step forward between each. Samples were taken facing in the direction of the sun. The contents of the net were emptied into a white dissection tray, and all ground beetles were removed and stored. These were placed into the freezer overnight, and finally into 70% ethyl alcohol.

### 2.4. Hand Searching

Hand searching consisted of two different methods:

- leaf litter, gravel, moss and debris were filtered through a garden sieve into a white dissection tray.
- tussocks of grass and clumps of moss were collected and pulled apart into the white dissection tray.

Beetles collected from the tray were placed into the freezer overnight and transferred to tubes containing 70% ethyl alcohol.

### 2.5. Identification and Ecology

All ground beetle specimens apart from *Amara* spp. (a particularly challenging genus) were identified by Nessa Darcy. The beetles were examined under an Optika Lab-20 stereo microscope (7x…45x magnification). Information on ground beetle ecology in Table 2 comes from the *Ground Beetles of Ireland* website (National Museums Northern Ireland, 2006) and the book *The Carabidae (ground beetles) of Britain and Ireland* by Martin L. Luff (2007). Nomenclature used for carabid identification follows Luff (2007).

After the ground beetle study was completed, all non-carabid beetle specimens and the unidentified individuals of *Amara* spp. were sent to Roy Anderson for identification. Notes on the non-carabid beetle results can be found in the appendix. All arachnid specimens were sent to Myles Nolan for identification.

### 2.6. Vegetation Characteristics Survey

A visual estimate survey of vegetation characteristics was undertaken in a 4 m x 4 m square around each pitfall trap. Percentage cover of the following vegetation characteristics were recorded: leaf litter/debris, bracken, heather, gorse, bramble, scrub (total), herbs, graminoids, open ground, moss, dead heather. Also recorded were the number of trees, percentage canopy cover, average diameter of tree trunks at breast height, average height of understory, and notes on abundant plant species or other significant features.

Trees are defined here as woody plants whose height exceeded 2 metres. This includes tall gorse which, as it reaches this height, loses its bushy structure and forms a tree-like shape with thick woody trunks surrounded

by open space beneath a spiny canopy. Understory is defined as any vegetation which did not fit this definition of a tree, from short post-burn regrowth of heather to dense stands of bracken. Open ground was recorded where understory vegetation was completely absent.

### 2.7. Fire Records

Hans Visser provided information on recent and historical records of fires on the landscape of Howth Head.

### 2.8. Data Analysis

Analyses of Variance (ANOVAs) were performed to test for differences in species richness and diversity between habitat types. Multivariate Canonical Correspondance Analysis (CCA) was used to test species response to habitat type, site, vegetation and ground traits. Stacked bar plots were produced to visualise the effects of vegetation traits on species richness and composition.

Fig. 3. Hand searching moss from beneath mature heather. Note the patches of dead heather in the background. The second image is of *Bradycellus ruficollis* with moss under the microscope.

# 3. RESULTS

## 3.1. Sampling Effort

| Pitfall Traps per Habitat Type | | Pitfall Traps per Site | |
|---|---|---|---|
| Bracken | 8 | Bellingham's Farm | 5 |
| Gorse dominated heath | 11 | Ben of Howth | 10 |
| Grassland | 9 | East Mountain | 14 |
| Heather dominated heath | 18 | Red Rock | 13 |
| Heath other | 4 | Shielmartin | 12 |
| Woodland | 4 | **Total** | **54** |
| **Total** | **54** | | |

Table 1. Distribution of pitfall traps throughout habitat types and sites.

A total of 54 pitfall traps were set across the study sites, as detailed in Table 1. In addition to the pitfall traps, one sweep sample and one hand-searched sample were taken near each pitfall trap location. Vegetation surveys were completed for all trap locations. Four trays of gravel and debris from a beach at Red Rock were hand searched, unsuccessfully, in the hope of finding some coastal species.

## 3.2. Ground Beetle Species List

A total of 355 individual ground beetles were caught: 298 from pitfall traps, 49 from sieving and hand-searching, zero from sweep net samples, and eight opportunistic finds. From these samples, 29 ground beetle species were identified (including three identified by Roy Anderson at a later stage). Table 2 details the presence or absence of each ground beetle species from all samples (pitfall traps, sweeps, sieving, hand searching and opportunistic finds), in each of the main habitat types on Howth Head, with notes on their conservation significance or known distribution. *Trechus obtusus* and *Trechus quadristriatus* have been grouped together in the table due to difficulty in separating their identities. Both species appear to be present in Howth.

One species, *Laemostenus terricola*, was found only in the gorse dominated heathland. Two species - *Harpalus affinis, Olisthopus rotundatus* - were restricted to the heather dominated heathland only. *Pterostichus melanarius, P. strenuus* and *P. vernalis* were recorded only from grassland, and *Bradycellus sharpi* only from bracken. Woodland contained no unique species. Only *Abax parallelepipedus* was captured in all habitat types.

Roy Anderson's results included three *Amara* species captured in pitfall traps, each species from one site only. *Amara aenea* (3) was recorded from grassland trap G5 on East Mountain, *A. apricaria* (1) from gorse dominated heathland trap F8 at Red Rock, and *A. communis* (7) from grassland trap G4 at Red Rock. A specimen of *Harpalus latus* (G2), one *Paradromius linearis* (B3) and three *Trechus quadristriatus* (two in G2, one in H3) also turned up in the samples. As they were identified after the study was completed, these specimens were not included in the data analysis or in Table 3 below, but they are included in the discussion and site summaries with notes on their ecology and conservation significance.

| | Conservation status/ distribution | Gorse dom. heath | Heather dom. heath | Heath Other | Grass land | Bracken | Wood land |
|---|---|---|---|---|---|---|---|
| *Abax parallelepipedus* (Piller & Mitterpacher, 1783) | Widespread and common | X | X | X | X | X | X |
| *Amara aenea* (Degeer, 1774) | Widespread, fairly common in gardens and sandy areas near the coast. | | | | X | | |
| *Amara apricaria* (Paykull, 1790) | Widespread and fairly common in well drained coastal sites, rarer inland. | X | | | | | |
| *Amara communis* (Panzer, 1797) | Widespread in moss and litter in farmland and heath in northern counties, status elsewhere data deficient. | | | | X | | |
| *Badister bullatus* (Schrank, 1798) | Widespread and fairly common, particularly on coasts | | | | X | | X |
| *Bradycellus harpalinus* (Serville, 1821) | Widely distributed, coastal heath, dunes | | X | X | X | X | |
| *Bradycellus ruficollis* (Stephens, 1828) | Widely distributed but restricted to dry *Calluna* heath | X | X | | | | |
| *Bradycellus sharpi* (Joy, 1912) | Widespread but local, woodland near acid heath | | | | | X | |
| *Bradycellus verbasci* (Duftschmid, 1812) | Widespread and common. Well drained areas near coast | | | X | | | |

| | Conservation status/ distribution | Gorse dom. heath | Heather dom. heath | Heath Other | Grass land | Bracken | Wood land |
|---|---|---|---|---|---|---|---|
| *Calathus fuscipes* (Goeze, 1777) | Widespread in dryish terrain | | X | | X | | |
| *Calathus melanocephalus* (Linnaeus, 1758) | Widespread and common in dryish open habitat | X | | | X | | |
| *Carabus problematicus* (Herbst, 1786) | Widespread and frequent in upland *Calluna* heath, forest | X | X | X | | X | |
| *Harpalus affinis* (Schrank, 1781) | Restricted to free-draining soils, where it is common | | X | | | | |
| *Harpalus latus* (Linnaeus, 1758) | Widespread and common | | | X | X | | |
| *Harpalus rufipes* (Degeer, 1774) | Widespread and common | X | | X | X | X | |
| *Laemostenus terricola* (Herbst, 1784) | Widespread but very local, probably under-recorded | X | | | | | |
| *Nebria brevicollis* (Fabricius, 1792) | Very common | X | X | X | X | | X |
| *Notiophilus aquaticus* (Linnaeus, 1758) | Widespread but local, well drained heath, stony stream edges | X | X | X | | | |
| *Notiophilus biguttatus* (Fabricius, 1779) | Very common, more shady habitats | X | X | | | | |
| *Notiophilus germinyi* (Fauvel, 1863) | Widespread but local. Dry heath, rough grassland, sandy coastal habitats. | X | | | X | | |
| *Olisthopus rotundatus* (Paykull, 1790) | Widespread and moderately frequent on high ground, xerophilous, open ground | | X | | | | |
| *Paradromius linearis* (Olivier, 1795) | Locally common, in suitable localities | | X | | X | X | |
| *Pterostichus madidus* (Fabricius, 1775) | Widespread and fairly common | X | | | X | | |

| | Conservation status/ distribution | Gorse dom. heath | Heather dom. heath | Heath Other | Grass land | Bracken | Wood land |
|---|---|---|---|---|---|---|---|
| *Pterostichus melanarius* (Illiger, 1798) | Widespread and abundant | | | | X | | |
| *Pterostichus niger* (Schaller, 1783) | Widespread and common | X | X | | X | X | X |
| *Pterostichus strenuus* (Panzer, 1796) | Widespread and abundant | | | | X | | |
| *Pterostichus vernalis* (Panzer, 1795) | Widespread and fairly common | | | | X | | |
| *Trechus obtusus* (Erichson, 1837) / *T. quadristriatus* (Schrank, 1781) | Very common/ widespread but less frequent than *T. obtusus* | X | X | | X | X | X |
| **Total No. of Species** | | **14** | **13** | **8** | **18** | **8** | **5** |

**Table 2. Ground beetle species in six main habitat types on Howth Head (X = present).**

Table 3 details the presence or absence of each ground beetle species from all pitfall trap samples included in the analysis, in each of the study sites on Howth Head. All sites contained *Abax parallelepipedus, Carabus problematicus*, and *Pterostichus niger*. Species unique to each site are discussed in the individual site reports.

| | Bellingham's Farm | Ben of Howth | East Mountain | Red Rock | Shielmartin |
|---|---|---|---|---|---|
| *Abax parallelepipedus* | X | X | X | X | X |
| *Bradycellus harpalinus* | | | X | | |
| *Bradycellus verbasci* | | | | X | |
| *Calathus fuscipes* | X | X | | | |
| *Calathus melanocephalus* | | | | X | |
| *Carabus problematicus* | X | X | X | X | X |
| *Harpalus affinis* | | | X | | |
| *Harpalus latus* | | | | X | |
| *Harpalus rufipes* | X | | X | X | |
| *Laemostenus terricola* | X | | | | |
| *Nebria brevicollis* | X | X | | X | |
| *Notiophilus aquaticus* | X | | X | X | |

| | Bellingham's Farm | Ben of Howth | East Mountain | Red Rock | Shielmartin |
|---|---|---|---|---|---|
| *Notiophilus biguttatus* | | | X | | |
| *Olisthopus rotundatus* | | X | X | | |
| *Pterostichus madidus* | X | | | X | |
| *Pterostichus melanarius* | | | X | X | |
| *Pterostichus niger* | X | X | X | X | X |
| *Pterostichus strenuus* | | | X | X | |
| *Pterostichus vernalis* | X | | | | |
| *Trechus obtusus* | X | X | X | X | |
| *Trechus quadristriatus* | | X | X | | |
| **Total No. of species** | **11** | **8** | **13** | **13** | **3** |
| **No. of traps** | **5** | **10** | **14** | **14** | **12** |
| **No. of species per trap** | **2.2** | **0.8** | **0.93** | **0.93** | **0.25** |

**Table 3. A comparison of species composition in pitfall traps at the five study sites (X = present).**

### 3.3. Analysis of Habitat Types

There was no statistically significant difference in abundance between habitats (Fig. 4, ANOVA $F_{5,45}$= 2.1, P=0.082). Neither was there a significant difference in species richness between habitats (Fig. 5, ANOVA $F_{5,45}$= 1.49, P=0.212 ). However, when viewed in a stacked bar plot, it is clear that the composition of ground beetle species assemblages differs considerably between some of the habitat types (Fig. 6).

A Canonical Correspondence Analysis diagram of plots (pitfall trap samples plus the hand search samples taken close to the traps) constrained by habitat type (Fig. 7) placed the plots from heather-dominated heathland, grassland and heath apart from each other, forming distinct polygons, while gorse-dominated heath, woodland and bracken are close together near the meeting point of the two axes. This shows that there are distinctly different assemblages associated with heather-dominated heathland, grassland and heath other, while the assemblages found in gorse-dominated heathland, woodland and bracken are less distinct, having fewer species unique to each habitat type. As the latter three habitat types did not form wider polygons, this indicates that the plots are very similar within each of these habitat types. Being close together on the diagram means they also share common species between them. A similar pattern emerged from an analysis of ground beetle species constrained by habitat type (also Fig. 7).

The pie chart diagram in Fig. 8 shows the top 10 beetles with most unique habitat use. *Bradycellus verbasci* and *Harpalus latus* are only found in heath other. Three species of the *Pterostichus* genus are restricted to the grassland plots. *Bradycellus ruficollis* and *Olisthopus rotundatus* are almost exclusively found in heather-dominated heathland. The three species in the centre each inhabit a unique combination of habitat types. *Harpalus rufipes* may prefer more herbaceous habitats to the heather-dominated heathland from which it is

absent. *Notiophilus aquaticus* is in all heathland types, suggesting that vegetation structure may be more important to it than plant species composition. *Bradycellus harpalinus* is in all habitats associated with succession from heathland to grassland.

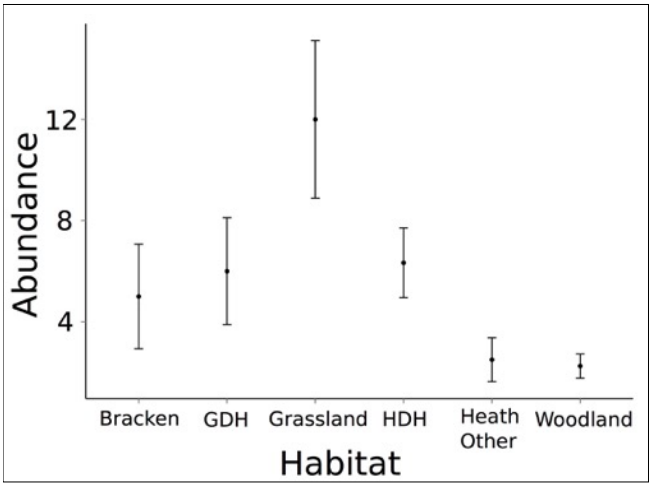


Fig. 4: Mean abundance (+/-) S.E. across six habitat types: Bracken, Gorse dominated heathland (GDH), Grassland, Heather dominated heathland (HDH), Heath Other and Woodland.

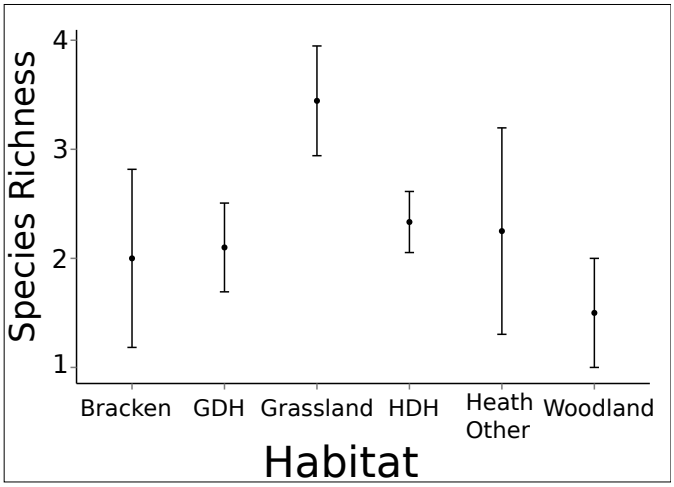


Fig. 5: Mean species richness (+/-) S.E. across six habitat types: Bracken, Gorse dominated heathland (GDH), Grassland, Heather dominated heathland (HDH), Heath Other and Woodland.

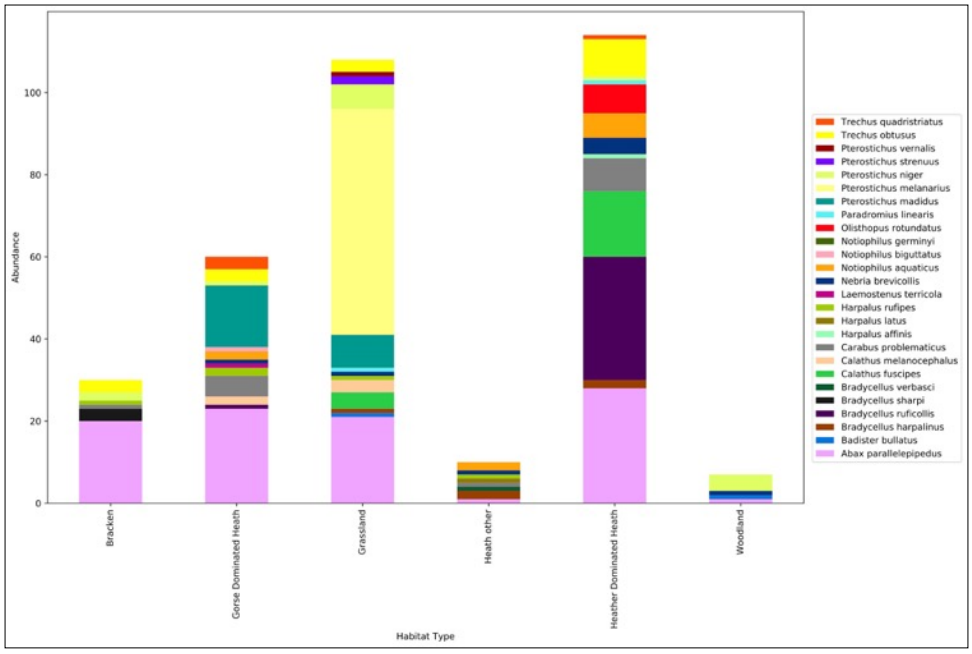


Fig. 6. Species abundance and composition compiled from all samples in each habitat type.

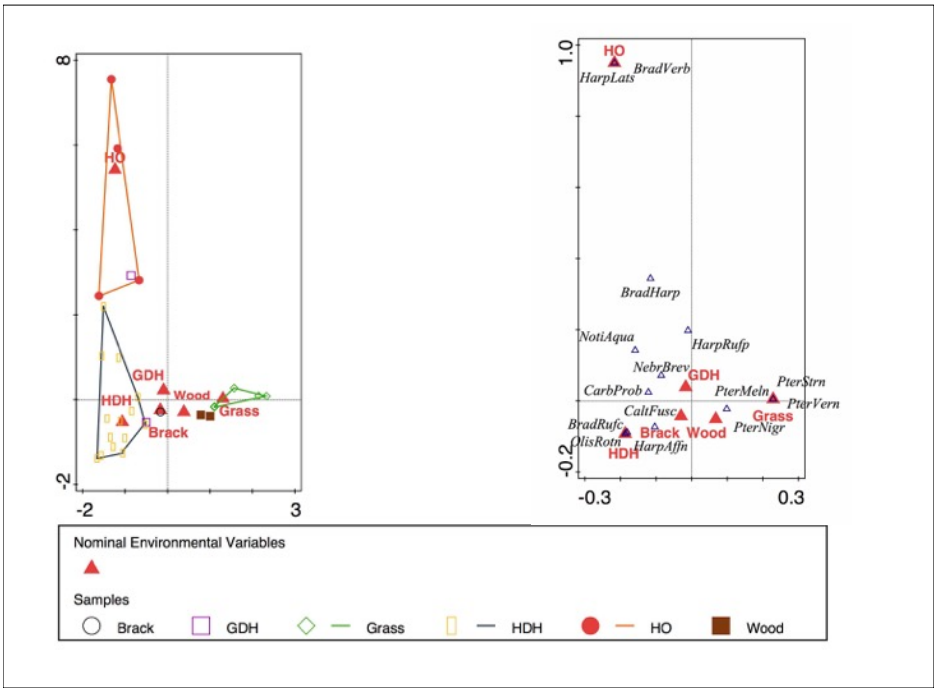


Fig. 7. A CCA (Canonical Correspondence Analysis) plot diagram. Polygons show positions of plots from different habitat types. The second diagram shows positions of ground beetle species from different habitat types.

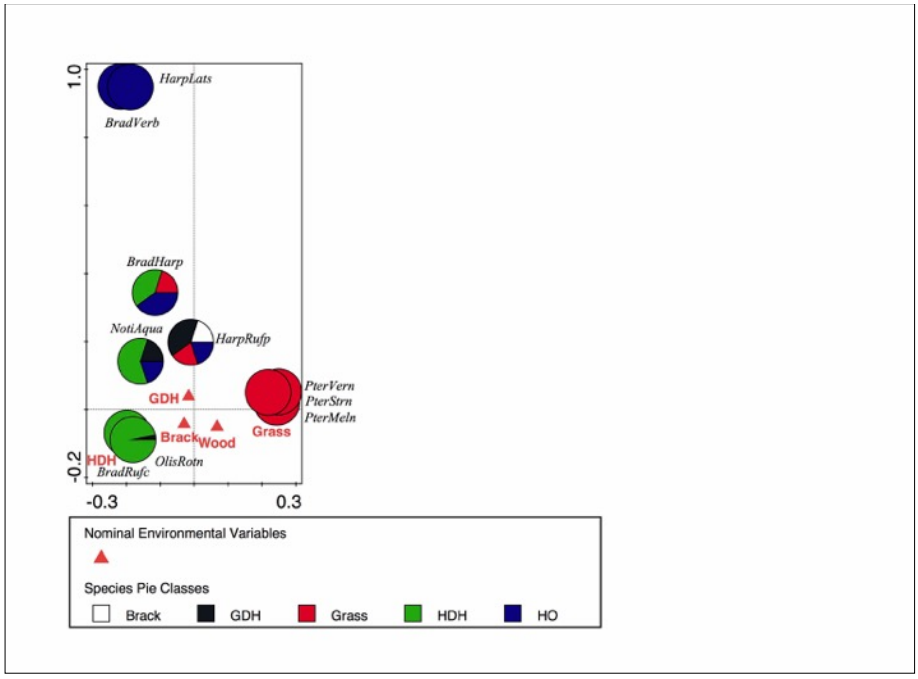


Fig. 8. Species pie charts for top 10 beetles with most unique habitat use. Positions of circles are staggered for graphical purposes.

### 3.5. Analysis of Vegetation Characteristics

The between-habitat difference of the carabid assemblages in this study was principally determined by the percentage cover of heather and moss, and the height of understory vegetation. This is illustrated by the graph in Fig. 9. This is supported by the graph in Fig. 10, which also shows that graminoids and herbs drive a distinct assemblage of ground beetle species (with several *Pterostichus* species), different from that found in heather-dominated heathland. It shows the influence of bramble, gorse and bracken on a third, less clearly separated group. This suggests that the ground beetle species composition is affected by different stages in heathland development and succession, by the contrast in structure between grasslands and heathland, and by overgrowth or colonisation of these habitats by scrub and bracken.

The stacked bar plot in Fig. 11 explores the relationship of the ground beetle communities to the percentage cover of heather among three heathland types: heather-dominated heathland, heath other (which is a mosaic of dwarf shrubs, grasses, herbs and open ground), and gorse-dominated heathland. The purpose was to show how ground beetle species assemblages may change as heather-dominated heathland becomes overgrown with gorse or grasses. Note that the distribution of *Bradycellus ruficollis* is almost entirely restricted to habitats with more than 60% cover of heather.

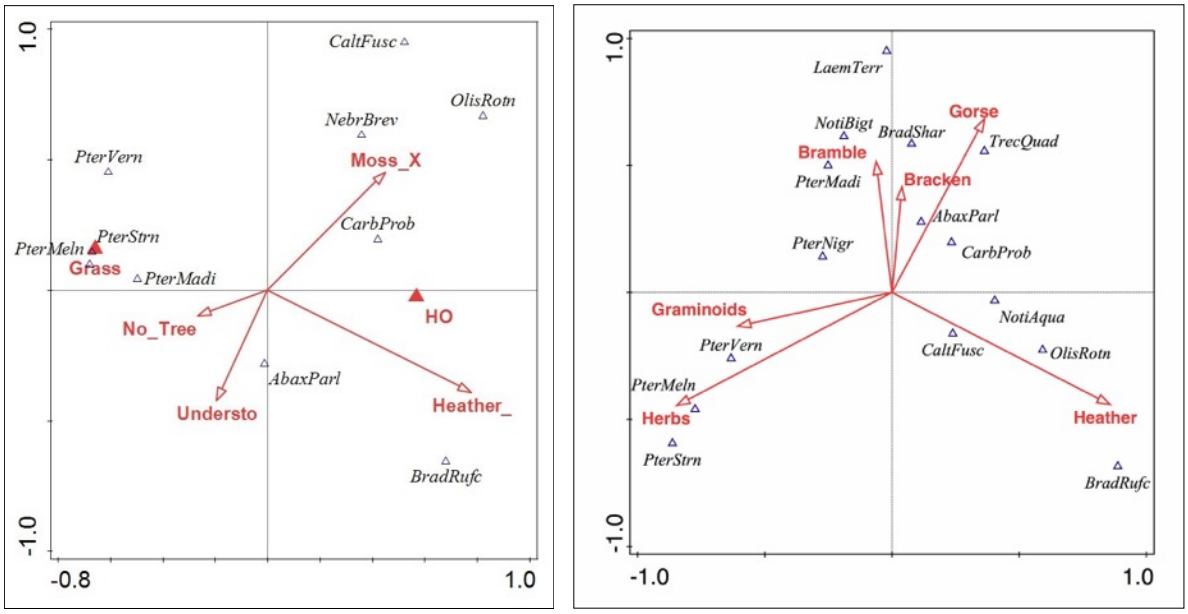


Fig. 9. (Left) A CCA (Canonocial Correspondance Analysis) examining the effect of the most important measured traits on beetle community composition, determined by an interactive forward selection procedure. Axis 1 and 2 explain 13.6% of variation. Top 15 most important species are shown.

Fig. 10. (Right) A CCA (Canonical Correspondence Analysis) examining the effect of surrounding vegetation on beetle community composition. Axis 1 and 2 explain 12.4% amount of variation. Top 15 most important species are shown.

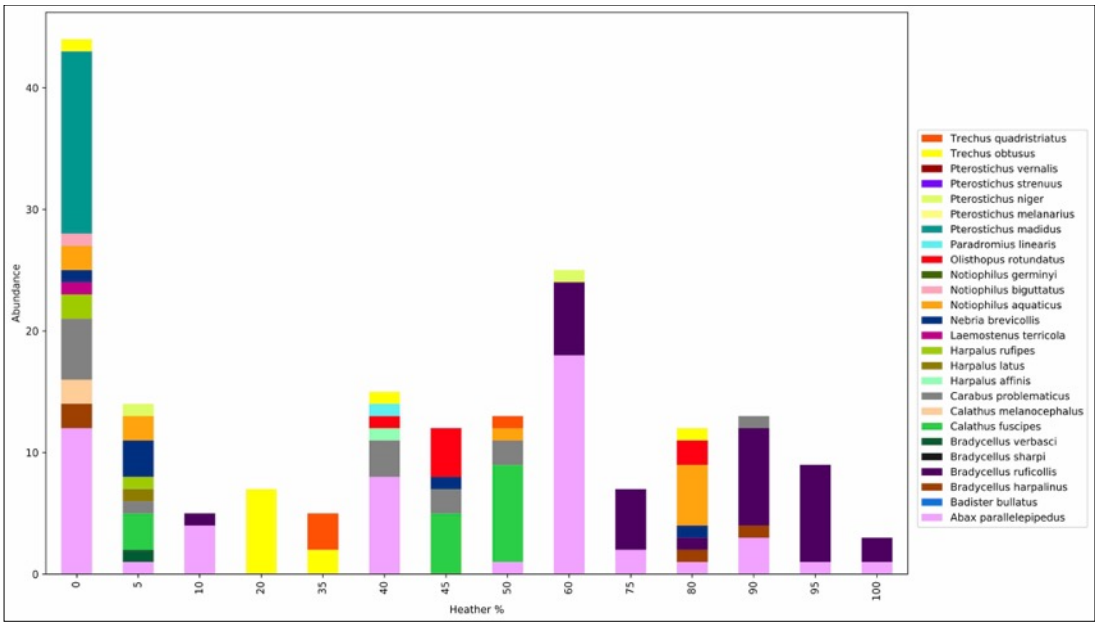


Fig. 11. A stacked bar plot showing species composition in relation to percentage cover of heather in all heathland types surveyed.

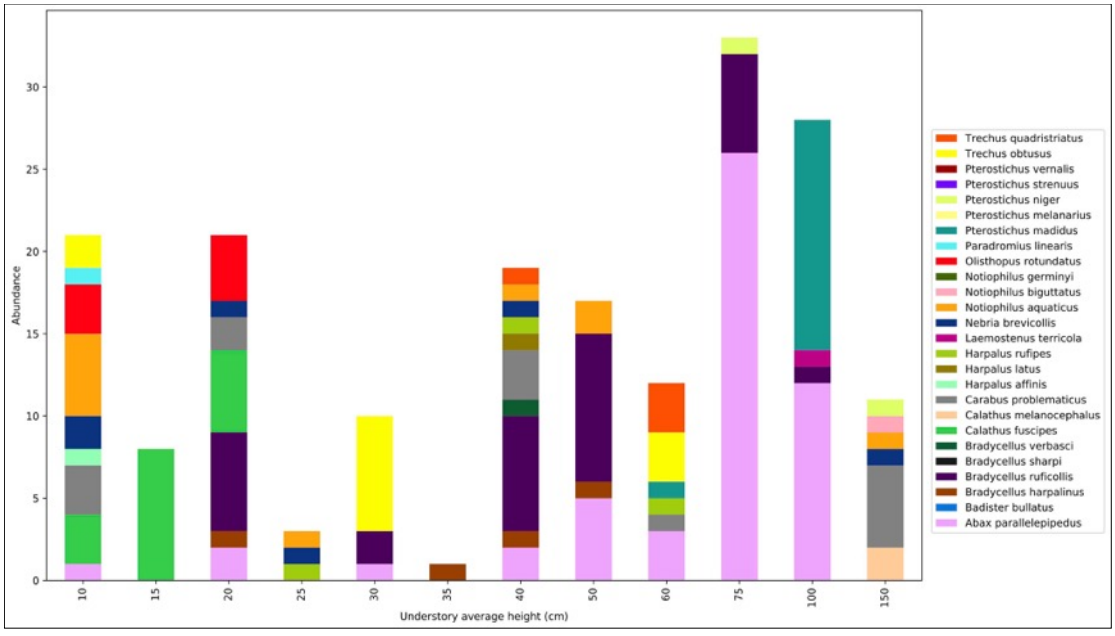


Fig. 12. A stacked bar plot showing species composition in relation to understory vegetation height (cm) in all heathland types surveyed.

*Olisthopus rotundatus* and *Calathus fuscipes* only occur in short vegetation (10 - 20 cm) In Fig. 12. *Pterostichus madidus* and *Abax parallelepipedus* prefer much taller vegetation, where the structure may be more similar to woodland conditions. *Bradycellus ruficollis* is in medium height vegetation (20 - 75 cm).

## 3.6. Analysis of Fire Data

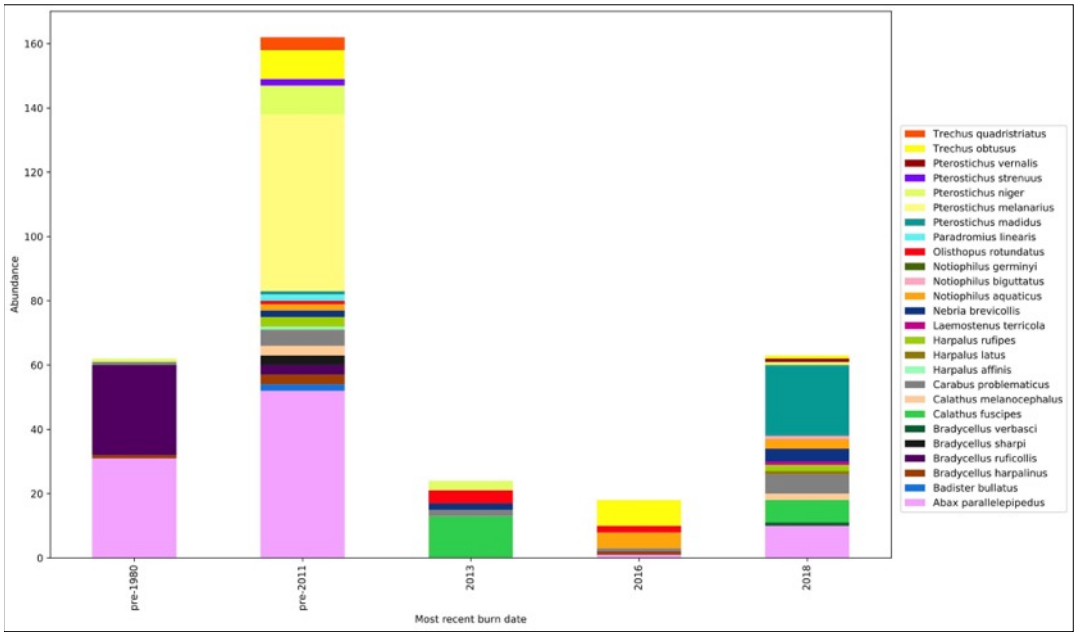


Fig. 13. Species composition of plots at different stages of development since most recently recorded burn.

Reflecting the results of the previous analyses, Fig. 13 illustrates that there is low species richness but mature heathland typical ground beetles are present in the oldest treatments (pre-1980), while the most recently burnt heathland has high species richness and contains species typical of early stage heathland. The pre-2011 data is the least reliable here and includes patches of habitat types which are less likely to have been affected by burning at all (e.g. grassland).

## 3.7. Heathland to Grassland Succession

The stacked bar plot in Fig. 14 explores the relationship of the ground beetle communities to the percentage cover of heather among three habitat types: heather-dominated heathland, heath other (which is a mosaic of dwarf shrubs, grasses, herbs and open ground), and grassland. The purpose was to show how ground beetle species assemblages may change as heather-dominated heathland is replaced by grasses. This can happen when old growth heather dies off, for example following a population explosion of heather beetle (*Lochmaea suturalis*).

*Bradycellus ruficollis*, a species typical of mature heathland, is only present in these habitats where heather cover is 60% or higher. *Calathus fuscipes* is found in heath and grassland with 0 - 50% heather cover, but no higher. *Olisthopus rotundatus* appears to favour mixed habitat with medium to high heather cover.

All of the common *Pterostichus* species found in this study favour grassland without any heather. It should be noted that soil acidity, and not simply vegetation management, could be an influential factor on the presence

or absence of heather. Most of the heather-free grassland on Howth exists on patches of calcareous soil, in contrast with the acid heathland.

These results are muddied somewhat by the fact that where heather cover is low in these data, it has not always been replaced by grassland but, often, gorse or open ground. *Notiophilus aquaticus* is present at 5%, 50% and 80% heather cover, but closer inspection of the data reveals that the heather is short and the vegetation quite open at all of its sites, suggesting that its ability to occupy those places is driven more by openness and age of the heathland than by the level of colonisation by grasses.

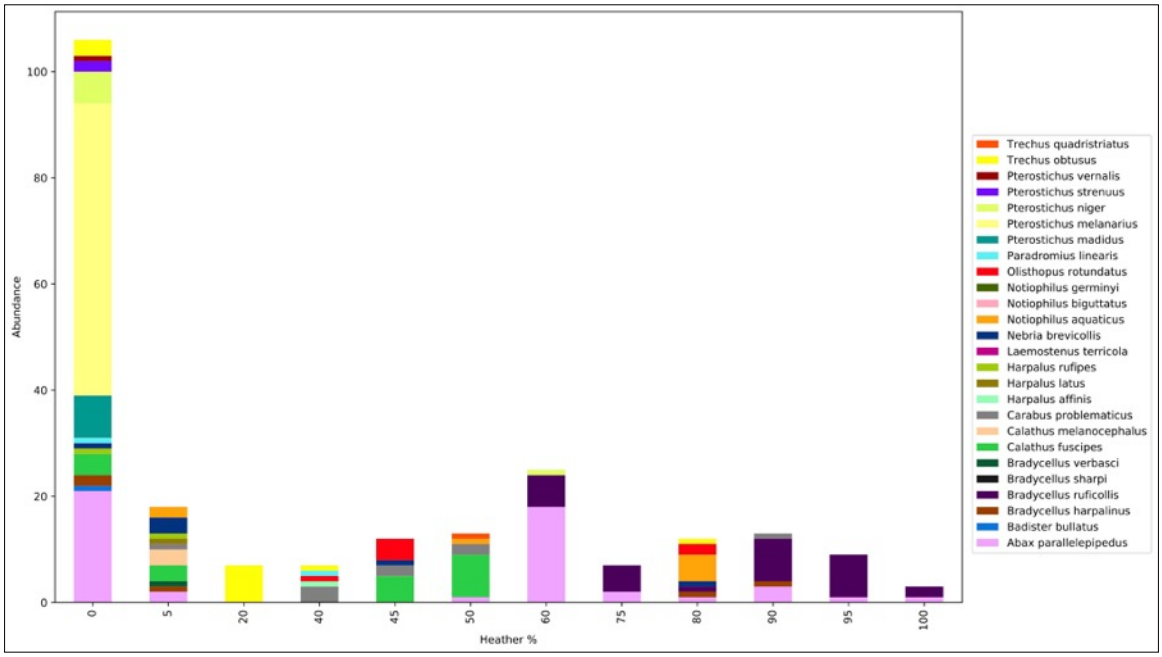


Fig. 14. Species composition in relation to percentage cover of heather in three habitat types combined: Heather-dominated heathland, Heathland other (heathland/grassland mix) and Grassland.

# 4. DISCUSSION

## 4.1. Conservation Significance and Ecology of Ground Beetle Species

The 29 ground beetle species recorded during this survey make up approximately 13.7% of the Irish carabid fauna. The most species-rich habitat types surveyed in this study are heather dominated heathland (13), gorse dominated heathland (14), and grassland (18). The most commonly recorded species in this study were *Abax parallelepipedus* (94) and *Pterostichus melanarius* (55), both widespread and common in Ireland. The former is typical of woodland and dry *Calluna* heath, one of the most abundant habitat types on Howth Head, but it can be found in other habitats with vegetation structure that creates the same climatic conditions. The latter lives mostly in damp grasslands and woodland edges.

Heathlands generally exhibit relatively low species diversity, thus assessing their conservation significance relies more on the uniqueness, rarity or typicalness of the species recorded (Gardner, 1991). Many of the species recorded during this study are common and have a wide geographical distribution in Ireland. However, there are a few with local distribution or which are restricted to specific habitat types or features (*Bradycellus ruficollis*, *B. sharpi, Harpalus affinis*, *Carabus problematicus*, *Notiophilus aquaticus*, and *N. germinyi*) or which tend to be found in small numbers (*Laemostenus terricola*, *Paradromius linearis)*. Others are of interest due to their primarily coastal distribution (*Bradycellus harpalinus*, *B. verbasci, Amara aenea, A. apricaria*). Appropriate management of the preferred habitats of these rarer or more restricted species should be made a conservation priority in Fingal County Council's management plan. In the case of Howth Head, this means facilitating the continuation of the diverse range of habitat types and structures which are allowing these varied species to coexist. The inability of these species to survive in alternative habitat types puts them at risk of being lost from sites such as Howth when their essential habitats (such as heathland) become degraded and fragmented. These species will be discussed in the context of their habitats in the following sections.

In urban Dublin, where heathland is not an abundant habitat, the presence of heathland-typical species such as *Bradycellus ruficollis, Olisthopus rotundatus, Notiophilus aquaticus* and *N. germinyi,* becomes even more important. *Bradycellus ruficollis,* a tiny (2.5 - 3.4 mm) dark brown species with pale appendages and a pale stripe down the midline of the elytra, is restricted to moderately dry mature heathland at low-to-moderate altitudes, where it lives in moss. The special combination of climatic and geological conditions on Howth Head suits certain species that would normally live in very different habitat. For instance, *Carabus problematicus*, a large (20 - 28 mm) black beetle with a purple metallic sheen (cover image, © Roy Anderson), is associated with *Calluna* heath and woodland in upland areas generally above 200 m in altitude. Yet here it is recorded in every study site on Howth Head, whose highest point is only 171 m above sea level.

Generally ground beetles complete their life cycle and reproduce in one year, then die. But some large beetles can live for up to four years. *Carabus problematicus* can have an annual life cycle in locations above 800 m above sea level and a biennial one in higher altitudes, where it is colder and food may be more scarce (Lövei and Sunderland, 1996). It overwinters as a larva in the Netherlands (Rijnsdorp, 1980). In Belgium, it appears to be much more restricted to forest, particularly old growth forest, than in Ireland and hibernates under tree bark there (Gaublomme et al., 2013). Many species, such as *Nebria brevicollis*, go through a period of rest in the

middle of summer, after emerging from their pupae and feeding vigorously for a couple of weeks in spring or early summer. They may aggregate in large groups under logs or rocks until the next peak in activity, reproducing in autumn (Forsythe, 2000). Other species reproduce in spring (Lövei and Sunderland, 1996). Rotten logs, stones, bark, grass tussocks, moss and soil, also provide essential shelter for overwintering (Luff, 2007).

Ground beetles can be predators, omnivorous (eating a mix of live prey, carrion and plant matter) or seed-eating. European species have been found to eat "aphids, spiders, lepidopteran larvae and adults, fly larvae, mites, heteropterans, opilionids, beetles, springtails… enchytraeid worms, lumbricid worms, nematodes, hymenopterans, beetle larvae, eggs, centipedes, millipedes, mollusks, spores, fungal hyphae, seeds, and pollen" and each other (Lövei and Sunderland, 1996). *Abax parallelepipedus* eats slugs and snails. *Harpalus rufipes* and *Amara* species eat seeds. *Bradycellus ruficollis*, the species most typical of mature heathland in this survey, feeds on the seeds and leaves of *Calluna* heather as well as Collembola (springtails), specifically *Onychiurus* sp., to a lesser extent (Delaney, 1960; Talarico et al., 2016).

*C. problematicus*, like some other carnivorous species, digests its food (e.g. slugs, earthworms) externally and swallows only fluids or semi-fluids, while *Notiophilus* species may rapidly dismember their prey (usually springtails) and swallow the fragments. The *Pterostichus* species are generalists, and will catch live prey or scavenge on dead prey, rotting vegetables and fruit (Luff, 2007). The ground beetle species *Pterostichus melanarius, Harpalus affinis* and *H. rufipes* (which are found on Howth) will eat the seeds of the following plants: *Alopecurus* sp. (foxtail grass), *Cirsium arvense* (creeping thistle), and *Senecio* sp. (groundsel, ragwort) (Petit et al., 2014). All three of these grow on Red Rock (Brady, 2018). The light sandy soil and perpetual disturbance of dry heathland favours annual/ephemeral plant species with high seed production (Telfer and Eversham, 1996). Besides the Harpalini (including *Harpalinus rufipes*, found in Howth), whose larvae and adults eat seeds, the larvae of most ground beetles appear to be mainly carnivorous and use external digestion (Forsythe, 2000).

Carabids often lay their eggs, pupate, and spend their larval stage in the soil, making soil humidity an important habitat characteristic for ground beetle species (Lövei and Sunderland, 1996; Luff, 2007). Some, such as *Abax* species, will take care of the developing eggs (Luff, 2007).

### 4.2. Heathland Management

The distribution of ground beetle species across heathland sites is strongly affected by average vegetation height and percentage cover of heather and gorse. Heathland-typical species were more common in places with higher percentage cover of heather and low to medium cover of gorse. Overgrowth of heathland by gorse, which forms a more open vegetation structure when it reaches a certain height, may be problematic for these species. Vegetation height was the factor which determined whether the heathland species assemblages were more typical of open, pioneer heath or of closed, mature heath where abundant moss can grow. Gardner, et al. (1997), also found different species assemblages were associated with *Calluna* height in Scottish heather moorlands.

Fig. 15. *Bradycellus ruficollis* on moss. © Roy Anderson

The majority of *Bradycellus ruficollis* specimens were taken from hand-searched samples of moss which has formed a thick layer beneath the canopy of the mature heather. They do not appear to venture very actively from this micro-habitat, as no specimens fell into the pitfall traps.

*B. ruficollis* was not found at locations where the vegetation had been burned in the past seven years, or where grasses were present. Similarly, Bargmann, et al., (2015) found it only in leaf litter in heathland patches of later successional stages. Loss of mature heathland through overgrazing or succession to grassland would likely result in the loss of this species from much of Howth Head. In a study by Buchholz, et al., (2013) 35 species were lost due to succession from dry grassland and heathland to grass-invaded and tree-dominated sites.

Conversely, if all heathland is left to mature, growing tall and losing botanical and structural diversity in the process, the species who prefer much younger, more open heathland will be negatively affected. *Notiophilus aquaticus* was found primarily in heathland which had been burned in the past three years, including areas which were burned only one year before, where much of the ground was still scorched and bare. It was never found in mature heathland. *Olisthopus rotundatus* was found in building heathland which had been burned at least 3 - 6 years previously. *Calathus fuscipes* was found in heathlands which had been burned between one and six years previously. These three species are associated with open, dry habitats including well drained

heaths.  Bargmann, et al., (2015) also found *N. aquaticus* and *C. fuscipes* only in pioneer and building heathland, and *O. rotundatus* only in building heathland.

A rotational burning regime would be useful in maintaining this spatial and temporal diversity in beetle communities across the heathland. Burning also helps the heather to remain vigorous and prevents it from becoming overgrown with scrub. Bargmann, et al., (2015) recommend prescribed burns that create a mosaic of different heathland development stages, preferably with a bias toward younger stages (0 - 14 years). McFerran, et al., (1995) wrote that "the maintenance of a mosaic of stands of varying age of *Calluna* is as essential for the conservation of invertebrate groups as it is for the management of plant species and vertebrates, such as red grouse."

It is important to ensure that areas of mature heathland are left intact during this process, however, as it will take the same number of years (20 - 40) for the burnt areas to build up that same structure which suits the mature heathland-typical species that currently occur there. This will help the remaining populations of those species to colonise other areas as they mature. Small flightless species (such as *Bradycellus ruficollis* and *Paradromius linearis* which are usually wingless) may have trouble repopulating a burnt area if burnt patches are too large and the next source population is far away (Bargmann, et al., 2015).

Large flightless species such as *Carabus problematicus* may also be susceptible to the effects of decreasing patch size and fragmentation, due to their inability to disperse long distance and their avoidance of edge habitats. Gaublomme, et al. (2013) observed that this species was never recorded in forests of less than 30 ha in area. Moss seems to be an important habitat feature associated with *B. ruficollis,* probably because it provides a moist micro-climate in dry heath, preventing these tiny beetles from becoming desiccated*. B. ruficollis* was found abundantly in hand-searched moss samples under mature heather but never in nearby pitfall traps, which could suggest that it avoids areas of open ground*.* These features of habitat patches should be kept in mind as changes are observed following the implementation of management measures.

While heavy grazing (>2 ewes ha -1) can negatively affect heathland-typical ground beetle species and reduce species richness (McFerran, et al., 1994; Gardner, et al., 1996), a loss of grazers results in overgrowth and eventual loss of heathland, followed by succession of gorse, bracken and grassland. Howth Head is experiencing some of these effects, as grazing by farm animals ceased in the 1940s, besides some sporadic grazing at Red Rock until the early 1990s (Hans Visser, pers. comm.). Light grazing can add structural heterogeneity to heathland vegetation in ways that burning cannot. Ideally, goats or livestock animals should be reintroduced in low numbers to suitable parts of the heathland to achieve this, in combination with the rotational burning regime. The effect that these treatments will have on ground beetle assemblages should be monitored over subsequent years.

The stacked bar plots in Fig. 13 and Fig. 14 show that dramatic changes in species composition can occur in response to changes in the ratio of heather to gorse and grass, or heather to grassland, in habitats as succession takes place.

**Heather beetle (*Lochmaea suturalis*)**

Although the heather beetle is a chrysomelid, not a carabid, it deserves mention as its larvae were caught in substantial numbers in the pitfall traps. This species can have a significant impact on the health of *Calluna* heather, the primary food plant of this species and the main type of heather in Howth. Defoliation from outbreaks of *L. suturalis* can kill off patches of heather, which can then be succeeded by grass-rich vegetation, where the soil is sufficiently nutrient-rich, changing the makeup of the landscape.

| Site | No. of Heather Beetle Larvae |
|---|---|
| **Bellingham's Farm** | 0 |
| **Ben of Howth** | 93 |
| **East Mountain** | 248 |
| **Red Rock** | 0 |
| **Shielmartin** | 246 |

A total of 587 larvae of *L. suturalis* were caught in traps in heather- and gorse-dominated heath at East Mountain, Ben of Howth and Shielmartin. The highest numbers were found in traps in mature heathland where percentage cover of heather was very high (80 - 100%). On Shielmartin in particular, dead patches of heather were quite evident, affecting the moisture content of the soil (Ladekarl et al., 2001) and causing several pitfall traps to flood. One trap there collected 114 individual heather beetle larvae. Similar numbers were caught on East Mountain. However, the present survey did not attempt to determine whether these dead patches were caused by heather beetles outbreaks or other factors.

Fig. 16. Adult and larval form of the heather beetle (Lochmaea suturalis).

As soil nitrogen levels rise due to pollution and climate change, conditions become more favourable for the colonisation of damaged heathland by grasses instead of regrowth of heather. Research also indicates that *L. suturalis* thrives on increased soil nitrogen, increasing the risk of population outbreaks (Taboada, et al., 2016). Infestations can also increase the nutrient content of the soil beneath, reducing its suitability for heather and increasing its suitability for grasses and trees (Rosenburgh & Marss, 2010). Stevens, et al. (2016) predict reductions in species richness in heathlands due to nitrogen deposition. The only way this can be sufficiently mitigated is by reducing nitrogen emissions at a national and global scale and should be a priority for government environmental agencies.

On a more local level, it may be useful to identify and support species which predate on heather beetles. According to Taboada (2016), predacious ground beetles may not be very effective in controlling heather beetle populations. They prefer alternative prey where available as heather beetle larvae contain toxic compounds and have low food value. Ground beetles were even less likely to feed on larvae which had been feeding on more nitrogen-rich heather. The hieroglyphic ladybird (*Coccinella hieroglyphica*) and heather ladybird (*Chilocorus bipustulatus*), on the other hand, prey mainly on heather beetle (Anderson, 2006). Both ladybirds have been recorded from Dublin, but were not found on Howth during this survey, so they are unlikely to occur in numbers great enough to have an impact on heather beetle populations. Similarly, the heather shield bug (*Rhacognathus punctatus*) which also feeds on heather beetle (Gillingham et al., 2015) is unlikely to have a significant impact.

Gillingham et al. (2015) carried out a desk study of heather beetle research thus far, in an attempt to determine whether there were scientific grounds for suggestions that burning heather outside of permitted heather-burning season could help to regenerate heather after an infestation, or even help to control heather beetle. In a previous literature review, Rosenburgh & Marss (2010) sought to assess existing knowledge on the impacts of heather beetle and identify gaps and recommendations for further research. They provide an extensive description of heather beetle ecology. For instance, like *Bradycellus ruficollis*, heather beetle larvae are more abundant where there is an underlying moss carpet to provide moisture.

Both reviews found that much of the past research is unreliable or unsuitable to answer the necessary questions about the impact and control of heather beetles, and also that it is unclear whether age of heather affects presence or absence of heather beetle. They list specific topics for further research. They note that there may be good potential for parasites, parasitoids and fungal pathogens to control heather beetle populations. Burning, cutting and flailing could also help to limit numbers, but further experimentation is required to ascertain the most effective use of these methods. Howth Head could be a suitable study site for a comparison of the effectiveness of different burning and cutting methods at the affected sites. In the meantime, until evidence based methods for heather beetle control are established, focus should be on restoring Howth's heathland where it has been damaged or killed.

### 4.3. Grassland

Grasslands were the most species-rich habitat in this study. The majority of their species are widespread and common with much crossover occurring with other habitat types. The following species were found only as individuals or in small numbers among the samples from Howth.

*Paradromius linearis* is one of the few species from the grassland sites which has a local, restricted distribution. It tends to climb vegetation on dunes, riverine marshes, lakeshores and well-drained grasslands. Here, it was found in a hand-searched grass tussock at G2, a grassland location on East Mountain which has very dense sward and calcareous plant species such as bird's foot trefoil and ladies' bedstraw. Unusually, one of the other sites where it was found was heather-dominated heath with short vegetation and lots of open ground. The third specimen was found at B3, among tall bracken with small amounts of gorse and grasses. *Calathus melanocephalus* was found on dry grassland with small amounts of heather, and also on a gorse-dominated heathland site recently burned and recolonising with bracken and herbs. It is associated with grasslands on well drained, sandy soils, such as dunes.

*Badister bullatus*, of which two specimens were captured in grassland and woodland at Red Rock, is widespread and quite common in dry habitats, even in gardens and waste ground, and especially in coastal habitats such as dunes. *Amara aenea*, found in G5 (Darcy, 2020), shares similar habitat preferences. In contrast, *Pterostichus vernalis* prefers wet habitats. A fairly widespread and common species, it can be found in "montane blanket peat, lakeshores, fens, pastures and agricultural land". It was found in the field at Bellingham's Farm. Outside of the northern counties of Ireland, the distribution of *Amara communis* is not well recorded. In the north of the island it is widespread in moss and litter on farmland and sometimes heathland. Seven specimens were found in G4 at Red Rock (Darcy, 2020).

### 4.4. Bracken

Species richness in most of the bracken habitat samples was very low, with 0 - 2 species each, usually including the common species *Abax parallelipedus, Pterostichus niger* or *Trechus obtusus*. However, B3 on East Mountain is a very interesting exception. Seven species were recorded here, including *Bradycellus sharpi, Carabus problematicus* and *Paradromius linearis* (Darcy, 2020). *B. sharpi* is widespread but local, normally recorded from woodland next to acid heath or where drainage of lowland raised bog allows birch seedlings to grow, forming acid woodland. *C. problematicus* is associated mainly with *Calluna* heath or forest in hilly areas. *P. linearis* has a local, restricted distribution. It is more commonly associated with dune vegetation, riverine marshes, lakeshores and well-drained grasslands.

A closer inspection of the vegetation characteristics of B3 reveals that it contains patches of gorse and grasses, suggesting it is a transitional habitat where bracken may be colonising land which was recently heathland. It forms part of a diverse patchwork of bracken, gorse and heather dominated heathland, and transitional heathland/grassland on this side of Howth Head. Transitional habitats are important for ground beetles, many of which use multiple habitat types at different stages of their life cycle (Lovei and Sunderland, 1996).

The flora beneath the bracken stands in Howth varies greatly from patch to patch. Woodland-type plants such as bluebells and brambles were observed under patch B4 at East Mountain, while a patch of meadowsweet at B1 might indicate the presence of a seepage. Often, however, there is little but a thick mat of dead bracken leaves beneath the dense canopy. Its vigour and ability to form a monoculture like this pose a considerable threat to heathland habitats and species.

Where grazing no longer takes place, dense stands of bracken can take over and are very difficult to get rid of. Bracken is toxic to livestock if consumed for several weeks, but where alternative forage is available they will avoid it. Therefore, grazing should help to limit bracken to its current distribution in the Howth sites. Cattle trampling can help to limit its spread, sheep trampling less so. SEARS (the Scottish governmental organisation, *Scotland's Environmental and Rural Services*) have produced a detailed guide to managing or eradicating bracken called *Bracken Control: A guide to best practice* (SEARS, 2008).

### 4.5. Woodland

The four woodland plots sampled during this study are very different in botanical and structural composition. The aim was not to thoroughly assess woodland management but to discover whether any species of conservation interest were inhabiting these patches. Only four common, generalist species were found, none of which were unique to this habitat type: *Pterostichus niger*, *Pterostichus melanarius*, *Abax parallelepipedus* and *Trechus obtusus*.

It may be advisable to prevent further encroachment of birch woodland on to the heathland, although it does suit some species such as *Bradycellus sharpi*. Ings and Hartley (1999) found that adding young pine trees to moorland has little effect on species richness, but as trees mature and grow larger, the species richness of ground beetles falls.

### 4.6. Other Factors Affecting Conservation

This study was somewhat restricted, by the focus on managing the main vegetation types on Howth Head. An alternative field methodology, unconstrained by the scientific approach necessary for assessing the effects of vegetation management, would be expected to find different species. It would allow for more targeted rummaging in unusual spot habitats, such as beaches, streams and seepages on cliffs, and the Bog of Frogs.

A number of factors other than vegetation structure can influence the distribution of ground beetle species. Hydrology is one example, and the lack of hygrophilous species from most of the Howth sample locations is cause for concern. From previous reports such as Declan Doogue's discussion document *Protecting Howth's Habitats* it appears that many of Howth's small streams and seepages have been lost to draining and culverting over the years. Rehabilitation of these, where possible, and preventing the loss of others may ensure a future for wet grassland beetle species on Howth Head. An area which has been invaded by birch or rhododendron often indicates the location of a wet area. "Maximum carabid diversity may thus be expected on moorland areas that include both wet and dry areas and show a high degree of structural heterogeneity within the dwarf shrub community." (Gardner et al 1997)

Microclimate is another factor. It may play a part in the distribution of the more xerophilous (dry habitat typical) species found in this survey, such as *Calathus fuscipes*. The sun trap formed by the sheltered, south-facing rocky outcrops at Red Rock and Bellingham's Farm may create a warmer, dryer, microclimate than might be found on the shaded north faces of East Mountain. Gardner, et al., (1997) found that soil organic content also influenced ground beetle assemblages in heathland, perhaps due to its effect on soil humidity. Sandy soils drain more quickly while humus holds moisture. Organic content can also influence the availability of preferred prey and seed species.

Even after considering all ecological factors, a conservation plan will only work with the support of the local community and stakeholders. Increased engagement with the public on the topic of the significance and needs of Howth's invertebrates might raise awareness and garner more support for burning regimes and fencing to facilitate grazing. Dedicated amateur naturalists should be encouraged and supported in collecting records of ground beetles and other insects, contributing to our understanding of the distribution of species across habitats and locations. These objectives might be achieved through collaboration with the Dublin Bay Biosphere Partnership or by teaming up with local naturalists and tour guides such as Shane's Howth Adventures.

# 5. SITE REPORTS

The following reports outline significant features and specific management suggestions for each study site. The species lists include additional opportunistic finds and *Amara* species from pitfall traps which were identified at a later stage and not included in the data analysis.

## BELLINGHAM'S FARM

| Bellingham's Farm Carabid Species List | |
|---|---|
| **Species (* = unique to this site in this survey)** | **No. of individuals** |
| *Abax parallelepipedus* | 10 |
| *Calathus fuscipes* | 7 |
| *Calathus melanocephalus* | 2 |
| *Carabus problematicus* | 5 |
| *Harpalus rufipes* | 1 |
| *Laemostenus terricola** | 1 |
| *Nebria brevicollis* | 3 |
| *Notiophilus aquaticus* | 1 |
| *Notiophilus biguttatus** | 1 |
| *Pterostichus madidus* | 22 |
| *Pterostichus niger* | 1 |
| *Pterostichus vernalis** | 1 |
| *Trechus obtusus* | 1 |

Species richness per pitfall trap was highest by far at Bellingham's Farm, with 11 species caught in only five traps. The low number of traps was due to only a small section of the site being accessible and without horses. One trap was set in grassland, one in a gorse thicket within the grassland, and three across an area of burnt heathland with varying degrees of regrowth, including an almost bare rocky area with shallow soil (H12) and another where a variety of tall herbaceous plants have recolonised.

The level of diversity here contrasts starkly with that of Shielmartin and, to a lesser extent, Ben of Howth. Both of those sites have greater expanses of more uniform, old growth heather-dominated heath and mature gorse, while Bellingham's Farm is being recolonised with diverse vegetation after a burn in 2018. This contrast supports the findings of Bergmann, et al., (2015) that there are clear compositional differences between

assemblages from year to year after burning. They recommend rotational burning to create a mosaic of heathland of different ages as a way to support landscape scale biodiversity.

*Notiophilus aquaticus* is present here, in trap F2, set among recently burned gorse with abundant open ground, as well as several open sites on Red Rock. It is not found in any of the more mature heathland sites. This is in line with Bergmann's (2015) findings that it is characteristic of heathland from 0 to 14 years old.

Two ground beetle species were found only at this site. The first, *Laemostenus terricola,* is a large dark brown beetle with blue-green metallic elytra, was caught in the stand of mature gorse within the grassland (F3). It has a local distribution, and is rarely sampled in multiples. It is associated with mammal burrows, particularly those of rabbits, and crevices of brickwork. As a result, it may be under-recorded. Telfer and Eversham (1996) found *L. terricola* at Breckland in traditional arable, grass heath and sand dune.

The second, *Pterostichus vernalis,* is a widespread and common species. It is typical of the grassland habitat in which it was trapped (G8), living under stones and in litter and moss in moist meadows.


Fig. 17. Location of pitfall traps on Bellingham's Farm. G = grassland, F = gorse-dominated heathland, H = heather-dominated heathland.

The priority here is to monitor the beetle assemblage to observe how it changes in response to successional changes following the burn in 2018. Some removal of bracken may be necessary. The grassland can continue to be managed as it has been, and the stand of gorse scrub retained within it. Along with the rabbits, these features may be making it possible for an interesting species such as *L. terricola* to find the habitat features and foods that it requires.

**Non-carabid species at Bellingham's Farm**

An individual of the staphylinid beetle *Micropeplus fulvus* was found in F4 (Darcy, 2020). This small rove beetle species has a localised distribution, in moss, decaying vegetation, wetland margins and similar substrates. Trap F4 was set in a recently burnt patch of tall gorse, with abundant herbs (60%), and some brambles, bracken and grasses.

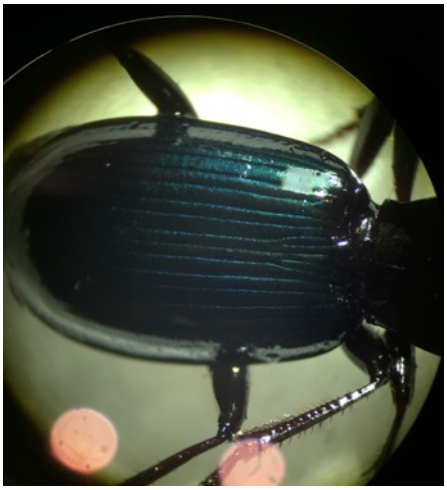

Fig. 18. The characteristic flat, metallic elytra of *Laemostenus terricola.* The burnt gorse at Bellingham's Farm, with open rocky soil in the background. Note the bracken recolonising.

## BEN OF HOWTH

| Ben of Howth Carabid Species List | |
|---|---|
| **Species** | **No. of individuals** |
| *Abax parallelepipedus* | 6 |
| *Bradycellus ruficollis* | 3 |
| *Calathus fuscipes* | 13 |
| *Carabus problematicus* | 2 |
| *Nebria brevicollis* | 2 |
| *Olisthopus rotundatus* | 3 |
| *Pterostichus niger* | 4 |
| *Trechus obtusus/quadristriatus* | 7 |

Ben of Howth is the highest location on the peninsula of Howth. The area in which the samples were taken is mostly exposed and windy, with South West and East facing slopes. At this site, three traps were set in gorse-dominated heath, five in heather-dominated heath, and two in woodland (one immature birch woodland, and one mature birch and holly). Species richness per pitfall trap was comparatively low on Ben of Howth, with eight species found in ten traps.

Large areas of the heathland on this site have been left to grow for many years and the vegetation is bushy and dense, with patches of dead heather (93 heather beetle larvae were caught on this site). There are also a number of areas where it has been more recently burned (even within the past three years) and where the soil is rocky, creating more open vegetation.

There were no species unique to this site. *Bradycellus ruficollis* and *Olisthopus rotundatus*, species of mature and building heathland respectively, were both present. *Calathus fuscipes* was the only species here typical of young, open heathland. Maintaining the structural diversity which exists here, using a rotational burning regime or grazing where possible, could be expected to increase ground beetle species diversity and improve the quality of the habitat. It is important to ensure that sufficient mature heathland remains at all times to support the continued presence of *B. ruficollis* and other mature heathland specialists.

### Non-carabid species on Ben of Howth

One specimen of *Pirapion immune*, a weevil, was taken from F6 (Darcy, 2020). This species is local and rare in Ireland, usually feeding on broom but also known to eat gorse (*Ulex* sp.).

Two specimens of *Leptinus testaceus* (family Leiodidae) were caught in trap F11. This tiny species lives in mammal burrows, like the carabid *Laemostenus terricola* which was found in a similar habitat type at Bellingham's Farm. Its distribution is localised but it may be under-recorded due to its lifestyle.

Fig. 19. *Pterostichus niger*, and the silver birch woodland near Windgate Road, Ben of Howth.

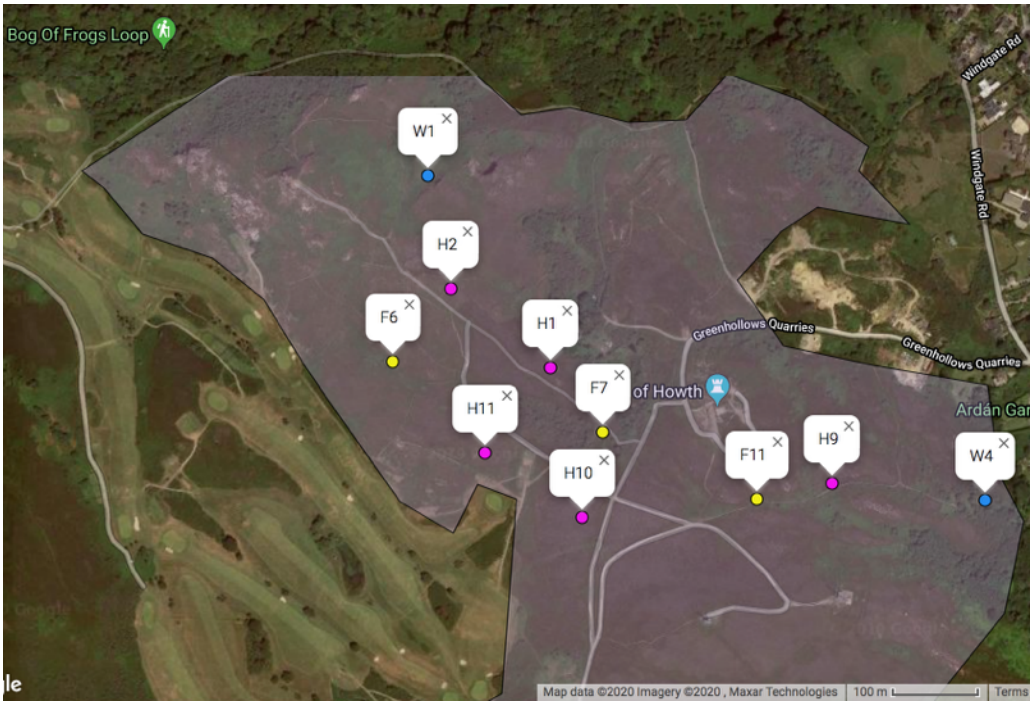


Fig. 20. Locations of pitfall traps on Ben of Howth. F = gorse-dominated heathland, H = heather-dominated heathland, W = woodland.

## EAST MOUNTAIN

| East Mountain Carabid Species List | |
|---|---|
| **Species (* = unique to this site in this survey)** | **No. of individuals** |
| *Amara aenea* | 3 |
| *Abax parallelepipedus* | 10 |
| *Bradycellus harpalinus* | 3 |
| *Bradycellus ruficollis* | 2 |
| *Bradycellus sharpi** | 3 |
| *Carabus problematicus* | 6 |
| *Harpalus affinis** | 1 |
| *Harpalus latus* | 2 |
| *Harpalus rufipes* | 2 |
| *Notiophilus aquaticus* | 6 |
| *Notiophilus germinyi* | 1 |
| *Olisthopus rotundatus* | 3 |
| *Paradromius linearis** | 3 |
| *Pterostichus melanarius* | 8 |
| *Pterostichus niger* | 2 |
| *Trechus obtusus/quadristriatus* | 16 |

East Mountain is a mainly East and South East facing linear site which incorporates the most popular stretch of the Howth cliff walk. *Platyderus depressus* (Audinet-Serville, 1821), whose range in Ireland is restricted to Howth, was most recently recorded from a garden on East Mountain. However, it was not found during this survey.

Sixteen of the study's 29 species were found here, reflecting the diversity of habitats within the site. It features a mosaic of heather and gorse dominated heathland, grassland and bracken, with an abundance of transitional habitats. Transitional habitats are of great use to ground beetles, many of which use different habitats at different times of the year. East Mountain had the highest number of records of *Carabus problematicus* out of all of the sites (6 individuals, from traps H4, H7, H8 and B3). 248 heather beetle larvae were also captured in pitfall traps.

*Bradycellus ruficollis,* this study's most typical species of mature heathland, was recorded from H3. *Notiophilus aquaticus*, typical of pioneer and building heathland, is also here, at H5 and H8. H4 was the most interesting

sample site on East Mountain. This pitfall trap gathered three specimens of *C. problematicus*, one *Olisthopus rotundatus* and the only *Harpalus affinis* specimen in the whole survey. One *Paradromius linearis* was caught there in a hand searched sample. *H. affinis* can be common in suitable habitat, but this shiny, metallic species is restricted to free-draining soils, almost entirely in coastal areas.

The vegetation at H4 is made up of a short, dense mix of heather (*Calluna vulgaris* and bell heather) and gorse, and 40% of the vegetation survey quadrat was open, rocky ground. Average vegetation height, with areas of open ground included, was 10 cm. It is possible that the site was last burnt before 2011, but the fire record for this site is unreliable. As with the heathland at other sites, a rotational burning regime would maintain diversity across East Mountain's heathland areas and light grazing, where possible, would bring additional structural heterogeneity.


Fig. 21. Pitfall trap locations on East Mountain. Clockwise from top left, north to south locations. B = bracken, F = gorse-dominated heathland, G = grassland, H = heather-dominated heathland, SH = heath other.

*Paradromius linearis*, a species of widespread but local distribution, was found only on East Mountain. It is associated with grass tussocks on sand dunes, riverine and lakeshore habitats, and better-drained mineral soils. In addition to the record from H4, an individual was recorded from the tussocky flower-rich calcareous grassland at G2, and in bracken with some gorse and grasses at B3. Any mowing or grazing regime implemented at G2 should aim to retain the tussocky nature of the grassland sward.

East Mountain also contains B3, the one bracken site in this study which was found to contain ground beetle species of conservation interest, *Bradycellus sharpi, Carabus problematicus* and *Paradromius linearis* in particular. *B. sharpi* likes damp habitats, as do a couple of other species found on East Mountain.

Only one gorse-dominated site (F1) was sampled on East Mountain. A single *Abax parallelepipedus* was the only carabid found there.

Roy Anderson's identification added a new carabid species to the data set. *Amara aenea* is widespread, and fairly common in gardens and sandy areas near the coast. Here, three individuals were found in G5.

Fig. 22. Transitional habitat between heathland and grassland, and *Paradromius linearis*.

**Non-carabid species on East Mountain**

*Atheta hypnorum* is a rove beetle species of local distribution and rarely recorded but it is abundant on Howth Head, primarily in the bracken sites. On East Mountain it was sampled at B1, B2 and B4. It was most abundant at B1 which is an almost monoculture stand of bracken (100% bracken in the vegetation survey) on the steep side of a rocky outcrop. This indicates that, although there are few carabid species of conservation interest in the bracken patches on Howth Head, this habitat type is useful for other uncommon beetle species. Therefore, the eradication of bracken is an unnecessary goal, provided that proper heathland management prevents it from taking over other important habitats.

Two individuals of the round fungus beetle *Leiodes calcarata* were trapped at B1, B3, and three specimens at SH4. It feeds on underground fungi.

A single *Xantholinus elegans* (family Staphylinidae) was found in grassland site G1. This is an unusual habitat for what is usually a seashore species (Roy Anderson, pers. comm., 20 April 2020).

A sweep of another bracken site, B4, produced a Speckled Bush Cricket (*Leptophyes punctatissima* (Bosc, 1792)). This insect appears to be restricted, in Ireland, to the South and South East. Patches of gorse and grasses among and alongside the bracken at these two sites may be contributing to their suitability for interesting species. It may be worth trying to maintain the transitional state of these bracken sites, monitoring their development. Bracken is likely to be much more of a problem where it forms dense monocultures, as in other parts of East Mountain.

## RED ROCK

| Red Rock Carabid Species List | |
|---|---|
| **Species (* = unique to this site in this survey)** | **No. of individuals** |
| *Abax parallelepipedus* | 16 |
| *Amara apricaria** | 1 |
| *Amara communis** | 7 |
| *Badister bullatus** | 2 |
| *Bradycellus harpalinus* | 2 |
| *Bradycellus verbasci** | 2 |
| *Calathus melanocephalus* | 3 |
| *Carabus problematicus* | 1 |
| *Harpalus latus* | 1 |
| *Harpalus rufipes* | 3 |
| *Nebria brevicollis* | 3 |
| *Notiophilus aquaticus* | 4 |
| *Notiophilus germinyi* | 1 |
| *Pterostichus madidus* | 1 |
| *Pterostichus melanarius* | 48 |
| *Pterostichus niger* | 5 |
| *Pterostichus strenuus** | 2 |
| *Trechus obtusus* | 3 |

Red Rock is a warm, sheltered, South West facing mosaic of very diverse habitats, including grassland with orchids, bracken, gorse scrub, a conifer plantation and several types of dry siliceous heath. It has been the subject of a thorough botanical survey by Catriona Brady (2018), who found several rare and important plant species.

In 2018, a fire spread across the heathland at the top of the rocky outcrops, burning quite intensely due to abundant debris which had built up underneath the mature gorse. At the time the present survey was undertaken the ground was still scorched black but heather, gorse, grasses, herbs and mosses were recolonising.

A diverse range of ground beetle species have also entered this area of pioneer heathland. The most important of these from a habitat typicalness point of view, are *Notiophilus aquaticus, Bradycellus harpalinus*, and *Carabus problematicus*. *N. aquaticus* is particularly associated with recently burnt young heathland. It was

found here at F8 (cleared gorse area), SH3 (recently burned heath on rocky outcrop) and on East Mountain at H5 (very short, patchy, rocky heathland) and H8 (taller heathland but with open areas). It is not found in any of the more mature heathland sites. This is in line with Bergmann's (2015) findings that it is characteristic of heathland from 0 to 14 years old. It is useful to have recorded baseline data so soon after the burn. It will be interesting to observe how the beetle community changes over the years as the heath recovers.

*Notiophilus germinyi,* typical of dry heath and dry grassland, was found opportunistically in short grass at G7. *Bradycellus verbasci* was found in SH2. Although common, it is restricted to well-drained soils near the coast.


Fig. 25. Pitfall trap locations at Red Rock. B = bracken, F = gorse-dominated heathland, G = grassland, SH = heath other, W = woodland.

The grasslands at Red Rock also host a diverse community of ground beetles, although nothing uncommon. Managing the grasslands for the important flora they host is unlikely to pose any threat to the ground beetles. Ideally, any mowing or grazing regime should be rotational and aim to promote structural diversity as well as floral diversity, especially maintaining areas of long tussocky grass year round. Insects need tussocky grass to shelter, nest and pupate in. Generally, mowing once a year in September or October will bring about good results, as it ensures that flowers have time to set seed. Where possible, remove grass cuttings to reduce nutrient input. Some of them can be left aside to offer further shelter to invertebrates.

Roy Anderson's identifications added two new species to the data set for Red Rock. *Amara apricaria* is widespread and fairly common in well drained coastal sites, but rarer inland. *Amara communis* is widespread in the northern counties, found in moss and litter in farmland and heath. Its status elsewhere on this island is not well known.

The lack of hygrophilous species was noticeable again here and could be remedied by encouraging the natural hydrology of the site. Wet flushes in calcareous grasslands can provide important habitat for uncommon wetland beetles. Brady (2018) has identified damp hollows near pitfall trap locations G3, G4 and G5.

The carabid samples taken from woodland on Red Rock were low in diversity and of little conservation interest. However, the sheltered woodland glade provides good conditions to support peacock butterfly

Fig. 26. Clockwise from top left: Heath other - a mix of dwarf shrub, grasses and herbs; the grassland and conifer plantation; *Badister bullatus*, found in grassland and woodland at this site; a spider makes use of burnt gorse branches, where heather and gorse are beginning to recolonise the scorched ground at Red Rock.

caterpillars, many of which were seen on nettles next to trap W2, and a rare rove beetle species was also caught here (see non-carabid species at Red Rock below).

**Non-carabid species at Red Rock**

*Atheta hypnorum*, the rove beetle which is normally rare but has been found in abundance on Howth Head, is present on Red Rock (Darcy, 2020). Two individual specimens were trapped at the woodland site W2.

A *Mycetoporus angularis* individual was trapped in bracken at B5. This uncommon rove beetle is a mountain summit species, but here it was found not far from sea level. It could be a blow-in from Shielmartin, the steep hill which rises above Red Rock.

Nine specimens of the rove beetle *Oxypoda brachyptera*, which does not appear to exist in the northern part of the island, were taken from G6, a grassland which consists of more herbaceous plants than grasses.

An individual of *Quedius nigriceps*, a localised rove beetle which is normally found in sandy pinewoods, was caught in SH1 on Red Rock (mixed transitional heathland, with a high percentage of graminoids).

Two specimens of *Tasgius morsitans*, a rove beetle of southern distribution, were found at F8, a gorse-dominated heathland site which was cleared in 2019. Another was found in G9, a dry grassland with small patches of bramble, heather, herbs, moss and open ground.

This selection of interesting non-carabid beetles reflects the diversity of habitats at Red Rock, and further highlights its significance for beetle conservation.

## SHIELMARTIN

| Shielmartin Carabid Species List | |
|---|---|
| **Species** | **No. of individuals** |
| *Abax parallelepipedus* | 52 |
| *Bradycellus harpalinus* | 1 |
| *Bradycellus ruficollis* | 28 |
| *Carabus problematicus* | 1 |
| *Notiophilus germinyi* | 1 |
| *Pterostichus niger* | 3 |

Shielmartin was the site with least species richness. Large swathes of the heathland are very mature (over 40 years in parts) and much of the vegetation is quite uniform. Moss is plentiful beneath the heather. This suits *Bradycellus ruficollis* very well; it is most abundant at this site. Another interesting species which was found opportunistically on a path next to gorse (F5) at this site is *Notiophilus germinyi.* Typical of heaths and dry grasslands, this species is widespread but local across Ireland. *Bradycellus harpalinus* is also typical of coastal heaths and dunes, though recorded widely, sometimes in gardens.

There are many patches of dead heather on Shielmartin. Where this occurs, the ground can become quite waterlogged, as there is no vegetation to absorb rainwater. It may be interesting to observe what grows there and whether hygrophilous ground beetle species will colonise these wet areas. 246 larvae of the heather beetle were caught on this site, so outbreaks of this species may be a factor in the heather die-off.

Fig. 23. Mature and dying heather at the exposed top of Shielmartin Hill, and *Notiophilus germinyi*. Note the metallic purple sheen of this species.

Patchy rotational burning and grazing could increase carabid diversity and ensure the continued regeneration of this habitat for *B. ruficollis* and other heathland typical beetle species. Vegetation management should aim for structural and age diversity, and to maintain some areas of mature heather with good growth of mosses. As with the other sites, returning the hydrology of the site back to its natural state, if any alterations have been made in the past, could be very beneficial for hygrophilous ground beetles and would increase diversity.

**Non-carabid species on Shielmartin**

*Atheta hypnorum*, the uncommon rove beetle found in abundance in bracken on East Mountain, was recorded on Shielmartin from B6 and B7. This further supports the case for leaving at least some of the bracken patches in place, for non-carabid species, and merely ensuring that they do not spread into the other important habitats. *Neuraphes angulatus* is a scarce rove beetle which usually lives in moss. Here it was found in bracken site B6. Along with the discovery of *Atheta hypnorum* in bracken sites at East Mountain, this highlights the potential for bracken, often considered poor habitat, to support unusual and uncommon beetles at Howth Head. It also demonstrates that a survey of one family of invertebrates may be insufficient for assessing the full conservation potential and habitat quality of a site. Two individuals of the localised rove beetle *Quedius nigriceps* were caught in heather-dominated heathland at H15. This species is normally found in sandy pinewoods.


Fig. 24. Pitfall trap locations on Shielmartin Hill. B = bracken, F = gorse-dominated heathland, H = heather-dominated heathland.

# SUMMARY OF FINDINGS

- Despite the degradation of Howth's heathland habitat through the loss of traditional heathland management practices, a community of heathland typical ground beetle species exists on Howth Head.
- An assemblage most closely associated with building or mature heath, with taller vegetation and formation of moss underneath the canopy, includes *Bradycellus ruficollis, Notiophilus germinyi, Bradycellus harpalinus*, and more common species such as *Abax parallelepipedus* and *Carabus problematicus.*
- Another group associated with younger pioneer or building heathland, with shorter, more open vegetation, includes *Notiophilus aquaticus, Olisthopus rotundatus,* and *Harpalus affinis*. The latter is restricted to coastal areas.
- *Harpalus latus, Bradycellus verbasci* and *Bradycellus sharpi* occupy the transitional habitats between heathland and grassland, or heathland and woodland.
- Due to the rarity of heathland habitat in Dublin, management measures should be put in place to sustain this habitat and its associated ground beetle communities. A rotational burning and cutting regime combined with grazing would be ideal to create a mosaic of young and mature heather and other habitat types associated with the heathland such as grassland, gorse and bracken stands.
- Heather beetle can cause significant damage to heathland. It is suggested to trial cutting and burning experiments to determine the most effective and efficient way to restore the heathland after it has been damaged by heather beetle. On a national or global level, reducing nitrogen emissions would be beneficial.
- *Paradromius linearis*, a tussocky grassland species with local distribution, occurs on East Mountain. Grassland can be managed for floral diversity and important plant species without impacting this ground beetle species, provided that mowing or grazing is rotational, ensuring that grass tussocks always remain and sward height varies.
- While few carabids of conservation interest were found in Howth's bracken sites, a number of significant uncommon beetles from other families occupy these spots (e.g. *Atheta hypnorum*). For that reason, eradication of bracken is not a desirable goal for the management plan. Heathland management should aim to prevent bracken from spreading and taking over heathland and grassland.
- There were very few hygrophilous species captured. This is some cause for concern. Howth Head should be returned to a state as close to its natural hydrology as possible, by reactivating any water courses which have been cut off in the past.
- A more targeted, less scientifically restricted search of interesting spot habitats which are less common on Howth than the habitat types studied in this survey is likely to add greatly to the species list.
- Structural heterogeneity of vegetation and a range of naturally occurring wet and dry habitats will provide the best home for Howth's ground beetles.

- The most important heathland typical ground beetle species found in this survey are *Bradycellus ruficollis*, *B. harpalinus*, *Carabus problematicus, Harpalus affinis, Notiophilus aquaticus*, and *N. germinyi. Cicindela campestris* is another important heathland typical ground beetle which was not found in this survey but which has been recorded by others in Howth. These species are indicative of the existence of good quality, diverse heathland habitat in Howth and their presence should be monitored in order to measure the success of Fingal County Council's heathland management. *Bradycellus verbasci* and *B. sharpi* are two important transitional heathland habitat species to watch in Howth.
- Over the coming years, there is potential for an increase in heathland stenotopic species in response to good management practices. This study provides the baseline data by which to measure the success of the management plan.

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# APPENDIX 1: NON-CARABID BEETLES OF HOWTH 2019

## Introduction

In 2019, Fingal County Council commissioned a survey of the ground beetle (Carabidae) species of Howth Head in County Dublin in order to gain an increased understanding of the relationship between ground beetles, habitat types and vegetation structure at this location. This information will inform the council's vegetation management plan for Howth's heather and gorse dominated heathland and associated habitats, such as grassland, bracken and woodland. Full details of the methodology, results and conclusion of the survey are available in a report titled Howth Ground Beetle Survey 2019 (Darcy, 2020). Darcy identified all of the carabid species, and all other beetle specimens were sent to Roy Anderson for identification (R. Anderson, personal communication, April 20, 2020). This short note summarises the results of this identification work and provides information on species of interest and their relationship with the habitat in which they were captured.

## Methodology

For the purpose of sampling carabid beetles, fifty-four pitfall traps were set on Howth Head for two 14 - 19 day periods between July and October. These were distributed across a range of habitat patches representative of the main habitat types on Howth Head: heather dominated heathland, gorse dominated heathland, bracken, grassland, woodland, and a patchy transitional habitat which comprised a mix of heathland, grassland and other vegetation (called 'heath other'). From these samples, a total of 1443 non-carabid beetles, both adults and larvae, were taken. Near each of the trap locations, one sweep net sample and one hand-searched sample of leaf litter, moss or debris was taken, but only carabids were collected from these. These samples were sent to Roy Anderson, along with 18 carabid samples (adults and larvae) which could not be identified by Nessa Darcy. Comments on the ecology, distribution and conservation significance of each species were provided by Roy Anderson unless otherwise referenced.

## Results

108 species of non-carabid beetle were identified. Six species of carabid were identified: *Amara aenea, Amara apricaria, Amara communis, Harpalus latus, Paradromius linearis* and *Trechus quadristriatus*. The three *Amara* species are new additions to the 2019 Howth carabid dataset (Darcy, 2020). Species of particular conservation interest in the context of Ireland are outlined below, with comments on their ecology and distribution.

## Non-Carabid Species of Interest

***Atheta hypnorum***

Family: *Staphylinidae*

This rove beetle species is normally local and rarely recorded but it is abundant on Howth Head, primarily in the bracken sites. It was sampled at B1, B2 and B4 on East Mountain, B6 and B7 at Shielmartin and W2 at Red Rock. It was most abundant at B1 which is an almost monoculture stand of bracken (100% bracken in the vegetation survey) on the steep side of a rocky outcrop. There is one small interesting spot a few metres from the pitfall trap location, however, which looks like a seepage or seasonally waterlogged patch with meadowsweet and rosebay willowherb. Site B1 was probably most recently burnt in 2015. Throughout the other sites where it was found, it appears to live in dense, tall bracken or other herbaceous plants, with some bramble and leaf litter.

***Leiodes calcarata***

Family: *Leiodidae*

This round fungus beetle is very variable in size (1.8 - 4 mm) and in colour. It is usually brown or reddish brown, but some are much darker than others (NatureSpot, 2020). It feeds on truffles (underground fungi). Single specimens if *L. calcarata* were found at two dense bracken sites B1 and B3, and 3 specimens in the transitional heathland site SH4, which primarily consists of grasses. All three sites are on East Mountain.

***Leptinus testaceus***

Family: *Leiodidae*

This 2 - 2.5 mm flat, blind, yellow beetle is an ectoparasite (eating secretions, nest refuse, mites and fleas) in the underground burrows of mice, shrews and other small mammals, as well as the nests of social Hymenoptera (wasps, ants and bees). It is occasionally found under rotten wood or stones (UK Beetles, 2020). It is widespread but very local in Ireland and Britain, although it may be under-recorded, given the nature of its lifestyle.

Two specimens were found in pitfall trap F11 in gorse dominated heathland on Ben of Howth, with some bramble, heather, leaf litter and open ground. This is similar to the habitat in which the ground beetle *Laemostenus terricola,* another inhabitant of small mammal burrows, was found at Bellingham's Farm.

***Micropeplus fulvus***

Family: *Staphylinidae*

This small rove beetle species has a localised distribution, in moss and similar substrates. One specimen was found at F4 on Bellingham's Farm, a recently burnt patch of tall gorse, with abundant herbs (60%), and some brambles, bracken and grasses. They can be found in decaying vegetation as well as damp wetland margins, feeding on plant material and mould, and adults disperse on summer evenings. (UK Beetles, 2020).

***Mycetoporus angularis***
Family: *Staphylinidae*

This rove beetle is a mountain summit species, but here a single specimen was found in bracken (B5), not far from sea level at Red Rock. It could be a blow-in from Shielmartin, an exposed hill which rises above Red Rock. The species is rare enough in Great Britain to be designated Nationally Scarce, although it may be under-recorded (Lane, 2019).

***Neuraphes angulatus***
Family: *Staphylinidae*

*N. angulatus* is scarce and usually lives in moss. One specimen was captured in site B6, an area of 80% bracken at Shielmartin. The rest of the area is bramble, leaf litter and debris, and open ground. This species is local and rare in Great Britain too (UK Beetles).

***Oxypoda brachyptera***
Family: *Staphylinidae*

This species has not been previously recorded by Roy Anderson and does not appear to occur in Northern Ireland. Nine specimens were found in pitfall trap G6 at Red Rock, which is in a dense, high-floristic grassland. 60% of the vegetation consists of herbaceous plants including legumes and plantains.

***Pirapion immune***
Family: *Brentidae*

One specimen of *P. immune*, a wood-eating straight-snouted weevil, was collected from F6 on Ben of Howth. This species is local and rare in Ireland, usually feeding on broom but also known to eat gorse (*Ulex* sp.). Adults mate in spring and lay their eggs in freshly developing stems, where the larvae live in chambers which cause swellings in the stems (UK Beetles).

***Quedius nigriceps***
Family: *Staphylinidae*

Two individuals of *Q. nigriceps* were caught in H15 on Shielmartin (heather dominated heathland) and SH1 on Red Rock (mixed transitional heathland, with a high percentage of graminoids). It is a very localised species, usually found in sandy pinewoods.

***Tasgius morsitans***
Family: *Staphylinidae*

Two specimens of *T. morsitans* were found in F8 (gorse dominated heathland which was cleared in 2019), and one in G9 (grassland with some heather, herbs and moss), both at Red Rock. It is a species of southern distribution. The most northerly extent of its Irish range is Dublin. It is a ground dwelling beetle, found in a range of habitats from woodland to well drained arable fields, and shelters under logs and stones (NatureSpot, 2020).

***Xantholinus elegans***
Family: *Staphylinidae*

One specimen of *X. elegans* was caught in the dense tussocky grassland of G1 on East Mountain. This is an unusual habitat for what is usually a seashore species.

## Additional Notes

The presence of some scarce and specialised beetle species in bracken sites around Howth head indicates that, although this habitat type does not seem to be of great conservation significance for ground beetles (Darcy, 2020), it does have conservation value. This highlights the benefit of surveying as many taxa as possible during the preparation of a management plan. In terms of a management approach for Howth head, these results demonstrate that an attempt to eradicate bracken from these sites could be detrimental to the beetle fauna. However, the other habitat types (heather and gorse dominated heathland, mixed heathland and grassland) have conservation importance both for carabids and some uncommon species of other beetle families. Therefore, attempts should be made to prevent bracken from further encroaching onto those sites. SEARS (the Scottish governmental organisation, Scotland's Environmental and Rural Services) have produced a detailed guide to managing or eradicating bracken called Bracken Control: A guide to best practice (SEARS, 2008).

The abundance of *Atheta hypnorum*, a species which is so uncommon elsewhere in Ireland, further supports Howth's reputation as a unique area of ecological significance.

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# APPENDIX 2: GROUND BEETLE DATA

The following tables contain the numbers of each carabid species collected from each pitfall trap, and GPS coordinates for each pitfall trap location.

| | Ap | As | Bb | Bh | Br | Bs | Bv | Cf | Cm | Cp | Ha | Hl | Hr | Lt | Nbr | Na | Nbi | Ng | Or | Pl | Pma | Pme | Pn | Ps | Pv | To/q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B1** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **B2** | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| **B3** | 1 | | | | | 3 | | | | 1 | | | 1 | | | | | | | | | | 1 | | | 2 |
| **B4** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **B5** | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **B6** | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **B7** | 5 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **B8** | 12 | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| **F1** | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **F2** | | | | | | | | | 2 | 5 | | | | | 1 | 1 | 1 | | | | | | | | | |
| **F3** | 8 | | | | | | | | | | | | | 1 | | | | | | | 14 | | | | | |
| **F4** | | | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | 1 |
| **F5** | 2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **F6** | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| **F7** | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| **F8** | | 1 | | | | | | | | | | | 1 | | | 1 | | | | | | | | | | |
| **F9** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **F10** | 8 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **F11** | 4 | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| **G1** | 2 | | | | | | | | | | | | | | | | | | | | | 1 | | | | |

| | Ap | As | Bb | Bh | Br | Bs | Bv | Cf | Cm | Cp | Ha | Hl | Hr | Lt | Nbr | Na | Nbi | Ng | Or | Pl | Pma | Pme | Pn | Ps | Pv | To/q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **G2** | 5 | | | | | | | | | | | | | | | | | | | 1 | | 6 | 1 | | | |
| **G3** | 2 | | 1 | | | | | | | | | | 1 | | | | | | | | 1 | 8 | | | | |
| **G4** | | 7 | | | | | | | | | | | | | | | | | | | | 4 | | | | |
| **G5** | | 3 | | | | | | | | | | | | | 1 | | | | | | | 28 | 2 | 1 | | |
| **G6** | 6 | | | | | | | | | | | | | | | | | | | | | 8 | 2 | 1 | | 2 |
| **G7** | 4 | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| **G8** | 1 | | | | | | | 4 | | | | | | | | | | | | | 7 | | 1 | | 1 | |
| **G9** | 1 | | | 1 | | | | | 3 | | | | | | | | | | | | | | | | | |
| **H1** | | | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| **H2** | | | | | | | | 5 | | 2 | | | | | 1 | | | | 4 | | | | | | | |
| **H3** | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | |
| **H4** | | | | | | | | | | 3 | 1 | | | | | | | | 1 | 1 | | | | | | 1 |
| **H5** | | | | | | | | | | | | | | | | 5 | | | 2 | | | | | | | 1 |
| **H6** | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| **H7** | 1 | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| **H8** | | | | | | | | | | 1 | | | | | | 1 | | | | | | | | | | 1 |
| **H9** | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| **H10** | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **H11** | | | | | | | | 8 | | | | | | | | | | | | | | | | | | |
| **H12** | 1 | | | | | | | 3 | | | | | | | 2 | | | | | | | | | | | |

| | Ap | As | Bb | Bh | Br | Bs | Bv | Cf | Cm | Cp | Ha | Hl | Hr | Lt | Nbr | Na | Nbi | Ng | Or | Pl | Pma | Pme | Pn | Ps | Pv | To/q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **H13** | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **H14** | 2 | | | 1 | 7 | | | | | 1 | | | | | | | | | | | | | | | | |
| **H15** | 18 | | | | 6 | | | | | | | | | | | | | | | | | | 1 | | | |
| **H16** | 1 | | | | 5 | | | | | | | | | | | | | | | | | | | | | |
| **H17** | 1 | | | | 2 | | | | | | | | | | | | | | | | | | | | | |
| **H18** | 1 | | | | 8 | | | | | | | | | | | | | | | | | | | | | |
| **SH1** | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| **SH2** | | | | | | | 1 | | | 1 | | 1 | 1 | | 1 | | | | | | | | | | | |
| **SH3** | | | | | | | | | | | | | | | | 2 | | | | | | | | | | |
| **SH4** | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| **W1** | | | | | | | | | | | | | | | | | | | | | | | 3 | | | |
| **W2** | | | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| **W3** | 1 | | 1 | | | | | | | | | | | | | | | | | | | | 1 | | | |
| **W4** | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |

**Appendix 1. Carabid data from pitfall traps and hand searching.**

*Ab = Abax paralellepipedus*
*As = Amara spp.*
*Bb = Badister bullatus*
*Bh = Bradycellus harpalinus*
*Br = Bradycellus ruficollis*
*Bs = Bradycellus sharpi*
*Bv = Bradycellus verbasci*
*Cf = Calathus fuscipes*
*Cm = Calathus melanocephalus*
*Cp = Carabus problematicus*
*Ha = Harpalus affinis*
*Hl = Harpalus latus*
*Hr = Harpalus rufipes*
*Lt = Laemostenus terricola*
*Nbr = Nebria brevicollis*
*Na = Notiophilus aquaticus*
*Nbi = Notiophilus biguttatus*
*Ng = Notiophilus germinyi*
*Or = Olisthopus rotundatus*
*Pl = Paradromius linearis*
*Pma = Pterostichus madidus*
*Pme = Pterostichus melanarius*
*Pn = Pterostichus niger*
*Ps = Pterostichus strenuus*
*Pv = Pterostichus vernalis*
*To/q = Trechus obtusus/quadristriatus*

| Trap Code | Site | Habitat Type | Latitude | Longitude |
|---|---|---|---|---|
| **B1** | East Mountain | Bracken | -6.04858249425887 | 53.3846194077651 |
| **B2** | East Mountain | Bracken | -6.04650914669036 | 53.382256470505 |
| **B3** | East Mountain | Bracken | -6.04845106601715 | 53.3749156502753 |
| **B4** | East Mountain | Bracken | -6.05415880680078 | 53.3698653017223 |
| **B5** | Red Rock | Bracken | -6.08387768268584 | 53.3684953954579 |
| **B6** | Shielmartin | Bracken | -6.07920753770143 | 53.3686987823372 |
| **B7** | Shielmartin | Bracken | -6.08370560221941 | 53.3747998858368 |
| **B8** | Shielmartin | Bracken | -6.08128021471769 | 53.3736656047901 |
| **F1** | East Mountain | Gorse dominated heathland | -6.04675590991972 | 53.3786086186233 |
| **F2** | Bellinghams Farm | Gorse dominated heathland | -6.08710764907867 | 53.3667483972883 |
| **F3** | Bellinghams Farm | Gorse dominated heathland | -6.08645788394482 | 53.366831084763 |
| **F4** | Bellinghams Farm | Gorse dominated heathland | -6.08655553311676 | 53.3659822075193 |
| **F5** | Shielmartin | Gorse dominated heathland | -6.08478301205308 | 53.3716363879418 |
| **F6** | Ben of Howth | Gorse dominated heathland | -6.07533928938776 | 53.3737706300368 |
| **F7** | Ben of Howth | Gorse dominated heathland | -6.07162836939662 | 53.3730213717123 |
| **F8** | Red Rock | Gorse dominated heathland | -6.09030056745381 | 53.3685211278995 |
| **F9** | Shielmartin | Gorse dominated heathland | -6.07869280502766 | 53.3689348586401 |
| **F10** | Shielmartin | Gorse dominated heathland | -6.0831720102635 | 53.3743558545163 |
| **F11** | Ben of Howth | Gorse dominated heathland | -6.06890500523715 | 53.3723261347538 |
| **G1** | East Mountain | Grassland | -6.04673638009098 | 53.3798113000145 |

| Trap Code | Site | Habitat Type | Latitude | Longitude |
|---|---|---|---|---|
| **G2** | East Mountain | Grassland | -6.04634553194045 | 53.3791318165756 |
| **G3** | Red Rock | Grassland | -6.09574913978575 | 53.3716864406698 |
| **G4** | Red Rock | Grassland | -6.09467625617979 | 53.3703934080264 |
| **G5** | Red Rock | Grassland | -6.09497129917143 | 53.3699613215373 |
| **G6** | Red Rock | Grassland | -6.09375894069669 | 53.3690075151053 |
| **G7** | Red Rock | Grassland | -6.09169900417326 | 53.3689435004861 |
| **G8** | Bellinghams Farm | Grassland | -6.08681126498253 | 53.3670846792435 |
| **G9** | Red Rock | Grassland | -6.08845889568328 | 53.368828273929 |
| **H1** | Ben of Howth | Heather dominated heath | -6.07254191302329 | 53.3736985875791 |
| **H2** | Ben of Howth | Heather dominated heath | -6.07430848293572 | 53.3745302400118 |
| **H3** | East Mountain | Heather dominated heath | -6.04630529880523 | 53.3826916319708 |
| **H4** | East Mountain | Heather dominated heath | -6.04824453592299 | 53.3771413900771 |
| **H5** | East Mountain | Heather dominated heath | -6.05093604885605 | 53.3786315052336 |
| **H6** | East Mountain | Heather dominated heath | -6.04785737582114 | 53.3763998235142 |
| **H7** | East Mountain | Heather dominated heath | -6.04989359155861 | 53.375072716785 |
| **H8** | East Mountain | Heather dominated heath | -6.05282843112943 | 53.371542416699 |
| **H9** | Ben of Howth | Heather dominated heath | -6.06756809168129 | 53.3724886598563 |
| **H10** | Ben of Howth | Heather dominated heath | -6.07199122198492 | 53.3721230831494 |
| **H11** | Ben of Howth | Heather dominated heath | -6.07370389625996 | 53.3728070464482 |
| **H12** | Bellinghams Farm | Heather dominated heath | -6.08619393781394 | 53.3661468700071 |

| Trap Code | Site | Habitat Type | Latitude | Longitude |
|---|---|---|---|---|
| **H13** | Shielmartin | Heather dominated heath | -6.08521367423803 | 53.3713778062289 |
| **H14** | Shielmartin | Heather dominated heath | -6.08278677799374 | 53.372066421484 |
| **H15** | Shielmartin | Heather dominated heath | -6.08233256266088 | 53.3726248238733 |
| **H16** | Shielmartin | Heather dominated heath | -6.08148816973537 | 53.3720949199548 |
| **H17** | Shielmartin | Heather dominated heath | -6.08368473128051 | 53.3737248648455 |
| **H18** | Shielmartin | Heather dominated heath | -6.08216903173 | 53.3739964804178 |
| **SH1** | Red Rock | Heath other | -6.08774006366729 | 53.3680408841143 |
| **SH2** | Red Rock | Heath other | -6.08810308389933 | 53.367220801351 |
| **SH3** | Red Rock | Heath other | -6.08966530301244 | 53.3677700674658 |
| **SH4** | East Mountain | Heath other | -6.0502105951309 | 53.3732642713912 |
| **W1** | Ben of Howth | Woodland | -6.07471257448194 | 53.3757237144792 |
| **W2** | Red Rock | Woodland | -6.09383940696715 | 53.37050863035 |
| **W3** | Red Rock | Woodland | -6.09345853328704 | 53.3699805254743 |
| **W4** | Ben of Howth | Woodland | -6.06485386379628 | 53.3723113826042 |

**Appendix 2. Sample site information including study site, habitat type, and coordinates for the location of each pitfall trap.**