Common Standards Monitoring of Nationally Important cave invertebrate assemblages in Ogof Draenen and Ogof Ffynnon Ddu, 2023 and 2024

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Cynhaliwyd arolygon o’r casgliadau o infertebratau mewn dwy system ogofâu fawr yng Nghymru, Ogof Ffynnon Ddu ac Ogof Draenen, i ddarparu data sylfaenol y gellir cymharu monitro cyflwr yn y dyfodol yn ei erbyn ac i dreialu’r dulliau sydd eu hangen ar gyfer arolygon o’r fath yn y safleoedd astudio ac mewn safleoedd ogofâu dynodedig posibl eraill ledled Cymru. Mae’r ddwy ogof wedi bod yn destun ymchwiliadau biolegol yn y gorffennol, yn bennaf i ffawna infertebratau ar y tir yn Ogof Ffynnon Ddu a’r ffawna infertebratau dyfrol yn Ogof Draenen, gan ganiatáu i ganlyniadau’r arolwg cyfredol gael eu gwerthuso’n feirniadol o’u cymharu â data hanesyddol.

Samplwyd y casgliadau o infertebratau dyfrol o gynefinoedd nant a merddwr o fewn yr ogofâu trwy gyfnod o rwydo a amserwyd, gyda phum safle nant a phedwar cynefin merddwr wedi’u dewis ym mhob ogof i ffurfio sail rhwydwaith monitro yn y dyfodol. Ymchwiliwyd i gasgliadau o infertebratau daearol ym mharth trothwy mynedfeydd yr ogofâu ac o fewn amgylchedd yr ogof ddofn (parth tywyll). Mae gan bob ogof dair mynedfa a archwiliwyd am eu ffawna, trwy chwilio’r ddaear â llaw. Ymhellach i mewn i'r ogof ddofn, dewiswyd pedwar safle daearol ar gyfer samplu infertebratau daearol gan ddefnyddio cyfuniad o dri dull, sef chwilio â llaw, gosod padiau sgwrio fel llochesau artiffisial, a gosod pydewau maglu ag abwyd. Cynhaliwyd arolygon yn y gwanwyn / ar ddechrau’r haf (mis Mai / mis Mehefin 2023) ac yn y gaeaf (mis Ionawr / mis Chwefror 2024 a 2025).

Cofnododd yr arolwg yn Ogof Ffynnon Ddu gyfanswm o 84 o dacsonau infertebratau gwahanol, gan gynnwys 32 o dacsonau dyfrol (29 mewn nentydd ac 16 mewn cynefinoedd merddwr), 19 o dacsonau daearol o fewn amgylchedd yr ogof ddofn, a 33 o dacsonau ychwanegol yn nhrothwyau’r tair mynedfa. Roedd y rhestrau’n cynnwys pedwar stygobiont, pump eustygophile, dau troglobiont, 16 eutroglophile a chwe subtroglophile (mae’r dynodiadau hyn yn ymwneud â chysylltiad rhywogaethau â’r amgylchedd tanddaearol; gweler adran 1.2 o’r adroddiad am ddiffiniadau llawn). O'r tacsonau a gofnodwyd, roedd 30 wedi’u cofnodi yn yr ogof yn flaenorol, ac roedd 54 o gofnodion newydd wedi’u ychwanegu, yn bennaf o fewn y bïom dyfrol. Roedd y cramenogion stygobiontig *Niphargus fontanus, Microniphargus leruthi*, *Proasellus cavticus* ac *Antrobathynella stammeri* yn bresennol yn y ddwy ogof. Cofnodwyd y rhywogaeth olaf am y tro cyntaf yn Ogof Ffynnon Ddu, ac felly dyma’r trydydd lleoliad yn unig yng Nghymru lle gwyddys ei bod yn bresennol. Mae presenoldeb y deudroediad stygobiontig *Crangonyx subterraneus*, a gofnodwyd yn flaenorol yn Ogof Ffynnon Ddu ond nad yw wedi’i gasglu ers 1951 er gwaethaf ymdrechion lluosog, yn cael ei gwestiynu ac efallai ei fod yn gamadnabyddiaeth bosibl o *Microniphargus*, sef genws nad oedd yn hysbys ei fod yn bresennol ym Mhrydain ar y pryd, er na ellir diystyru’r hen gofnod hwn yn llwyr. Mae cyfanswm y tacsonau infertebratau sy’n bresennol yn Ogof Ffynnon Ddu bellach yn 123 o rywogaethau, gan gynnwys pum stygobiont (gan gynnwys *C. subterraneus*), deg eustygophile, pedwar troglobiont, 26 eutroglophile a saith subtroglophile.

Cofnododd yr arolwg yn Ogof Draenen gyfanswm o 84 o dacsonau infertebratau gwahanol, gan gynnwys 36 o dacsonau dyfrol (35 mewn nentydd a 15 mewn cynefinoedd merddwr), 20 o dacsonau daearol o fewn amgylchedd yr ogof ddofn, a 28 o dacsonau ychwanegol yn nhrothwyau'r tair mynedfa. Roedd y rhestrau'n cynnwys pum stygobiont, pum eustygophile, pedwar troglobiont, naw eutroglophile a saith subtroglophile. O'r tacsonau a gofnodwyd, roedd 34 wedi'u cofnodi yn yr ogof yn flaenorol, ac roedd 48 o gofnodion newydd wedi'u ychwanegu, yn bennaf o fewn y bïom daearol. Cofnodwyd trydedd rywogaeth deudroediad stygobiontig, *Niphargus aquilex*, o darddell i'r system mewn arolwg cynharach, ond ni chafodd ei chofnodi erioed yn yr ogof ei hun, felly gallai fod yn bresennol o fewn y ddyfrhaen garstig ehangach. Casglwyd un sbesimen o'r ostracod stygobiontig *Fabaeformiscandona wegelini* o S5 yn Ogof Draenen, sef yr ail leoliad y mae'n bresennol ynddo ym Mhrydain, a'r cyntaf yng Nghymru. Cofnodwyd ail ostracod stygobiontig, *F. breuili*, yn ystod arolwg blaenorol. Cofnodwyd y pry cop troglobiontig prin *Porrhomma rosenhaueri* yn Siambr y Garn, ac felly dyma'r trydydd safle yn unig lle mae'r rhywogaeth yn bresennol ym Mhrydain, ac mae pob un ohonynt yn ne Cymru. Mae'n bosibl bod dau sbesimen sy'n perthyn i'r genws *Cryptopygus* yn nosbarth Collembola, a gasglwyd yn T2 yng nghyfres rhaeadrau Ogof Draenen, yn rhywogaeth nas gwyddid amdani'n flaenorol, sydd angen ymchwiliad pellach.

Mae cyfanswm y tacsonau infertebratau a ddogfennwyd yn Ogof Draenen bellach yn 124 o rywogaethau, gan gynnwys chwe stygobiont (saith yn cynnwys *N. aquilex*), 11 eustygophile, pum troglobiont, deg eutroglophile a saith subtroglophile. Mae nifer y stygobiontau, y mwyaf amrywiol ar gyfer unrhyw ogof ym Mhrydain, a phresenoldeb y pry cop *Porrhomma rosenhaueri*, yn golygu bod Ogof Draenen, sydd heb unrhyw amddiffyniad deddfwriaethol ar hyn o bryd, yn ymgeisydd amlwg i'w ddynodi ar sail ei ffawna infertebratau ogofâu.

Mae ffawna infertebratau daearol Ogof Ffynnon Ddu yn sylweddol fwy amrywiol na ffawna Ogof Draenen, o bosibl oherwydd ei hanes hirach o gofnodi biolegol o'i chymharu ag Ogof Draenen, a ddarganfuwyd mor ddiweddar â dechrau'r 1990au. Mae rhywogaethau Collembola yn benodol yn llawer mwy amrywiol a niferus yn Ogof Ffynnon Ddu. Mae *Campodea cf. wallacei*, yn urdd Diplura, yn elfen amlwg o ffawna daearol parth tywyll Ogof Draenen a geir mewn niferoedd sylweddol ym mhob un o'r safleoedd daearol.

Ymddengys fod gwahaniaethau tymhorol yn fach iawn rhwng arolygon y gaeaf ac arolygon yr haf yn y ddwy ogof, ar wahân i ychydig o safleoedd allweddol yn Ogof Ffynnon Ddu lle roedd llifoedd dŵr uchel yn y brif ddyfrffos yn gwneud mynediad i leoliadau samplu yn hynod beryglus yn y gaeaf ac efallai fod wedi arwain at fflysio infertebratau o rai safleoedd nentydd. Roedd effeithiau tymhorol yn fwy amlwg yn yr arolygon o'r trothwyau, gan fod y gymuned barwydol yn cynnwys nifer o rywogaethau subtroglophilig allweddol sy'n defnyddio'r trothwy ar gyfer naill ai gaeafgysgu neu saib yn eu datblygiad yn ystod yr haf.

Daeth cymhariaeth o effeithiolrwydd gwahanol ddulliau samplu a ddefnyddiwyd yn yr arolwg i'r casgliad, er bod rhwydo cynefinoedd dyfrol yn hynod effeithiol, bod y dulliau daearol wedi dangos graddau amrywiol o lwyddiant. Y dull mwyaf effeithlon oedd pydewau maglu ag abwyd. Arweiniodd chwilio â llaw yn yr ogof ddofn at ganfod ychydig iawn o sbesimenau, ond o'r rhai a gasglwyd roedd rhai yn gofnodion allweddol, gan gynnwys *Porrhomma rosenhaueri* yn Ogof Draenen. Roedd gosod padiau sgwrio fel lloches artiffisial wedi arwain at hyd yn oed lai o ganlyniadau ac, oherwydd yr amser sylweddol a gymerwyd i'w gosod, eu hadfer a'u prosesu, argymhellwyd na ddylid eu defnyddio ar gyfer monitro yn y dyfodol; felly, y ffordd orau o samplu'r casgliadau o infertebratau daearol yn yr ogof ddofn yw defnyddio cyfuniad o faglau pydew ag abwyd a chwilio'r ardal ehangach â llaw.

Mae canlyniadau'r arolwg sylfaenol hwn, ynghyd ag archwiliad o'r data hanesyddol ar gyfer y ddwy ogof, wedi galluogi llunio set o rywogaethau a chymunedau infertebratau targed y gellir asesu monitro cyflwr yn eu herbyn yn y dyfodol. Mae amcan cadwraeth wedi'i ddatblygu ar gyfer Ogof Ffynnon Ddu ac Ogof Draenen i asesu a yw ffawna infertebratau'r ogof mewn cyflwr ffafriol. Mae hyn yn gosod trothwyau terfyn is ar gyfer ffawna sy'n gysylltiedig â chynefinoedd nant uwch-lefel-trwythiad, merddwr, ogof ddofn ddaearol a throthwy daearol. Mae'n debygol y bydd angen addasu'r amcanion cadwraeth o ystyried rhywogaethau newydd sy'n cael eu cofnodi ac wrth i brofiad gael ei ennill o fonitro'r ffawna. Ar sail yr amcanion cadwraeth presennol, **ystyrir bod casgliadau o infertebratau ogofâu mewn cyflwr ffafriol ar hyn o bryd yn Ogof Ffynnon Ddu ac Ogof Draenen**.

Mae'n ymddangos bod y protocolau a chyfyngiadau presennol ar gyfer mynediad i'r ogofâu a'r ymdrechion cadwraeth ynddynt, dan nawdd eu cyrff rheoli priodol (Clwb Ogofâu De Cymru ar gyfer Ogof Ffynnon Ddu a Grŵp Rheoli Ogofâu Pwll Du ar gyfer Ogof Draenen), yn llwyddiannus wrth gynnal cynefinoedd addas ar gyfer eu casgliadau o infertebratau ogofâu ac felly dylid eu cadw.

Executive summary

Surveys of the invertebrate assemblages in two large Welsh cave systems, Ogof Fynnon Ddu (OFD) and Ogof Draenen, were carried out to provide base-line data against which future condition monitoring can be compared and to trial the methods required for such surveys at both the study sites and other potential designated cave sites across Wales. Both caves have been the subject of biological investigations in the past, primarily of the terrestrial invertebrate fauna in OFD and the aquatic invertebrate fauna in Ogof Draenen, allowing the results of the current survey to be critically evaluated against historical data.

The aquatic invertebrate assemblages of both stream and lentic habitats within the caves were sampled by a timed period of netting, with five stream sites and four lentic habitats selected in each cave to form the basis of a future monitoring network. Terrestrial invertebrate assemblages were investigated in both the threshold zone of the cave entrances and within the deep cave (dark zone) environment. Each cave has three entrances that were investigated for their fauna, using manual ground searching. Further into the deep cave four terrestrial sites were selected for terrestrial invertebrate sampling involving a combination of three methods, manual searching, the placement of scouring pads as artificial refugia, and baited pitfall trapping. Surveys were carried out in spring / early summer (May / June 2023) and winter (January / February 2024 and 2025).

The survey in OFD recorded a total of 84 distinct invertebrate taxa, including 32 aquatic taxa (29 in streams and 16 in lentic habitats), 19 terrestrial taxa within the deep cave environment and an additional 33 taxa in the thresholds of the three entrances. The lists included 4 stygobionts, 5 eustygophiles, 2 troglobionts, 16 eutroglophiles and 6 subtroglophiles (these designations relate to the affiliation of species with the subterranean environment; see Section 1.2 of the report for full definitions). Of the taxa recorded, 30 had previously been recorded from the cave, adding 54 new records, mostly within the aquatic biome. The stygobiontic Crustacea *Niphargus fontanus, Microniphargus leruthi*, *Proasellus cavticus* and *Antrobathynella stammeri* were present in both caves. The last species was recorded for the first time in OFD, at only its third known location in Wales. The presence of the stygobiontic amphipod *Crangonyx subterraneus*, previously recorded in OFD but not collected since 1951 despite repeated attempts, is called into question as a possible misidentification of *Microniphargus*, which was not known to occur in Britain at that time, although this old record cannot be discounted entirely. The total number of invertebrate taxa known from OFD now stands at 123 species, including 5 stygobionts (including *C. subterraneus*), 10 eustygophiles, 4 troglobionts, 26 eutroglophiles and 7 subtroglophiles.

The survey in Ogof Draenen recorded a total of 84 distinct invertebrate taxa, including 36 aquatic taxa (35 in streams and 15 in lentic habitats), 20 terrestrial taxa within the deep cave environment and an additional 28 taxa in the thresholds of the three entrances. The lists included 5 stygobionts, 5 eustygophiles, 4 troglobionts, 9 eutroglophiles and 7 subtroglophiles. Of the taxa recorded, 34 had previously been recorded from the cave, adding 48 new records, mostly within the terrestrial biome. A third stygobiontic amphipod species *Niphargus aquilex* was recorded from a resurgence for the system in an earlier survey, but has never been recorded in the cave itself, thus might be present within the wider karstic aquifer. A single specimen of the stygobiontic ostracod *Fabaeformiscandona*

wegelini was collected from S5 in Ogof Draenen, its second location in Britain and the first for Wales. A second stygobiontic ostracod *F. breuili*,was recorded during a previous survey. The rare troglobiontic spider *Porrhomma rosenhaueri* was recorded in Cairn Chamber, making this just the third site for the species in Britain, all in south Wales. Two specimens belonging to the Collembola genus *Cryptopygus*, collected at T2 in the Waterfall Series of Ogof Draenen might be a previously unknown species, requiring further investigation.

The total number of invertebrate taxa documented from the Ogof Draenen now stands at 124 species, including 6 stygobionts (7 if one includes *N. aquilex*), 11 eustygophiles, 5 troglobionts, 10 eutroglophiles and 7 subtroglophiles. The number of stygobionts, the most diverse for any British cave, and the presence of the spider *Porrhomma rosenhaueri* make Ogof Draenen, which currently lacks any legislative protection, a prime candidate for designation on the basis of its cave invertebrate fauna.

The terrestrial invertebrate fauna of OFD is considerably more diverse than that of Ogof Draenen, possibly due to its longer history of biological recording compared to Ogof Draenen, which was discovered as recently as the early 1990s. The Collembola in particular are significantly more diverse and abundant in OFD. The dipluran *Campodea cf. wallacei* is a prominent element of the dark zone terrestrial fauna in Draenen being found in significant numbers at all of the terrestrial sites.

Seasonal differences appeared to be minimal between the winter and summer surveys within both caves, aside from a few key sites in OFD where high flows in the main conduit made access to sampling locations extremely hazardous in the winter and might have resulted in the flushing out of invertebrates at some stream sites. Seasonal effects were more pronounced in the threshold surveys, since the parietal community includes a number of key subtroglophilic species that utilise the threshold for either winter hibernation or summer diapause.

A comparison of the efficacy of different sampling methods employed in the survey concluded that whilst netting of aquatic habitats was highly effective, the terrestrial methods displayed varying degrees of success. The most efficient method was the baited pitfall trapping. Manual searching in the deep cave resulted in very few specimens, but of those collected some were key records, including that of *Porrhomma rosenhaueri* in Ogof Draenen. The placement of scouring pads as artificial refugia yielded even less results and due to the considerable time in placing, retrieving and processing these, it was recommended that they are not used in future monitoring; thus, the terrestrial invertebrate assemblages of the deep cave are best sampled using a combination of baited pitfall traps and manual searching of the wider area.

The results of this baseline survey, coupled with an examination of the historical data for both caves, has enabled the compilation of a set of target invertebrate species and communities against which future condition monitoring can be assessed. A Conservation Objective has been developed for both OFD and Ogof Draenen to assess if the cave invertebrate faunas are in favourable condition. This sets lower limit thresholds for faunas associated with vadose stream, lentic, terrestrial deep cave and terrestrial threshold habitats. The Conservation Objectives are likely to require adjusting in the light of new species being recorded and as experience is gained in monitoring the fauna. On the basis of the current Conservation Objectives, **cave invertebrate assemblages are considered to be currently in favourable condition in both Ogof Ffynnon Ddu and Ogof Draenen**.

The current protocols and restrictions for accessing the caves and the conservation efforts within them, under the auspices of their respective management bodies (the South Wales Caving Club [SWCC] for OFD and Pwll Du Cave Management Group [PDCMG] for Ogof Draenen), appear to be successful in maintaining suitable habitats for their cave invertebrate assemblages and should therefore be retained.

1. Introduction

1.1 Background

Across Britain there are a number of cave systems that are either designated as Sites of Special Scientific Interest (SSSIs) in their own right or lie beneath designated areas. In Scotland, these include the Traligill caves and those in the Allt Nan Uamh valley in the northwest at Assynt. Across England, approximately 30 SSSIs are cave systems or include caves (or mines) within the designated area. However, almost all of these designations are based on geological features, including cave sediments, mineral deposits and passage morphology; their rich palaeontological deposits; or a combination of the two. Although many of Britain's caves provide valuable habitats for a range of subterranean fauna, their ecology has commonly been overlooked, or has played only a minor role, in their designation as SSSIs, mostly being limited to their importance as roost sites for rare bat species. Invertebrates within the caves are rarely mentioned by Natural England, with SSSI citations for just two sites - the Buckfastleigh Caves and Pridhamsleigh Cavern mentioning the endemic stygobiontic shrimp *Niphargus glenniei* (Spooner, 1952), which occurs within them, though both sites were also designated for geological features and in the case of the Buckfastleigh Caves for their bat roosts and palaeontology (Knight, 2017). One of the recent outstanding exceptions is Pen Park Hole near Bristol which is one of the first sites to be designated for both its outstanding geological features resulting from its formation by rising hydrothermal groundwaters and, following a commissioned invertebrate survey, its community of cave invertebrates (Knight, 2014, 2017).

The situation is somewhat better in Wales, where invertebrates are notified features of Ogof Ffynnon Ddu-Pant Mawr SSSI (cave invertebrate assemblage), Mynyddoedd Llangynidr a Llangatwg, Cefn yr Ystrad a Comin Merthyr SSSI (cave invertebrate assemblage) and Garth Wood SSSI (the troglobiontic money spider *Porrhomma rosenhaueri*) and qualifying features of Ogof Ffynnon Ddu SSSI (cave invertebrate assemblage) and Nant Glais Caves SSSI (*Porrhomma rosenhaueri*). The most famous is the Ogof Ffynnon Ddu (OFD) National Nature Reserve (NNR), which is incorporated within Ogof Ffynnon Ddu SSSI and Ogof Ffynnon Ddu-Pant Mawr SSSI in Powys (which also include part of the nearby Dan yr Ogof system). The geological and geomorphological interest of the two SSSIs is centred on the cave and the fact that within Ogof Ffynnon-Ddu-Pant Mawr SSSI the undulating upland plateau above the system supports the finest limestone pavement in mid and southern Wales. Here, the biological interest is due primarily to the list of scarce plant species on the plateau, but the citation also states: "…*the biological interest of the cave system itself has been extensively explored. A number of rare crustacean species restricted to subterranean habitats are of particular note. Part of the water catchment of the cave system is included in the SSSI in order to safeguard the invertebrate fauna and the active geomorphological processes requiring water*" (Knight, 2017). However, the citation provides no further detail on the fauna of the cave system, which is especially of note for its diverse Collembola assemblage (Jefferson & Chapman, 1979; Jefferson *et al*., 2004), nor the actual crustacean species, which include *Niphargus fontanus* Bate, 1859, *Microniphargus leruthi* Schellenberg, 1934, *Proasellus cavaticus* (Leydig, 1871), and *Crangonyx subterraneus* Bate, 1859, the latter known from just two other caves in Britain, both in the Cheddar Gorge (Knight, 2015) of the Mendip Hills. It should be noted that *C. subterraneus* has not been recorded in OFD since 1951, despite repeated searches, and it is possible that the original record was in error and a misidentification of *Microniphargus*.

Garth Wood SSSI near Cardiff includes Lesser Garth Cave, one of just two sites (the other being Ogof y Ci) in which Britain's only troglobiontic spider *Porrhomma rosenhaueri* (L. Koch, 1872) occurs. The designation is based primarily on the biological interest of the site's semi-natural broad-leaved woodland; in particular its stands of beech (*Fagus sylvatica*), growing near the western limit of its natural range. However, the citation further states that the site is also of special interest for the nationally rare *P. rosenhaueri* within Lesser Garth Cave (Knight, 2017). Although Natural Resources Wales (NRW) has instigated a programme of monitoring for *P. rosenhaueri* in Lesser Garth (Carter, 2010a; Carter *et al.*, 2010) and Ogof y Ci (Carter, 2018), the Garth citation fails to mention the other elements of the cave's fauna, which is quite diverse for such a small system, including populations of *N. fontanus* and *P. cavaticus*.

The recently notified Mynyddoedd Llangynidr a Llangatwg, Cefn yr Ystrad a Comin Merthyr SSSI encompasses and extends two previous SSSIs and includes Usk Bat Sites SAC. Among its numerous geological, habitat and species features are caves, hibernating bats and a nationally important cave invertebrate assemblage. This comprises 23 species including the springtail *Disparrhopalites patrizii* at its only Welsh locality, the hoglouse *Proasellus cavaticus,* the groundwater amphipods *Microniphargus leruthi* and *Niphargus fontanus* and the syncarid *Antrobathynella stammeri.* Key cave systems include Agen Allwedd and Ogof Daren Cilau, as well as various other smaller caves. Water from the two large systems drains into the Clydach Gorge via a subterranean conduit, and there are several other caves, notably Craig a Ffynnon, within the limestone cliffs and slopes.

Other designated Welsh sites that also contain caves include reaches of the Gower Coast designated as SSSI, which contain various coastal limestone caves above the tidal limit; the geologically diverse Otter Hole, one of the best decorated caves in Britain, which lies on the banks of the lower, tidal River Wye and thus is within the River Wye SSSI and Wye Valley Woodlands SSSI and Special Area of Conservation (SAC); and Clydach Gorge (Cwm Clydach SSSI), which is designated primarily for to its ancient semi-natural beech woodlands. The second longest cave system in Britain, Ogof Draenen, partially underlies the Gilwern Hill and Blorenge SSSIs near Abergavenny and although the cave Siambre Ddu, a large chamber directly above Ogof Draenen, to which it is connected beneath a boulder collapse too small for humans, but which allows the transit of bat species, is designated a SSSI on account of its importance as a roosting site for several bat species, Ogof Draenen itself has no formal conservation designation. There are numerous other designated sites across Wales that also include caves and mines within their boundaries.

Although there are the few examples quoted above where mention is made of cave invertebrates, in most cases they have received little more than a footnote in the SSSI designations. Many surface SSSIs across Britain have been notified on the basis of their rare or unusual communities of invertebrates, either in combination with other features or as the sole designated feature. This state of affairs is undoubtedly due to a general lack of information and systematic recording of subterranean invertebrates, which is not surprising given their cryptic habitats and the extreme difficulties in being able to directly study such species *in situ*. The subterranean fauna lives within the fissure network of karstic (e.g. limestone, dolomite, chalk) and fractured (e.g. sandstone, granite) rock strata, or within unconsolidated sediments, such as the gravel beds beneath riverbeds and floodplains, and thus in most cases it is not directly accessible to humans. Sampling is thus often restricted to 'sampling windows' into the environment, in the form of wells, boreholes and springs for aquatic species or excavating and placing baited traps, or other specialised techniques, to investigate terrestrial habitats such as the Mesovoid Shallow Substratum (MSS, also known as the Milieu Souterrain Superficiel). Culver and Pipan (2014, 2019) provide excellent summaries of the different types of subterranean habitats and their invertebrate communities. The exception to this is the opportunity provided by caves (or their artificial analogue mines), into which subterranean fauna migrates, either actively or passively (i.e. dropping into cave passages from fissures in the roof or being washed into systems by groundwater flow), which allow humans to directly study subterranean fauna. It is thus no surprise that much of our knowledge of subterranean biodiversity is based on studies in caves and a traditionally speleo-centric bias to the subject. However, this is increasingly regarded as rather limited in most modern research, with greater awareness of the diverse range of subterranean habitats and communities that exist outside of caves, following the adaptation of novel methods and techniques for their research.

Although there is a long history of biological recording in caves of the British Isles, systematic surveys of the invertebrate fauna of British caves are lacking, due to the general perceived scarcity of the fauna, resulting from localised extirpations during the repeated glacial cycles of the Pleistocene, and a lack of experienced cave biologists (biospeleologists). From 1938 to 1972 cavers, under the auspices of the Cave Research Group of Great Britain (CRG), collected specimens of invertebrates on an *ad hoc* basis which were then sent to various experts for determination. These paper records have recently been digitised by the biological recorder of the British Cave Research Association (Graham Proudlove) to form the *Hazelton* database, hosted on the BCRA website (Proudlove & Burn, 2020). This database forms a valuable set of historical information, but the records are now quite old and are almost entirely based on *ad hoc* collecting during caving trips. Some systematic surveys of British caves have been carried out but are either limited to just the aquatic fauna e.g. Gunn *et al*. (2000) and Wood & Gunn (2000) in the Peak-Speedwell system of Derbyshire; Knight (2011), Swildon's Hole, Mendips; Knight *et al.* (2018), Ogof Draenen; and Edington (1977) Dan-yr-Ogof, or, with the exception of Pen Park Hole (Knight, 2014, 2017) require updating, such as the work in OFD by Jefferson and Chapman (1979; Jefferson *et al.*, 2004) and Otter Hole (Chapman, 1979). Some information can be gathered from analysis of the *Hazelton* data, but overall, the invertebrate assemblages of many British cave systems remain either unknown or poorly studied at best. This situation is not unique to Britain and was the theme of the 6th Eurospeleo Protection Symposium held on the island of Vilm, Germany in October 2021, which aimed to assess current cave monitoring practices across Europe and provide recommendations for improvements in monitoring the EU habitat type (designated under the EU Habitats Directive) 8310 "Caves not open to the public" (Weigand *et al*., 2022).

To address this knowledge gap, Natural Resources Wales (NRW) has initiated a project to develop methods and undertake baseline surveys of cave invertebrate assemblages at two key sites, Ogof Ffynnon Ddu (OFD) in the Swansea Valley and Ogof Draenen, near Abergavenny. This project will provide both baseline data for future condition monitoring of the two sites and an assessment of various sampling methods and their practicalities for assessing the invertebrate assemblages of other sites across the principality. This will be the first such initiative in the British Isles and could signal a new approach to the study of the subterranean biome within the UK.

1.2 The classification of subterranean invertebrate species and the British fauna

Globally, the subterranean invertebrate fauna consists of a variety of species across many phyla. The species found underground include a mixture of obligatory subterranean species as well as far more species that do not spend their entire life cycle there, being either transient visitors or accidentals. Historically, the study of subterranean fauna has been littered with a plethora of confusing terminology used to describe the ecological affiliations of invertebrate species. Although it has been the subject of much justified criticism, the Schiner-Racovitza (Racoviţă) classification is still widely accepted, although increasingly being considered by many to be redundant. This classification has not always been stable, and there has not been a consensus as to the definition of the various terms. Several recent reviews on the topic have been published (e.g. Sket, 2008; Trajano, 2012; Trajano & de Carvalho, 2017) and it is the definitions of Sket (2008) that are used in this report. Sket's definitions are as follows, with alternatives that will be found in the literature placed in parentheses:

Troglobiont: Strongly bound to subterranean habitats (troglobite, stygobite). British examples: amphipods in the genus *Niphargus*, a few species of Collembola (springtails), the spider *Porrhomma rosenhaueri*.

Eutroglophile: Essentially surface species able to maintain permanent subterranean populations (troglophile, stygophile). British examples: many species of Collembola and mites, the amphipod *Gammarus pulex*.

Subtroglophile: Species inclined to perpetually or temporarily inhabit subterranean habitats but intimately associated with surface habitats for some biological function (daily e.g. feeding, seasonally, or during their life history e.g. reproduction) (habitual trogloxene). British examples: the mosquito *Culex pipiens*, tissue and herald moths, some bats.

Trogloxene: Species occurring sporadically in subterranean habitats but unable to establish permanent subterranean populations (accidental trogloxene, accidental); includes many species across a variety of animal groups.

Originally the terms using the stem "trog-" referred to all animals found in caves and other subterranean sites, and this is followed in Sket's usage above. More recently, the stem "stygo-" has been used to differentiate aquatic from terrestrial animals with "stygo-" for aquatic and “trog-“ for terrestrial. This convention is not always followed and in general the “trog-” terms are still applicable to all animals, although both are widely used in the literature. Animals living in caves are also described in the literature as “cavernicolous” or “cavernicoles”.

Compared with the subterranean fauna of mainland Europe and other parts of the world, the British fauna has relatively few troglobionts (approx. 4 species) and stygobionts (approx. 14 species). It is generally accepted that the British and Irish subterranean fauna, as well as that of most of northwest Europe, is impoverished as a result of the Pleistocene glaciations and that the present-day subterranean biota of Britain and Ireland is largely the result of post-glacial colonisation from un-glaciated areas in the south (Robertson *et al.,* 2009, Proudlove *et al.,* 2003), although there is a small group of pre-glacial relict species that survived in sub-glacial refugia (Proudlove *et al*., 2003; McInerney *et al*., 2014). The British cave fauna is thus dominated by troglophiles, stygophiles and accidentals (trogloxenes and stygoxenes), with many records on *Hazelton* from the threshold zone or the shallow part of the dark zone.

Chapman (1993) and Moseley (2016) raise interesting objections to the Schiner-Racovitza system arguing that it focusses attention on the non-adaptive or regressive features of certain ancient cavernicoles rather than the adaptive features that allow all subterranean invertebrates to survive underground. This leads to the definition of morphologically defined troglobionts as being the ‘true’ inhabitants of subterranean habitats and the dismissal of the British and Irish cave fauna as being of relatively little interest. In fact, the subterranean fauna of the British Isles is in a dynamic phase of colonisation and adaptation brought about by the Pleistocene extinctions and thus provides rich grounds for research into the processes of cavernicolous evolution. With the exception of the relatively few troglobiontic species, by far the majority of the taxa recorded in subterranean habitats in the British Isles is similar to that in adjacent surface biomes. This suggests that most of the British and Irish subterranean fauna are epigean, post-glacial colonists that are still in the process of actively invading available niches underground, either for the resources they contain (e.g. flood debris and leaf litter in the threshold), the relatively stable environmental conditions, or as part of their life cycle.

The stygobionts consist of species in several Crustacea groups, including the Ostracoda, Copepoda, Syncarida, Isopoda and Amphipoda, many of which are recorded more commonly from groundwaters, saturated gravels in springs, or the hyporheic, rather than from caves. Two oligochaete species *Trichodrilus cantabrigiensis* (Beddard, 1908) and *T. allobrogum* Claparede, 1862 are only known in Britain from single well sites each and thus their designation as stygobiontic is based on very limited data. The diving beetle *Hydroporus ferrugineus* Stephens, 1829 is associated with springs, where it is usually recorded after heavy rainfall; the larval stage is believed to be obligatory subterranean and it is thought that the adult might be too, being washed out of the habitat during high groundwater flows. However, this is based on limited knowledge of its life cycle, so it is probably best regarded as a stygophilic species.

The troglobionts are limited to the spider *Porrhomma rosenhaueri* and three species of Collembola, *Oligaphorura schoetti* (Lie Pettersen, 1897), *Disparrhopalites patrizii*

(Cassagnau & Delamare, 1953) and *Pseudosinella dobati* Gisin, 1966. The status of *Pseudosinella dobati* in Britain is in considerable doubt and most specimens recorded as such in the past are believed to in fact be *Pseudosinella immaculata* (Lie Pettersen, 1896) (Hopkin, 2007). A fourth collembolan, *Folsomia agrelli* Gisin, 1944, is also only known from subterranean sites and thus likely to be troglobiontic, although again the status of this species in Britain is in doubt and British specimens might represent a previously unknown cryptic species. A fifth springtail species, *Hymenaphorura nova* Pomorski, 1990, is a new species described from the hyporheos. There is also a group of eight terrestrial mites, notably *Poecilophysis spelaea* (Wankel, 1891), that might also be troglobiontic in Britain, although this is based on limited data; and there is considerable doubt over the taxonomic validity of four of them.

The ecological status of the species in this report are those stated in Knight *et al*. (in prep.), in which species have been allocated to one of the aforementioned ecological groupings based on current knowledge and expert judgement. For example, if all records for a species are from subterranean habitats and it exhibits morphological and physiological adaptations to subterranean life it is considered to be a troglobiont. If it is known to establish viable subterranean populations and/or occurs regularly in subterranean habitats over a wide geographical range then it is considered a eutroglophile.

1.3 Invertebrate communities of British caves

Chapman (1993) describes several potential communities of invertebrates within British caves including: the "wall association" or parietal community of the cave threshold; the terrestrial mud bank community; freshwater stream communities; pool-surface associations; and "batellites" invertebrate communities associated with bat roosts. To this list can be added the invertebrate communities of static water bodies, ranging from small cave pools to sometimes quite substantial subterranean lakes, and invertebrates associated with films of percolating water, the hygropetric community.

The parietal community is predominately made up of various species of subtroglophiles and trogloxenes that utilise the threshold for shelter as part of their life cycle, either for winter hibernation or summer diapause, as well as several eutroglophilic species of spider that prey upon them. Soil, vegetable debris and dead wood also accumulates within the threshold zone of caves and Moseley (2016) identified a distinct community of threshold "soil litter" fauna, often overlooked by biospeleologists, consisting of a suite of species amongst the accumulated debris in cave thresholds, similar to that of the adjacent surface environment. This led Moselely (2016) to consider the threshold community to consist of both the "true" parietal fauna and a "derived" parietal fauna, consisting of leaf litter species that might move on to the walls of the cave to graze on the moist films of algae and cyanobacteria in the shallow threshold. Most of these threshold species do not penetrate further into caves, although various eutroglophilic millipedes and the aforementioned spiders might occur within the deep threshold and even the shallow parts of the dark zone of caves.

Sinking streams and percolating water transport substantial amounts of silt and debris into caves which can accumulate as organic-rich mud and provide a rich habitat for invertebrates in some caves. Fungi and bacteria will form biofilms on the surface, a rich source of nutrition for various Collembola and millipede species, which in turn are preyed upon by mites and beetles, notably the eutroglophilic carabid *Trechoblemus micros* (Herbst, 1784). Nematodes and earthworms might be found within the mud itself, and a diverse community of this nature has been described from mud banks in Ingleborough Cave in the Yorkshire Dales (Piearce, 1975; Gidman, 1975; Piearce & Wells, 1977) and the tidal entrance series of Otter Hole in the lower Wye Valley (Chapman, 1979). In addition to mud banks in caves, coarse clasts, ranging from pebbles to boulders, provide a network of spaces within which invertebrates can shelter, analogous to talus slopes on the surface.

The invertebrate communities of vadose cave streams will vary depending on whether the stream is allogenic (derived from the surface i.e. it sinks at the cave entrance) or autogenic (fed by percolating groundwater) in nature. Allogenic streams will generally support a community of aquatic invertebrates similar to that of watercourses within the overlying surface environment, although considerably less diverse. This biota will consist of various aquatic life stages of insect groups, notably Ephemeroptera, Plecoptera and Trichoptera, washed into the cave, and if sufficient food is also carried in such species can potentially persist for some time, although the adult stages will not be able to survive and breed underground. The ubiquitous surface amphipod *Gammarus pulex* (Linnaeus, 1758) often forms a more permanent element of this community, being capable in suitable conditions of forming eustygophilic populations. Autogenic streams tend to contain the more specialist elements of the aquatic fauna, often dominated by stygobiontic Crustacea, such as *Niphargus* species and *Proasellus cavaticus*. A study in Swildon's Hole (Knight, 2011) documented a community of predominately washed-in stygoxenes in the allogenic main stream, with some Plecoptera and Ephemeroptera nymphs present over 1km underground, whilst autogenic tributaries within the same cave contained a community of stygobiontic Crustacea species and eustygophilic taxa.

Cave pools fed by percolating water, as opposed to pools left behind by receding flood levels in stream passages, may harbour diverse communities of invertebrates in otherwise lifeless cave passages (Chapman, 1993). Percolating water is often rich in organic matter carried in from the overlying soil and this can form a rich nutritional source for the growth of fungal and bacterial biofilms on the surface of silt at the bottom of such pools. These pools are often colonised by various small invertebrate taxa, typically Copepoda and Ostracoda, that live within the meso-cavernous fissures (or epikarst, the zone of fractured rock that is sometimes present between the soil and underlying karst, in which a shallow, but substantial, perched aquifer can form) above cave passages and can be displaced and washed out by high groundwater discharge. This fauna has been little studied in a British context, although where investigated (notably Slovenia), the epikarst has been shown to contain a diverse fauna, mostly dominated by copepod and ostracod species, some of which can be considered "epikarst specialists" (Brancelj, 2002, 2015; Pipan, 2005; Pipan & Culver, 2007). A preliminary study of the fauna in percolating water within three British caves, including Ogof Draenen, has already produced some interesting results (Knight *et al*., 2024). Pools can also provide a more 'sheltered' aquatic environment for many small species and those less well adapted to cope with the fast and often sporadic flow regime of streams.

The term hygropetric was first coined by Sket (2004) to describe thin sheets of water permanently flowing over vertical rock faces whilst working in caves in the Dinaric karst, where he identified several beetle species that were specialists of the habitat, as well as the amphipod *Typhlogammarus mrazeki* Schäferna 1907 (Culver & Pipan, 2019). The habitat has not been investigated in detail outside of the Balkans and certainly not in a British context, although Knight (2011) mentions a substantial population of *Gammarus pulex*, as well as the diving beetle *Agabus guttatus* (Paykull, 1798) living in a film of water flowing down the wall of Manor Farm Swallet on the Mendips; and Wood and Greenwood (2004) describe a population of the trickle midge *Thaumalea verralli* Edwards, 1929 grazing on algae in a film of water flowing over illuminated limestone and calcite flowstone in the threshold zone of Peak Cavern, Derbyshire.

In addition to the aquatic element of cave pools, the water surface itself can also harbour its own specialised fauna, described by Chapman (1993) as the 'pool association' or neuston community. This is based around a group of Collembola, many of which are cave-adapted with sturdy claws that enable them to penetrate the surface meniscus and move across it, grazing on micro-flora either on the film itself or associated with the decaying remains of animals, such as Diptera, trapped within the meniscus. Acari, notably *Rhagidia* species, either prey on animals trapped in the meniscus or the Collembola themselves.

The group of invertebrates associated with bats and bat roosts (the 'batellites' of Chapman [1993]) includes both bat parasites, such as the tick *Ixodes vespertilionis* Koch, 1844 and three species of wingless Diptera in the family Nycteribidae, and taxa associated with guano piles or feeding upon bat carcasses. Guano communities are important components of the biota of many tropical caves, where they consist of a bewildering array of 'guanophage' species representing a multitude of different taxa, often present in huge numbers (Culver & Pipan, 2019). In Britain only two species, the lesser and greater horseshoe bats, regularly use caves in sufficient numbers to create guano accumulations, although where substantial roosts exist the guano beneath will be colonised by bacteria and fungi as it decays, attracting Collembola, millipedes, fungus gnats (Mycetophilidae), sciarid flies and especially the eutroglophilic snail *Oxychilus cellarius* (O.F. Mũller, 1774). This is one of the few species capable of secreting chitinase, allowing it to digest insect remains within the guano. Such concentrations of potential prey will in turn attract mites, spiders and the rove beetle *Quedius mesomelinus* (Marsham, 1802), which has been observed close to guano mounds (Chapman, 1993).

1.4 The subterranean invertebrate fauna of Wales

South Wales, along with the Mendip Hills of Somerset, received a lot of biological attention during the period of *ad hoc* collecting that contributed to the *Hazelton* database, possibly due to the size and complexity of some of its cave systems, which offer a variety of challenges to the sporting speleologist, and the presence of several troglobiontic species in the area. Despite almost all of the caves being covered by ice sheets during the last glaciation, *Niphargus fontanus* and *Proasellus cavaticus* occur widely, both in caves within the Brecon Beacons and in the west in Carmarthenshire (Proudlove *et al*., 2003; Fowles, 1994). They have also been recorded from other habitats including springs, wells and boreholes, most notably in the Vale of Glamorgan but including sites elsewhere across south Wales. *Niphargus aquilex* Schiődte, 1855 is comparatively rare in caves, with records from just Ogof y Pebyll near Bridgend and Paviland Cave on the Gower (and a possible erroneous record from Agen Allwedd), but is also known from riverine gravels, boreholes and a well from Monmouthshire to Pembrokeshire. *Crangonyx subterraneus* has been recorded from the lake in Ogof Pant Canol, a small cave linked to the Ogof Ffynnon Ddu system and has recently (2011/12) been collected from springs and wells in Glamorgan (Farr & Lambourne, 2011). Recent additions to the fauna include the syncarid *Antrobathynella stammeri*, discovered in 2012 in Ogof Draenen (Knight *et al.,* 2018), and *Microniphargus leruthi*, recorded in Wales for the first time in 2011 from the Schwyll spring outflow in the Vale of Ogmore, Glamorgan (Farr & Lambourne, 2011) and since recorded across southern Wales from Monmouthshire to Pembrokeshire, in caves, boreholes, wells and springs. The widespread occurrence of stygobiontic Crustacea in previously glaciated areas of south Wales raises interesting questions as to whether the caves were recolonised by surviving populations from the Mendip Hills (unglaciated during the Devensian), following the retreat of the ice sheets and extirpation of local populations, or whether they survived in subterranean refugia close to the edge of the last glacial limit (Chapman, 1993; Proudlove *et al.,* 2003).

A wide selection of other subterranean invertebrates has been recorded from caves in south Wales, including subtroglophiles, eutroglophiles, trogloxenes and the troglobiontic springtails *Oligaphorura schoetti*, *Pseudosinella dobati* (Jefferson, 1989), although as noted above, there is some doubt over the latter's status in Britain, and *Disparrhopalites patrizii*, known from Agen Allwedd, one of only three caves from which this species has been recorded, and the only one north of Devon. Ogof y Ci, near Merthyr Tydfil and Lesser Garth Cave, near Cardiff are the only two British caves from which the troglobiontic spider *Porrhomma rosenhaueri* has been recorded (Carter, 2010a, 2018; Carter *et al.* 2010). Several other systems have been the subject of detailed studies, most notably Dan yr Ogof, Ogof Ffynnon Ddu and Ogof Draenen.

Hazelton lists records from several caves and mines in north Wales, although the region's subterranean biodiversity appears to be considerably less than in the south. Whether this is a sampling artefact as caves in this area are generally less visited, or due to the region being even further north of the Last Glacial Maximum requires further investigation. Records include the springtail *Oligophorura schoetti* (Ceiriog Cave, Ogof Dydd Byraf, Ogof Hsep Alyn and Minera Quarry Cave), *Speolepta leptogaster* larvae (Leet Cave and Maeshafn Cave) and the beetle *Hydroporus ferrugineus* (Ceiriog Cave). The remainder of the fauna consists of trogloxenes and a few eutroglophiles and is consistent with data from Yorkshire and other glaciated regions. The stygobiontic shrimp *Niphargus aquilex* has been recorded from several sites in the area including riverine gravels on the Afon Hirnant (Hynes, 1961) and Afon Elwy (Rees, 1983); springs near Dyserth and on Anglesey (Bratton, 2006); and from a borehole in Carboniferous limestone and two further wells on Anglesey. *Microniphargus leruthi* has also recently been recorded, along with *N. aquilex*, from the Ffynnon Asaph, a spring near Dyserth (records on the Hypogean Crustacea Recording Scheme [HCRS] database). These results indicate that both species have either re-colonised the north Wales area or managed to survive the glaciations in subterranean refugia. Systematic studies of the caves and mines in this area are lacking

(Jefferson, 1989) and might provide further information on the possible occurrence of the two species in this habitat.

1.5 Study sites

1.5.1 Ogof Ffynnon Ddu (OFD)

Located in the Tawe Valley, Powys and within the Brecon Beacons National Park, Ogof Ffynnon Ddu is the deepest and third longest system in Britain, with over 50km of surveyed passage and a vertical range of 300m. The system is very complex and contains a variety of passage types, with great diversity in age and morphology, from active streamway to dry high-level relict tunnels, containing clastic sediments and speleothems (Jefferson *et al.,* 2004). Several smaller streams in higher level passages drain into the major conduit at the base of the system which takes a considerable volume of water following high rainfall. The system is also thought to be very old and has probably been developing for at least one million years (Jefferson *et al*., 2004). The cave and enclosing land were designated a National Nature Reserve by the Nature Conservancy Council (NCC) in October 1975 due to their national significance and threats from quarrying.

The system extends from near its sink at Pwll Byfre (SN875166) to the resurgence at Ffynnon Ddu (SN847151). The resurgence was the first point of exploration and although digging entered Ogof Pant Canol (later connected to OFD I via a tight squeeze), it was not until 1946 that the present lower entrance was dug open and OFD I entered and explored up to Dip Sump and Boulder Chamber. Diving in the sump eventually reached OFD II in 1966, whilst at the same time digging extended the Cwm Dwr Quarry Cave, originally discovered by quarrying, which eventually provided a dry connection to OFD II in 1967. These breakthroughs led to the rapid discovery of many new passages in the upper part of the cave. During one of these, often very lengthy, trips a boulder pile containing snail shells was found and subsequent radio detection showed it to be close to the surface. It was soon dug open, providing the upper entrance to the system. This new entrance considerably shortened subsequent exploratory trips and enabled the discovery of OFD III in October 1967 and further exploration over the next two years, culminating in the publication of the survey in 1969 (Smart & Christopher, 1989). Access to the cave is controlled by a management committee and overseen by South Wales Caving Club, which has its headquarters close to the cave's Cwm Dwr entrance.

Jefferson and Chapman (1979) carried out an extensive faunal study after being awarded a grant by the NCC in 1979. The results of the survey were summarised as a report to the NCC that was outside of the public domain (Smart & Christopher, 1989). With the permission of the Countryside Council for Wales (the successor to NCC in Wales and one of the three merged bodies that later formed NRW), Jefferson, Chapman and Proudlove compiled a paper (Jefferson *et al*., 2004) that included the findings of the 1979 report, along with additional data in Carter (1995) and other sources after 1979 (notably Jefferson [1989] who compiled data for the cave on the *Hazelton* database) as well as incorporating modern changes in the taxonomy and nomenclature of many of the species listed in the 1979 report. Sixty-two invertebrate taxa were recorded within the system, including three troglobionts (the Collembola *Oligophorura schoetti* and *Pseudosinella dobati* and *Folsomia agrelli*) and two stygobionts (*Proasellus cavaticus* and *Niphargus fontanus*) and numerous other troglophiles, stygophiles and trogloxenes. The Collembola were found to be particularly numerous and diverse, and the paper discusses the correlation of species pairs on pool surfaces. A further unusual record from the system was that of the worm *Aeolosoma hemprichi* (Bruch, 1855) (Aphanoneura), a population of which occurred in a drip-fed pool, where it was monitored from 1972 to 1978, and was probably able to maintain itself for that time period by feeding on the silt at the bottom of the pool and by asexually reproducing by fission (Chapman, 1993; Jefferson, 1989; Jefferson *et al.*, 2004).

The survey method was predominately manual searching, with some bait trapping also being carried out. Observations on abundance, behaviour and habitat of the various taxa were made, and temperature and relative humidity were recorded at some locations. Although sites where fauna were found were marked on to a survey plan of the cave, it was not possible in some cases to determine where exactly each species was recorded.

In addition to the work in the cave system, a survey of the spider fauna of the uplands above OFD was conducted by Carter (2010b). Sampling in The Lake in Ogof Pant Canol has recorded *Niphargus fontanus, Proasellus cavaticus* and *Crangonyx subterraneus* (one record from 1951) as well as a recent (2016) record of *Microniphargus leruthi* (HCRS data). *Microniphargus* and *C. subterraneus* had not previously been recorded elsewhere in the system thus making the lake in Ogof Pant Canol an important site in which four stygobiontic species are known to occur.

The invertebrate data collected from the cave prior to the current survey is summarised in Appendix C. A total of 69 distinct taxa (e.g. where *Rhagidia* sp. and *Rhagidia punkva* are present, then only one would be counted as distinct) have been recorded including 8 troglobionts, 30 eutroglophiles (23 terrestrial and 7 aquatic) and 7 subtroglophiles (all terrestrial). The troglobionts include the Crustacea *N. fontanus, P. cavaticus, Microniphargus* and *C. subterraneus*, the three aforementioned Collembola species (although note the status of *Foldsomia agrelli* in Britain is uncertain), as well as a single record of the mite *Poecilophysis* (formerly *Rhagidia*) *spelaea* from Cwm Dwr. Note that the ecological status of this last species is uncertain, but it is definitely one of the commonest terrestrial mites recorded in British and Irish caves across a wide geographical range. The majority of the taxa are terrestrial, since studies in the cave have concentrated on this biome, with little in the way of systematic aquatic surveys.

1.5.2 Ogof Draenen

Ogof Draenen lies beneath the southern edge of the Brecon Beacons National Park, on the northeastern margins of the south Wales coalfield. Containing over 70km of known passage, it is the second largest system in Britain and one of the 40 longest caves in the world; this length is increasing with new discoveries. The cave comprises a complex multi-phase network of fossil and hydrologically active passages, extending beneath Blorenge SSSI and Gilwern Hill SSSI to the southwest of Abergavenny, with numerous fine streamways, avens and chambers. Within the cave, there are many areas of fine speleothems, including spectacular helictites and anthodites, and areas with gypsum needles and flowers lining the walls; as well as extensive sediment deposits that have been valuable in describing the geomorphology of the system (Farrant & Simms, 2011). Other features of Ogof Draenen include unusual fossils, such as the dorsal and pectoral spines from species of extinct shark (Kendall & Hicks, 2003). The importance of the cave was recognised in a special issue of Cave and Karst Science (Vol. 38, No. 1 issued in April 2011) dedicated to the cave, which detailed the history of its exploration, and the research carried out within it (see Farrant & Simms, 2011; Kendall & Guilford, 2011; Lovett, 2011; Maurice & Guilford, 2011). Caves and hibernating Lesser Horseshoe Bats *Rhinolophus hipposideros* are qualifying features of both Blorenge SSSI and Gilwern Hill SSSI.

Access to the cave is via a gated, locked entrance (SO24631178) and access, exploration and scientific work is controlled by the Pwll Du Cave Management Group (PDCMG). The cave is a relatively recent discovery being first entered in 1994, with rapid exploration and discoveries in the next few years after this (Lovett, 2011). Much of the cave follows horizontal development and is relatively shallow, with many passages not that far from the surface. Although highly controversial, this latter feature has led to several other entrances being unofficially excavated in the intervening decades. Although efforts have been made to close these unofficial entrances with mixed success, two, Drws Cefn and The Nunnery Entrance remain open. As of 2024, a further entrance has been added via Ogof Tarddiad Pwll Du. This entrance is located within woodland that is part of the Gilwern Hill SSSI and has landowner permission for access by bona fide cavers.

The drainage of the karst is extensive and complicated, with various watersheds having been identified within the cave system (Maurice & Guilford, 2011). There are many small sinking streams and seepages on the moorland above the cave associated with the boundary between the Carboniferous aged limestones and the overlying Marros Group sandstones (Maurice & Guilford, 2011). The flows in these stream sinks have not been measured, and are highly variable, but are visually estimated to have flows of a few litres/second following rainfall, with the largest increasing to a few 10s l/s following prolonged rain. Tracer testing has demonstrated that some of these sinks are connected to the major stream passages within the cave, and that these resurge as springs and upwellings in the Afon Lwyd valley about 8km to the south of the known cave, in a different topographical catchment (Gascoine, 1995; Maurice & Guilford, 2011).

The pattern of drainage has changed significantly over the millennia during four distinct phases (Farrant & Simms, 2011) but today there are principally two major flow paths. Most of the water in the cave is drained via three major streamways: Big Country, Into the Black in the Dollimores Series, and the Beyond a Choke Stream. These major streams must unite somewhere beyond the known cave because they are all connected to the major resurgences to the south of the cave (Maurice & Guilford, 2011). The water in the northern part of the cave under Gilwern Hill flows northwards and drains into the Cwm Dyar valley via four spring resurgences.

Many of the vadose streams within the system are underfit streams, flowing beneath extensive boulder deposits in some of the larger passages and the water is only accessible at certain locations. Examples include the streams in Upstream Passage and White Arch Passage, near the entrance, and War of the Worlds in the far reaches of the cave. In other regions, the streams are much more open along their lengths, including the Beyond a Choke streamway and the streams in Agent Blorenge, Dollimore's and parts of Big Country.

As the cave was not discovered and entered until 1994, there are no available records on *Hazelton.* Some biological records for the cave are held by Peter Smith, the biological recorder for the PDCMG, and although there is a large amount of information on bats within the cave (Kendall & Guilford, 2011), invertebrate records are lacking. Various species, notably a suite of Gastropoda and Diptera, typical of the parietal community, have been noted near the entrance, although the threshold fauna is notably sparse compared to many other Welsh caves. This may be because the entrance is sealed and narrow, and the initial passages are wet. In addition to the threshold data, several records of aquatic Crustacaea, based on *ad hoc* collecting by the author (LK) prior to 2012, include *Gammarus pulex, Niphargus fontanus* and *Proasellus cavaticus*. The common frog (*Rana temporaria* Linnaeus, 1758) has also been observed in the entrance series.

Three species of bat regularly utilise the cave: the lesser horseshoe (*Rhinolophus hipposideros* (Bechstein, 1800)), the greater horseshoe (*Rhinolophus ferrumequinum* (Schreber, 1774)) and Natterer's bat (*Myotis nattereri* (Kuhl, 1817)). Kendall and Guilford (2011) describe 15 years of observations of bats within the system, of which the lesser horseshoe is by far the most common species encountered. Siambre Ddu cave, a large chamber located above the main cave system, has been designated a SSSI on account of its value as a roost for horseshoe bats, on the limit of their distribution range (Kendal & Guilford, 2011). Siambre Ddu provides several routes into Ogof Draenen, used extensively by the bats, which are inaccessible to humans, thus most bat activity within the system is concentrated in the relict passages close to Siambre Ddu. Present day numbers of bats in the cave are relatively low but this has obviously not always been the case, with huge piles of guano seen in Raiders Passage, as well as scatterings of fine guano in many passages, suggesting that at some time in the past the cave was much more heavily used by bats than today. These are some of the largest accumulations of ancient bat guano known in Britain which are thought to date from the Iron Age and medieval periods (Leroy & Simms, 2006). Although Siambre Ddu, as well as the overlying Blorenge and Gilwern Hill are designated as SSSIs, despite an abundance of unusual and important geological and biological features, Ogof Draenen itself does not have any formal recognition of, or protection for, its scientific importance.

From 2012 to 2015, an extensive survey of the invertebrate fauna in aquatic habitats throughout the cave was undertaken by Knight *et al.* (2018). Sampling involved a combination of kick and sweep netting with a FBA pattern pond net fitted with a 250-micron mesh collecting bag; with smaller nets also used where required, along with visual searching in some of the smaller pools. Fifty-nine sites were sampled, with the majority consisting of stream sites throughout the cave and a few static pools.

The survey produced interesting results with most sites primarily dominated by stygobiontic Crustacea, with lesser numbers of epi-benthic fauna present at some of the sites known to be close to surface sinks. The stygobiontic isopod *Proasellus cavaticus* was the commonest species recorded with numbers in excess of 100 at several sites (212 at one site on the White Arch series stream and 383 and 131 at two sites on the Agent Blorenge stream), followed by much lesser numbers of the stygobiontic amphipods *Niphargus fontanus* and *Microniphargus leruthi*, the first records of this species from a Welsh cave system. The syncarid *Antrobathynella stammeri* was recorded from four sites on the main stream, two sites on the Agent Blorenge stream, the main stream in Big Country and from streams in the Dollimore Series, the first documented occurrence of this species in Wales.

In addition to surveying streams within the cave, sampling was also carried out of the fauna in known sinks and resurgences (springs), identified and documented by previous dye-tracing investigations (e.g. Maurice & Guilford, 2011). Many of the resurgences also contained stygobiontic Crustacea, with *Niphargus aquilex* also being collected, in addition to *Microniphargus* and *Proasellus cavaticus*, at the Ogof Cwm Dyar spring. If the Ogof Cwm Dyar resurgence is hydrologically connected to the system then this makes a total of six stygobiontic Crustacea (including *F. breuili*, see below), the most diverse stygobiontic fauna in any British or Irish cave. The Cwm Dyar resurgence lies within the Blaen Dyar Valley, sandwiched between Gilwern Hill and Llanelly Hill, and is also known to be fed by surface sinks on Gilwern Hill, thus the occurrence of *N. aquilex* in the spring might indicate that this species is more likely to be associated with the hyporheic zone underlying the valley stream, rather than the actual cave; in essence, an inhabitant of the wider karstic aquifer rather than the cave *per se.*

Later work has included sampling of dripping water from the cave ceiling and drip-fed pools over a period of six years from 2016 to 2022, as part of a larger investigation into the fauna of percolating water in three caves across Britian. Collecting and filtering the dripping water recorded a variety of cyclopoid and harpacticoid copepod and ostracod species, including the first British record of the stygobiontic ostracod species *Fabaeformiscandona breuili* (Paris, 1920) (Knight & Mori, 2022; Knight *et al.*, 2024).

The invertebrate data collected from the cave prior to the current survey is summarised in Appendix D. If the data from the sinks and resurgences in Knight *et al*. (2018) is discounted, a total of 90 distinct taxa (e.g. where Oligochaeta, *Stylodrilus* sp. and *Stylodrilus lemani* are present then only one would be counted as distinct) have been recorded from the cave, the majority of which are aquatic reflecting the nature of the studies conducted within the system. The data includes 5 troglobionts (all aquatic), 15 eutroglophiles (11 aquatic and 4 terrestrial), and 5 subtroglophiles (all terrestrial), representing a very diverse subterranean fauna.

2. Methods & materials

As part of the scoping process for the project a sampling protocol was first designed and presented to NRW outlining guidelines for how the surveys would be undertaken. This is included in Appendix A. This protocol stipulated that for an initial baseline survey ideally at least two sampling visits should be undertaken to each cave, in late spring / early summer (May to June) and late autumn / winter (November to February). This would investigate any occurrence of seasonality in the invertebrate assemblages, a factor that, with the exception of threshold communities, has not been investigated in a systematic way in

British caves before. The first set of sampling was undertaken during spring / early summer 2023, with a follow up winter survey in early 2024, although as described below, extremely wet weather in early 2024 meant that three of the aquatic sites in OFD could not be safely sampled until the following winter (January 2025).

As per the protocol in Appendix A, invertebrate sampling in both caves was divided between the aquatic and terrestrial biomes. The locations of the sampling sites are illustrated in Figures 1 to 4 and 7 to 9 below and site photographs are included in Appendix B. The choice of sampling sites depended on several factors including representation of key invertebrate assemblages and habitats likely to be present in each system, local hydrology, and ease of access for future monitoring to be undertaken. The latter precluded locations that were too far from known entrances, and which would involve long technically difficult trips, especially as these would involve the transportation of rather bulky equipment and samples.

2.1 Aquatic invertebrate sampling

Both Ogof Draenen and OFD contain several subterranean stream catchments and in each cave five sites were selected for sampling on vadose streams and four in lentic habitats.

As per the recommended protocol in Appendix A, it was initially planned to undertake aquatic invertebrate sampling in both caves in May / June 2023 and January / February 2024. The Ogof Draenen aquatic surveys were undertaken during May 2023 and in January and early February 2024. The initial survey in OFD was undertaken during June 2023. However, the winter survey encountered problems with a period of heavy rainfall in early 2024, from late January to early April. The lower part of the main streamway in OFD I carries the water from the whole of the system upstream and can be extremely hazardous to enter in high flows, especially as there are several deep potholes within the stream bed that are almost impossible to see in turbulent flows and necessitate crossing by narrow scaffolding poles, fixed in the stream bed for this purpose. Thus, in addition to a turbulent and very strong flow, falling into one of these potholes in such conditions would most probably be fatal. The sites within OFD II could be accessed via relatively dry routes from Top Entrance or Cwm Dwr and were thus sampled during February 2024. However, accessing sites S1 and S2 in OFD I required advancing up the main stream, along the aforementioned dangerous section. Despite repeated visits during February 2024, levels in the main stream did not drop sufficiently to make this safe, with the final attempt, including sampling of Site L2, undertaken on 1st March. It was felt that sampling after this, even if the water levels dropped sufficiently, would be too close to the previous May / June sampling window for any meaningful comparisons of the data. At Site L1, throughout early 2024, the entire chamber holding the lake was full of so much water that the entrance to the chamber was sumped, also making sampling here impossible. Thus, it was not until January 2025 that it was finally possible to complete the winter survey for OFD and sample sites S1, S2 and L1.

At each aquatic sampling site, a three-minute timed period of netting (primarily ‘kick sampling’ on streams), with a FBA pattern pond net fitted with a 250µm mesh collecting bag was the preferential method, although some smaller pools required a slight variation in this method, detailed below. After sampling, all samples were preserved *in situ* in 4% formalin solution and packed in bags, then in sturdy Nalgene plastic containers for transportation out of the cave and later sorting and identification in the laboratory. Laboratory analysis involved washing the sample through a stacked set of sieves of different apertures to split it into fractionated portions and then placing a small amount of each portion into a large petri dish for sorting and the picking out of specimens beneath a stereo microscope. Samples containing a high amount of fine gravel or sand were dealt with using the floatation method of Anderson (1959) to separate organic matter from the mineral substrate.

Before netting, the surfaces of lentic habitats were searched for neuston fauna, predominately Collembola, which were collected either with forceps or a small brush and placed in a separate vial of preservative.

Water chemistry parameters including temperature, conductivity, pH and total dissolved solids were measured with a Hanna Instruments compact pocket meter at all aquatic sampling sites. Other physical parameters including average width of channel, average depth and estimates of substrate composition were also assessed at each of the stream sites.

2.1.1 Ogof Ffynnon Ddu

Sites sampled in OFD for their aquatic invertebrate fauna included:

Site S1: OFD I, Main Stream, immediately downstream exit of upstream sump in OFD I;

Site S2: OFD I, Waterfall Series Stream, at exit of ‘Wet Way’;

Site S3: OFD II, Salubrious Passage Stream, upstream junction to The Trident, by wedged boulder;

Site S4: OFD II, Main Stream, at confluence of Cwm Dwr Stream;

Site S5: Cwm Dwr Quarry Cave, Cwm Dwr Stream, 5m upstream confluence with Main Stream;

Site L1: Ogof Pant Canol, The Lake;

Site L2: OFD I, gour pools on ‘The Toast Rack’;

Site L3: OFD II, pool immediately past the gate to ‘The Columns.’ Due to logistical difficulties in obtaining the gate key to this protected part of the cave in February 2024, a pool of similar size, near to the gate was instead sampled for the winter survey;

Site L4: OFD II, large pool by 'The Trident'.

The situation in OFD is the opposite to that in the shallow horizontally developed Ogof Draenen. Being a much deeper system, the main drainage in OFD is via the large main stream conduit running through the lowest level of the system, which is fed by several smaller tributaries that flow into it from the higher fossil galleries above. However, due to the main conduit taking a substantial amount of flow, especially in wet weather, for most of its length the stream flows in a smooth channel of heavily scoured bedrock, totally unsuitable for the establishment of an aquatic invertebrate community. Thus, whilst static pools are fairly common in the upper levels of the cave, the main stream could only be sampled at two locations, the exit of the sump in OFD I and at the confluence of the Cwm Dwr Stream, where the flow is sufficiently slowed that coarse clasts accumulate in the stream bed, providing shelter for aquatic invertebrates.

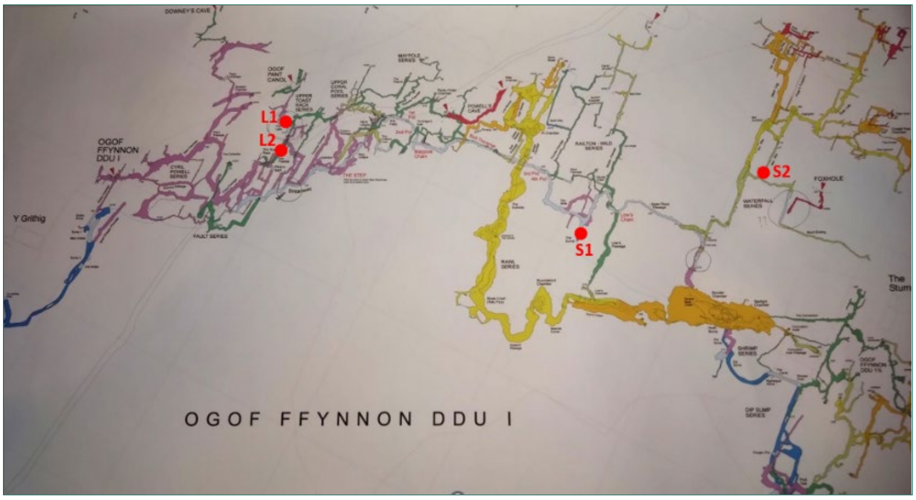

Figure 1. Survey of OFD I showing locations of aquatic invertebrate sampling sites S1, S2, L1 and L2.

Figure 2. Survey of Cwm Dwr Quarry Cave and part of OFD II, showing locations of aquatic invertebrate sampling sites S4 and S5.

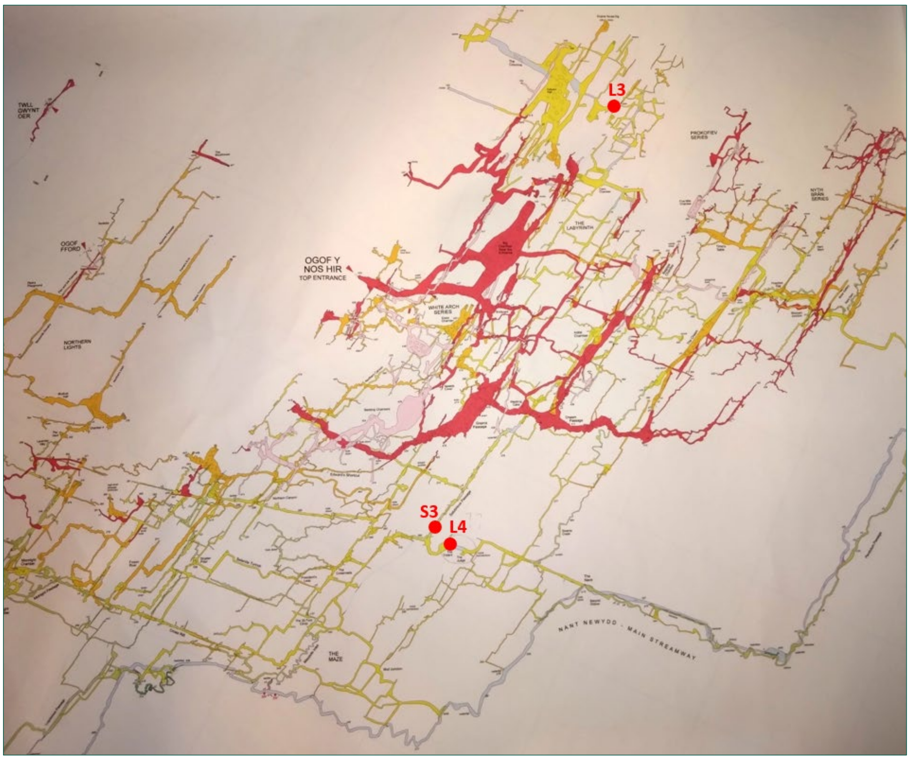

Figure 3. Survey of part of OFD II, showing locations of aquatic invertebrate sampling sites S3, L3 and L4.

2.1.2 Ogof Draenen

Sites sampled in Ogof Draenen for their aquatic invertebrate fauna included:

Site S1 (Site 10 in Knight *et al.* 2018): Beyond A Choke Stream, 5m downstream Agent Blorenge confluence;

Site S2 (Site 25 in Knight *et al.* 2018): Agent Blorenge Stream, 2m upstream Beyond A Choke confluence;

Site S3 (Site 12 in Knight *et al.* 2018): Beyond A Choke Stream, just downstream of Gilwern Passage and Tea Junction;

Site S4 (Site 5 in Knight *et al.* 2018): Stream upstream Tea Junction, 'Bogus Camp' just upstream Tea Junction;

Site S5 (Site 2 in Knight *et al.* 2018): Stream flowing from calcited choke south of Outcast Passage to Cairn Junction, 10m downstream 5m waterfall;

Site L1 (Site 27 in Knight *et al.* 2018): Static linear pools along Haggis Basher;

Site L2 (Site 16 in Knight *et al.* 2018): Small inlet pools above waterfall, Lamb and Fox Chamber, below first inlet above waterfall;

Site L3: Pools in vicinity of Giles Shirt, Gilwern Passage;

Site L4 (Site 3a in Knight *et al*. 2018): Large pool below 4m rope climb at end of entrance series, just before climb up to Cairn Junction.

Trips to the streams in Big Country and Dollimore series can be serious undertakings so sampling was mostly limited to the main catchment in the system, the Beyond A Choke Stream. In its upper reaches, this is fed by the stream taking water flowing through the Entrance Series, the stream that flows southwards from Outcast Passage to join the former at Cairn Junction, and the stream flowing through White Arch to join the other two streams at Tea Junction. There is also some flow southwards from the lower reaches of Gilwern Passage that joins just downstream of Tea Junction. A key feature of many of the vadose catchments in Ogof Draenen is that much of their length consists of 'underfit' streams, flowing beneath large piles of boulders that have accumulated over the years and cover the floors of many of the passages and chambers throughout the cave. It is only downstream of Tea Junction that the course of the Beyond A Choke Stream is accessible for any significant length. In its lower reaches, the Beyond A choke Stream is joined by another major tributary, the Agent Blorenge Stream, before it sinks at its current known limit in the cave, Rifleman's Chamber, from where it has been traced to its resurgence in the Afon Lwyd Valley to the south.

Sampling sites were also chosen to correspond to those in Knight *et al*. (2018) for further comparison.

Site S5 was primarily chosen as the choke just upstream of this location, from which much of the stream's flow originates, connects to the base of a surface doline containing a small ephemeral stream, where Knight *et al*. (2018) recorded elements of the benthic surface fauna washed in from above.

The boulder floors that characterise much of the system also mean that lentic habitats are scarce in Ogof Draenen as much of the flow originating as waterfalls in various avens, or percolating from above rapidly drains through the floor to the 'underfit' streams, with there being few areas of compacted silt suitable for holding water. There are a few such locations where relatively large pools are present, including immediately below the 'Giles Shirt' formation in Gilwern Passage and the large pools at the end of Morgannwg Passage. However, such pools are lined with calcite crystals and delicate floating rafts and any sampling in such beautiful locations would cause irreversible damage to the delicate speleothems.

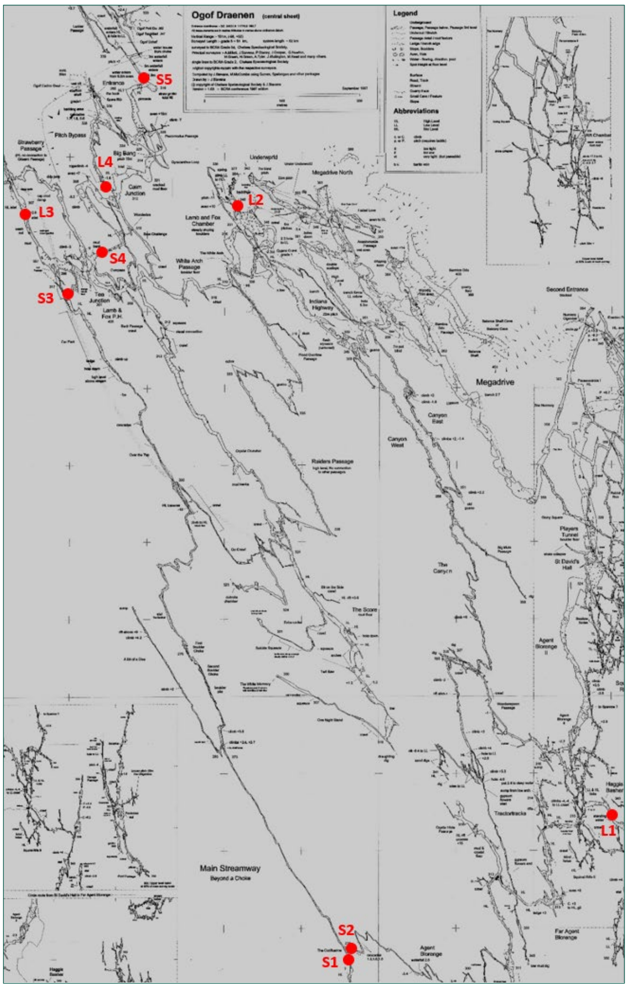

Figure 4. The locations of the aquatic sampling sites in Ogof Draenen. Note that due to the size of the system only part of the survey is shown for illustrative purposes.

The pools along Haggis Basher (Site L1) in fact lie in the channel of a small ephemeral stream, but for most of the time no flow is evident, and the site can be classified as lentic.

The same is true for the pools above Lamb and Fox Chamber (Site L2) which are fed by a higher-level dripping inlet that in wet conditions provides enough flow to form a small stream in this passage. The pools in this ephemeral stream bed are quite small in size thus rather than sampling by netting, the pools were bailed dry with a jug and filtered through a plastic sampling bottle (Brancelj, 2004). Several pools in the vicinity of Giles Shirt include a larger pool, fed by a high-level inlet a few metres further up Gilwern Passage, and a small pool just below Giles Shirt that receives overflow from the large, calcite-lined pool at the base of the formation. These were split into two sites (3a and 3b respectively), with 3a sampled by two minutes netting with the standard FBA net and 3b by an additional one-minute netting with a smaller hand net, fitted with a 15cm wide frame.

2.2 Terrestrial invertebrate sampling

The terrestrial sampling involved surveys of both the fauna in the threshold of the cave entrances and that of sites deeper within each system.

As per the protocol, sampling of the threshold fauna involved timed manual searches only. Five minutes of active searching for fauna was carried out at six locations, 6m apart, making a total of 30 minutes searching. Particular attention was paid to the walls and ceiling of the threshold as this is where much of the parietal community of the threshold occurs. Specimens not easily determined in the field were collected with forceps or pooters and placed in vials of preservative for later examination and identification.

Each cave had three entrances: OFD bottom entrance (OFD I); Cwm Dwr (OFD II) and top entrance (OFD II); Ogof Draenen Main entrance, Nunnery entrance and Drws Cefn, at which manual searches were carried out in early July 2023 and early January 2024.

Deeper into each cave, four sites were sampled in May / June 2023 in OFD and June / July 2023 in Ogof Draenen, with winter surveys undertaken in February / March 2024. Each of the four terrestrial sites were the subject of more detailed study involving a combination of three methods:

- Manual search: five-minutes of searching at 6 points, 6m apart;
- Place 6 baited pitfall traps (see Figure 5) at least 3m apart, trialling different types of bait including crab, mince and honey on a sequential basis. A preserving solution of a 1:1 mixture of 10% DMDM hydantoin and propylene glycol, with a few drops of detergent to break up water tension, was added to each trap to a depth of a couple of centimetres. The baits were then placed in small, perforated tubes, secured across the mouth of the trap with a wire support. These were then left in place for approximately one month, at the end of which the pitfall traps were removed and sealed with a screw top lid to allow transfer from the cave for later sorting under a low power microscope;
- Close to each trap, place a metal scouring pad under a stone or similar sheltered place, to be bagged and removed at the same time as the traps. On removal the fauna was extracted using the Tullgren funnel method running over a period of 3 days (see Figure 6).

Although sequential baiting was undertaken during the first sampling event in 2023 to enable some comparison between different baits, this was rather complex to perform. Also given that it was quite challenging to find sites with suitable substrate for trap placement this led to high variability between sites, thus it was hard to determine if one bait type was performing better than the others. For the second winter survey, it was decided to use processed cheese as bait in all the traps instead. A more detailed study, with better established controls would be required to determine the effectiveness of different bait traps in the future.

Figure 5. Andrew Lewington setting up a baited pitfall trap at T1 in Ogof Ffynnon Ddu.

Figure 6. Tullgren funnel extraction setup.

2.2.1 Ogof Ffynnon Ddu

Finding sites with suitable, relatively fine substrate, for setting up the baited pitfall traps was a particular challenge in the Ogof Ffynnon Ddu system. The four sites sampled in OFD for their terrestrial invertebrate fauna included:

Site T1: Passage off Shale Chamber in mud floored passage with small streamway (OFD II). Selected as previous survey work (Jefferson & Chapman, 1979) had found cave fauna in this area;

Site T2: Far end of Big Chamber (OFD II) in mixed loose gravel and rocks with some seeps;

Site T3: Waterfall Series (OFD I). A deep cave site to allow comparison with T4. Mix of dry passage with rocky floor leading to small stream passage;

Site T4: Main route along Flood Passage, beyond Skeleton Chamber intersection. Quite a long section along this main route as suitable trap placement positions were difficult to find with traps located in a mix of small gravels and sediment.

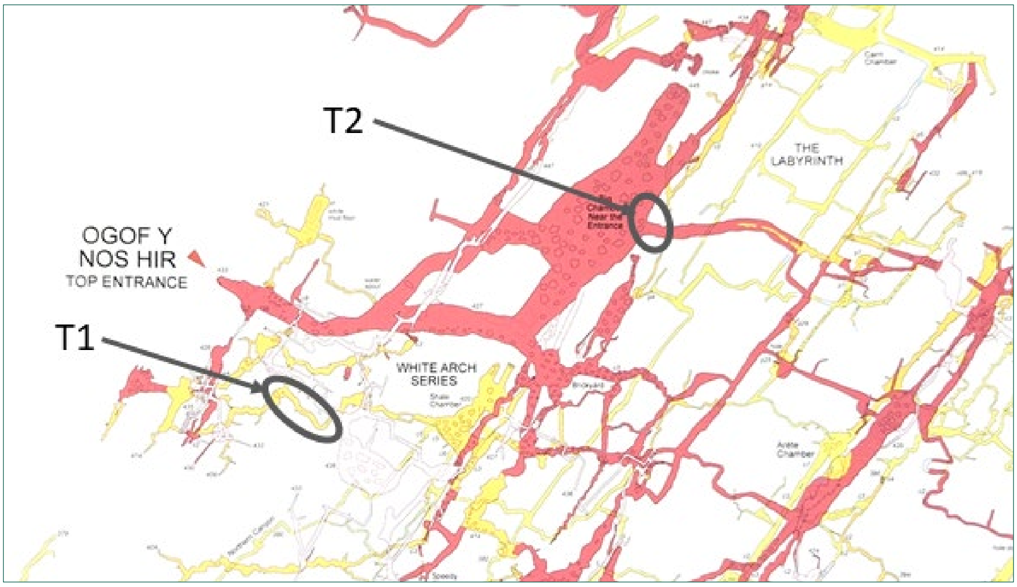

Figure 7. Locations of sample sites T1 and T2 in Ogof Ffynnon Ddu II.

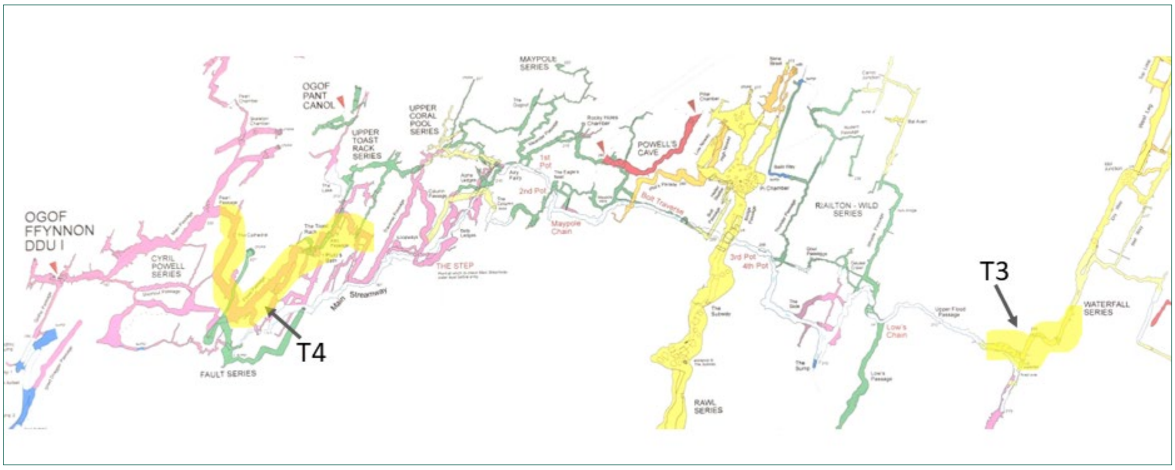

Figure 8. Locations of sample sites T3 and T4 in Ogof Ffynnon Ddu I.

2.2.2 Ogof Draenen

The main sites sampled in Ogof Draenen for their terrestrial invertebrate fauna included:

Site T1: End of Entrance Series, prior to 4m rope climb down. Traps in mix of sediment pockets and amongst rockier substrates. The manual searching also encompassed the adjacent Cairn Chamber during July 2023 (listed as Site T1a in Table 9 of the Results);

Site T2: Waterfall Series area, between Straw Grotto and waterfall. Primarily traps placed in soft sediments near stream. Note this is the same location as aquatic sampling site S5;
Site T3: Beginning of Gilwern Passage, in vicinity of Giles Shirt. Traps in mix of placement due to difficulty in finding suitable locations. Aquatic invertebrate sampling was carried out in pools in this area (Site L3);

Site T4: Margins of streamway before Tea Junction. Traps placed primarily in soft sediments. This location corresponds with aquatic sampling site S4.

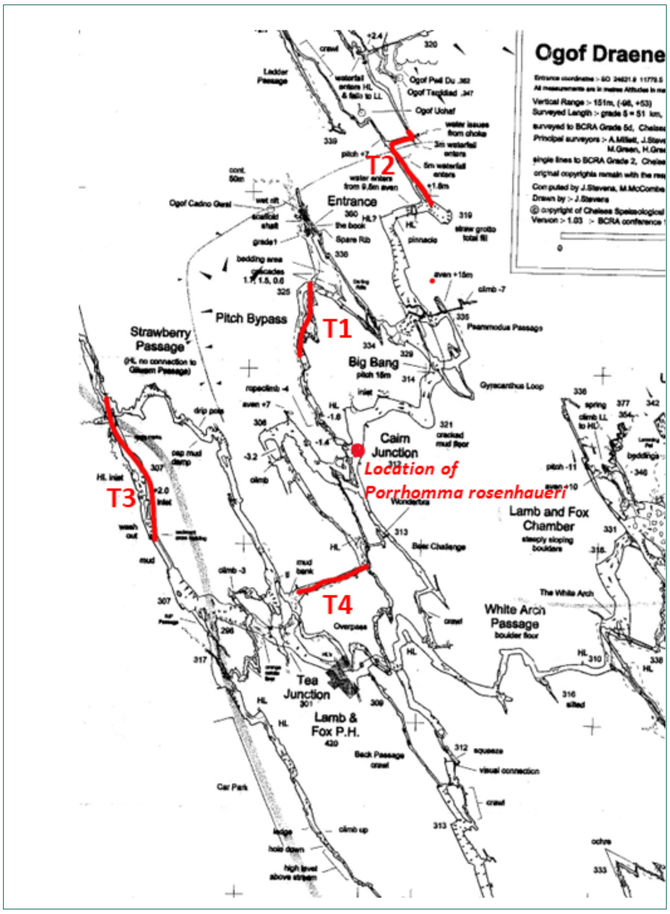

Figure 9. Locations of the terrestrial invertebrate sampling sites in Ogof Draenen.

3. Results

3.1 Ogof Ffynnon Ddu

Overall, the current survey recorded a total of 84 distinct invertebrate taxa, including 32 aquatic taxa (29 in streams and 16 in lentic habitats), 19 terrestrial taxa (including the beetle *Ptenidium brenskei* Flach, 1887 at aquatic site L1) within the deep cave environment and an additional 33 taxa in the thresholds of the three entrances. The lists included 4 stygobionts, 5 eustygophiles, 2 troglobionts, 16 eutroglophiles and 6 subtroglophiles. Of the taxa recorded, 30 had previously been recorded from the cave, adding 54 new records, mostly within the aquatic biome, making a total of 123 invertebrate taxa now known from the system. This represents almost 50% of the 69 taxa previously recorded in the cave over the course of many years, suggesting that the species accumulation for the cave is far from reaching an asymptote and yet further sampling efforts are required before it would be possible to provide a comprehensive list for the entirety of such a large cave system; although the current survey has certainly begun to construct a robust baseline. This is also represented amongst the Collembola, a group for which OFD is known to be a particularly rich site, with the record of the eutroglophilic species *Onychiurus ambulans* (Linnaeus, 1758) an additional record to the fauna. 3 troglobionts, 15 eutroglophiles and 1 subtroglophile previously recorded from the cave were not recorded in the present survey. In addition to *P. brenskei* collected from the surface of the Lake in Ogof Pant Canol (L1) Collembola were also noted, and believed collected from, the surfaces of pools at L3 and L4. However, upon examination in the laboratory the tubes were either found to be empty or specimens too damaged for accurate identification; greater care will be required for the collection of surface Collembola from the neuston in future surveys. The results of the survey are summarised in Table 1 below, whilst Tables 2 to 5 list the taxa recorded in their various biotopes.

3.2 Ogof Draenen

Overall, the current survey recorded a total of 84 distinct invertebrate taxa, including 36 aquatic taxa (35 in streams and 15 in lentic habitats), 20 terrestrial taxa (including the additional records of the spider *Oonops domesticus / pulcher* from S3 and *Folsomia agrelli* at L4) within the deep cave environment and an additional 28 taxa in the thresholds of the three entrances. The lists included 5 stygobionts, 5 eustygophiles, 4 troglobionts, 9 eutroglophiles and 7 subtroglophiles. Of the taxa recorded, 34 had previously been recorded from the cave, adding 50 new species, mostly within the terrestrial biome, making a total of 126 invertebrate taxa now documented from the system. This represents almost 40% of the taxa previously known from the cave, mostly recorded during a detailed survey of aquatic habitats throughout the cave over the course of several years. It should be noted that ten of the taxa previously recorded were chironomid species and genera, a group that was not determined further than family level in the current survey. Also eight of the records included harpacticoid copepod species and the ostracod *Fabaeformiscandona breuili* which were collected in percolating water using specialised equipment by Knight *et al.* (2024), thus the true habitat of these species is more likely to be the fissure network, or epikarst aquifer, above the cave and the mesh size of the aquatic nets used in the current survey would have been too big to retain specimens of these tiny species. However, this still leaves some 38 taxa previously known from the cave that were not recorded during the present study, suggesting, as with OFD, that the inventory of invertebrate species within the Ogof Draenen system is still likely to be far from complete. However, the list of cavernicolous species showed less discrepancy, with just 1 troglobiont, the aforementioned ostracod *F. breuili*, and 7 eutroglophiles not recorded during the current survey. As in OFD, additional Collembola species were observed on the surfaces of pools at several lentic sites, including L1, L3 and especially L4, but again specimens were either missing from tubes or too damaged for identification. However, it is noteworthy that the neuston sample from L4, including the troglobiontic mite *Poecilophysis spelaea*, the dipluran *Campodea cf. wallacei* and the troglobiontic collembolan *Folsomia agrelli* (a new record for the cave) hint at the existence of a neuston community that will require further investigation. The results of the survey are summarised in Table 6 below, whilst Tables 7 to 10 list the taxa recorded in their various biotopes.

Table 1. Summary of the invertebrate taxa recorded in Ogof Ffynnon Ddu.

Invertebrate taxa	No. taxa	Troglobionts	Eutroglophiles	Subtroglophiles
Aquatic taxa	**32**	**4:** *Niphargus fontanus, Microniphargus leruthi, Proasellus cavaticus, Antrobathynella stammeri*	**5:** *Dorydrilus michaelseni, Diacyclops bicuspidatus, Paracyclops fimbriatus, Cavernocypris subterranea, Soldanellonyx chappuisi*	**0**
Terrestrial taxa: deep cave	**19**	**2**: *Poecilophysis spelaea, Oligaphorura schoetti*	**9**: *Blaniulus guttulaus, Schaefferia emucronata, Onychiurus ambulans, Deuteraphorura cebennaria, Pseudosinella immaculata, Pygmarrhopalites pygmaeus, Arrhopalites caecus, Lesteva pubescens, Ochthephilus aureus*	**0**
Terrestrial taxa: threshold	**33**	**0**	**7:** *Oxychilus cellarius, Nanogona polydesmoides, Brachydesmus superus, Meta menardi, Metellina merianae, Nesticus cellulanus, Scoliocentra villosa*	**6**: *Stenophylax permistus, Scoliopteryx libatrix, Limonia nebeculosa, Culex pipiens, Heleomyza serrata / captiosa, Exallonyx longicornis*
Key historical records not found in current survey	**39**	**3:** *Crangonyx subterraneus, Folsomia agrelli, Pseudosinella dobati*	**15:** *Phagocata vitta, Aelosoma hemprichi, Gammarus pulex, Androniscus dentiger, Acanthocyclops vernalis, Megacyclops viridis, Palliduphantes pallidus, Folsomia diplophthalma, Folsomia candida, Megalothorax minimus, Speolepta leptogaster, Trichocera maculipennis, Trechoblemus micros, Choleva agilis, Quedius mesomelinus*	**1:** *Triphosa dubitata*

Table 2. List of aquatic invertebrate taxa recorded in streams in Ogof Ffynnon Ddu. Species highlighted in red are stygobionts and those in blue eustygophiles.

Site number	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5
Date	01/06/2023	18/01/2025	01/06/2023	18/01/2025	02/06/2023	17/02/2024	18/06/2023	18/02/2024	18/06/2023	18/02/2024
Watercourse	Main stream	Main stream	Waterfall series stream	Waterfall series stream	Salubrious passage stream	Salubrious passage stream	Main stream	Main stream	Cwm Dwr stream	Cwm Dwr stream
Location	OFD I sump exit	OFD I sump exit	Exit of wet way	Exit of wet way	U/S junction to Trident, by wedged boulder	U/S junction to Trident, by wedged boulder	Cwm Dwr confluence	Cwm Dwr confluence	5m U/S confluence with main stream	5m U/S confluence with main stream
TAXA	-	-	-	-	-	-	-	-	-	-
TRICLADIDA	-	-	-	-	-	-	-	-	-	-
PLANARIIDAE	-	-	-	-	-	-	-	-	-	-
Polycelis felina (Dalyell, 1814)	1	-	-	1	-	-	-	-	-	-
NEMATODA	-	-	1	-	-	-	-	-	-	-
OLIGOCHAETA	-	-	-	-	-	-	-	-	-	-
LUMBRICIDAE	-	-	-	-	-	**N**	-	-	-	-
Eiseniella tetraedra (Savigny, 1826)	-	-	1	-	-	**O**	-	-	-	-
LUMBRICULIDAE	-	-	-	-	-	-	-	-	-	-
Stylodrilus heringianus Claparède, 1862	1	-	1	-	1	**F**	3	-	-	-
Stylodrilus sp. (juv.)	-	-	1	-	-	**A**	6	-	1	-
Lumbriculus variegatus Claparède, 1862	-	1	-	-	-	**U**	-	2	-	-
Eclipidrilus lacustris (Verill, 1871)	-	-	-	2	-	**N**	2	3	1	-
DORYDRILIDAE	-	-	-	-	-	**A**	-	-	-	-
Dorydrilus michaelseni Piguet, 1913	-	1	-	-	-	-	-	-	-	-
Dorydrilus / Trichodrilus (juvs.)	44	33	13	18	4	-	10	16	24	3
ENCHYTRAEIDAE	-	-	-	-	-	-	-	-	-	-
Enchytraeidae spp.	1	2	-	-	-	-	-	2	-	-
TUBIFICIDAE	-	-	-	-	-	-	-	-	-	-
Tubifex tubifex (Mũller, 1774)	-	-	-	-	-	-	-	1	-	1
Oligochaeta spp.	5	3	1	17	3	-	3	7	7	1
CRUSTACEA	-	-	-	-	-	-	-	-	-	-
BATHYNELLIDAE	-	-	-	-	-	-	-	-	-	-
Antrobathynella stammeri (Jakobi, 1954)	-	-	-	-	-	-	1	-	4	-
NIPHARGIDAE	-	-	-	-	-	-	-	-	-	-
Niphargus fontanus Bate, 1859	1	3	1	5	2	-	3	1	-	-

Site number	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5
Date	01/06/2023	18/01/2025	01/06/2023	18/01/2025	02/06/2023	17/02/2024	18/06/2023	18/02/2024	18/06/2023	18/02/2024
Watercourse	Main stream	Main stream	Waterfall series stream	Waterfall series stream	Salubrious passage stream	Salubrious passage stream	Main stream	Main stream	Cwm Dwr stream	Cwm Dwr stream
Location	OFD I sump exit	OFD I sump exit	Exit of wet way	Exit of wet way	U/S junction to Trident, by wedged boulder	U/S junction to Trident, by wedged boulder	Cwm Dwr confluence	Cwm Dwr confluence	5m U/S confluence with main stream	5m U/S confluence with main stream
PSEUDONIPHARGIDAE	-	-	-	-	-	-	-	-	-	-
Microniphargus leruthi Schellenberg, 1934	-	-	-	-	2	-	-	-	2	-
ASELLIDAE	-	-	-	-	-	-	-	-	-	-
Proasellus cavaticus (Leydig, 1871)	134	64	6	18	-	-	5	8	63	19
COPEPODA	-	-	-	-	-	-	-	-	-	-
Diacyclops bicuspidatus (Claus, 1857)	-	-	-	-	-	-	-	1	-	-
Eucyclops serrulatus	2	-	-	-	-	-	1	-	-	-
Cyclopoida spp.	-	-	3	4	-	-	-	-	-	-
OSTRACODA	-	-	-	-	-	-	-	-	-	-
Cavernocypris subterranea (Wolf, 1920)	-	2	-	-	-	-	-	-	-	-
ACARI	-	-	-	-	-	-	-	-	-	-
HALACARIDAE	-	-	-	-	-	-	-	-	-	-
Soldanellonyx chappuisi Walter, 1917	-	3	-	-	-	-	-	-	3	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-
LEUCTRIDAE	-	-	-	-	-	-	-	-	-	-
Leuctra inermis Kempny, 1899	-	-	-	-	-	-	3	1	-	-
Leuctra hippopus Kempny, 1899	-	1	-	-	-	-	-	-	-	-
Leuctra sp. (1st instar)	1	18	-	2	-	-	-	-	-	-
TAENIOPTERYGIDAE	-	-	-	-	-	-	-	-	-	-
Brachyptera risi (Morton, 1896)	-	-	-	-	-	-	-	1	-	-
EPHEMEROPTERA	-	-	-	-	-	-	-	-	-	-
HEPTAGENIIDAE	-	-	-	-	-	-	-	-	-	-
Electrogena lateralis (Curtis, 1834)	1	6	-	-	-	-	2	-	1	-
Rhithrogena semicolorata (Curtis, 1834)	-	-	-	-	-	-	3	4	-	-
Rhithrogena sp.	-	6	-	-	-	-	-	-	-	-
Ecdyonurus sp.	-	8	-	-	-	-	-	2	-	-
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-
Paraleptophlebia sp.	-	-	-	-	-	-	-	1	-	-
BAETIDAE	-	-	-	-	-	-	-	-	-	-

Site number	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5
Date	01/06/2023	18/01/2025	01/06/2023	18/01/2025	02/06/2023	17/02/2024	18/06/2023	18/02/2024	18/06/2023	18/02/2024
Watercourse	Main stream	Main stream	Waterfall series stream	Waterfall series stream	Salubrious passage stream	Salubrious passage stream	Main stream	Main stream	Cwm Dwr stream	Cwm Dwr stream
Location	OFD I sump exit	OFD I sump exit	Exit of wet way	Exit of wet way	U/S junction to Trident, by wedged boulder	U/S junction to Trident, by wedged boulder	Cwm Dwr confluence	Cwm Dwr confluence	5m U/S confluence with main stream	5m U/S confluence with main stream
Baetis sp. (1st instar)	-	3	-	-	-	-	1	4	-	-
TRICHOPTERA	-	-	-	-	-	-	-	-	-	-
PHILOPOTAMIDAE	-	-	-	-	-	-	-	-	-	-
Wormaldia occipitalis (Pictet, 1834)	-	-	-	-	-	-	-	1	-	-
POLYCENTROPODIDAE	-	-	-	-	-	-	-	-	-	-
Plectrocnemia sp.	-	-	-	-	-	-	3	-	-	-
Polycentropodidae spp. (indet. 1st instar)	-	1	-	-	-	-	-	-	-	-
DIPTERA	-	-	-	-	-	-	-	-	-	-
CHIRONOMIDAE	-	-	-	-	-	-	-	-	-	-
Chironomidae spp.	2	2	-	3	6	-	3	-	-	-
SIMULIIDAE	-	-	-	-	-	-	-	-	-	-
Simulium sp.	-	2	-	-	-	-	1	-	-	-
Nos. Distinct Taxa	**10**	**15**	**7**	**8**	**5**	**0**	**14**	**15**	**8**	**3**
Nos. Stygobionts	**2**	**2**	**2**	**2**	**2**	**0**	**3**	**2**	**3**	**1**
Nos. Eustygophiles	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**
PHYSICAL CHARACTERISTICS	-	-	-	-	-	-	-	-	-	-
Average Width (m)	1	1	0.5	1	1	1.5	2	3	0.5	1.25
Average Depth (cm)	30-100	30-100	5-10	15	5-10	10-15	10-20	40	10-20	30
Temperature (°C)	9.7	9.7	10.2	9.9	9.2	10	10.2	9.6	9.9	9.7
Conductivity (µScm)	251	501	385	459	263	508	253	102	328	217
pH	7.16	8.2	7.66	7.37	7.99	8.18	7.48	7.66	7.4	8.05
Total Dissolved Solids (ppm)	126	210	192	215	131	253	123	546	164	109
SUBSTRATE (%)	-	-	-	-	-	-	-	-	-	-
Sand	5	10	10	10	45	90	0	0	5	2
Gravel	40	40	60	40	35	7	1	1	30	25
Pebbles	40	40	15	30	5	2	9	9	30	30
Cobbles	15	10	10	17	5	0	50	50	30	40
Boulders	0	0	5	3	10	1	40	40	5	3
Bedrock	15	15	5	5	0	0	0	0	0	0

Table 3. List of aquatic invertebrate taxa recorded in lentic habitats in Ogof Ffynnon Ddu. Species highlighted in red are stygobionts and those in blue eustygophiles.

Site number	L1	L1	L2	L2	L3	L3	L4	L4
Date	01/06/2023	18/01/2025	01/06/2023	01/03/2024	02/06/2023	17/02/2024	02/06/2023	17/02/2024
Location	The lake in Ogof Pant Canol	The lake in Ogof Pant Canol	Pools on the Toast Rack	Pools on the Toast rack	Pool immediately past gate to the Columns	Pool close to the Columns	Pool by the Trident	Pool by the Trident
TAXA	-	-	-	-	-	-	-	-
NEMATODA	-	-	1	-	-	-	-	-
OLIGOCHAETA	-	-	-	-	-	-	-	-
LUMBRICIDAE	-	-	-	-	-	-	-	-
Lumbricidae sp. (indet)	-	1	-	-	-	-	-	-
LUMBRICULIDAE	-	-	-	-	-	-	-	-
Stylodrilus heringianus Claparède, 1862	-	-	7	12	-	-	-	-
Stylodrilus sp. (juv.)	-	-	9	-	-	-	-	-
Lumbriculus variegatus Claparède, 1862	-	-	-	6	-	2	-	-
Eclipidrilus lacustris (Verill, 1871)	-	-	-	7	-	-	-	-
Dorydrilus / Trichodrilus (juvs.)	4	-	23	48	-	-	16	20
ENCHYTRAEIDAE	-	-	-	-	-	-	-	-
Enchytraeidae spp.	-	-	6	1	-	2	-	3
Oligochaeta spp.	-	-	4	21	1	7	5	-
CRUSTACEA	-	-	-	-	-	-	-	-
NIPHARGIDAE	-	-	-	-	-	-	-	-
Niphargus fontanus Bate, 1859	6	4	-	8	2	-	-	-
PSEUDONIPHARGIDAE	-	-	-	-	-	-	-	-
Microniphargus leruthi Schellenberg, 1934	58	2	9	12	4	5	-	-
ASELLIDAE	-	-	-	-	-	-	-	-
Proasellus cavaticus (Leydig, 1871)	-	-	2	-	-	1	-	-
COPEPODA	-	-	-	-	-	-	-	-
Paracyclops fimbriatus (Fischer, 1853)	37	-	7	9	1	-	8	2
Eucyclops serrulatus	-	-	1	-	-	-	-	-
OSTRACODA	-	-	-	-	-	-	-	-
Cavernocypris subterranea (Wolf, 1920)	-	-	202	116	-	-	-	-

Site number	L1	L1	L2	L2	L3	L3	L4	L4
Date	01/06/2023	18/01/2025	01/06/2023	01/03/2024	02/06/2023	17/02/2024	02/06/2023	17/02/2024
Location	The lake in Ogof Pant Canol	The lake in Ogof Pant Canol	Pools on the Toast Rack	Pools on the Toast rack	Pool immediately past gate to the Columns	Pool close to the Columns	Pool by the Trident	Pool by the Trident
ACARI	-	-	-	-	-	-	-	-
HALACARIDAE	-	-	-	-	-	-	-	-
Soldanellonyx chappuisi Walter, 1917	1	-	-	-	-	-	-	-
DIPTERA	-	-	-	-	-	-	-	-
CHIRONOMIDAE	-	-	-	-	-	-	-	-
Chironomidae spp.	-	-	8	18	-	-	-	-
CERATOPOGONIDAE	-	-	-	-	-	-	-	-
Sphaeromias sp.	-	-	-	1	-	-	-	-
LIMONIIDAE	-	-	-	-	-	-	-	-
Molophilus sp	-	-	1	1	-	-	-	-
Nos. Distinct Taxa	**5**	**3**	**11**	**12**	**4**	**4**	**2**	**3**
Nos. Stygobionts	**2**	**2**	**2**	**2**	**2**	**2**	**0**	**0**
Nos. Eustygophiles	**2**	**0**	**2**	**2**	**1**	**0**	**1**	**1**
ADDITIONAL TERRESTRIAL TAXA	-	-	-	-	-	-	-	-
COLLEMBOLA	-	-	-	-	-	5	3	5
COLEOPTERA	-	-	-	-	-	-	-	-
PTILINIDAE	-	-	-	-	-	-	-	-
Ptenidium cf. brenskei Flach, 1887	-	1	-	-	-	-	-	-
PHYSICAL CHARACTERISTICS	-	-	-	-	-	-	-	-
Temperature (ºC)	9.3	9.2	9.7	9.5	9.9	9.9	9.3	9.7
Conductivity (µScm)	347	386	352	300	266	186	314	322
pH	8.06	7.92	8.21	7.74	7.59	8.11	7.78	7.79
Total Dissolved Solids (ppm)	175	183	176	150	133	113	157	174

Table 4. List of terrestrial invertebrate taxa collected from the deep cave environment in Ogof Ffynnon Ddu. Species highlighted in red are troglobionts and those in blue eutroglophiles. Records appended with ‘MS’ are those obtained during the timed manual searches and those with ‘Sc’ are those collected from the scouring pads; all other records were obtained from the baited pitfall traps. Dates listed are those on which the traps were removed for examination.

Site number	OFD II T1	OFD II T1	OFD II T2	OFD II T2	OFD I T3	OFD I T3	OFD I T4	OFD I T4
Date	09/06/2023	09/03/2024	09/06/2023	09/03/2024	11/06/2023	09/03/2024	11/06/2023	09/03/2024
Location	Passage off shale chamber with small streamway	Passage off shale chamber with small streamway	Far end big chamber	Far end big chamber	Waterfall series	Waterfall series	Section of main route along flood passage	Section of main route along flood passage
TAXA	-	-	-	-	-	-	-	-
DIPLOPODA	-	-	-	-	-	-	-	-
BLANIULIDAE	-	-	-	-	-	-	-	-
Blaniulus guttulatus (Fabricus, 1798)	-	-	-	-	-	-	-	1 (MS)
ACARI	-	-	-	-	-	-	-	-
RHAGIDIIDAE	-	-	-	-	-	-	-	-
Poecilophysis spelaea (Wankel, 1861)	-	-	-	3	-	-	-	-
DAMAEIDAE	-	-	-	-	-	-	-	-
Damaeus crispatus (Kulczynski, 1902)	-	-	-	-	-	-	1	-
Acari sp.	-	-	-	-	-	-	-	2
COLLEMBOLA	-	-	-	-	-	-	-	-
HYPOGASTRURIDAE	-	-	-	-	-	-	-	-
Schaefferia emucronata Absolon, 1900	-	-	4	-	-	-	4	1
ONYCHIURIDAE	-	-	-	-	-	-	-	-
Onychiurus ambulans (Linnaeus, 1758)	-	1	-	-	-	-	-	-
Deuteraphorura cebennaria (Gisin, 1956)	-	-	-	-	-	-	1	1
Oligaphorura schoetti (Lie-Pettersen, 1897)	-	2	2	1	-	-	-	1
ENTOMOBRYIDAE	-	-	-	-	-	-	-	-
Pseudosinella immaculata (Lie Petterson, 1896)	1	1	-	-	-	-	4	2
ARRHOPALITIDAE	-	-	-	-	-	-	-	-
Pygmarrhopalites pygmaeus (Vargovitch, 2009)	2	1	6	2	1	-	12 (3 from Sc)	5
Arrhopalites caecus (Tullberg, 1871)	1	-	-	-	-	-	-	-
PSOCOPTERA	-	-	-	-	-	-	-	-

Site number	OFD II T1	OFD II T1	OFD II T2	OFD II T2	OFD I T3	OFD I T3	OFD I T4	OFD I T4
Date	09/06/2023	09/03/2024	09/06/2023	09/03/2024	11/06/2023	09/03/2024	11/06/2023	09/03/2024
Location	Passage off shale chamber with small streamway	Passage off shale chamber with small streamway	Far end big chamber	Far end big chamber	Waterfall series	Waterfall series	Section of main route along flood passage	Section of main route along flood passage
ELIPSOCIDAE	-	-	-	-	-	-	-	-
Elipsocidae sp.	-	-	-	-	-	-	-	1
LIPOSCELIDAE	-	-	-	-	-	-	-	-
Liposcelis cf. entomophila (Enderlein, 1907)	4	-	-	-	-	-	-	-
Liposcelis sp	-	-	-	-	-	-	-	1
DIPTERA	-	-	-	-	-	-	-	-
SCIARIDAE	-	-	-	-	-	-	-	-
Bradysia cf. forficulata (Bezzi, 1914)	-	-	1	-	-	-	2	-
Bradysia sp.	-	-	-	1	-	-	-	1
PHORIDAE	-	-	-	-	-	-	-	-
Triphleba lugubris (Meigen, 1830)	2	-	-	7	-	-	2	3
COLEOPTERA	-	-	-	-	-	-	-	-
STAPHYLINIDAE	-	-	-	-	-	-	-	-
Lesteva pubescens Mannerheim, 1830	-	-	-	-	-	-	-	1
Ochthephilus aureus (Fauvel, 1871)	-	-	-	-	-	1	1	6
ELATERIDAE	-	-	-	-	-	-	-	-
Athous haemorrhoidalis (Fabricus, 1801)	-	-	1	-	-	-	-	-
LEIODIDAE	-	-	-	-	-	-	-	-
Choleva glauca Britten, 1918	-	-	-	-	-	-	1	-
Coleoptera sp. (larvae)	-	-	-	-	-	-	2	-
Nos. Distinct Taxa	**5**	**4**	**5**	**5**	**1**	**1**	**9**	**13**
Nos. Troglobionts	**0**	**1**	**1**	**2**	**0**	**0**	**0**	**1**
Nos. Eutroglophiles	**3**	**3**	**2**	**1**	**1**	**1**	**5**	**7**
Nos. Subtroglophiles	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 5. List of terrestrial invertebrate taxa recorded in the thresholds of the three Ogof Ffynnon Ddu entrances. Species highlighted in blue are eutroglophiles and those in green subtroglophiles. “x” denotes presence of taxa.

Entrance & date	OFD 1 summer 6/7/2023	OFD 1 winter 4/1/2024	Cwm Dwr summer 6/7/2023	Cwm Dwr winter 4/1/2024	OFD 2 summer 6/7/2023	OFD 2 winter 4/1/2024
TAXA	-	-	-	-	-	-
OLIGOCHAETA	-	-	-	-	-	-
LUMBRICIDAE	-	-	-	-	-	-
Eiseniella tetraedra (Savigny, 1826)	-	X	-	-	-	-
Aporrectodea sp. ?	-	X	-	-	-	-
GASTROPODA	-	-	-	-	-	-
ARIONIDAE	-	-	-	-	-	-
Arion ater	X	-	X	-	-	-
Slug indet. sp.	-	-	X	-	-	-
PATULIDAE	-	-	-	-	-	-
Discus rotundatus (O.F. Mũller, 1774)	-	-	-	-	X	-
OXYCHILIDAE	-	-	-	-	-	-
Oxychilus cellarius (O.F. Mũller, 1774)	X	-	-	-	X	X
CRUSTACEA	-	-	-	-	-	-
ISOPODA	-	-	-	-	-	-
ONISCIDAE	-	-	-	-	-	-
Oniscus asellus Linnaeus, 1758	-	-	-	-	X	X
DIPLOPODA	-	-	-	-	-	-
CRASPEDOSOMATIDAE	-	-	-	-	-	-
Nangona polydesmoides (Leach, 1815)	X	-	-	-	-	-
POLYDESMIDAE	-	-	-	-	-	-
Brachydesmus superus Latzel, 1884	-	X	-	-	-	-
OPILIONES	-	-	-	-	-	-
SABACONIDAE	-	-	-	-	-	-
Sabacon viscayanum ramblaianum Martens, 1983	X	-	-	-	-	X
PHALANGIIDAE	-	-	-	-	-	-
Phalangium sp.	-	-	-	-	X	-
ARANEAE	-	-	-	-	-	-
TETRAGNATHIDAE	-	-	-	-	-	-
Meta menardi (Latreille, 1804)	X	X	X	-	X	-
Metellina merianae (Scopoli, 1763)	-	X	-	X	X	X
Metellina mengei (Blackwall, 1869)	X	-	-	-	-	-
Meta / Metellina sp.	-	-	-	-	-	X
NESTICIDAE	-	-	-	-	-	-
Nesticus cellulanus (Clerck, 1757)	-	X	X	X	-	-
AGELENIDAE	-	-	-	-	-	-
Eratigena saeva (Blackwall, 1844)	-	-	-	X	-	-
Tegenaria silvestris Koch, 1872	-	-	X	X	X	X

Entrance & date	OFD 1 summer 6/7/2023	OFD 1 winter 4/1/2024	Cwm Dwr summer 6/7/2023	Cwm Dwr winter 4/1/2024	OFD 2 summer 6/7/2023	OFD 2 winter 4/1/2024
LINYPHIIDAE	-	-	-	-	-	-
Tenuiphantes zimmermanni Bertkau, 1890	-	-	X	-	-	-
Porrhomma cf. pallidum Jackson, 1913	-	-	X	-	-	-
COLLEMBOLA	-	X	X	-	-	-
ARCHAEOGNATHA	-	-	-	-	-	-
MACHIIDAE	-	-	-	-	-	-
Dilta hibernica (Carpenter, 1907)	X	-	-	-	-	-
TRICHOPTERA	-	-	-	-	-	-
LIMNEPHILIDAE	-	-	-	-	-	-
Stenophylax permistus (McLachlan, 1895) adults	X	-	-	-	X	-
LEPIDOPTERA	-	-	-	-	-	-
EREBIDAE	-	-	-	-	-	-
Scoliopteryx libatrix (Linnaeus, 1758)	-	-	-	-	X	-
DIPTERA	-	-	-	-	-	-
TRICHOCERIDAE	-	-	-	-	-	-
Trichocera regelationis (Linnaeus, 1758)	-	X	-	-	-	-
LIMONIIDAE	-	-	-	-	-	-
Limonia nebeculosa Meigen, 1804	X	-	-	-	-	-
Lipsothrix remota (Walker, 1848)	-	-	X	-	-	-
PEDICIIDAE	-	-	-	-	-	-
Dicranota claripennis (Verrall, 1888)	-	X	-	-	-	-
BOLITOPHILIDAE	-	-	-	-	-	-
Bolitophila cf. cinerea Meigen, 1818	X	-	-	-	-	-
Bolitophilidae sp.	-	-	-	-	-	X
CULICIDAE	-	-	-	-	-	-
Culex pipiens Linnaeus, 1758	-	X	-	-	-	X
DIXIDAE	-	-	-	-	-	-
Dixidae sp.	X	-	-	-	-	-
HELEOMYZIDAE	-	-	-	-	-	-
Heleomyza serrata / captiosa	X	X	X	X	X	X
Scoliocentra villosa (Meigen, 1830)	X	X	-	-	-	-
Gymnomus caesius (Meigen, 1830)	X	-	X	-	-	-
MYCETOPHILIDAE	-	-	-	-	-	-
Rymosia fasciata (Meigen, 1804)	-	X	-	-	-	-
Mycetophilidae sp.	-	X	-	-	-	-
SPHAEROCERIDAE	-	-	-	-	-	-
Sphaeroceridae sp.	X	X	-	-	-	-
HYMENOPTERA	-	-	-	-	-	-
PROCTOTRUPIDAE	-	-	-	-	-	-
Exallonyx longicornis (Nees, 1834)	X	-	-	X	-	-
CHIROPTERA	-	-	-	-	-	-

Entrance & date	OFD 1 summer 6/7/2023	OFD 1 winter 4/1/2024	Cwm Dwr summer 6/7/2023	Cwm Dwr winter 4/1/2024	OFD 2 summer 6/7/2023	OFD 2 winter 4/1/2024
RHINOLOPHIDAE	-	-	-	-	-	-
Rhinolophus ferrumequinum (Schreber, 1774)	-	-	-	-	-	X
VESPERTILIONIDAE	-	-	-	-	-	
Myotis mystacinus / brandtii	-	-	-	-	-	X
Nos. Distinct Taxa (excluding Chiroptera)	**16**	**14**	**10**	**6**	**10**	**9**
Nos. Troglobionts	**0**	**0**	**0**	**0**	**0**	**0**
Nos. Eutroglophiles	**4**	**5**	**2**	**2**	**3**	**2**
Nos. Subtroglophiles	**4**	**2**	**1**	**2**	**3**	**2**

Table 6. Summary of the invertebrate taxa recorded in Ogof Draenen.

Invertebrate taxa	No. taxa	Troglobionts	Eutroglophiles	Subtroglophiles
Aquatic taxa	**34**	**5:** *Niphargus fontanus, Microniphargus leruthi, Proasellus cavaticus, Antrobathynella stammeri, Fabaeformiscandona wegelini*	**5:** *Dorydrilus michaelseni, Gammarus pulex, Paracyclops fimbriatus, Cavernocypris subterranea, Soldanellonyx chappuisi*	**0**
Terrestrial taxa: deep cave	**20**	**4**: *Poecilophysis spelaea, Oligaphorura schoetti, Folsomia agrelli, Porrhomma rosenhaueri*	**3**: *Schaefferia emucronata, Deuteraphorura cebennaria, Pygmarrhopalites pygmaeus*	**2**: *Stenophylax permistus, Heleomyza serrata / captiosa*
Terrestrial taxa: threshold	**28**	**0**	**6:** *Oxychilus cellarius, Meta menardi, Metellina merianae, Nesticus cellulanus, Palliduphantes pallidus, Speolepta leptogaster*	**5**: *Triphosa dubitata, Scoliopteryx libatrix, Limonia nebeculosa, Culex pipiens, Exallonyx longicornis*
Key historical records not found in current survey	**56**	**1:** *Fabaeformiscandona breuili*	**7:** *Phagocata vitta, Blaniulus guttulatus, Diacyclops languidoides, Graeteriella (cf. boui??), Bryocamptus echinatus, Bryocamptus zschokkei, Bryocamptus pygmaeus*	**0**

Table 7. List of aquatic invertebrate taxa recorded in streams in Ogof Draenen. Species highlighted in red are stygobionts and those in blue eustygophiles.

Site number	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5
Date	15/05/2023	27/01/2024	15/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	02/02/2024
Watercourse	Beyond A Choke stream	Beyond A Choke stream	Agent Blorenge stream	Agent Blorenge stream	Beyond A Choke stream	Beyond A Choke stream	Stream u/s Tea Junction	Stream u/s Tea Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction
Location	5m downstream Agent Blorenge confluence	5m downstream Agent Blorenge confluence	2m upstream confluence with Beyond A Choke stream	2m upstream confluence with Beyond A Choke stream	Just below confluence of Gilwern passage and Tea Junction	Just below confluence of Gilwern passage and Tea Junction	Bogus camp, u/s Tea Junction	Bogus camp, u/s Tea Junction	10m d/s 5m waterfall	10m d/s 5m waterfall
TAXA	-	-	-	-	-	-	-	-	-	-
MICROTURBELLARIA	-	-	-	2	-	-	-	-	-	-
TRICLADIDA	-	-	-	-	-	-	-	-	-	-
PLANARIIDAE	-	-	-	-	-	-	-	-	-	-
Polycelis felina (Dalyell, 1814)	-	-	-	1	-	-	-	-	-	-
NEMATODA	20	2	3	21	11	2	25	5	46	9
OLIGOCHAETA	-	-	-	-	-	-	-	-	-	-
LUMBRICULIDAE	-	-	-	-	-	-	-	-	-	-
Stylodrilus heringianus Claparède, 1862	2	5	-	16	1	-	11	1	-	-
Stylodrilus sp.(juvs.)	-	-	-	9	-	-	-	3	-	-
Lumbriculus variegatus Claparède, 1862	1	5	1	-	-	-	6	10	2	13
Eclipidrilus lacustris (Verill, 1871)	93	10	-	-	2	-	-	-	1	-
DORYDRILIDAE	-	-	-	-	-	-	-	-	-	-
Dorydrilus michaelseni Piguet, 1913	-	2	-	2	-	-	-	-	-	-
Dorydrilus / Trichodrilus (juvs.)	5	37	51	51	25	3	65	63	77	62
ENCHYTRAEIDAE	-	-	-	-	-	-	-	-	-	-
Enchytraeidae spp.	-	13	-	-	-	1	7	2	6	-
NAIDIDAE	-	-	-	-	-	-	-	-	-	-
Nais elinguis Mūller, 1774	-	-	-	-	-	-	-	-	-	3
Pristina sp.	-	-	-	-	-	-	-	-	2	-
TUBIFICIDAE	-	-	-	-	-	-	-	-	-	-
Limnodrilus udekemianus Claparède, 1862	-	-	-	-	-	-	-	-	-	1
Limnodrilus sp. (juv.)	-	-	-	-	2	-	-	-	-	-

Site number	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5
Date	15/05/2023	27/01/2024	15/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	02/02/2024
Watercourse	Beyond A Choke stream	Beyond A Choke stream	Agent Blorenge stream	Agent Blorenge stream	Beyond A Choke stream	Beyond A Choke stream	Stream u/s Tea Junction	Stream u/s Tea Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction
Location	5m downstream Agent Blorenge confluence	5m downstream Agent Blorenge confluence	2m upstream confluence with Beyond A Choke stream	2m upstream confluence with Beyond A Choke stream	Just below confluence of Gilwern passage and Tea Junction	Just below confluence of Gilwern passage and Tea Junction	Bogus camp, u/s Tea Junction	Bogus camp, u/s Tea Junction	10m d/s 5m waterfall	10m d/s 5m waterfall
Oligochaeta spp.	42	18	150	177	35	10	39	94	59	19
BIVALVIA	-	-	-	-	-	-	-	-	-	-
SPHAERIIDAE	-	-	-	-	-	-	-	-	-	-
Euglesa personata (Malm, 1855)	-	-	-	-	-	-	-	-	-	1
Euglesa sp.	-	-	-	-	-	-	-	-	1	1
ACARI	-	-	-	-	-	-	-	-	-	-
HALICARIDAE	-	-	-	-	-	-	-	-	-	-
Soldanellonyx chappuisi Walter, 1917	-	1	-	-	-	-	-	-	-	-
CRUSTACEA	-	-	-	-	-	-	-	-	-	-
BATHYNELLIDAE	-	-	-	-	-	-	-	-	-	-
Antrobathynella stammeri (Jakobi, 1954)	3	4	10	5	-	-	-	-	-	-
GAMMARIDAE	-	-	-	-	-	-	-	-	-	-
Gammarus pulex (Linnaeus, 1758)	-	-	-	-	-	-	-	1	-	11
Gammarus pulex / fossarum	-	-	-	2	-	-	3	-	4	-
NIPHARGIDAE	-	-	-	-	-	-	-	-	-	-
Niphargus fontanus Bate, 1859	1	2	-	-	2	-	-	3	-	-
PSEUDONIPHARGIDAE	-	-	-	-	-	-	-	-	-	-
Microniphargus leruthi Schellenberg, 1934	2	-	-	-	-	-	-	-	-	-
ASELLIDAE	-	-	-	-	-	-	-	-	-	-
Proasellus cavaticus (Leydig, 1871)	49	18	53	102	35	1	23	21	4	6
COPEPODA	-	-	-	-	-	-	-	-	-	-
Eucyclops serulatus (Fischer, 1851)	5	-	-	-	4	-	2	3	-	-
Paracyclops fimbriatus (Fischer, 1853)	4	3	-	3	1	-	1	2	1	1
Megacyclops gigas	-	-	-	-	-	-	-	-	3	-
OSTRACODA	-	-	-	-	-	-	-	-	-	-
Cavernocypris subterranea (Wolf, 1920)	30	16	39	149	-	-	-	-	-	-

Site number	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5
Date	15/05/2023	27/01/2024	15/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	02/02/2024
Watercourse	Beyond A Choke stream	Beyond A Choke stream	Agent Blorenge stream	Agent Blorenge stream	Beyond A Choke stream	Beyond A Choke stream	Stream u/s Tea Junction	Stream u/s Tea Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction
Location	5m downstream Agent Blorenge confluence	5m downstream Agent Blorenge confluence	2m upstream confluence with Beyond A Choke stream	2m upstream confluence with Beyond A Choke stream	Just below confluence of Gilwern passage and Tea Junction	Just below confluence of Gilwern passage and Tea Junction	Bogus camp, u/s Tea Junction	Bogus camp, u/s Tea Junction	10m d/s 5m waterfall	10m d/s 5m waterfall
Fabaeformiscandona wegelini (Petkovski, 1962)	-	-	-	-	-	-	-	-	-	1
Pseudocandona sp.	-	-	-	1	-	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-
LEUCTRIDAE	-	-	-	-	-	-	-	-	-	-
Leuctra hippopus Kempny, 1899	-	-	-	-	-	-	-	-	-	1
Leuctra sp.	-	-	-	-	-	-	-	-	-	2
NEMOURIDAE	-	-	-	-	-	-	-	-	-	-
Nemoura cambrica gp.	-	1	-	-	-	-	-	-	-	-
Nemoura sp. (1st instar)	-	-	-	1	-	-	2	1	2	1
EPHEMEROPTERA	-	-	-	-	-	-	-	-	-	-
BAETIDAE	-	-	-	-	-	-	-	-	-	-
Baetis sp. (1st instar)	-	-	-	1	-	-	-	-	-	-
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-
Habrophlebia fusca (Curtis, 1834)	-	-	-	-	-	-	-	-	1	-
TRICHOPTERA	-	-	-	-	-	-	-	-	-	-
POLYCENTROPODIDAE	-	-	-	-	-	-	-	-	-	-
Plectrocnemia geniculata McLachlan, 1871	-	-	-	-	-	-	-	-	1	3
Plectrocnemia sp.	-	-	1	-	-	-	2	-	11	9
PHILOPOTAMIDAE	-	-	-	-	-	-	-	-	-	-
Wormaldia occipitalis (Pictet, 1834)	-	-	-	-	-	-	-	-	1	6
DIPTERA	-	-	-	-	-	-	-	-	-	-
CHIRONOMIDAE	-	-	-	-	-	-	-	-	-	-
Pentaneura sp.	-	-	-	-	-	-	-	-	3	-
Chironomidae spp.	2	-	-	1	3	-	-	19	4	20
SIMULIIDAE	-	-	-	-	-	-	-	-	-	-
Simulium cryophilum (Rubstov, 1959)	-	-	-	-	-	-	-	5	1	1

Site number	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5
Date	15/05/2023	27/01/2024	15/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	27/01/2024	14/05/2023	02/02/2024
Watercourse	Beyond A Choke stream	Beyond A Choke stream	Agent Blorenge stream	Agent Blorenge stream	Beyond A Choke stream	Beyond A Choke stream	Stream u/s Tea Junction	Stream u/s Tea Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction	Stream flowing from calcited choke south of Outcast Passage to Cairn Junction
Location	5m downstream Agent Blorenge confluence	5m downstream Agent Blorenge confluence	2m upstream confluence with Beyond A Choke stream	2m upstream confluence with Beyond A Choke stream	Just below confluence of Gilwern passage and Tea Junction	Just below confluence of Gilwern passage and Tea Junction	Bogus camp, u/s Tea Junction	Bogus camp, u/s Tea Junction	10m d/s 5m waterfall	10m d/s 5m waterfall
Simulium sp.	-	-	-	-	-	-	-	1	2	-
CERATOPOGONIDAE	-	-	-	-	-	-	-	-	-	-
Palpomyia / Bezzia gp.	1	-	-	-	-	-	1	-	-	-
Sphaeromias sp.	-	-	-	1	-	-	-	-	6	14
Nos. Distinct Taxa	**14**	**13**	**7**	**16**	**10**	**4**	**12**	**13**	**18**	**17**
Nos. Stygobionts	**4**	**3**	**2**	**2**	**2**	**1**	**1**	**2**	**1**	**2**
Nos. Eustygophiles	**2**	**4**	**1**	**4**	**1**	**0**	**2**	**2**	**2**	**2**
ADDITIONAL TERRESTRIAL TAXA	-	-	-	-	-	-	-	-	-	-
ARANEAE	-	-	-	-	-	-	-	-	-	-
OONOPIDAE	-	-	-	-	-	-	-	-	-	-
Oonops domesticus / pulcher	-	-	-	-	1	-	-	-	-	-
PHYSICAL CHARACTERISTICS	-	-	-	-	-	-	-	-	-	-
Average Width (m)	2	2	0.75	1	1	1	1-2	2	1	1.5
Average Depth (cm)	20-40	30-40	5-10	10-15	20	20	5-20	20	10	15
Temperature (°C)	8.7	8.7	8	8.9	8.4	8.6	8.5	8.4	8.7	8.7
Conductivity (µScm)	206	178	185	177	222	153	238	175	216	156
pH	7.9	7.92	7.95	7.92	8.13	7.9	8.05	7.88	7.91	8.2
Total Dissolved Solids (ppm)	103	78	92	90	111	77	119	93	108	78
SUBSTRATE (%)	-	-	-	-	-	-	-	-	-	-
Sand	25	20	30	15	20	30	3	2	3	1
Gravel	50	60	67	80	73	38	70	70	40	9
Pebbles	10	10	2	0	2	2	22	20	40	25
Cobbles	10	5	0	0	0	0	3	5	15	50
Boulders	5	5	1	5	5	30	2	3	2	15
Bedrock	30	30	10	10	20	20	0	0	5	0

Table 8. List of aquatic invertebrate taxa recorded in lentic habitats in Ogof Draenen. Species highlighted in red are stygobionts and those in blue eustygophiles.

Site number	L1	L1	L2	L2	L3	L3	L4	L4
Date	15/05/2023	27/01/2024	14/05/2023	02/02/2024	14/05/2023	02/02/2024	14/05/2023	02/02/2024
Location	Static linear pools along Haggis Basher passage	Static linear pools along Haggis Basher passage	Pools below small inlet above waterfall in Lamb & Fox chamber	Pools below small inlet above waterfall in Lamb & Fox chamber	Pools in vicinity of Giles Shirt, Gilwern passage	Pools in vicinity of Giles Shirt, Gilwern passage	Large pool beneath 4m rope climb, end of Entrance series	Large pool beneath 4m rope climb, end of Entrance series
TAXA	-	-	-	-	-	-	-	-
NEMATODA	-	4	-	-	1	-	-	-
OLIGOCHAETA	-	-	-	-	-	-	-	-
LUMBRICULIDAE	-	-	-	-	-	-	-	-
Stylodrilus heringianus Claparède, 1862	1	-	-	1	-	-	-	-
DORYDRILIDAE	-	-	-	-	-	-	-	-
Dorydrilus michaelseni Piguet, 1913	-	-	4	2	-	-	-	-
Dorydrilus / Trichodrilus (juvs.)	19	2	6	6	7	-	6	10
ENCHYTRAEIDAE	-	-	-	-	-	-	-	-
Enchytraeidae spp.	2	-	1	3	2	-	-	-
NAIDIDAE	-	-	-	-	-	-	-	-
Nais elinguis Mũller, 1774	-	-	-	-	-	-	-	1
TUBIFICIDAE	-	-	-	-	-	-	-	-
Tubifex ignotus (Stolc, 1886)	-	-	-	2	-	-	-	-
Oligochaeta spp.	10	11	11	8	9	5	2	-
CRUSTACEA	-	-	-	-	-	-	-	-
NIPHARGIDAE	-	-	-	-	-	-	-	-
Niphargus fontanus Bate, 1859	2	2	-	1	4	2	2	1
PSEUDONIPHARGIDAE	-	-	-	-	-	-	-	-
Microniphargus leruthi Schellenberg, 1934	3	3	1	-	1	1	2	2
ASELLIDAE	-	-	-	-	-	-	-	-
Proasellus cavaticus (Leydig, 1871)	6	1	-	-	1	1	-	-
COPEPODA	-	-	-	-	-	-	-	-
Eucyclops serulatus (Fischer, 1851)	2	1	-	-	-	-	-	-
Paracyclops fimbriatus (Fischer, 1853)	-	2	-	1	-	-	-	8
OSTRACODA	-	-	-	-	-	-	-	-
Cavernocypris subterranea (Wolf, 1920)	1	-	-	-	-	-	-	-
TRICHOPTERA	-	-	-	-	-	-	-	-
PHILOPOTAMIDAE	-	-	-	-	-	-	-	-

Site number	L1	L1	L2	L2	L3	L3	L4	L4
Date	15/05/2023	27/01/2024	14/05/2023	02/02/2024	14/05/2023	02/02/2024	14/05/2023	02/02/2024
Location	Static linear pools along Haggis Basher passage	Static linear pools along Haggis Basher passage	Pools below small inlet above waterfall in Lamb & Fox chamber	Pools below small inlet above waterfall in Lamb & Fox chamber	Pools in vicinity of Giles Shirt, Gilwern passage	Pools in vicinity of Giles Shirt, Gilwern passage	Large pool beneath 4m rope climb, end of Entrance series	Large pool beneath 4m rope climb, end of Entrance series
Wormaldia occipitalis (Pictet, 1834)	-	-	-	1	-	-	-	-
DIPTERA	-	-	-	-	-	-	-	-
CHIRONOMIDAE	-	-	-	-	-	-	-	-
Chironomidae spp.	-	4	-	-	-	-	-	-
SIMULIIDAE	-	-	-	-	-	-	-	-
Simulium cryophilum (Rubstov, 1959)	-	1	-	-	-	-	-	-
Simulium sp.	-	1	-	-	-	-	-	-
Nos. Distinct Taxa	**8**	**8**	**3**	**7**	**6**	**4**	**3**	**5**
Nos. Stygobionts	**3**	**3**	**1**	**1**	**3**	**3**	**2**	**2**
Nos. Eustygophiles	**1**	**1**	**1**	**2**	**0**	**0**	**0**	**1**
ADDITIONAL TERRESTRIAL TAXA	-	-	-	-	-	-	-	-
ACARI	-	-	-	-	-	-	-	-
RHAGIDIIDAE	-	-	-	-	-	-	-	-
Poecilophysis spelaea (Wankel, 1861)	-	-	-	-	-	-	1	-
COLLEMBOLA	-	-	-	-	-	-	-	-
ISOTOMIDAE	-	-	-	-	-	-	-	-
Folsomia agrelli Gisin, 1944	-	-	-	-	-	-	1	-
Collembola sp.	-	-	-	-	-	-	2	30
DIPLURA	-	-	-	-	-	-	-	-
CAMPODEIDAE	-	-	-	-	-	-	-	-
Campodea cf. wallacei Bagnall, 1918	-	-	-	-	-	-	3	-
PSOCOPTERA	-	-	-	-	-	-	-	-
TROGIIDAE	-	-	-	-	-	-	-	-
Cerobasis guestfalica (Kolbe, 1880)	-	-	-	-	2	-	-	-
Trogiidae sp.	-	1	-	-	-	-	-	-
PHYSICAL CHARACTERISTICS	-	-	-	-	-	-	-	-
Temperature (°C)	8.7	8.7	8.5	8.5	9.4	9.4	8.6	8.7
Conductivity (µScm)	277	220	171	171	279	274	379	136
pH	7.9	7.92	8	8	8.02	8.15	8	8.41
Total Dissolved Solids (ppm)	131	219	86	86	167	140	173	68

Table 9: List of terrestrial invertebrate taxa collected from the deep cave environment in Ogof Draenen. Species highlighted in red are troglobionts, those in blue eutroglophiles, and those in green subtroglophiles. Records appended with 'MS' are those obtained during the timed manual searches and those with 'Sc' are those collected from the scouring pads; all other records were obtained from the baited pitfall traps. Dates listed are those on which the traps were removed for examination.

Sample number	Draenen T1	Draenen T1	Draenen T1a	Draenen T2	Draenen T2	Draenen T3	Draenen T3	Draenen T4	Draenen T4
Date	09/07/2023	19/03/2024	09/07/2023	09/07/2023	19/03/2024	09/07/2023	19/03/2024	09/07/2023	19/03/2024
Location	Entrance series, section prior to rope climb down	Entrance series, section prior to rope climb down	Cairn Chamber	Waterfall Series area	Waterfall Series area	Gilwern passage	Gilwern passage	Streamway before Tea Junction	Streamway before Tea Junction
ACARI	-	-	-	-	-	-	-	-	-
RHAGIDIIDAE	-	-	-	-	-	-	-	-	-
Poecilophysis spelaea (Wankel, 1861)	-	1	-	-	-	-	-	-	-
Acari sp.	-	-	-	-	-	-	-	1	-
ARANEAE	-	-	-	-	-	-	-	-	-
LINYPHIIDAE	-	-	-	-	-	-	-	-	-
Porrhomma rosenhaueri (Koch, 1872)	-	-	1 (MS)	-	-	-	-	-	-
COLLEMBOLA	-	-	-	-	-	-	-	-	-
HYPOGASTRURIDAE	-	-	-	-	-	-	-	-	-
Schaefferia emucronata Absolon, 1900	-	-	-	-	-	1 (Sc)	-	-	-
ONYCHIURIDAE	-	-	-	-	-	-	-	-	-
Deuteraphorura cebennaria (Gisin, 1956)	1	-	-	-	-	-	-	-	-
Oligaphorura schoetti (Lie-Pettersen, 1897)	-	-	-	-	-	2 (1 from Sc)	-	1	-
ISOTOMIDAE	-	-	-	-	-	-	-	-	-
Cryptopygus sp. (New to UK?)	-	-	-	-	2	-	-	-	-
ARRHOPALITIDAE	-	-	-	-	-	-	-	-	-
Pygmarrhopalites pygmaeus (Vargovitch, 2009)	7	1	-	2	1	-	2	-	-
DIPLURA	-	-	-	-	-	-	-	-	-
CAMPODEIDAE	-	-	-	-	-	-	-	-	-
Campodea cf *wallacei* Bagnall, 1918	20	16	1 (MS)	81	282	1	2	6	46
TRICHOPTERA	-	-	-	-	-	-	-	-	-
PHILOPOTAMIDAE	-	-	-	-	-	-	-	-	-
Wormaldia occipitalis (Pictet, 1834) adult	-	-	-	1 (MS)	-	-	-	-	-

Sample number	Draenen T1	Draenen T1	Draenen T1a	Draenen T2	Draenen T2	Draenen T3	Draenen T3	Draenen T4	Draenen T4
Date	09/07/2023	19/03/2024	09/07/2023	09/07/2023	19/03/2024	09/07/2023	19/03/2024	09/07/2023	19/03/2024
Location	Entrance series, section prior to rope climb down	Entrance series, section prior to rope climb down	Cairn Chamber	Waterfall Series area	Waterfall Series area	Gilwern passage	Gilwern passage	Streamway before Tea Junction	Streamway before Tea Junction
LIMNEPHILIDAE	-	-	-	-	-	-	-	-	-
Stenophylax permistus (McLachlan, 1895) adult	-	-	-	1 (MS)	-	-	-	-	-
PSOCOPTERA	-	-	-	-	-	-	-	-	-
TROGIIDAE	-	-	-	-	-	-	-	-	-
Cerobasis guestfalica (Kolbe, 1880)	-	-	-	-	-	-	-	1	-
LIPOSCELIDAE	-	-	-	-	-	-	-	-	-
Liposcelis sp	-	-	-	-	-	-	2	-	-
DIPTERA	-	-	-	-	-	-	-	-	-
MYCETOPHILIDAE	-	-	-	-	-	-	-	-	-
Exechiopsis subulata (Winnertz, 1864)	1	-	-	-	-	-	-	-	-
SCIARIDAE	-	-	-	-	-	-	-	-	-
Bradysia cf. forficulata (Bezzi, 1914)	1	-	-	5	-	-	-	1	-
Bradysia sp.	1	-	-	1	-	-	-	-	-
BOLITOPHILIDAE	-	-	-	-	-	-	-	-	-
Bolitophila cinerea Meigen, 1818	-	-	1 (MS)	-	-	-	-	1 (MS)	-
HELEOMYZIDAE	-	-	-	-	-	-	-	-	-
Heleomyza serrata / captiosa	-	3	1 (MS)	-	3	-	-	-	-
PHORIDAE	-	-	-	-	-	-	-	-	-
Triphleba lugubris (Meigen, 1830)	-	1	-	26	-	-	-	-	-
Phoridae sp.	-	-	-	2	-	-	-	-	-
HYMENOPTERA	-	-	-	-	-	-	-	-	-
TRICHOGRAMMATIDAE	-	-	-	-	-	-	-	-	-
Trichogramma sp.	-	-	-	-	-	1 (Sc)	-	-	-
COLEOPTERA	-	-	-	-	-	-	-	-	-
LEIODIDAE	-	-	-	-	-	-	-	-	-
Choleva lederiana Reitter, 1902	-	-	-	-	1	-	-	-	-

Sample number	Draenen T1	Draenen T1	Draenen T1a	Draenen T2	Draenen T2	Draenen T3	Draenen T3	Draenen T4	Draenen T4
Date	09/07/2023	19/03/2024	09/07/2023	09/07/2023	19/03/2024	09/07/2023	19/03/2024	09/07/2023	19/03/2024
Location	Entrance series, section prior to rope climb down	Entrance series, section prior to rope climb down	Cairn Chamber	Waterfall Series area	Waterfall Series area	Gilwern passage	Gilwern passage	Streamway before Tea Junction	Streamway before Tea Junction
Nos. Distinct Taxa	**5**	**5**	**4**	**6**	**5**	**4**	**3**	**6**	**1**
Nos. Troglobionts	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**0**
Nos. Eutroglophiles	**2**	**1**	**0**	**1**	**1**	**1**	**1**	**0**	**0**
Nos. Subtroglophiles	**0**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**

Table 10. List of terrestrial invertebrate taxa recorded in the thresholds of the three Ogof Draenen entrances. Species highlighted in blue are eutroglophiles and those in green subtroglophiles. “x” denotes presence of taxa.

Entrance & date	Main entrance summer 4/7/2023	Main entrance winter 7/1/2024	Nunnery entrance summer 4/7/2023	Nunnery entrance winter 7/1/2024	Drws Cefn summer 4/7/2023	Drws Cefn winter 7/1/2024
TAXA	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	-
BOETTGERILLIDAE	-	-	-	-	-	-
Boettgerilla pallens Simroth, 1912	-	X	-	-	-	-
LIMACIDAE	-	-	-	-	-	-
Lehmannia marginata (O.F. Mũller, 1774)	-	-	-	-	-	X
Slug indet. sp.	X	-	-	-	X	-
OXYCHILIDAE	-	-	-	-	-	-
Oxychilus cellarius (O.F. Mũller, 1774)	-	-	X	-	-	-
CRUSTACEA	-	-	-	-	-	-
ISOPODA	-	-	-	-	-	-
ONISCIDAE	-	-	-	-	-	-
Oniscus asellus Linnaeus, 1758	-	-	-	-	X	-
DIPLOPODA	-	-	-	-	-	-
CHORDEUMATIDAE	-	-	-	-	-	-
Melogona gallica (Latzel, 1884)	-	-	X	-	-	-
ACARI	-	-	-	-	X	-
OPILIONES	-	-	-	-	-	-
SABACONIDAE	-	-	-	-	-	-
Sabacon viscayanum ramblaianum Martens, 1983	X	X	-	-	-	-
ARANEAE	-	-	-	-	-	-
TETRAGNATHIDAE	-	-	-	-	-	-
Meta menardi (Latreille, 1804)	X	X	X	X	X	X
Metellina merianae (Scopoli, 1763)	-	-	X	-	-	X
NESTICIDAE	-	-	-	-	-	-
Nesticus cellulanus (Clerck, 1757)	X	-	-	-	-	X
LINYPHIIDAE	-	-	-	-	-	-
Palliduphantes pallidus (Cambridge, 1871)	X	X	-	-	-	-
Saaristoa firma (Cambridge, 1905)	-	-	-	-	-	X
Linyphiidae sp.	-	-	-	-	X	-
LEPIDOPTERA	-	-	-	-	-	-
GEOMETRIDAE	-	-	-	-	-	-
Triphosa dubitata (Linnaeus, 1758)	-	X	-	X	-	X
Colosygia pectinataria (Knoch, 1781)	-	-	X	-	-	-
EREBIDAE	-	-	-	-	-	-
Scoliopteryx libatrix (Linnaeus, 1758)	-	-	-	X	-	X
GLYPHIPTERIGIDAE	-	-	-	-	-	-
Digitivalva pulicariae (Klimesch, 1956)	X	-	X	-	-	-

Entrance & date	Main entrance summer 4/7/2023	Main entrance winter 7/1/2024	Nunnery entrance summer 4/7/2023	Nunnery entrance winter 7/1/2024	Drws Cefn summer 4/7/2023	Drws Cefn winter 7/1/2024
Lepidoptera indet.	-	-	X	-	-	-
DIPTERA	-	-	-	-	-	-
TRICHOCERIDAE	-	-	-	-	-	-
Trichocera major Edwards, 1921	-	-	-	X	-	-
LIMONIIDAE	-	-	-	-	-	-
Limonia nebeculosa Meigen, 1804	X	-	X	-	X	-
BOLITOPHILIDAE	-	-	-	-	-	-
Bolitophila cinerea Meigen, 1818	X	-	-	-	-	-
CECIDOMYIDAE	-	-	-	-	-	-
Cecidomyidae sp.	-	-	X	-	-	-
CULICIDAE	-	-	-	-	-	-
Culex pipiens Linnaeus, 1758	-	-	-	X	-	-
HELEOMYZIDAE	-	-	-	-	-	-
Heleomyza serrata / captiosa	X	X	-	X	-	X
Eccoptomera longiseta (Meigen, 1830)	X	-	-	-	-	-
Gymnomus caesius (Meigen, 1830)	X	-	X	-	-	-
MYCETOPHILIDAE	-	-	-	-	-	-
Speolepta leptogaster (Winnertz, 1863) adults	-	-	X	-	-	-
Speolepta leptogaster (Winnertz, 1863) larvae	-	-	-	-	-	X
Tarnania cf. nemoralis (Edwards, 1941)	-	-	-	-	X	-
Mycetophilidae sp.	X	-	X	-	-	X
PSYCHODIDAE	-	-	-	-	-	-
Psychodidae sp.	X	-	-	-	X	-
SCIARIDAE	-	-	-	-	-	-
Sciaridae sp.	-	X	-	-	-	-
SPHAEROCERIDAE	-	-	-	-	-	-
Sphaeroceridae sp.	X	-	-	-	X	X
HYMENOPTERA	-	-	-	-	-	-
ICHNEUMONIDAE	-	-	-	-	-	-
Ichneumonidae sp.	-	-	-	-	X	-
PROCTOTRUPIDAE	-	-	-	-	-	-
Exallonyx longicornis (Nees, 1834)	-	-	-	-	-	X
Proctotrupidae sp.	-	-	X	-	-	-
COLEOPTERA	-	-	-	-	-	-
LEIODIDAE	-	-	-	-	-	-
Choleva glauca Britten, 1918	-	-	X	-	-	-
Nos. Distinct Taxa	**14**	**7**	**12**	**6**	**10**	**11**
Nos. Troglobionts	**0**	**0**	**0**	**0**	**0**	**0**
Nos. Eutroglophiles	**3**	**2**	**4**	**1**	**1**	**4**
Nos. Subtroglophiles	**2**	**2**	**1**	**4**	**1**	**4**

4. Discussion

This case study represents the first effort to establish surveys in British cave systems in which a set number of designated sites have been sampled using methods designed to offer a degree of repeatability, such that the initial baseline results can be critically appraised against future surveys. This is also the first time in which such sites and methods have been investigated in two distinct seasons, offering a degree of comparability in seasonal variations of the fauna within the two systems.

4.1 Ogof Ffynnon Ddu: species and communities of note

Ogof Fynnon Ddu has a long history of biological recording, including both during the Hazleton-Glennie period of British cave biology and the NCC survey of Jefferson and Chapman (1979). Much of this work was done on a rather *ad hoc* basis, with the aim being to provide a descriptive list of species within the system. The current survey is of particular value in that it provided a much more detailed focus on aquatic habitats within the cave that was lacking in previous research. Subsequently it is no surprise that the majority of the new records added to the taxa list are of aquatic invertebrates, or at least the aquatic stages of various insect groups.

The stygobiontic Crustacea *Proasellus cavaticus, Niphargus fontanus, Microniphargus leruthi* were already known from the system but the records of *Antrobathynella stammeri* are the first from OFD at its third known location in Wales, having been previously recorded in Ogof Draenen by Knight *et al.* (2018) and in Dan yr Ogof in 2021; and also more recently (2025) at a fourth location in Agen Allwedd (HCRS data). The species was recorded in small numbers at sites S4 and S5, in the vicinity of the confluence of the Main Stream and Cwm Dwr Stream in June 2023.

The amphipod *Crangonyx subterraneus* was not recorded in the Ogof Pant Canol lake (L1) and has not been collected from this location since it was recorded by E.A. Glennie in 1951, along with *Proasellus cavaticus* and *Niphargus fontanus*. The latter two species have been recorded in the lake on three occasions - in 1947, 1948 and 1951. A visit to the lake by L. Knight and A. Lewington in 2016 to try and obtain further *C. subterraneus* specimens only collected *N. fontanus* and *Microniphargus*, both of which were also present during the current survey, the latter in large numbers. *Microniphargus* is a relatively recent addition to the British fauna, being first recorded in Ireland in 2006 by Arnscheidt *et al.* (2008, 2012) and later in Britain by Knight (2011), when it was first recorded in Swildon's Hole in 2010 (Knight & Gledhill, 2010). Although it is much smaller than *C. subterraneus*, the two species share some morphological similarities that differentiate them from *Niphargus*, notably the rectangular shape of the gnathopods which are triangular in *Niphargus* species. Glennie was certainly aware of the stygobiontic Crustacea fauna of the British Isles and indeed published widely on the subject in the 1950s and 1960s. However, as *Microniphargus* was unknown in Britain at the time, there is the suggestion that he might have collected *Microniphargus* that he mistakenly assumed were juvenile *C.*

subterraneus. In Britain, the latter is more widely recorded from the interstitial habitat, springs, wells and boreholes, rather than caves and its distribution appears to show a strong correlation with aquifers in chalk or limestone. It is only known from three caves, the Pant Canol record and two caves in Cheddar Gorge, Reservoir Hole and Gough's Cave, the latter two sites being the only confirmed modern records (Knight, 2015). In conclusion, whilst it cannot be said for certain, it is unlikely that *C. subterraneus* occurs in the OFD system.

Other species of interest (eustygophiles) include: the cyclopoid copepod *Paracyclops fimbriatus* (Fischer, 1853), present at all four lentic sites; *Diacyclops bicuspidatus* (Claus, 1857) a single specimen of which was recorded at S1 in January 2025; the halicarid mite *Soldanellonyx chappuisi* Walter, 1917 at S1, S5 and L1; the ostracod *Cavernocypris subterranea* (Wolf, 1920), present in small numbers at S1 in January 2025 and in particularly large numbers in the pools at L2 in both seasons; and the oligochaete *Dorydrilus michaelseni* Piguet, 1913, a single specimen of which was recorded at S4 in January 2025. Most small species of *Dorydrilus / Trichodrilus* oligochaetes are also associated with groundwater and the unidentified juveniles within many of the samples could also be regarded as stygophilic, although without further determination their ecological status is uncertain.

Overall numbers and diversity of invertebrates was slightly less in lentic habitats in comparison to the stream sites, with Oligocheata and stygobionts (and especially *C. subterranea* at L2) making up larger proportions of the assemblages. *Antrobathynella* was limited to the stream community, whilst *P. fimbriatus* appeared to only occur in lentic habitats. *Proasellus cavaticus* was most abundant in stream sites, whilst overall *N. fontanus* and, more notably, *Microniphargus*, were proportionally more abundant in lentic sites. This is probably due to the lack of flow being more conducive to small species such as copepods and *Microniphargus*. *Niphargus* is also known to prefer slower flows, generally preferring the margins of cave streams. Ginet (1960) stated that *Niphargus* is not a good swimmer, and it has been observed to be prone to washing out by strong currents in cave streams, suggesting it is somewhat rheophobic, preferring calm water (Mathieu & Turquin, 1992), probably due to its rather long legs attracting considerable drag. Conversely, the dorsal-ventrally flattened body shape of *P. cavaticus* would make it better equipped to cope with faster flow regimes and it might be the case that this species selectively prefers cave streams as a way to avoid *N. fontanus*, which has been observed preying upon *P. cavaticus* in Welsh cave systems (Glennie, 1956; Chapman, 1993; Knight & Johns, 2015).

Washed-in stygoxene taxa within the stream community were most obvious at the two main stream sites (S1 and S4) in small numbers, including species of Plecoptera, Ephemeroptera and Trichoptera; those at S1 having survived a long way underground from the main surface sink at Pwll Byfre. The absence of the amphipod *Gammarus pulex* from the stream assemblage is somewhat surprising, given this species often occurs in large numbers in cave streams with any degree of surface connectivity, and its previous records from the cave. It is certainly a species that should be looked for in future surveys. The problems associated with collecting elements of the neuston community from lentic sites were mentioned in the Results section, and despite Collembola being observed on the surface of pools at L3 and L4 these were not determined further; this remains a neglected aspect of the community structure of the cave. Jefferson *et al*. (2004) noted that Collembola occurred widely on pool surfaces throughout the cave and discuss the association of various species within the neuston. The occurrence of the beetle *Ptenidium brenskei* in the aquatic sample from L1 is probably a result of the specimen being washed into the net from the adjacent shore whilst sampling and reflects the relative closeness of this site to the surface.

For the terrestrial fauna, as expected the greatest diversity was found in the threshold zone of the caves, which is also the most studied due to accessibility. The list of species included many of the typical elements of the parietal community, including common seasonal subtroglophiles such as *Stenophylax permistus* (McLachlan, 1895), *Scoliopteryx libatrix* (Linnaeus, 1758), *Culex pipiens* Linnaeus, 1758, *Limonia nebeculosa* Meigen, 1804 and *Heleomyza serrata / captiosa*, and eutroglophilic spiders such as *Meta menardi* (Latreille, 1804), *Metallina merianae* (Scopoli, 1763) and *Nesticus cellulanus* (Clerck, 1757).

The proctotrupid wasp *Exallonyx longicornis* (Nees, 1834) was an unusual element of the community as, although known from the threshold of a few caves and mines in Mendips, Devon and Wales, it is not a regular member of the parietal community, although Novak *et al.* (2010) found it to be quite common in caves in Europe. Proctotrupid wasps parasitise the grubs of various Coleoptera and Diptera, with *E. longicornis* targeting Carabidae, Staphylinidae (Askew, 1971) and Mycetophilidae (Noyes *et al.,* 1999) in particular, and it might be the case that they regularly enter the threshold of caves in search of suitable hosts. Another unusual species recorded was the harvestman (Opiliones) *Sabacon viscayanum ramblianum* Martens, 1983. This species is rare in Britain having only been recorded from 29 locations, 23 of which are in South Wales. It was first recorded in the UK on the Gower in the 1980s (Abbott, 1981) and has been spreading across Wales steadily since, with several records from caves, including Lesser Garth Cave and Ogof y Ci, where it was recorded in 2017 (Carter, 2018), with further records from Agen Allwedd, Ogof Pen Eryr and Porth yr Ogof (A. Lewington, pers. obs.), suggesting it has a positive association with caves and is possibly spreading into this habitat in Britain.

The tissue moth (*Triphosa dubitata* (Linnaeus, 1758)) and the gnat *Speolepta leptogaster* (Winnertz, 1863) were noticeably absent from the threshold in the current survey, despite previous records from the cave. It should be noted that all three entrances to OFD are gated with heavy metal doors. Whilst controlling access and thus providing a degree of protection to the system, such gates might also restrict the fauna within the threshold zone, in comparison to that of more open cave entrances elsewhere.

As expected the dark zone terrestrial fauna deeper into the cave showed a considerable decrease in diversity. Although OFD is notable for its diverse community of cavernicolous Collembola throughout, only 50% of the species previously recorded from the cave were collected in the current survey, although this did include a new record, that of the eutroglophile *Onychiurus ambulans*, suggesting that it is likely there are still species to be discovered. Amending the aforementioned shortcomings in thoroughly investigating the neuston community in future surveys might address this gap in future surveys.

Pygmarrhopalites pygmaeus (Vargovitch, 2009) was the most common species recorded, being present at all four of the terrestrial sites. The troglobiontic species *Oligaphorura schoetti* was recorded at sites T1, 2 and 4, whilst the troglobiontic mite *Poecliophysis spelaea* was recorded at T2 in the winter 2024 survey.

Other eutroglophilic species recorded in both the threshold and deep cave environments included the millipedes *Nanogona polydesmoides* (Leach, 1815), *Brachydesmus superus* Latzel, 1884 and *Blaniulus guttulatus* (Fabricus, 1798), the snail *Oxychilus cellarius* (O.F. Mũller, 1774) and the fly *Scoliocentra villosa* (Meigen, 1830). The winter gnat *Trichocera maculipennis* Meigen, 1818 was not recorded. Jefferson and Chapman (1979) noted this species as being widespread but infrequent throughout the system, with remains widespread and common. Open liver baits attracted large numbers of the larvae, but this method was not employed in the current study. Similarly, the woodlouse *Androniscus dentiger* Verhoeff, 1908, a fairly common eutroglophile in many caves and previously recorded from OFD, was not observed. This is likely to reflect the sparsity of the British cave fauna in general and the fact that their distributions tend to be very much clumped in nature, concentrating around suitable resources where available.

Within the Diptera, a number of species were recorded including potentially two species of Sciaridae. However, only female specimens of Sciaridae were collected which are difficult to identify to species level, although some female specimens were nominally identified as *Bradysia* cf *forticulat*a (Bezzi, 1914) using the collections at Amgueddfa Cymru – National Museum Wales. Also recorded was the phorid *Triphleba lugubris* (Meigen, 1830) in both OFD and Ogof Draenen, which has been previously unrecorded from caves in South Wales. A voucher was identified by the Diptera specialist John Deeming and deposited into the collections of Amgueddfa Cymru. It is interesting that whilst this species has not previously been recorded from caves in South Wales, *Triphleba antricola* (Schmitz, 1918) has been. This latter species is one of the commonest phorids found in European caves (Disney, 2012) and both Langourov (2000) and Smith (1989) regard is a troglophile, suggesting other species in the genus may also have an association with subterranean environments.

Amongst the four species of Coleoptera collected were the eutroglophiles *Lesteva pubescens* Mannerheim, 1830 and *Ochthephilus aureus* (Fauvel, 1871), the latter appearing to be a well-established part of the fauna along the Flood Passage section of OFD I. The records of *Choleva glauca* Britten, 1918 and *Athous haemorrhoidalis* (Fabricus, 1801) are new for the system, the former also present along Flood Passage. Although *O. aureus* has been previously recorded within OFD I and some other cave sites in South Wales, neither species has been widely recorded in the UK and both specimens have been deposited into the voucher collections at Amgueddfa Cymru. Another eutroglophile, the carabid *Trechoblemus micros* (Herbst, 1784), recorded by Jefferson and Chapman (1979) as widespread but infrequent, was not recorded; they did note its apparent scarcity in OFD, since this is otherwise one of the commonest terrestrial beetles in British caves.

Other new records for OFD included several specimens of Psocoptera, at sites T1 and T4, with those at T1 tentatively identified as *Liposcelis entomophila* (Enderlein, 1907). The Psocoptera as a group appear not to have been previously recorded from Welsh caves.

4.2 Ogof Draenen: species and communities of note

In contrast to OFD, much of the previous research conducted in Ogof Draenen has focused on aquatic habitats. The taxa recorded from the stream and lentic sites were similar to those recorded throughout the cave by Knight *et al*. (2018), although lacking in chironomid diversity, due to the previous survey including determinations of this group beyond family level. Notable were the five stygobionts *N. fontanus, Microniphargus, P. cavaticus*, *Fabaeformiscandona wegelini* (Petkovski, 1962) and *Antrobathynella*, the latter present at sites S1 and S2, along with large numbers of the ostracod *Cavernocypris subterranean.* The single specimen of the stygobiontic ostracod *F. wegelini*, collected at S5 in winter, is new for the cave, making Ogof Draenen its only Welsh location, and the second location for this species in Britain, having previously been collected from drip-fed pools in Swildon's Hole (Knight & Mori, 2022). A total of six (seven if one also includes the record of *N. aquilex* from the Ogof Cwm Dyar resurgence discussed in Section 1.4.2) stygobiontic species are now known from Ogof Draenen, making it the most diverse stygobiontic fauna recorded in a British cave.

Differences between the stream and lentic communities were similar to those observed in OFD, with large numbers of *P. cavaticus* at the stream sites, whilst much lower numbers of *P. cavaticus* and higher numbers of *N. fontanus* and *Microniphargus* were present at lentic sites. One notable difference was that stream sites contained a higher diversity and abundance of Oligochaeta, the reverse of the situation in OFD. Also, unlike OFD, the copepod *P. fimbriatus* appeared to be much more widespread in stream compared to lentic sites. *Dorydrilus michaelseni* was recorded in small numbers at S1, S2 and L2, whilst just a single specimen of *S. chappuisi* was recorded at S1 in January 2024.

Various stygoxene aquatic insect larvae and *Gammarus* were recorded in small numbers throughout the stream sites, but were most noticeable at S4, the upper reaches of the system's main watercourse and especially S5, a site known to be close to one of the surface sinks sampled by Knight *et al*. (2018).

Collembola were observed on the surfaces of pools at several lentic sites, most noticeably L4 from which the troglobiontic mite *Poecilophysis spelaea*, the dipluran *Campodea cf. wallacei* Bagnall, 1918 and the troglobiontic collembolan *Folsomia agrelli*, were collected in May 2023, suggesting that the neuston community might be more widespread in the cave than currently known. The spider *Oonops dosmesticus / pulcher* from the margins of S3, is a very unusual record as this species is not known from British caves. As it was collected incidentally during aquatic netting it was not possible to determine if the single specimen was washed in from the surface, although its condition would suggest otherwise. Similarly, the specimens of the psocopterans *Cerobasis guestfalica* (Kolbe, 1880) from L3 and T4 and *Liposcelis* sp. at T3 are of note.

The parietal threshold community showed many similarities to that of OFD, with a similar list of eutroglophiles and subtroglophiles, including *Exallonyx longicornis* and *Sabacon viscayanum ramblianum*, as well as *Triphosa dubitata* and both larvae and adults of *Speolepta leptogaster* which were not recorded from OFD.

Within the deep cave, the fauna included the troglobionts *Poecilophysis spelaea, Folsomia agrelli* and *Oligaphorura schoetti*, as well as a single specimen of the troglobiontic spider *Porrhomma rosenhaueri* in Cairn Chamber, making this just the third site for this species in Britain, all in South Wales (Lesser Garth Cave and Ogof y Ci [Nant Glais Caves]).

Eutroglophiles within both the deep cave and threshold included: the spiders *Meta menardi, Metellina merianae, Nesticus cellulanus* and *Palliduphantes pallidus* (Cambridge, 1871); *Oxychilus cellarius*; and the sprjngtails *Schaefferia emucronata* Absolon, 1900, *Deuteraphorura cebennaria* (Gisin, 1956) and *Pygmarrhopalites pygmaeus* which, as in OFD, was the most widespread and abundant species. Two specimens of Collembola, in the genus *Cryptopygus*, collected at T2 in the Waterfall Series, did not key out in the established keys of Hopkin (2007) and Fjellberg (2007), and might well be a previously unknown species that requires further investigation. The dipluran *Campodea cf wallacei* was particularly abundant throughout the system at all four terrestrial sites, especially T2, and can often be observed on the surfaces of pools and rocks throughout the cave. The identification is still a comparative one as the Diplura are a poorly understood group within the UK fauna and this is potentially a new record for the UK, although further research is required.

Eutroglophilic millipedes and Coleoptera were noticeably lacking in Ogof Draenen, with just two beetle records - *Choleva glauca* in the threshold of the Nunnery Entrance in summer 2023 and *Choleva lederiana* Reitter, 1902 at T2 in March 2024. All *Choleva* species are generalist scavengers, typically in or near small mammal runs and burrows or amongst rock debris (Duff, 2012). *Choleva agilis* (Illiger, 1798) is considered a eutroglophile, being known from several caves across Britain and with a substantial established population documented in Agen Allwedd (Hazleton, 1971*). Choleva lederiana* is a very similar species often found in caves and rocky debris in upland areas and due to their very similar morphology there has been confusion between the two in the past, such that Duff (2012) states that all records before 2003 should be treated with caution; thus much of the information on *C. agilis* regarding its affiliation for subterranean habitats might in fact apply to *C. lederiana*. It is believed that the preferred habitus of *C. lederiana* suggests it is a glacial relic, indicating that habitats such as caves are potential refugia in a warming climate.

4.3 Comparison of the fauna in the two caves

Overall, the invertebrate assemblages of both caves are quite similar in diversity and composition in both aquatic and terrestrial habitats and it is likely that future surveys of this nature will reveal similar faunas in other large cave systems across South Wales, notably those of the Llangattock escarpment above Crickhowell.

One notable difference between the two systems is the considerably more diverse and abundant Collembola fauna of OFD compared to Ogof Draenen. With the current available data, it is hard to ascertain if this might be a sampling artefact, i.e. the long history of biological recording in OFD has produced more data. However, the current survey recorded 7 species in OFD, 50% of the 14 known from the system, and 5 in Ogof Draenen, including a potentially new species of *Cryptopygus*, with a further two, *Protaphorura armata* (Tullberg, 1869) and *Parisotoma notabilis* Schäffer, 1896 collected from the margins of aquatic habitats by Knight *et al.* (2018). The dipluran *Campodea cf wallacei* is widespread in Ogof Draenen, where it is clearly a key component of the terrestrial invertebrate assemblage, but appears to be absent from OFD. Diplurans are quite common in caves worldwide (Conde, 1955; Sendra *et al*., 2013) but have been overlooked in a British context. They occupy a similar niche to Collembola, and it could be that their abundance in Ogof Draenen has competitively excluded some Collembola species, although further research will be required to determine this.

Several, relatively common terrestrial eutroglophiles known from OFD appear to be absent from Ogof Draenen. Aside from the records of single specimens of *C. lederiana* and *C. glauca,* Coleoptera were almost absent in comparison to OFD. However, this might also be a sampling artefact, and future surveys of the terrestrial invertebrates in Ogof Draenen are likely to significantly increase the number of species. There are records of "Staphylinidae" and "Carabidae" in the PDCMG records, but without determination beyond family the diversity of these two groups remains unknown. The results of the current survey suggest that full inventories of the invertebrate species inhabiting both cave systems are far from complete.

4.4 The effects of seasonality on the survey

It is generally considered that due to the rather buffered environment and relatively low fluctuations in environmental parameters, the stable environment of the deep cave habitat is not likely to exhibit much in the way of seasonality. In many older works (e.g. Racoviță, 1907; Poulson & White, 1969), the environmental constancy of subterranean habitats has been overemphasised, but nevertheless they do show considerably less amplitude of variation in environmental parameters in comparison to epigean habitats due to their isolation from the surface environment. Hawes (1939) argued that the cycle of annual flooding in caves in the Dinaric karst was vital to the timing of reproduction, availability of food, and dispersal and colonisation into caves, and that this cycle replaced the circadian rhythm absent in many subterranean organisms. Cave ecosystems in Britan rely on the input of exogenous matter from the surface to provide the most basic level of their food chains and increasing groundwater flow in the wet winter months is liable to result in increased nutritional input.

The impact of seasonality on the vadose stream communities in both caves was not entirely clear. One assumption was that the increased input of water at sinks feeding into the caves would result in greater flushing through of fauna in the streams and potentially an increase in the ingress of stygoxenes from the surface. This certainly occurred at S1 and S4 in OFD during the winter survey, although the diversity and abundance of stygoxenes was low in both seasons. This was less obvious at S4 and S5 in Ogof Draenen, with the only significant difference being an increase in the numbers of chironomid larvae in the winter.

In OFD, *Antrobathynella* was only recorded at S4 and S5 during June 2023 and was absent in February 2024, but in Ogof Draenen it was present in both seasons at S1 and S2. The stygobiontic ostracod *F. wegelini* was only recorded in Draenen at S5 in the winter. Numbers of *P. cavaticus* at stream sites in OFD were higher in the summer survey compared to winter, although once again this was less clear cut in Ogof Draenen, with numbers actually increasing at S2 in the winter. In OFD, several key species including *C. subterranea, D. michaelseni*, and *D. bisetosus* were only recorded in the winter, whilst in Ogof Draenen there appeared to be little effect on the presence of *P. fimbriatus* and *C. subterranea* in the streams, although numbers of the latter species at S2 significantly increased in the winter. Overall, the effect of seasonality on stream sites in both caves was unclear with some sites recording higher diversity and some lower in winter. At S3 in OFD, whilst this site was the least diverse of all the stream sites anyway, fauna was completely absent in the winter. It might be the case that streams in OFD are subjected to much greater flushing than those in Ogof Draenen during wet weather and this is certainly the case with the main conduit at the base of the cave.

As expected the effects of seasonality were even less significant in lentic habitats, with species composition being fairly similar in both seasons, although it could be claimed that the lower diversity of the lentic assemblages compared to those of the streams would curtail seasonal variation and that ideally a much higher number of sites in both habitats would be required to truly gauge any significant seasonal changes in community composition. One noteworthy exception was the ‘Lake’ at L1 in OFD, where winter sampling produced significantly less diversity and much lower numbers of *Microniphargus.* However, this was most likely due to the high winter levels necessitating a change in the sampling method. In the summer, levels were low enough that it was possible to wade around the lake basin and kick / sweep with the net. In winter, high levels meant that only a small portion of the shore was accessible for net sweeping, with the deeper water having to be sampled using a trawl net, making coverage of the habitat far less efficient.

Season also had virtually no effect on the terrestrial sampling in the deep cave, except that single specimens of some species were recorded in either summer or winter, more a result of two visits, rather than one, increasing the likelihood of collecting taxa. One notable difference was that numbers of *C. cf. wallacei* increased significantly at T2 and T4 in Ogof Draenen in the winter survey; at the latter site, it was the only species present in winter. This could be due to T4 being adjacent to a stream (Site S4) and rising water levels in the winter, prior to sampling had washed out other terrestrial taxa. This increase in numbers could also be due to seasonal downwards migration of this species in the soil and an increased likelihood of it entering the cave system beneath.

As expected, the only true seasonality was noted in the data from the threshold surveys, where various subtroglophiles use the threshold as a place of shelter at varying times of the year. Adults of the caddis *Stenophylax permistus* and the cranefly *Limonia nebeculosa* use the habitat for a period of summer diapause, whilst species such *as Scoliopteryx libatrix, Triphosa dubitata* and *Culex pipiens* use it for winter hibernation, with the eutroglophilic spider population present all year round (Chapman, 1993; Knight *et al*., in prep.).

Overall, aside from the seasonal threshold visitors listed above, the fauna of both caves appeared to exhibit little in the way of seasonality in their occurrence, although it could be argued that many more sites throughout the different biotopes would be required to investigate the phenomenon more thoroughly.

4.5 Critical appraisal of the methods & recommendations for future surveys

Timed netting of aquatic habitats is widely recognised as an effective method in sampling such habitats on the surface (Drake *et al.,* 2007) and is just as effective underground. The standard FBA pattern pond net includes a variant in which the 1m long handle can break down into three separate parts, making it relatively easy to transport through a cave. There are also nets with smaller frame sizes to sample narrow streams and even the option to pump and filter the water from small pools as described by Brancelj (2004). Larger lakes can be sampled using a combination of netting around the margins and the use of a trawl net for the deeper reaches, as was used at L1 in OFD in the winter, although this method is less efficient than being able to cover the whole waterbody with a pond net. The methods described above have provided robust data from cave aquatic habitats during several studies (e.g. Knight, 2011; Knight *et al*., 2018, 2022) and should be adopted to assess the invertebrate assemblages of vadose cave streams and lentic habitats in future CSM surveys.

Sampling the terrestrial fauna involved a combination of three methods - manual searching, the placement of scouring pads to act as artificial refugia and baited pitfall traps.

Manual searching in the thresholds produced robust results, recording many of the key species that make up the parietal assemblage, especially as many of these are to be found on the walls and ceiling, often where they are more obvious to find. The use of a pooter is recommended for capturing Diptera as this minimises damage to delicate structures that might be required for identification (e.g. wing venation). Pitfall trapping was not employed and might have collected more of the terrestrial eutroglophiles present, although a single visit in each season with manual searching appears to be sufficient in providing a list of the majority of the species inhabiting cave thresholds.

Manual searching within the deep cave environment appeared to be much less effective, collecting very small numbers of specimens. This is not surprising, given the sparsity of the British cave fauna and the fact that most temperate cave ecosystems rely on the input of exogenous matter from the surface. Hence, they tend to be resource-limited (Gibert & Deharveng, 2002), leading to the fauna having clumped distributions (spatial aggregation) centred around available nutrition. However, it should be noted that the manual searching did produce some interesting records of a few species that were not collected in the pitfall traps, notably the spider *Porrhomma rosenhaueri*, the fly *Bolitophila cinerea* Meigen, 1818 and the specimens of adult caddis (*Wormaldia occipitalis* (Pictet, 1834) and *Stenophylax permistus*) on the cave wall at T2 in Ogof Draenen, and the eutroglophilic millipede *Blaniulus guttulatus* at T4 in OFD. Thus, although generally unproductive, this method is still a valuable adjunct to the pitfall trapping and should be retained for future surveys.

The failure to successfully collect Collembola from pool surfaces and thus to effectively investigate the neuston assemblage has been discussed. The only case where this was successful was at L4 in Ogof Draenen during the summer, where two important records were obtained - the troglobiontic mite *Poecilophysis spelaea* and springtail *Folsomia agrelli*, the latter the only record for this important species from Ogof Draenen during the survey. Collecting specimens by 'floating them' on to a paint brush held just beneath the surface was thought to have been effective in the past, but many specimens were obviously lost during transferral to small vials. An alternative method might be to consider 'netting' specimens from the surface with a fine mesh tea strainer, then placing them into a smaller container of water for collection with a brush or forceps. Sampling the neuston community on larger pools can be particularly problematic, as it involved considerable effort not to disrupt the water and cause ripples and to minimise disturbance to the habitat prior to aquatic sampling. It might be worth considering this as a separate activity to aquatic sampling, in that pools are the subject of their own targeted manual searching using the method described above; selecting an area with many small pools and then sampling a set number at any given location.

The use of scouring pads as artificial refugia was surprisingly ineffective. Peter Shaw and L. Knight (unpublished data) used them very effectively in Baker's Pit, Devon to sample the Collembola of the cave, almost doubling the known list of species in one sampling event. Both baited and un-baited pads were used in Baker's Pit, although both proved equally effective at attracting Collembola. During the current survey, the number of specimens obtained from the scouring pads was minimal and it was felt that the effort involved in placing, collecting and processing them did not justify the results. However, it should be noted that the single specimens of the hymenopteran *Trichogramma* sp. and the eutroglophilic springtail *Schaefferia emucronata,* collected via this method in Ogof Draenen, were the only records of these species for this cave in the current survey. It might prove to be the case that the method will be more effective in other cave systems and its use in future surveys should not be entirely discounted. However, for further monitoring in the two caves investigated it does not appear to be particularly efficient.

The main method employed for sampling the terrestrial invertebrate assemblage of the deep cave environment was the use of baited pitfall traps. Initially it was planned to use a variety of baits, both carbohydrate and protein based (meat, treacle and crab), but this was abandoned in favour of processed cheese. Note that unprocessed cheese can often come with its own fauna of cheese mites and thus is to be avoided. Also, the time between deployment and collection was changed from the recommended 7-10 days in the protocol (Appendix A) to one month, as it was felt that given the scarcity of terrestrial fauna in British caves, a longer period of placement would improve the effectiveness of the traps whilst not causing much of an impact on the cave's fauna.

The placement of the traps was problematic at some locations in both caves, as it was often hard to find locations with sufficiently soft substrate in which they could be buried (many of the passages consisted of beds of large clasts), which could somewhat limit surveys. Pitfall traps also limit the survey to sampling those elements of the invertebrate fauna that are sufficiently mobile and potentially attracted to the bait used. A more detailed, targeted study into the effectiveness of different types of bait is perhaps required to refine the method further. Overall, the use of bait traps, accompanied by manual searching appeared to be the most practicable method for assessing the terrestrial invertebrate assemblage of the deep cave in the current survey and is recommended for future CSM monitoring.

Aside from the expected influence on the threshold surveys, seasonality appeared to have very little effect on the results further into the dark zone, apart from the inherent hazards of accessing some sites during high winter stream flows. A few extra species were recorded during the winter surveys, but it could equally be argued that increasing the number of sampling visits will obviously increase the number of taxa. It is recommended that for baseline surveys of a cave system then at least two visits in different seasons are still undertaken to produce a comprehensive list of taxa. However, for future CSM monitoring in OFD and Ogof Draenen it is likely that a single sampling event in the late spring / early summer will be sufficient to assess the invertebrate assemblages of the deep cave against the recommended condition targets below. The exception to this is the threshold, which due to the more seasonal nature of some of its parietal fauna will still require both winter and summer visits to be effectively investigated.

With the increasing development and improvement in eDNA techniques, these could be a viable option for condition monitoring, and might yet prove more effective, and certainly less intrusive, at assessing cave faunas in the future. Such methods are already being trialled in cave systems across Europe and their refinement will add yet another tool to the methods that can be employed in such surveys.

5. Conclusions

- Surveys of the invertebrate assemblages in two large Welsh cave systems, Ogof Fynnon Ddu (OFD) and Ogof Draenen were carried out to provide base-line data against which future condition monitoring can be compared and to trial the methods required for such surveys at both the study sites and other potential designated cave sites across Wales.

- Both caves have been the subject of biological investigations in the past, primarily of the terrestrial invertebrate fauna in OFD and the aquatic invertebrate fauna in Ogof Draenen, allowing the results of the current survey to be critically evaluated against historical data.

- The aquatic invertebrate assemblages of both stream and lentic habitats within the caves were sampled by a timed period of netting, with five stream sites and four lentic habitats selected in each cave to form the basis of a future monitoring network.

- Terrestrial invertebrate assemblages were investigated in both the threshold zone of the cave entrances and within the deep cave (dark zone) environment. Each cave has three entrances that were investigated for their fauna, using manual ground searching. Further into the deep cave, four terrestrial sites were selected for terrestrial invertebrate sampling involving a combination of three methods - manual searching, the placement of scouring pads as artificial refugia, and baited pitfall trapping.

- Surveys were carried out in spring / early summer (May / June 2023) and winter (January / February 2024 and 2025).

- The survey in OFD recorded a total of 84 distinct invertebrate taxa, including 32 aquatic taxa (29 in streams and 16 in lentic habitats), 19 terrestrial taxa within the deep cave environment and an additional 33 taxa in the thresholds of the three entrances. The lists include 4 stygobionts, 5 eustygophiles, 2 troglobionts, 16 eutroglophiles and 6 subtroglophiles. Of the taxa recorded, 30 had previously been recorded from the cave, adding 54 new records, mostly within the aquatic biome. The previous record of the stygobiontic amphipod *Crangonyx subterraneus* in the Pant Canol Lake (L1) is called into question as a possible misidentification of *Microniphargus*, and this species might not in fact occur within the OFD system. A total of 123 invertebrate taxa are now known from the system (including 5 stygobionts (including *C. subterraneus*), 10 eustygophiles, 4 troglobionts, 26 eutroglophiles and 7 subtroglophiles).

- The survey in Ogof Draenen recorded a total of 84 distinct invertebrate taxa, including 36 aquatic taxa (35 in streams and 15 in lentic habitats), 20 terrestrial taxa within the deep cave environment and an additional 28 taxa in the thresholds of the three entrances. The lists include 5 stygobionts, 5 eustygophiles, 4 troglobionts, 9 eutroglophiles and 7 subtroglophiles. Of the taxa recorded, 34 had previously been recorded from the cave, adding 48 new records, mostly within the terrestrial biome, making a total of 124 invertebrate taxa now documented from the system (including 6 stygobionts (7 if *N. aquilex* is included), 11 eustygophiles, 5 troglobionts, 10 eutroglophiles and 7 subtroglophiles. Ogof Draenen has the most diverse stygobiontic fauna recorded in a British cave.

- The stygobiontic Crustacea *Niphargus fontanus, Microniphargus leruthi*, *Proasellus cavaticus* and *Antrobathynella stammeri* were present in both caves. The last species was recorded for the first time in OFD, at only its third known location in Wales.

- A single specimen of the stygobiontic ostracod *Fabaeformiscandona wegelini* was collected from S5 in Ogof Draenen, its second location in Britain and the first for Wales.

- The rare troglobiontic spider *Porrhomma rosenhaueri* was recorded in Cairn Chamber in Draenen, making this just the third site for the species in Britain, all in South Wales.

- Two specimens belonging to the Collembola genus *Cryptopygus*, collected at T2 in the Waterfall Series of Ogof Draenen might be a previously unknown species, requiring further investigation.

- The terrestrial invertebrate fauna of OFD is considerably more diverse than that of Ogof Draenen, possibly due to its longer history of biological recording compared to Ogof Draenen, which was discovered as recently as the early 1990s. The Collembola in particular are significantly more diverse and abundant in OFD. The dipluran *Campodea cf. wallacei* is a prominent element of the dark zone terrestrial fauna in Ogof Draenen, being found in significant numbers at all of the terrestrial sites.

- Seasonal differences appeared to be minimal between the winter and summer surveys within both caves, aside from a few key sites in OFD where high flows in the main conduit made access to sampling locations extremely hazardous in the winter and might have resulted in the flushing out of invertebrates at some stream sites. Seasonal effects were more pronounced in the threshold surveys, since the parietal community includes a number of key subtroglophilic species that utilise the threshold for either winter hibernation or summer diapause.

- A comparison of the efficacy of different sampling methods employed in the survey concluded that whilst netting of aquatic habitats was highly effective, the terrestrial methods displayed varying degrees of success. The most efficient method was the baited pitfall trapping. Manual searching in the deep cave resulted in very few specimens, but of those collected some were key records, including that of *Porrhomma rosenhaueri* in Ogof Draenen. The placement of scouring pads as artificial refugia yielded even less results and due to the considerable time in placing, retrieving and processing these, it was recommended that they are not used in future monitoring; thus the terrestrial invertebrate assemblages of the deep cave are best sampled using a combination of baited pitfall traps and manual searching of the wider area.

- The results of the base-line survey, coupled with an examination of the historical data for both caves has enabled the compilation of a set of target invertebrate species and communities against which future condition monitoring can be assessed.

- The current protocols and restrictions for accessing the caves and the conservation efforts within them, under the auspices of their respective management bodies (i.e.

the South Wales Caving Club [SWCC] for OFD and Pwll Du Cave Management Group [PDCMG] for Ogof Draenen), appear to be successful in maintaining suitable habitats for their cave invertebrate assemblages and should therefore be retained.

6. Guidelines for future CSM monitoring: target species and communities

Favourable Condition should be assessed in future monitoring based on the guidelines below:

Ogof Fynnon Ddu Vadose Stream invertebrate assemblage: Presence of ***Niphargus fontanus*** and ***Proasellus cavaticus*** in at least three of the five sites; ***Antrobathynella stammeri*** at S4 and / or S5. There should also be an element of stygoxene fauna (aquatic stages of Ephemeroptera, Plecoptera, Trichoptera and Diptera) at S1 and S4 to indicate continuing surface input.

Ogof Draenen Vadose Stream assemblage: Presence of ***Niphargus fontanus*** in at least two of the five sites; ***Proasellus cavaticus*** in at least four sites; ***Antrobathynella stammeri*** and ***Cavernocypris subterranea*** at S1 and / or S2. There should also be an element of stygoxene fauna (aquatic stages of Ephemeroptera, Plecoptera, Trichoptera and Diptera) and the amphipod ***Gammarus pulex*** at S4 and S5 to indicate continuing surface input.

Left: *Antrobathynella stammeri* © Ana Camacho. Right: *Proasellus cavaticus* © Andrew Lewington.

Ogof Fynnon Ddu Lentic Habitats invertebrate assemblage: Presence of ***Niphargus fontanus*** and ***Microniphargus leruthi*** in at least two of the four sites; ***Proasellus cavaticus*** in at least one site; ***Cavernocypris subterranea*** at L2.

Ogof Draenen Lentic Habitats invertebrate assemblage: Presence of ***Niphargus fontanus*** and ***Microniphargus leruthi*** in at least three of the four sites; ***Proasellus cavaticus*** in at least one site.


Left: *Niphargus fontanus* © Andrew Lewington. Right: *Microniphargus leruthi* © Marcin Penk.

Other eustygophilic species occur in both caves but much more sporadically and although their presence will further indicate Favourable Condition, they are present in such small numbers that the recording of these species cannot be guaranteed in future surveys, thus they should not qualify as key species in determining condition. The same can be said of the two stygobiontic ostracods *F. breuili* and *F. wegelini*, which have each been recorded as single specimens just once in Ogof Draenen.

Ogof Fynnon Ddu 'Deep Cave' Terrestrial invertebrate assemblage: Presence of ***Pygmarrhopalites pygmaeus*** in at least two of the four sites; ***Ochthephilus aureus*** at T4. Presence of at least one of the following troglobionts: ***Poecliophysis spelaea, Oligaphorura choetti, Folsomia agrelli, Pseudosinella dobati***. Presence of at least 5 of the following eutroglophic species: ***Androniscus dentiger, Schaefferia emucronata, Onychiurus ambulans***, ***Deuteraphorura cebennaria, Pygmarrhopalites pygmaeus, Arrhopalites caecus, Folsomia diplophthalma, Folsomia candida, Megalothorax minimus, Pseudosinella immaculata, Trichocera maculipennis, Choleva agilis, Trechoblemus micros, Quedius mesomelinus, Lesteva pubescens, Blaniulus guttatus, Nangona polydesmoides, Brachydesmus superus, Oxychilus cellarius***.

Ogof Draenen 'Deep Cave' Terrestrial invertebrate assemblage: Presence of ***Campodea cf. wallacei*** at T2 and in at least two of the four sites. Presence of at least one of the following troglobionts: ***Poecliophysis spelaea, Oligaphorura schoetti, Folsomia agrelli, Porrhomma rosenhaueri***. Presence of at least 2 of the following eutroglophic species: ***Androniscus dentiger, Schaefferia emucronata, Deuteraphorura cebennaria, Pygmarrhopalites pygmaeus, Trechoblemus micros, Blaniulus guttulatus, Nanogona polydesmoides, Brachydesmus superus, Oxychilus cellarius***.

Porrhomma rosenhaueri © Julian Carter

Ogof Fynnon Ddu Threshold Terrestrial invertebrate assemblage: Presence of the spiders ***Meta menardi*** and ***Metellina merianae*** in at least one of the three entrances. Presence of at least five of the following subtroglophiles: ***Stenophylax permistus, Scoliopteryx libatrix, Triphosa dubitata, Limonia nebeculosa, Culex pipiens, Heleomyza serrata / captiosa, Exallonyx longicornis.*** Presence of at least 5 of the following eutroglophic species: ***Nesticus cellulanus, Palliduphantes pallidus, Speolepta leptogaster, Trichocera maculipennis, Androniscus dentiger, Schaefferia emucronata, Onychiurus ambulans, Deuteraphorura cebennaria, Pseudosinella dobati, Arrhopalites caecus, Pygmarrhopalites pygmaeus, Folsomia diplophthalma, Folsomia candida, Megalothorax minimus, Pseudosinella immaculata, Trichocera maculipennis, Choleva agilis, Trechoblemus micros, Quedius mesomelinus, Lesteva pubescens, Blaniulus guttulatus, Nanogona polydesmoides, Brachydesmus superus, Oxychilus cellarius.***


Left: The cave spider *Meta menardi*. Right: The herald moth *Scoliopteryx libatrix* © Andrew Lewington.

Ogof Draenen Threshold Terrestrial invertebrate assemblage: Presence of the spiders ***Meta menardi*** and ***Metellina merianae*** in at least one of the three entrances. Presence of at least five of the following subtroglophiles: ***Stenophylax permistus, Scoliopteryx libatrix, Triphosa dubitata, Limonia nebeculosa, Culex pipiens, Heleomyza serrata / captiosa, Exallonyx longicornis.*** Presence of at least 3 of the following eutroglophic species: ***Nesticus cellulanus, Palliduphantes pallidus, Speolepta leptogaster, Androniscus dentiger, Schaefferia emucronata, Deuteraphorura cebennaria, Pygmarrhopalites pygmaeus, Trechoblemus micros, Blaniulus guttulatus, Nanogona polydesmoides, Brachydesmus superus, Oxychilus cellarius.***

The results of the current survey suggest that the list of terrestrial invertebrate taxa for both caves is far from complete so other species might well be recorded in future surveys, especially in Ogof Draenen, thus the guidelines above are rather arbitrary at this time and should be interpreted with caution. This is primarily due to the scarcity of the British cave fauna in general, with terrestrial species often present in very small numbers at very scattered localities. However, the results suggest that it should be possible to record approaching 50% of the taxa known from the cave using a combination of pitfall trapping and manual searching. Some of the eutroglophiles listed could potentially occur in either the threshold zone or the deep cave and future surveyors should bear this in mind when assessing the condition of the terrestrial invertebrate assemblages as a whole.
The Conservation Objective developed for each cave system (Tables 11 & 12) is likely to require adjusting and fine tuning in the light of new species being recorded and as experience is gained in monitoring the fauna.

Table 11. Conservation Objective for the cave invertebrate assemblage at Ogof Ffynnon Ddu.

Conservation Objective	To maintain Ogof Ffynnon Ddu cave invertebrate assemblage in Favourable Condition where:
Vadose Stream - Lower Limit	*Niphargus fontanus* present at 3 of 5 sites; *Proasellus cavaticus* present at 3 of 5 sites; *Antrobathynella stammeri* at 1 site (S4 or S5); and Stygoxene fauna present.
Lentic Habitat - Lower Limit	**and where:** *Niphargus fontanus* present at 2 of 4 sites; *Microniphargus leruthi* present at 2 of 4 sites; *Proasellus cavaticus* present at 1 site; and *Cavernocypris subterranea* present at 1 site (L2).

Conservation Objective	To maintain Ogof Ffynnon Ddu cave invertebrate assemblage in Favourable Condition where:
Terrestrial Deep Cave - Lower Limit	**and where:** *Pygmarrhopalites pygmaeus* present at 2 of 4 sites; *Ochthephilus aureus present* at 1 site (T4); 1 of 4 - *Poecliophysis spelaea, Oligaphorura shoetti, Folsomia agrelli* & *Pseudosinella dobati* - present; and 5 of 19 - A*ndroniscus dentiger, Schaefferia emucronata, Onychiurus ambulans, Deuteraphorura cebennaria, Pymarrhopalites pygmaeus, Arrhopalites caecus, Folsomia diplophthalma, Folsomia candida, Megalothorax minimus, Pseudosinella immaculata, Trichocera maculipennis, Choleva agilis, Trechoblemus micros, Quedius mesomelinus, Lesteva pubescens, Blaniulus guttatus, Nangona polydesmoides, Brachydesmus superus* & *Oxychilus cellarius* - present.
Terrestrial Threshold - Lower Limit	**and where:** *Meta menardi* present at 1 of 3 entrances; *Metellina merianae* present at 1 of 3 entrances; 5 of 7 - S*tenophylax permistus, Scoliopteryx libatrix, Triphosa dubitata, Limonia nebeculosa, Culex pipiens, Heleomyza serrata/captiosa* & *Exallonyx longicornis* - present; and 5 of 24 - *Nesticus cellulanus, Palliduphantes pallidus, Speolepta leptogaster, Trichocera maculipennis, Androniscus dentiger, Schaefferia emucronata, Onychiurus ambulans, Deuteraphorura cebennaria, Pseudosinella dobati, Arrhopalites caecus, Pygmarrhopalites pygmaeus, Folsomia diplophthalma, Folsomia candida, Megalothorax minimus, Pseudosinella immaculata, Trichocera maculipennis, Choleva agilis, Trechoblemus micros, Quedius mesomelinus, Lesteva pubescens, Blaniulus guttulatus, Nanogona polydesmoides, Brachydesmus superus* & *Oxychilus cellarius* - present.
Definition of Suitable Habitat	Cave system should support stream and pool features, dark conditions in the cave interior and a relatively undisturbed cave threshold.

Table 12. Conservation Objective for the cave invertebrate assemblage at Ogof Draenen.

Conservation Objective	To maintain Ogof Draenen cave invertebrate assemblage in Favourable Condition where:
Vadose Stream - Lower Limit	*Niphargus fontanus* present at 2 of 5 sites; *Proasellus cavaticus* present at 3 of 5 sites; *Antrobathynella stammeri* at 1 site (S1 or S2); *Cavernocypris subterranean* at 1 site (S1 or S2); *Gammarus pulex* at 1 site (S4 or S5); and Stygocene fauna present.
Lentic Habitat - Lower Limit	**and where:** *Niphargus fontanus* present at 3 of 4 sites; *Microniphargus leruthi* present at 3 of 4 sites; *Proasellus cavaticus* present at 1 site.
Terrestrial Deep Cave - Lower Limit	**and where:** *Campodea cf. wallacei* at 2 of 4 sites including T2; 1 of 4 - *Poecliophysis spelaea, Oligaphorura shoetti, Folsomia agrelli* & *Porrhomma rosenhaueri* - present; and 2 of 9 - *Androniscus dentiger, Schaefferia emucronata, Deuteraphorura cebennaria, Pygmarrhopalites pygmaeus, Trechoblemus micros, Blaniulus guttulatus, Nanogona polydesmoides, Brachydesmus superus* & *Oxychilus cellarius* - present.
Terrestrial Threshold - Lower Limit	**and where:** *Meta menardi* present at 1 of 3 entrances; *Metellina merianae* present at 1 of 3 entrances; 5 of 7 - *Stenophylax permistus, Scoliopteryx libatrix, Triphosa dubitata, Limonia nebeculosa, Culex pipiens, Heleomyza serrata/captiosa* & *Exallonyx longicornis* - present; and 3 of 12 - *Nesticus cellulanus, Pallidiphantes pallidus, Speolepta leptogaster, Androniscus dentiger, Schaefferia emucronata, Deuteraphorura cebennaria, Pygmarrhopalites pygmaeus, Trechoblemus micros, Blaniulus guttulatus, Nanogona polydesmoides, Brachydesmus superus* & *Oxychilus cellarius* - present.

Conservation Objective	To maintain Ogof Draenen cave invertebrate assemblage in Favourable Condition where:
Definition of Suitable Habitat	Cave system should support stream and pool features, dark conditions in the cave interior and a relatively undisturbed cave threshold.

7. Recommendations

- The cave invertebrate assemblages of both Ogof Ffynnon Ddu and Ogof Draenen should be monitored at least every ten years, using the Conservation Objectives (CO) developed as part of this baseline survey.
- The CO is likely to require adjusting and fine tuning in the light of new species being recorded and as experience is gained in monitoring the fauna
- As Ogof Draenen supports a nationally important cave invertebrate assemblage, with a uniquely rich stygobiontic fauna, the cave system should be a strong candidate for SSSI designation.
- The current protocols and restrictions for accessing the caves and the conservation efforts within them, under the auspices of their respective management bodies (the South Wales Caving Club [SWCC] for OFD and Pwll Du Cave Management Group [PDCMG] for Ogof Draenen), appear to be successful in maintaining suitable habitats for their cave invertebrate assemblages and should therefore be retained.

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Appendix A. Proposed protocol for the appraisal and future monitoring of the invertebrate assemblages of cave SSSIs in Wales

Rationale

Camacho (1992) describes a strategy for sampling aquatic habitats within caves but the broad principles in setting up such a survey are similar for both terrestrial and aquatic habitats. Divide the sampling area (the cave) into biotopes or sections (in the aquatic realm these can include gour pools, percolations, a subterranean river catchment, sandy beds etc.) and have at least one station (sampling site) in each biotope. The objective is then to describe what species are present and estimate their relative abundance at each location. This initial survey will then see the establishment of a set of sites and the basis of a future monitoring network.

Since the aim of the project is not to carry out a complete survey of each cave and every passage, which in many of the huge systems of Wales is liable to represent a long-term project with many visits, potentially over several years (e.g. Knight *et al.*, 2018), but to provide baseline data against which future monitoring can be compared, then the number of sites can be kept to a fairly low number that are relatively easy to access within the system. Invertebrate communities within caves often show distinct clumped distributions (Chapman, 1993; Culver & Pipan, 2019; Moldovan *et al.,* 2018) around available resources, which tend to be limited in most temperate caves, and this can help to provide targeted sampling sites rather than searching / sampling large extents of the cave system, much of which is liable to have very low invertebrate numbers. However, it should be stated that the nature and scarcity of cave invertebrates will invariably mean that they will not be easy to monitor (Hunt & Millar, 2001), and there is a lack of systematic survey data across Britain for comparison. To this end, the protocols described below are very much a first attempt at creating a set of standardised methods that are likely to be refined following the results of the first surveys.

Drake *et al.* (2007) provides a set of guidelines for surveying terrestrial and freshwater habitats for their invertebrate communities. These guidelines can be used for a variety of reasons including site SSSI selection and Common Standards Monitoring (CSM) of habitats and species. CSM does not aim to assess a site as a whole but targets notified features for which the site is designated. Coupled with analysis by the computer application Pantheon (formerly known as ISIS), it can identify key invertebrate assemblages of interest. The general principles and methods described within the guidelines have already been trialled and used successfully for monitoring sites designated for their invertebrate interest across the UK and therefore represent a basis on which to design a future monitoring protocol for the invertebrate assemblages of caves. Although these guidelines were written for use on surface habitats, many of the methods can be easily adapted for use underground. Hunt and Millar (2001) have published a guide for collecting cave invertebrates in New Zealand and provide some good information for adapting the methods of Drake *et al.* (2007).

Virtually all cave SSSIs across Britain are designated on the basis of their geological interest (speleothems, sediments, passage morphology etc.), their palaeontological remains, or their usage as bat roosts. Few citations mention their invertebrate interest, with the exception of two sites in Devon, in which the endemic stygobiontic shrimp *Niphargus glenniei* is mentioned and Pen Park Hole SSSI in Bristol, recently designated in 2017 and the first cave SSSI in England designated not only for its geological interest (a cave of hydrothermal origin) but for the importance of its invertebrate community, marking a departure from the historical norm (Knight, 2014, 2017). Within Wales, Ogof Ffynnon Ddu-Pant Mawr SSSI is designated in part for its cave invertebrate assemblage and Lesser Garth Cave (Garth Wood SSSI) is designated on the basis of it being one of only three sites in which the troglobiontic spider *Porrhomma rosenhaueri* occurs and a CSM programme is in place to monitor this feature (Carter, 2010a, 2018; Carter *et al*., 2010). The large Ogof Ffynnon Ddu (OFD) system, the deepest cave in the UK, lies beneath and is included within Ogof Ffynnon Ddu SSSI and Ogof Ffynnon Ddu- Pant Mawr SSSI and National Nature Reserve and mention is made of its use as a bat roost and the fact that it harbours various insect and stygobiontic Crustacea species, as well as a population of white trout.

Systematic surveys of the invertebrate fauna of British caves are lacking, due to the general perceived scarcity of the fauna, resulting from localised extirpations during the repeated glacial cycles of the Pleistocene, and a lack of experienced cave biologists (biospeleologists). From 1938 to 1972 cavers, under the auspices of the Cave Research Group of Great Britain, collected specimens of invertebrates on an ad hoc basis which were then sent to various experts for determination. These paper records have recently been digitised by the biological recorder of the British Cave Research Association (Graham Proudlove) to form the 'Hazelton' database, now hosted on the website of the BCRA. This database forms a valuable set of historical information, but the records are now quite old and are almost entirely based on ad hoc collecting during caving trips. Some systematic surveys of British caves have been carried out but are either limited to just the aquatic fauna e.g. Gunn *et al*. (2000) and Wood & Gunn (2000) in the Peak-Speedwell system of Derbyshire; Knight (2011), Swildon's Hole, Mendips; Knight *et al..,* (2018), Ogof Draenen; and Edington (1977) Dan-yr-Ogof, or, with the exception of Pen Park Hole (Knight, 2014, 2017) require updating, such as the work in OFD by Jefferson & Chapman (Jefferson & Chapman, 1979; Jefferson *et al.,* 2004) and Otter Hole (Chapman, 1979). Some information can be gathered from analysis of the 'Hazelton' data, but overall, the invertebrate assemblages of many British cave systems remain either unknown or poorly studied at best. To this end, the proposed monitoring of cave invertebrate assemblages in Wales will provide a valuable baseline for future comparison and could signal a new approach to the study of the subterranean biome within the UK.

When considering the management and conservation of cave invertebrate assemblages, one should consider that caves are just one aspect of a much larger network of subterranean fissures within the surrounding karst that is the true habitat of many of the species found within caves. By definition a "cave" is a subterranean space big enough for humans to enter and thus access and study the fauna. To a small beetle, a tube 5cm wide will be a “huge passage”. The fissure network provides colonisation routes for surface species and detritus (nutrition) to enter caves and allows the transit of animals between different cave systems in close proximity. Cave streams will eventually come to the surface as “resurgences”, in essence large springs. Thus, adjacent surface habitats are of just as much importance in terms of cave conservation as the cave itself. Ideally such habitats within the wider karst should also be sampled using various methods, including drift netting at known resurgences and baited pitfall traps buried within the surrounding karst if one is to consider the full community of subterranean invertebrate species within a region. Since the aim of the current project is to develop a relatively easily repeatable survey method for CSM, then these techniques are not considered further here. However, this continuity of habitats should certainly be considered in any assessment.

When sampling for cave invertebrates, consideration should always be given to the potential impact on populations of taxa that are scare and/or of limited distribution. The number of specimens that can be collected without impacting on the population very much depends on what is being collected. Stygobiotnic Crustacea, and most other aquatic fauna in cave streams, can potentially be quite abundant, with over 200 cave hoglice (*Proasellus cavaticus*) being documented at several sites in Ogof Draenen (Knight *et al*., 2018). Also the populations in caves are often only the “tip of the iceberg” and although some invertebrates might occur in caves as just isolated specimens, there are likely to be many more within the fissure network of the surrounding karst which cannot be surveyed. Aquatic taxa in particular experience rapid recolonisation following heavy rainfall and subsequent ‘wash out’. However, some taxa might have low population densities and reproductive rates, so can be particularly vulnerable to over collecting (Chapman, 1993; Culver & Pipan, 2019). There is no absolute number of specimens of each species which should be collected, and personal judgement and common sense must be applied in deciding how many are required. Some taxa (e.g. Acari, Collembola) can be extremely hard to identify without microscopic examination. Conversely, some are easily recognisable (e.g. tissue *Triphosha dubitata* and herald *Scoliopterix libatrix* moths), thus removing the need to collect. Photography can be a useful alternative to collecting larger species, but this will require sufficient photos of the salient features for determination, the necessary experience to do so, and the transport of delicate and expensive equipment into the cave. With some taxa, the key requirements for determination are only present in adults of one sex (e.g. certain water beetles require dissection of the male genitalia for identification to species). To this end, it is better to collect a small series of 6-10 animals rather than one or two for identification. Collecting 30 amphipods from a pool is not likely to impact the overall population but collecting half that number of carabid beetles in a bait trap could be highly detrimental (Millar & Hunt, 2001).

Habitats and potential sampling sites within caves

For monitoring purposes, habitats within the cave can be divided into two broad categories - aquatic and terrestrial - although considering the high levels of humidity in many caves the two can often overlap, with aquatic species venturing out on to wet silt banks and terrestrial animals being observed walking along the bottoms of small pools.

Drake *et al.* (2007) state that a minimum of four sites in each biotope is required for CSM and to provide robust survey data, whilst making a survey relatively easy to replicate in future monitoring cycles. This broad principle will be adopted within the proposed protocol.

Terrestrial habitats

With the exception of the parietal community (see below), there are no hard and fast rules where invertebrates might occur within a cave system, but when selecting sites it is best to consider three factors:

- Choose sites well away from an entrance to limit the occurrence of trogloxenes;
- Little or no obvious air movement;
- A source of food such as a stream or seep.

Significant air movement can lead to the drying out of cave substrates and most cave-adapted fauna prefer passages with high humidity (95%); the lack of Collembola from certain passages in Radford Cave, Devon was attributed to this factor by Wilson (1975). As mentioned above, the true habitat of many species found in caves is actually the sheltered conditions of the fissure network in the surrounding karst. The movement of a large active stream can induce air movement but conversely such stream passages can also provide a source of food and moisture.

In temperate regions, cave ecosystem energy inputs are limited to what enters the cave from the surface environment, essentially what falls into or is washed into the underground passages, including dead carcasses, plant detritus, organic matter in silts and the faecal pellets of animals in the overlying soil etc. Many invertebrates will have clumped distributions within a cave system around available sources of nutrition. Water, as streams or seeps, is one of the main agents responsible for transporting this matter further into the cave. Thus, as a general rule not much fauna will occur in old, dry, upper-level passages without some sort of food input. Cave passages close to the surface can be the exception to this. Sometimes root mats might penetrate into the cave passage from above and can be a very important source of nutrition. There might also be fissures in the passage roof that carry dripping water that has percolated through the overlying epikarst (if present) and soil, thus drip-fed pools in such passages can represent another sampling biotope (see below). These fissures can also present a viable colonisation route for soil fauna, which whilst it should not be considered “cave” fauna per se (trogloxenes) certainly contributes to the biomass and diversity of cave systems.

Large, clean-washed passages subject to regular flooding by a substantial stream are not likely to be worthwhile searching, although passages with smaller, even ephemeral, streams are likely to harbour fauna, as are those occasionally flooded by rising waters from stream passages below. The receding waters will deposit organic matter on muddy ledges and in nooks and crannies. Similarly, silt banks adjacent to streams with large amounts of wet organic matter (leaf deposits, twigs etc) deposited on them will provide rich hunting grounds. Although note that large accumulations of such deposits not far from an

entrance might also contain a large amount of surface species washed in by the stream that are liable to outcompete and exclude troglophiles / troglobionts.
Close to cave entrances a distinct community of invertebrates, the parietal (or cave threshold community) develops on the walls and ceiling. This community will include a large number of surface species that are using the dark, cool, sheltered conditions of the threshold, some of which regularly use cave thresholds as part of their life cycle (sub-troglophiles) either as part of a summer diapause (e.g. the caddis *Stenophylax permistus*) or winter hibernation (e.g. the mosquito *Culex pipiens* and tissue and herald moths). Whilst not limited to caves, these species are nevertheless a well-established element of the invertebrate assemblage and should certainly be considered in any inventory of cave taxa.

It is suggested a minimum of four sites within a cave well away from the entrance are selected for sampling the terrestrial fauna. In addition to this, one site should include the threshold zone of an entrance to sample the parietal fauna. In most cave systems this will involve a single site, but in some systems with multiple entrances then a site at each might be required. Sites further into the cave should ideally encompass different biotopes, including:

- Adjacent to a relatively slow-flowing, minor stream, not prone to frequent and rapid flooding, incorporating exposed sand / silt banks;
- Near to percolating water either dripping from an aven, or as percolation seeps down a cave wall;
- Roots penetrating passages close to the surface;
- Adjacent to and including accumulations of organic matter such as bat guano piles.

Aquatic habitats

Streams within caves are essentially of two kinds: allogenic, where the water is derived from the surface and the stream sinks at the cave entrance before passing through the system to another cave or a resurgence; or autogenic, in which the cave is fed by water percolating down through the overlying layers of soil, epikarst (if present) and fissures. Allogenic streams will contain a large amount of washed-in surface epi-benthic fauna (stygoxenes), often similar to and representative of other watercourses within the wider surface topology. As long as sufficient resources are carried in from the surface by the flow, such taxa can survive in caves. Many are the aquatic nymphs / larvae of terrestrial insects, which cannot complete their life cycle underground and will die upon metamorphosis into their adult form. However, some species, such as the amphipod *Gammarus pulex,* are capable of forming breeding subterranean populations (eustygophiles) in streams and consequently can make up a significant proportion of the biomass. Such taxa can competitively exclude the more specialist stygobiontic species which tend to be limited to autogenic streams. Knight (2011) certainly found this to be the case in Swildon's Hole on the Mendips, with the allogenic main stream dominated by eustygophiles and stygoxenes, with some aquatic insect species being present over 1km into the cave, whilst the autogenic tributaries harboured communities of predominately stygobiontic Crustacea.

As with the trogloxene species of the parietal, stygoxene communities, although not true cave fauna, should not be excluded from surveys, but in terms of the more specialist stygobiontic fauna, autogenic streams will provide better results.

Reaches of streams with very fast flows over a bedrock substrate are likely to produce poor results as much of the fauna will be washed out. Sites should ideally be selected where there is a slower flow and substantial deposits of mixed substrate (cobbles, pebbles, sand and silt) into which invertebrates can penetrate for shelter. It might be productive to consider sampling sites with different proportions of the above substrates as some species prefer either coarse (cobble and pebbles) or fine (sand and silt) clasts. Knight *et al.* (2018) found that the tiny stygobiontic syncarid *Antrobathynella stammeri* occurred at sites with a good proportion of sand in which this interstitial species lives. In streams that are very fast flowing throughout the cave, it might be better to sample back eddies, side flows and pools rather than the main channel.

Aside from streams, a considerable variety of lentic habitats can also occur in caves, including deep lakes, sump pools and drip-fed gour pools. Extensive lengths of static water along a stream are simply an extension of the stream itself and thus likely to harbour similar fauna, albeit with localised variation due to the flow regime. Lakes and sump pools, sometimes into which streams feed, often represent the upper level of the underlying phreatic zone, the layer of flooded passages beneath the air-filled passages of the vadose zone. Water levels will often fluctuate with the local groundwater table, and this is the habitat in which stygobiontic species are most likely to occur. Perched lakes sometimes occur in higher level passages where they are fed by percolating water, and are in essence large, drip-fed pools.

Some pools are present in higher level passages and either represent water left by receding flood levels, in which case they can harbour stranded elements of the cave stream fauna, or pools fed by percolating water from above. The latter are likely to contain a sparser fauna but could harbour specialist species of an overlying epikarst aquifer. The epikarst is the zone of fractured rock between the soil and the limestone bedrock, essentially a zone of weathered limestone which, depending on glacial history and surface topography, is not always present. This can retard the downwards movement of water to the extent that a perched aquifer forms above the cave roof. Studies (e.g. Brancelj, 2015; Pipan, 2005; Pipan & Brancelj, 2004) have found that this aquifer can contain a different fauna to that of the cave below, often dominated by small taxa such as Copepoda and Ostracoda, and sampling drip-fed pools beneath can offer a “sampling window” for this biotope. More detailed studies targeting this particular habitat require lengthy sampling methods involving the placement and maintenance of various devices to filter the dripping water over periods of months or even years, and thus beyond the remit of the current project.

Small cave pools also provide habitat for an element of the terrestrial fauna termed by Chapman (1993) ‘pool-surface associations’ (or the neuston community), consisting of several taxa, notably Collembola living on the surface meniscus and grazing on fungal hyphae / bacterial mats growing on the water surface or on the carcasses of insects that have become trapped in the meniscus. These grazers in turn attract various small predators, predominately Acari.

A minimum of four sites should be sampled along cave streams. It is not required to sample every stream in a cave system. Some large systems can contain multiple subterranean catchments, but if there are both allogenic and autogenic streams then sites should include both. If a predominately autogenic stream is known to have its source close to the surface but not directly connected (i.e. lies beneath a doline but cannot be reached due to debris etc), then at least one site should be close to this surface input.

A further four sites (minimum) should include lentic habitats within the cave, and aim to include the following:

- Large bodies of phreatic water, either lakes or sumps;
- Small, drip-fed pools, including gour pools, either adjacent to speleothems or in depressions in passages. Generally, pools with a silt substrate, rather than bare rock or a crystalline substrate of calcite, will be better, as the latter tend to support few taxa;
- Pools in the upper levels of passages above streamways, fed by seepages on cave walls, or laying in the courses of ephemeral streams that are dry at the time of sampling. With the first group, try and determine if they are drip-fed or contain water left behind by receding flood levels, in which case they are likely to harbour elements of the stream fauna, which could be better investigated by sampling the stream itself. Pools in the course of ephemeral streams could be a useful substitution for sampling the stream itself if it is dry at the time of the field visit.

Seasonality and number of sampling visits

As with all subterranean habitats, away from entrances cave passages tend to show fairly stable environmental parameters all year round with high humidity and the temperature remaining similar to that of the regional average annual air temperature on the surface. Thus, one can expect seasonal variations on the surface to have little influence on the cave environment and its biota. This is generally true, with most subterranean organisms showing a lack of circadian and seasonal cycles. However, flood events after high rainfall will result in an input of organic matter to the system and some taxa have developed life cycles to take advantage of such seasonal pulses, as suggested by Hawes (1939) for caves in the Dinaric Karst. Although no detailed research has been undertaken on this subject in temperate regions, as the rainfall in Britain can vary throughout the year it is unlikely that subterranean populations have adapted in this way.
Close to the cave entrance, environmental parameters show much more variation and seasonality, with a gradual zonation further from the entrance to the relative stability of the inner cave. There is certainly a degree of variability in the fauna of the parietal community, with certain species utilising the threshold in summer being replaced by others in the winter. To fully document this, at least two visits in summer and winter should be undertaken.

It is recommended that when establishing a baseline for future monitoring at least two sampling events in the cave system are undertaken, preferably at different times of the year and with a good interval of time between them to allow the cave fauna at a site to recover and recolonise following the first round of sampling, ideally two visits over two years. After the initial baseline has been established, then future CSM monitoring should require just a single visit.

Sampling methods - terrestrial habitats

With the exception of some surveys of the aquatic fauna, invertebrate data for British caves to date has mostly been obtained in an ad hoc fashion by manual searching alone. There is a wide variety of different sampling methods that have been used by researchers to sample cave biota across the world including leaf packs, pitfall traps (baited and un-baited) and artificial refugia.

Bait can be very useful in drawing out animals from nearby fissures to concentrate them in a small area where they will more easily be seen and collected. Disadvantages are that the setting and checking of bait will require at least two visits and can attract large numbers of trogloxenes that might not otherwise be present and can outcompete troglophiles and troglobionts, in essence a disruption of the ecosystem. Care must be taken to place bait in a location where it will not be washed away by floods and become a possible contaminant of cave waters. Different types of bait can attract different taxa and unprocessed, 'smelly' cheese, fish and decaying meat, all of which produce strong, pungent smells, have been used with success to draw animals from considerable distances. However, note that cheese can often contain numbers of cheese mites that will be introduced into the environment and thus might be best avoided. Over longer periods of time, the fungi and bacteria that colonise the decaying bait will attract grazers and then predators. There are several documented cases of parts of caves used by explorers as regular camping sites attracting fauna to particles of dropped food and refuse e.g. Otter Hole (Chapman, 1979), although fortunately modern cavers are much more aware of the environment and such incidences are now rare.

Hunt and Millar (2001) consider un-baited pitfall traps to be ineffective, although they have been used to successfully collect Collembola specimens in Baker's Pit, Devon. Baited pitfall traps have proven to be highly effective but can be detrimental to the cave fauna if left unattended for long periods, as the traps will continue to attract prey until the bait decays. There are several instances of the indiscriminate use of this method devastating populations of cave invertebrates, the most infamous being that of the Velika Pasica Cave in Slovenia (Brancelj, 2015).

Artificial substrates have proven to be effective. Metal scouring pads have been used in Baker's Pit and proved very efficient at collecting Collembola. Some were un-baited and some baited with cheese. The presence of bait appeared to have little effect on their overall effectiveness as the springtails appeared to be primarily attracted to the humidity entrapped within the dense wire mesh. Upon removal, the pads can be placed in a sealed plastic bag and the fauna subsequently removed using a Berlese Funnel (Berlese, 1905).

Leaf packs are essentially another form of artificial refugia in that mesh bags of woodland detritus and leaves are placed in passages to attract and become colonised by invertebrates. They have been used in both terrestrial and aquatic habitats in New Zealand caves (Hunt & Millar, 2001).

It is suggested that a combination of manual searching and baited pitfall traps are trialled for use in the project, with the placement of metal scouring pads for collecting Collembola. Despite the potential of bait traps to impact the fauna, it is felt that this could be outweighed by their effectiveness in drawing fauna from considerable distances, although they should not be deployed any longer than a maximum of 7-10 days. The first two proposed cave systems to be surveyed in this project, Ogof Ffynnon Ddu and Ogof Draenen, are very large systems so the localised use of such traps at just a few sites should not overtly impact the fauna of the cave. However, if it appears that they are entrapping more than 5-6 specimens of any one species then their use should be abandoned and possibly replaced with bait lures or leaf packs. In smaller cave systems where they could possibly draw in fauna from the whole cave their use is not recommended.

Each trap consists of a small polypropylene pot (disposable plastic drinking cups are a useful option) with a small amount (1-2cm depth) of propylene glycol placed in the bottom as preservative, a piece of bait (liver, fish, meat or a carbohydrate rich bait such as molasses) can then be placed on a hooked wire that can be hung over the side of the pot and suspended above the preservative. A few drops of detergent (surfactant) should be added to the preservative as this will entrap spiders more effectively (Drake *et al.,* 2007). A hole is excavated in sediment and the trap placed in it, with the sediment piled up around the rim so there is no gap. A flat stone should then be placed over the trap, propped up by smaller stones, to protect the trap from becoming flooded by drip water, whilst still allowing invertebrates access. As mentioned above, make sure the trap is not in a position where it will become flooded by rising waters. After 7-10 days, the trap's contents are emptied into a vial and the trap removed from the cave.

In surface habitats, Drake *et al*. (2007) recommend the placement of a minimum of 5 to 10 traps at a site, either in a straight line at 2m spacings or a 3 X 3 grid. Due to their potential impact, it is recommended that six traps are placed at each cave site, at least 3m apart, with half to contain a proteinaceous bait and half carbohydrate based, to potentially attract different elements of the fauna. At the same time the traps are deployed, six un-baited scouring pads are placed in sheltered positions nearby, under rocks or ledges.

Manual searching is analogous to the 'Ground searching' of Drake *et al.* (2007). Each sample consists of the combined catch from six separate five-minute searches. The timed periods add a degree of reproducibility. The six sampling points should be separated by an average of 6m to maximise local environmental variability, including different substrates and particle sizes, guano piles and accumulations of detritus. Sampling points can be both horizontal (the floor) and vertical (cave walls) in orientation.

Scan each area first, as some taxa might be out in the open, especially on damp silt and debris. Turn over rocks and boulders and search beneath. Gently break open larger twigs and branches which are well rotten as invertebrates will burrow into these. A sheet of black plastic could be useful for placing these items on as they are dissected, although note that in Britain not all cave-dwelling species are unpigmented (white) so it might be worth having both white and black plastic sheets for this operation. The only record of the troglophilic carabid beetle *Trechoblemus micros* from Pen Park Hole was of a single larva inside a piece of dissected rotten wood on the shore of the lake (Hazleton, 1963). Detritus and sections of guano piles can also be placed on a plastic sheet and gently pulled apart for examination. Specimens can be collected with forceps and pooters and placed into a vial. As mentioned above collect 6-10 specimens of obvious taxa and note any additional numbers.

Water seeps and wet walls, especially those with small nooks and crannies should be especially investigated for spiders, millipedes and *Speolepta* larvae. Lighting at an angle is useful in illuminating fine webs and their occupants. Millar and Hunt (2001) recommend focussing on a likely section of wall from 20-30cm away (close to but not at our limit of focus) then blow gently on the wall. If any out-of-focus movements become visible, then one can focus back in for potential specimens on threads.

Roots penetrating cave passages can be scanned and then shaken or gently teased apart above plastic sheeting, which is then examined to see what has become dislodged. Always document the specific methods used in the search so future surveys can replicate them.

To summarise, at each terrestrial invertebrate site the following sampling procedure is undertaken:

- Manual search: five-minutes of searching at 6 points, 6m apart;
- Place 6 baited (3 containing a protein-based bait and 3 carbohydrate-based) pitfall traps at least 3m apart, to be removed in 7-10 days;
- Close to each trap place a metal scouring pad under a stone or similar sheltered place, to be bagged and removed at the same time as the traps.

In addition to the terrestrial sites within the cave, the parietal fauna of the threshold should be surveyed in two seasons - summer and winter. A manual search only, with particular attention to the walls and ceiling should be sufficient for this. Baited pitfall traps are more likely to attract fauna from adjacent surface habitats rather than fauna from deeper in the cave.

Sampling methods - aquatic habitats

As with terrestrial habitats, many different methods have been used for sampling cave streams including the use of bait traps, artificial substrates, and leaf packets but the author has found the easiest method to reproduce and most successful in collecting specimens is that of simple kick sampling with a pond net. The FBA pattern pond net is widely used for sampling surface watercourses and conforms to a standardised frame size 25cm wide. This net can be produced with pole sections that can be screwed together, thereby making it easier to transport underground and provides the option of shorter lengths for use in low passages. A 15cm wide frame net is also available which might be an alternative in very small and narrow cave streams, although the net used should always be documented. A net fitted with a 250µm mesh collecting bag is best for collecting small animals such as copepods, without becoming too clogged by fine silt and sand during operation. A timed period of three minutes adds a degree of repeatability to the method. This method is analogous to the 'Pond-netting' of Drake *et al.* (2007), although field sorting is not viable in a cave and the bulk sample should be preserved *in situ* and placed within a strong container that can be transported out of the cave for analysis in the laboratory. Laboratory analysis involves washing the sample through a stacked set of sieves of different apertures to split it into fractionated portions and then placing a small amount of each portion into a large petri dish for sorting and the picking out of specimens beneath a stereo microscope. Samples containing a high amount of fine gravel or sand can be dealt with using the floatation method of Anderson (1959) to separate the organic matter from the mineral substrate.

Large bodies of static water can be sampled by the same method, if it is possible to reach all of the pool. The pond net can have additional poles fitted to extend its reach. Large subterranean lakes might require a combination of a timed period of sampling in the margins combined with the use of a trawl net to sample deeper water. A set number of trawls, if possible from different locations around the lake shore, will ensure an element of reproducibility. The actual number can be determined at the time of the field visit by the size of the waterbody, but three will generally be sufficient to obtain a representative sample of the fauna.

Smaller pools can be sampled by a combination of netting and sieving, depending on the size of the pool. Targeting a group of small pools and treating them all as one site is likely to be more productive than one large pool. The method used can depend on the depth and size of the pools and should be noted for future surveys. Netting is much more effective than manual searching, which is likely to miss small taxa such as copepods and ostracods buried in the sediment, but will only be suitable for pools of sufficient depth. A small aquarium net, with sufficiently small mesh size, could be used as an alternative to the aforementioned pond net in small, shallow pools. As with streams netting should be carried out for a timed period of three minutes, either in a single large pool, or across a group of pools.

Where pools in a cave are limited to small 'puddles' too shallow for netting, then an alternative method is that of bailing / pumping the water and filtering it through a square, plastic sampling bottle in which holes have been cut out in two of the sides and covered with a fine mesh (Brancelj, 2004). The water can either be bailed with a jug, or a hand-operated bilge pump can be more effective. The smallest pools can be emptied with a syringe or even pipette. Make sure that the substrate is well agitated during this operation to suspend animals in the water column. Always document the exact method followed for future surveys.

Note that the above sampling has the potential to completely empty a pool of its fauna or water. In most caves, this is not likely to present a problem as pools are often abundant, and pools fed by drip-water will rapidly refill after heavy rainfall, the flow carrying animals to recolonise the habitat. However, in caves where pools are scarce then consideration should always be given as to whether the sampling can have a negative impact. A netting time of less than three minutes could be employed and in extreme cases where pools are very limited and small throughout the cave, then the whole can be considered to be a single biotope and the sampling limited to manual searching. Sampling such caves after wet weather will mean that pools are likely to be more widely available, but conversely entry into some caves or passages might become more hazardous.

Before sampling for aquatic fauna in pools, a quick search for elements of the neuston community should be carried out. Illuminating from the side can make animals on the meniscus more obvious and the fauna can then either be picked up with forceps and placed directly into vials of preservative, or a more efficient method is to use a small paint brush. Place the brush just under the water surface and lift, floating animals become entangled in the bristles, which are then wiped off in a vial.

CSM methods summary

The CSM method to be adopted for assessing the invertebrate assemblages of caves should involve the following.

For terrestrial fauna a minimum of four sites to be selected within the dark zone of the cave. At each site the following sampling procedure is undertaken:

- Manual search: five-minutes of searching at 6 points, 6m apart;
- Place 6 baited pitfall traps at least 3m apart, to be removed in 7-10 days;
- Close to each trap place a metal scouring pad under a stone or similar sheltered place, to be bagged and removed at the same time as the traps.

In addition, at each entrance a set of manual searches is to be carried out, primarily targeting the parietal fauna; to be carried out on two occasions in summer and winter, to assess variability in the parietal community.

For aquatic fauna a minimum of four sites to be selected on streams, to include both allogenic and autogenic streams if present, as well as at least one site known to be close to surface inflows. Each site to be sampled by three minutes of active netting (kick sampling) with an FBA pattern pond net. Bulk samples to be preserved in situ and analysed in the laboratory.

Four additional sites to include lentic habitats. These can be either individual large pools/lakes or groups of smaller pools. Where possible these should also be sampled by three minutes of netting (kick sampling / sweeps), although the actual method employed may differ depending on the size / depth but should be documented for future surveys to repeat. Bulk samples to be preserved in situ and analysed in the laboratory. Prior to netting, a manual search should be carried out for elements of the neuston community on the surface of each pool.

For baseline surveys, ideally two sets of sampling visits should be undertaken in each cave, preferably over two years and in different seasons (e.g. in late spring / early summer [May / June]) of the first year and late autumn/winter (late November to February) of the second year. Future monitoring after the baseline has been established can then be undertaken with a single visit, although note there will still be the requirement for two seasonal (summer and winter) visits to fully assess the parietal community of the threshold.

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Appendix B. Invertebrate sampling site photos

Ogof Ffynnon Ddu aquatic sampling sites. Left photo – June 2023, right photo February 2024 / January 2025

Site S1.

Site S2.


Site S3.


Site S4.


Site S5.

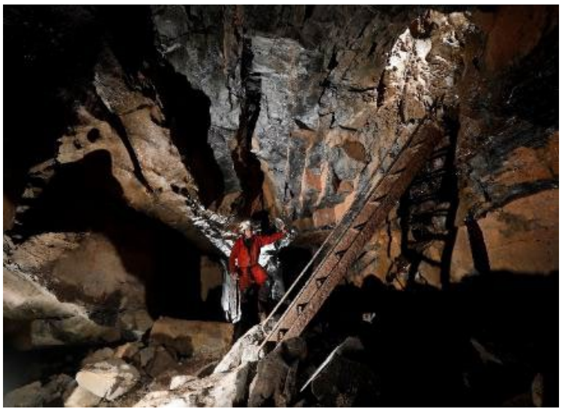
Site L1.

Site L2.

Site L3. Note change of site location between June 2023 and February 2024.


Site L4.

Ogof Ffynnon Ddu terrestrial sampling sites. Left photo – June 2023, right photo February 2024 / January 2025

Bottom entrance (OFD I)


Cwm Dwr entrance

Top entrance (OFD II)

Left: Site T1. Right: Site T2

Site T3


Site T4

Ogof Draenen aquatic sampling Sites. Left photo – May 2023, right photo January / February 2024


Left: Site S1 (January 2024, no 2023 photo available). Right: Site S2 (May 2023, no 2024 photo available).


Site S3


Site S4

Site S5 (May 2023, no 2024 photo available).


Site L1


Site L2 (January 2024, no 2023 photo available).


Site L3a


Site L3b

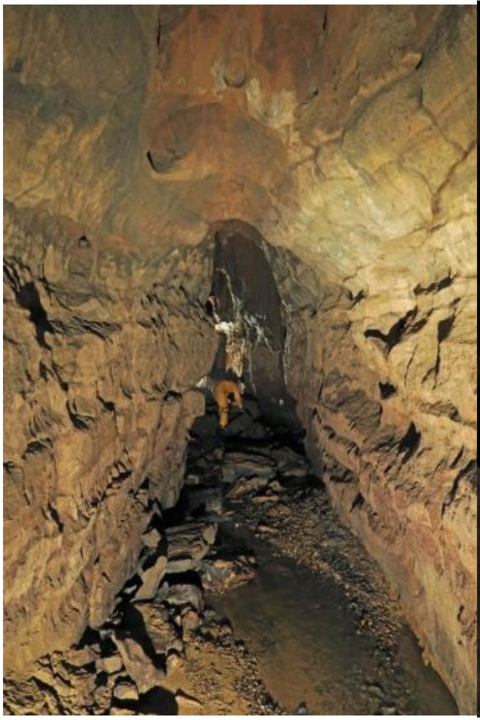
Site L4 (January 2024, no 2023 photo available)

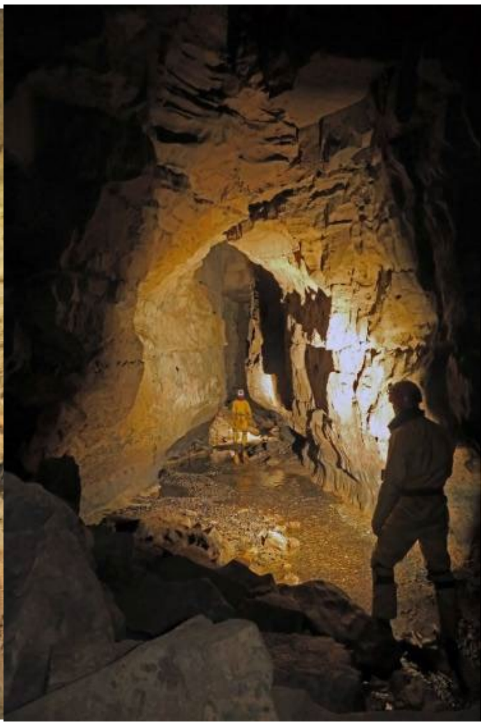
Ogof Draenen terrestrial sampling sites. Left photo – May 2023, right photo January / February 2024


Left: Main Entrance. Right: Nunnery Entrance


Drws Cefn

Site T1





Left: Site T2. Right: Site T4


Site T3

Appendix C. Invertebrate taxa recorded from Ogof Ffynnon Ddu prior to the current study

Data includes the original NCC survey (Jefferson & Chapman, 1979); records in Jefferson *et al.* (2004), mostly a collation of records on the *Hazelton* database by Jefferson (1989), as well as records of aquatic Crustacea by Carter (1995); and additional records held on the database of the Hypogean Crustacea Recording Scheme (HCRS) up to 2023. Presence is denoted by 'X'. Taxa highlighted in red are troglobionts (stygobionts), those in blue eutroglophiles (stygophiles) and those in green (subtroglophiles), using the definitions of Sket (2008).

Note 1: True ecological status of this species not known, probable troglobiont?
Note 2: Additional record from Cwm Dwr by J. Carter
Note 3: the status of this species is uncertain in Britain
Note 4: the status of this species is uncertain in Britain

Records from:	Jefferson & Chapman (1979)	Jefferson *et al.* (2004)	Additional *Hazelton* records omitted from Jefferson *et al.* (2004), and HCRS data prior to 2023
TAXA	-	-	-
TRICLADIDA	-	-	-
PLANARIIDAE	-	-	-
Phagocata vitta (Duges, 1830)	-	X	-
OLIGOCHAETA	-	-	-
LUMBRICIDAE	-	-	-
Lumbricidae spp.	X	X	-
ENCHYTRAEIDAE	-	-	-
Enchytraeidae spp.	X	X	-
APHANONEURA	-	-	-
AEOLOSOMATIDAE	-	-	-
Aelosoma hemprichi (Ehrenberg, 1831)	X	X	-
GASTROPODA	-	-	-
ZONITIDAE	-	-	-
Oxychilus cellarius (O.F. Mũller, 1774)	X	X	-
CRUSTACEA	-	-	-
CRANGONYCTIDAE	-	-	-
Crangonyx subterraneus Bate, 1859	-	X	X
GAMMARIDAE	-	-	-
Gammarus pulex (Linnaeus, 1758)	-	X	-
NIPHARGIDAE	-	-	-
Niphargus fontanus Bate, 1859	X	X	X
PSEUDONIPHARGIDAE	-	-	-
Microniphargus leruthi Schellenberg, 1934	-	-	X
TRICHONISCIDAE	-	-	-
Androniscus dentiger Verhoeff, 1908	X	X	-
Trichoniscus pusillus Brandt, 1833	-	X	-
ASELLIDAE	-	-	-
Proasellus cavaticus (Leydig, 1871)	X	X	X

Records from:	Jefferson & Chapman (1979)	Jefferson *et al*. (2004)	Additional *Hazelton* records omitted from Jefferson *et al*. (2004), and HCRS data prior to 2023
COPEPODA	-	-	-
Acanthocyclops vernalis (Fischer, 1853)	X	X	-
Paracyclops fimbriatus (Fischer, 1853)	X	X	-
Megacyclops viridis (Jurine, 1820)	X	X	-
OSTRACODA	-	-	-
Cavernocypris subterranea (Wolf, 1920)	X	X	-
SYMPHYLA	-	-	-
SCOLOPENDRELLIDAE	-	-	-
Symphylella vulgaris (Hansen 1903)	-	-	X
DIPLOPODA	-	-	-
CRASPEDOSOMATIDAE	-	-	-
Nanogona polydesmoides (Leach, 1815)	-	X	-
POLYDESMIDAE	-	-	-
Brachydesmus superus Latzel, 1884	-	X	-
BLANIULIDAE	-	-	-
Blaniulus guttulatus (Fabricus, 1798)	-	X	-
ACARI	-	-	-
VEIGAIIDAE	-	-	-
Veigaia nemorensis (Koch, 1839)	-	X	-
Veigaia sp.	X	-	-
RHAGIDIIDAE	-	-	-
Rhagidia punkva Zacharda, 1980	-	X	-
Rhagidia sp.	X	-	-
Poecilophysis spelaea (Wankel, 1861) (see note 1)	-	X	-
DAMAEIDAE	-	-	-
Damaeus crispatus (Kulczynski, 1902)	-	-	X
ARANEAE	-	-	-
LINYPHIIDAE	-	-	-
Tenuiphantes zimmermanni Bertkau, 1890	-	X	-
Palliduphantes pallidus (Cambridge, 1871)	-	X (see note 2)	-
TETRAGNATHIDAE	-	-	-
Metellina merianae (Scopoli, 1763)	-	X	-
Meta menardi (Latreille, 1804)	-	X	-
COLLEMBOLA	-	-	-
ONYCHIURIDAE	-	-	-
Oligaphorura schoetti (Lie-Pettersen, 1897)	X	X	-
Deuteraphorura cebennaria (Gisin, 1956)	X	X	-
Protaphorura armata gp. (Tullberg, 1869)	X	X	-
ISOTOMIDAE	-	-	-
Parisotoma notabilis Schäffer, 1896	X	X	-
Folsomia agrelli Gisin, 1944 (see note 3)	X	X	-
Folsomia diplophthalma (Axelson, 1902) (see note 4)	X	X	-
Folsomia fimetaria (Linnaeus, 1758)	-	X	-
Folsomia candida Willem, 1902	-	-	X
NEELIDAE	-	-	-

Records from:	Jefferson & Chapman (1979)	Jefferson *et al*. (2004)	Additional *Hazelton* records omitted from Jefferson *et al*. (2004), and HCRS data prior to 2023
Megalothorax minimus Willem 1900	X	X	-
ARRHOPALITIDAE	-	-	-
Pygmarrhopalites pygmaeus (Vargovitch, 2009)	X	X	-
Arrhopalites caecus (Tullberg, 1871)	-	X	-
HYPOGASTRURIDAE	-	-	-
Schaefferia emucronata gp. Absolon, 1900	X	X	-
ENTOMOBRYIDAE	-	-	-
Pseudosinella dobati (Gisin, 1965)	X	X	-
Pseudosinella immaculata (Lie Petterson, 1896)	-	X	-
TRICHOPTERA	-	-	-
POLYCENTROPODIDAE	-	-	-
Plectrocnemia geniculata McLachlan, 1871	-	X	-
LIMNEPHILIDAE	-	-	-
Stenophylax permistus (McLachlan, 1895) adults	X	X	-
LEPIDOPTERA	-	-	-
EREBIDAE	-	-	-
Scoliopteryx libatrix (Linnaeus, 1758)	X	X	-
GEOMETRIDAE	-	-	-
Triphosa dubitata (Linnaeus, 1758)	X	X	-
DIPTERA	-	-	-
CHIRONOMIDAE	-	-	-
Spaniotoma sp.	-	X	-
HELEOMYZIDAE	-	-	-
Heleomyza serrata (Linnaeus, 1758)	X	X	-
MYCETOPHILIDAE	-	-	-
Mycetophila ocellus Walker, 1848	-	X	-
Speolepta leptogaster (Winnertz, 1863)	X	X	-
Exechia parva Lundström, 1909	X	-	-
SCIARIDAE	-	-	-
Bradysia forficulata (Bezzi, 1914)	-	X	-
Sciara / Bradysia sp.	X	-	-
TRICHOCERIDAE	-	-	-
Trichocera maculipennis Meigen, 1818	X	X	-
PHORIDAE	-	-	-
Megaselia rufipes (Meigen, 1804)	-	X	-
Phora sp.	X	-	-
CULICIDAE	-	-	-
Culex pipiens Linnaeus, 1758	X	X	-
LIMONIIDAE	-	-	-
Limonia nebeculosa Meigen, 1804	X	X	-
HYMENOPTERA	-	-	-
PROCTOTRUPIDAE	-	-	-
Exallonyx longicornis (Nees, 1834)	-	X	-
COLEOPTERA	-	-	-
CARABIDAE	-	-	-
Trechoblemus micros (Herbst, 1784)	X	X	-

Records from:	Jefferson & Chapman (1979)	Jefferson *et al*. (2004)	Additional *Hazelton* records omitted from Jefferson *et al*. (2004), and HCRS data prior to 2023
Leistus spinibarbis (Fabricus, 1775)	-	X	-
Nebria brevicollis (Fabricus, 1792)	-	X	-
Pterosticus aethiops (Panzer, 1796)	-	X	-
Calathus fuscipes (Goeze, 1777)	-	X	-
LEIODIDAE	-	-	-
Choleva agilis (Illiger, 1798)	-	X	-
Catops nigricornis (Spence, 1813)	-	X	-
STAPHYLINIDAE	-	-	-
Quedius mesomelinus (Marsham, 1802)	-	X	-
Ochthephilus aureus (Fauvel, 1871)	-	X	-
Lesteva pubescens Mannerheim, 1830	X	X	-
Tetralaucopora longitarsis (Erichson, 1839)	-	X	-

Appendix D. Invertebrate taxa recorded from Ogof Draenen prior to the current study.

Data includes that held by the Pwll Du Cave Management Group (PDCMG) biological recorder, primarily records of terrestrial species in the threshold zone; additional observations by L. Knight prior to 2012; the survey of aquatic habitats by Knight *et al.* (2018), including records from the cave and its associated sinks and resurgences (springs) [C, Si, Sp in the table headings]; and taxa collected by sampling dripping water and drip-fed pools by Knight *et al.* (2024). Presence is denoted by 'X'. Taxa highlighted in red are troglobionts (stygobionts), those in blue eutroglophiles (stygophiles) and those in green (subtroglophiles), using the definitions of Sket (2008).

Records from:	PDCMG data	Knight	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2024)
TAXA	**-**	**-**	**C**	**Si**	**Sp**	-
MICROTURBELLARIA	**-**	-	X	-	-	-
TRICLADIDA	**-**	**-**	-	**-**	**-**	-
PLANARIIDAE	-	-	-	-	-	-
Polycelis felina (Dalyell, 1814)	-	-	-	-	X	-
Polycelis nigra / tenuis	-	-	X	-	-	-
Phagocata vitta (Duges, 1830)	-	-	-	-	-	X
Crenobia alpina (Dana, 1766)	-	-	X	-	-	-
NEMATODA	-	-	X	-	X	X
OLIGOCHAETA	-	-	-	-	-	-
LUMBRICIDAE	-	-	-	-	-	-
Eiseniella tetraedra (Savigny, 1826)	-	-	X	-	-	-
Indet. terrestrial Lumbricidae	-	-	X	X	X	-
LUMBRICULIDAE	-	-	-	-	-	-
Stylodrilus lemani (Grube, 1879)	-	-	X	-	X	-
Stylodrilus heringianus Claparède, 1862	-	-	X	-	-	-
Stylodrilus sp. (juv.)	-	-	X	-	X	-
Lumbriculus variegatus Claparède, 1862	-	-	X	X	X	-
Eclipidrilus lacustris (Verill, 1871)	-	-	X	-	X	-
Trichodrilus sp.	-	-	X	-	-	-
Dorydrilus / Trichodrilus juveniles	-	-	X	-	-	-
DORYDRILIDAE	-	-	-	-	-	-
Dorydrilus michaelseni Piguet, 1913	-	-	X	-	-	-
ENCHYTRAEIDAE	-	-	-	-	-	-
Achaeta sp.	-	-	X	-	X	-
Enchytraeidae spp.	-	-	X	X	X	-
NAIDIDAE	-	-	-	-	-	-
Nais elinguis Mũller, 1774	-	-	X	-	-	-
Nais alpina Sperber, 1948	-	-	-	-	X	-
TUBIFICIDAE	-	-	-	-	-	-
Limnodrilus udekemianus Claparède, 1862	-	-	X	-	-	-
Limnodrilus sp. (juv.)	-	-	X	-	X	-
Tubifex ignotus (Stolc, 1886)	-	-	X	-	-	-
Rhyacodrilus falciformis Bretscher, 1901	-	-	X	-	-	-

Records from:	PDCMG data	Knight	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2024)
Oligochaeta (indet.)	-	-	X	X	X	X
HIRUDINEA	-	-	-	-	-	-
GLOSSIPHONIIDAE	-	-	-	-	-	-
Glossiphonia complanata (Linnaeus, 1758)	-	-	-	-	X	-
GASTROPODA	-	-	-	-	-	-
ACICULIDAE	-	-	-	-	-	-
Acicula fusca (Montagu, 1803)	X	-	-	-	-	-
ELLOBIIDAE	-	-	-	-	-	-
Carychium minimum (O.F. Mũller, 1774)	X	-	-	-	-	-
PUPILLIDAE	-	-	-	-	-	-
Pupilla muscorum (Linnaeus, 1758)	X	-	-	-	-	-
CLAUSILIIDAE	-	-	-	-	-	-
Clausillia bidentata (Ström, 1765)	X	-	-	-	-	-
ENIDAE	-	-	-	-	-	-
Ena obscura (O.F. Mũller, 1774)	X	-	-	-	-	-
DISCIDAE	-	-	-	-	-	-
Discus rotundatus (O.F. Mũller, 1774)	X	-	-	-	-	-
ZONITIDAE	-	-	-	-	-	-
Vitrea contracta (Westerlund, 1871)	X	-	-	-	-	-
Oxychilus cellarius (O.F. Mũller, 1774)	X	-	-	-	-	-
HYGROMIIDAE	-	-	-	-	-	-
Trochulus hispidus (Linnaeus, 1758)	X	-	-	-	-	-
Trochulus striolatus (Pfeiffer, 1826)	X	-	-	-	-	-
PLANORBIDAE	-	-	-	-	-	-
Ancylus fluviatilis O.F. Mũller, 1774	-	-	-	-	X	-
*Bathyomphalus contortus (*Linnaeus, 1758*)*	-	-	-	-	-	-
HYDROBIIDAE	-	-	-	-	-	-
Potamopyrgus antipodarum (J.E. Gray, 1843)	-	-	-	-	X	-
LYMNAEIDAE	-	-	-	-	-	-
*Galba truncatula (*O.F. Mũller, 1774)	-	-	-	X	-	-
BIVALVIA	-	-	-	-	-	-
SPHAERIIDAE	-	-	-	-	-	-
Euglesa personata (Malm, 1855)	-	-	-	X	-	-
Euglesa casertana (Poli, 1791)	-	-	-	X	-	-
Euglesa nitida (Jenyns, 1832)	-	-	-	X	-	-
Eugelsa sp.	-	-	X	X	-	-
CRUSTACEA	-	-	-	-	-	-
BATHYNELLIDAE	-	-	-	-	-	-
Antrobathynella stammeri (Jakobi, 1954)	-	-	X	-	-	-
GAMMARIDAE	-	-	-	-	-	-
Gammarus pulex (Linnaeus, 1758)	-	X	X	X	X	-
NIPHARGIDAE	-	-	-	-	-	-
Niphargus fontanus Bate, 1859	-	X	X	-	X	-
Niphargus aquilex Schiödte, 1855	-	-	-	-	X	-
PSEUDONIPHARGIDAE	-	-	-	-	-	-
Microniphargus leruthi Schellenberg, 1934	-	-	X	-	X	X
ASELLIDAE	-	-	-	-	-	-
Proasellus cavaticus (Leydig, 1871)	-	X	X	-	X	X

Records from:	PDCMG data	Knight	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2024)
Proasellus meridianus (Racovitza, 1919)	-	-	X	-	-	-
Asellus aquaticus (Linnaeus, 1758)	-	-	-	-	X	-
CLADOCERA	-	-	-	-	-	-
Simocephalus vetulus (O.F. Mũller, 1778)	-	-	X	-	-	-
COPEPODA	-	-	-	-	-	-
Acanthocyclops robustus Sars, 1863	-	-	X	-	-	-
Eucyclops serulatus (Fischer, 1851)	-	-	X	-	-	-
Paracyclops fimbriatus (Fischer, 1853)	-	-	X	-	-	-
Paracyclops fimbriatus gp.	-	-	-	-	-	X
Tropocyclops prasinus (Fischer, 1860)	-	-	X	-	-	-
Diacyclops languidoides (Lilljeborg, 1901)	-	-	-	-	-	X
Graeteriella sp. *(c.f. boui??)*	-	-	-	-	-	X
Cyclopoida spp.	-	-	X	-	-	-
Bryocamptus echinatus (Mrázek, 1893)	-	-	-	-	-	X
Bryocamptus zschokkei (Schmeil, 1893)	-	-	-	-	-	X
Bryocamptus pygmaeus (G.O. Sars, 1863)	-	-	-	-	-	X
OSTRACODA	-	-	-	-	-	-
Cavernocypris subterranea (Wolf, 1920)	-	-	X	-	-	-
Fabaeformiscandona breuili (Paris, 1920)	-	-	-	-	-	X
Ostracoda sp. (indet.)	-	-	-	-	-	X
DIPLOPODA	-	-	-	-	-	-
BLANIULIDAE	-	-	-	-	-	-
Blaniulus guttulatus (Fabricus, 1798)	X	-	-	-	-	-
CHILOPODA	-	-	-	-	-	-
LITHOBIIDAE	-	-	-	-	-	-
Lithobius sp.	X	-	-	-	-	-
ACARI	-	-	-	-	-	-
Oribatei spp.	-	-	-	X	-	-
HALACARIDAE	-	-	-	-	-	-
Soldanellonyx chappuisi Walter, 1917	-	-	X	-	-	X
Halacaridae spp.	-	-	X	-	-	-
ARANEAE	-	-	-	-	-	-
TETRAGNATHIDAE	-	-	-	-	-	-
Meta menardi (Latreille, 1804)	-	X	-	-	-	-
COLLEMBOLA	-	-	-	-	-	-
ONYCHIURIDAE	-	-	-	-	-	-
Protaphorura armata (Tullberg, 1869)	-	-	X	X	-	-
ISOTOMIDAE	-	-	-	-	-	-
Parisotoma notabilis Schäffer, 1896	-	-	X	-	-	-
Isotomurus unifasciatus (Börner, 1901)	-	-	-	X	-	-
Isotomurus palustris (Mũller, 1776)	-	-	-	X	-	-
Isotoma anglicana Lubbock, 1862	-	-	-	X	-	-
TOMOCERIDAE	-	-	-	-	-	-
Tomocerus vulgaris (Tullberg, 1871)	-	-	-	-	X	-
ENTOMOBRYIDAE	-	-	-	-	-	-
Entomobrya intermedia Brook, 1884	-	-	-	X	-	-
Collembola (indet.)	-	-	-	X	-	-
DIPLURA	-	-	-	-	-	-

Records from:	PDCMG data	Knight	Knight *et al*. (2018)	Knight *et al*. (2018)	Knight *et al*. (2018)	Knight *et al*. (2024)
CAMPODEIDAE	X	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-
LEUCTRIDAE	-	-	-	-	-	-
Leuctra nigra (Olivier, 1811)	-	-	X	-	X	-
Leuctra fusca (Linnaeus, 1758)	-	-	X	-	X	-
Leuctra hippopus Kempny, 1899	-	-	-	X	X	-
Leuctra geniculata Stephens, 1836	-	-	-	-	X	-
Leuctra sp. (1st instar)	-	-	X	X	X	-
CHLOROPERLIDAE	-	-	-	-	-	-
Siphonoperla torrentium (Pictet, 1841)	-	-	X	-	-	-
NEMOURIDAE	-	-	-	-	-	-
Nemurella picteti Klapálek, 1900	-	-	-	-	X	-
Nemoura cambrica Stephens, 1836	-	-	-	X	-	-
Nemoura cinerea (Retzius, 1783)	-	-	-	X	-	-
Nemoura erratica Claassen, 1936	-	-	-	X	-	-
Nemoura sp. (1st instar)	-	-	X	X	X	-
EPHEMEROPTERA	-	-	-	-	-	-
HEPTAGENIIDAE	-	-	-	-	-	-
Electrogena lateralis (Curtis, 1834)	-	-	X	-	X	-
Electrogena sp.	-	-	-	-	X	-
Rhithrogena semicolorata (Curtis, 1834)	-	-	X	-	-	-
Ecdyonurus torrentis Kimmins, 1942	-	-	-	-	X	-
Heptageniidae sp. (1st instar)	-	-	-	-	X	-
LEPTOPHLEBIIDAE	-	-	-	-	-	-
Leptophlebiidae sp. (fragments)	-	-	X	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-
Serratella ignita (Poda, 1761)	-	-	-	-	X	-
BAETIDAE	-	-	-	-	-	-
Baetis rhodani / atlanticus	-	-	-	X	X	-
Baetis muticus (Linnaeus, 1758)	-	-	-	-	X	-
Baetis scambus Eaton, 1870	-	-	-	-	X	-
Baetis sp. (1st instar)	-	-	X	-	X	-
TRICHOPTERA	-	-	-	-	-	-
POLYCENTROPODIDAE	-	-	-	-	-	-
Plectrocnemia geniculata McLachlan, 1871	-	-	X	-	X	X
Plectrocnemia conspersa (Curtis, 1834)	-	-	-	X	X	-
Plectrocnemia sp.	-	-	X	-	X	X
Polycentropodidae spp.	-	-	X	-	-	-
HYDROPSYCHIDAE	-	-	-	-	-	-
Hydropsyche siltalai Doehler, 1963	-	-	-	-	X	-
Diplectrona felix McLachlan, 1878	-	-	-	X	-	X
RHYACOPHILIDAE	-	-	-	-	-	-
Rhyacophila dorsalis (Curtis, 1834)	-	-	-	-	X	-
PHILOPOTAMIDAE	-	-	-	-	-	-
Wormaldia occipitalis (Pictet, 1834)	-	-	X	-	X	-
Wormaldia sp.	-	-	X	-	-	-
SERICOSTOMATIDAE	-	-	-	-	-	-

Records from:	PDCMG data	Knight	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2024)
Sericostoma personatum (Spence in Kirby & Spence, 1826)	-	-	-	-	X	-
LEPIDOSTOMATIDAE	-	-	-	-	-	-
Crunoecia irrorata (Curtis, 1834)	-	-	-	-	X	-
LIMNEPHILIDAE	-	-	-	-	-	-
Stenophylax permistus (McLachlan, 1895) adults	X	-	-	-	-	-
Limnephilus centralis Curtis, 1834	-	-	-	X	-	-
Limnephilidae spp.	-	-	-	X	-	-
LEPIDOPTERA	-	-	-	-	-	-
GEOMETRIDAE	-	-	-	-	-	-
Triphosa dubitata (Linnaeus, 1758)	-	X	-	-	-	-
DIPTERA	-	-	-	-	-	-
CHIRONOMIDAE	-	-	-	-	-	-
Synthorthocladius semiviriens (Kieffer, 1909)	-	-	X	-	-	-
Orthocladius / Cricotopus gp.	-	-	X	X	X	-
Tvetenia sp.	-	-	X	X	X	-
Corynoneura sp.	-	-	X	-	-	-
Eukiefferiella sp.	-	-	X	X	X	-
Chaetocladius sp.	-	-	-	-	X	-
Metriocnemus sp.	-	-	-	-	X	-
Synorthocladius sp.	-	-	-	X	-	-
Brillia modesta (Kieffer, 1909)	-	-	X	-	-	-
Ablabesmyia sp.	-	-	X	X	X	-
Paramerina sp.	-	-	X	X	X	-
Macropelopia sp.	-	-	X	X	-	-
Microspectra sp.	-	-	X	-	X	-
Potthastia longimana (Kieffer, 1922)	-	-	-	-	X	-
Chironomidae spp.	-	-	X	X	X	X
SIMULIIDAE	-	-	-	-	-	-
Simulium cryophilum (Rubstov, 1959)	-	-	X	X	-	-
Simulium sp.	-	-	X	X	X	-
EMPIDIDAE	-	-	-	-	-	-
Chelifera sp	-	-	-	-	-	X
DIXIDAE	-	-	-	-	-	-
Dixa puberula Loew, 1849	-	-	-	-	X	-
CERATOPOGONIDAE	-	-	-	-	-	-
Palpomyia / Bezzia gp.	-	-	X	X	X	-
Sphaeromias sp.	-	-	X	X	X	-
Ceratopogonidae spp.	-	-	X	-	-	-
PSYCHODIDAE	-	-	-	-	-	-
Bazarella neglecta (Eaton, 1893)	-	-	-	X	-	-
Psychodidae sp. (pupa)	-	-	-	X	-	-
BIBIONIDAE	-	-	-	-	-	-
Bibio sp.	-	-	-	X	-	-
HELEOMYZIDAE	-	-	-	-	-	-
Heleomyza captiosa (Gorodkov, 1962)	X	-	-	-	-	-
Heleomyza captiosa / serrata	-	X	-	-	-	-
MYCETOPHILIDAE	-	-	-	-	-	-

Records from:	PDCMG data	Knight	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2018)	Knight *et al.* (2024)
Speolepta leptogaster (Winnertz, 1863)	X	-	-	-	-	-
CULICIDAE	-	-	-	-	-	-
Culex pipiens Linnaeus, 1758	-	X	-	-	-	-
TIPULIDAE	-	-	-	-	-	-
Nephrotoma sp.	-	-	-	-	X	-
PEDICIIDAE	-	-	-	-	-	-
Dicranota sp.	-	-	X	X	-	-
LIMONIIDAE	-	-	-	-	-	-
Limonia nebeculosa Meigen, 1804	X	-	-	-	-	-
Ormosia sp.	-	-	-	-	X	-
Phylidorea sp.	-	-	-	X	-	-
Neolimnomyia sp.	-	-	-	X	-	-
Eloeophila sp.	-	-	X	-	-	-
COLEOPTERA	-	-	-	-	-	-
SCIRTIDAE	-	-	-	-	-	-
Elodes sp. (larvae)	-	-	-	X	-	-
DYTISCIDAE	-	-	-	-	-	-
Agabus guttatus (Paykull, 1798)	-	-	-	X	-	-
Agabus sp. (larva)	-	-	-	X	-	-
Dytiscidae sp. (indet. larva)	-	-	-	-	X	-
HYDROPHILIDAE	-	-	-	-	-	-
Anacaena globulus (Paykull, 1798)	-	-	-	X	-	-
HELOPHORIDAE	-	-	-	-	-	-
Helophorus aequalis C.G. Thomson, 1868	-	-	-	X	-	-
Helophorus flavipes Fabricus, 1792	-	-	-	X	-	-
ELMIDAE	-	-	-	-	-	-
Elmis aenea (P.W.J. Mũller, 1806)	-	-	X	X	X	-
Limnius volckmari (Panzer, 1793)	-	-	-	-	-	X
Esolus parallelepipedus (P.W.J. Mũller, 1806)	-	-	-	-	X	-
Oulimnius sp. (larvae)	-	-	X	-	-	-
CARABIDAE	X	-	-	-	-	-
STAPHYLINIDAE	X	-	-	-	-	-

Appendix E. Glossary of terms used in this report.

Allogenic: Streams derived from the surface, i.e. they sink at a cave entrance, often carrying in with them surface aquatic (epi-benthic) invertebrate species. As opposed to autogenic, streams within a cave system that have their source underground, i.e. from percolating waters seeping through the overlying rocks and soil.

Anthodites: a cave formation (see "speleothem") consisting of radiating clusters of needle-like crystals, typically composed of the mineral aragonite, rather than the more common calcite.

Asymptote: A straight line that approaches a curve. In a species accumulation curve, a simple graph plotting number of taxa against given time / sampling effort, the closer the curve comes to asymptote then the greater the likelihood that the curve represents a full accounting of the true biodiversity (i.e. number of taxa) for a given habitat (e.g. a cave system). The further the distance from the asymptote then the greater the sampling effort still required to provide a full biodiversity inventory.

Autogenic: See "Allogenic" above.

Aven: vertical shafts that extend upwards from a cave passage. Some can be open at the top and provide a vertical point of entry (using ropes) but many are formed by percolating water and end below the surface.

Biome: areas of the planet with similar climate and landscape, e.g. tundra, rainforest, savannah.

Boulder collapse: a blockage in a cave passage or chamber, formed by the movement of boulders, most often due to tectonic activity in the past. Also known as a "boulder ruckle" by cavers.

Cavernicolous: living in caves and caverns.

Devensian: The Devensian Stage was the last major glacial period during the Pleistocene, lasting from approximately 120000 to 10000 years ago. During this period much of northern Britain was covered with extensive ice sheets, with peri-glacial (tundra) conditions to the south.

Diapause: A period of suspended development in invertebrates in which the metabolism is slowed to preserve resources, usually during a period of unfavourable environmental conditions, e.g. winter hibernation.

Doline field: A doline is a small (although note some examples can be huge in both diameter and depth), closed depression on the surface, formed from the dissolution of limestone or other soluble rocks. A doline field is a clustering of many such dolines.

Epi-benthic: Invertebrate species living in streams and rivers on the surface.

Epigean: relating to the surface, as opposed to hypogean, the sub-surface.

Epikarst: In karst regions the uppermost layer of weathered rock underlying the soil and overlying the bedrock beneath (see MSS), usually up to 10m thick. It differs from MSS in that due to dissolution processes and many solutional pockets within the epikarst, there is a great deal of heterogeneity within it, and whilst there is significant lateral transmission of water within the epikarst the vertical flow downwards through fissures is slowed, such that the epikasrt can retain a considerable amount of water as a perched aquifer above the water table, often harbouring a diverse range of specialist species (mostly micro-Crustacea such as Copepoda and Ostracoda). Water from this aquifer then slowly percolates down into cave passages below and can be a high source of organic input for cave systems. Whilst almost universal in karst regions, it can be absent in formerly glaciated areas and arid zones.

Eutroglophile: Essentially surface species able to maintain permanent subterranean populations (troglophile, stygophile). British examples: many species of Collembola and mites, the amphipod *Gammarus pulex*.

Exogenous: matter, usually organic (nutrition), derived from outside of a cave, i.e. the surface.

Fossil passages: Passages in caves that once held water (hydrologically active) but due to the continuing erosion of the limestone and development of new passages they have now become dry and abandoned as the water flows in passages at greater depth.

Geomorphology: The study of landscapes and landforms and the processes that shape them, such as tectonic movements and erosion.

Gnathopods: In Amphipoda (Crustacea) morphology the first two pairs of limbs (pereopods), modified to form grasping appendages, used in feeding, defence and occasionally locomotion, or to grasp females prior to mating (precopulatory guarding behaviour).

Gypsum needles / flowers. Formed of the sulphate mineral gypsum (selenite) these are generally deposited in relatively dry passages due to local feeding of solutions through pores in the rock under capillary pressure. Forming either needle-like crystals or crystal petals radiating from a central point (flowers). They grow from the base rather than the tip as in stalactites and stalagmites.

Helictites: contorted cave formations (see “speleothem”) which grow in twisted, curved or angular shapes.

Hydrologically active passages: Cave passages which still contain flowing water (streams), see “Fossil passages” above.

Hydrothermal groundwaters: Water rising from depth which has been in contact with deep geothermal hot rocks or magma. Such waters are often rich in minerals, especially sulphur which can be oxidised to sulphuric acid and dissolves limestone much more rapidly than carbonic acid, derived from atmospheric carbon dioxide; hence encourages much faster rates of cave formation.

Hypogean: relating to the sub-surface, as opposed to epigean, the surface.

Hyporheic zone / Hyporheos: the transitional zone between surface water in a stream or river and groundwater. Specifically, the saturated sediments beneath and beside the channel, where surface and ground water intermix and exchange nutrients, oxygen and other substances. It often harbours a mixture of both surface dwelling and subterranean species.

Karst: The landscape formed by the dissolution (by water over thousands of years) of soluble carbonate rocks such as limestone and dolomite. Karst is characterised by features such as cave systems, dolines and dry valleys due to its porous nature.

Last Glacial Limit (LGM): the furthest extent reached by the ice sheets at their maximum during the last major glacial stage of the Pleistocene (Devensian), approximately 26 to 22000 years ago. During this time ice sheets covered the whole of Scotland, almost all of Wales and Ireland, and England as far south as the Midlands. The movements of this ice and associated glaciers shaped much of the modern topography of the British Isles.

Lentic: Static water habitats (e.g. pools, ponds and lakes), as opposed to lotic, running water habitats (e.g. streams and rivers).

Lotic: Running water habitats (e.g. streams and rivers), as opposed to lentic, static water habitats (e.g. pools, ponds and lakes).

Mesovoid Shallow Substratum (or Milieu Souterrain Superficiel), MSS: A terrestrial subterranean habitat formed by the network of cracks, fissures and interstices inside rock debris. It can be exposed at the surface (e.g. talus slopes) but is more often covered with a layer of soil and overlies the bedrock beneath.

Niche (ecology): the specific role an organism plays within its ecosystem, essentially describing its habitat, resources it uses, and interactions with other organisms, its “lifestyle”.

Phreatic: The zone beneath the vadose zone that is saturated with water, either pores and conduits in rocks or larger passages in cave systems. The zone varies in depth below the surface due to fluctuations in groundwater levels and surface recharge of the aquifer, i.e. infiltrating water from the surface.

Pleistocene: The geological epoch from 2.58 million to 11700 years ago, during which the earth experienced periods of intense cooling (glaciations), in which ice covered much of the southern and northern regions, interspersed with warm (interglacial) periods.

Rheophobic: an organism that dislikes fast flowing waters.

Resurgence: where cave streams emerge at the surface, similar to groundwater emerging as springs. Resurgences can sometimes be open passage that can allow entry into a cave system.

Sink: where a surface stream flows underground, often at the entrance to a cave, although sometimes the water will flow through narrow fissures that do not allow entry. Sinks generally occur at a geological boundary, from low permeability rocks, supporting surface waterbodies, to high permeability rocks (e.g. easily dissolved by water such as limestone) filled with subterranean fissures and conduits, hence little surface flow.

Speleology: an umbrella term encompassing the scientific study of caves, within which there are various sub-disciplines such as cave formation (speleogenesis), and biology (biospeleology). Speleologists is a term sometimes also used to refer to cave explorers.

Speleothem: a general name for formations in caves usually made of calcite deposited by percolating waters but can also consist of other minerals such as aragonite. Examples include stalactites, stalagmites and helictites.

Subtroglophile: Species inclined to perpetually or temporarily inhabit subterranean habitats but intimately associated with surface habitats for some biological function (daily e.g. feeding, seasonally, or during their life history e.g. reproduction) (habitual trogloxene). British examples: the mosquito *Culex pipiens*, tissue and herald moths, some bats.

Sump: a cave passage filled with water, sometimes delimitating the upper boundary of the phreatic zone but can often be much shorter "perched sumps" in the vadose zone; representing a lower section of cave stream passage filled with water. Usually require cave diving techniques and equipment to pass.

Threshold: the zone near a cave entrance into which some light penetrates. Can be divided into the shallow threshold, near the entrance, and the deep threshold in which light levels drop considerably as one transitions to the dark zone where light is completely absent. The threshold also experiences a zonation of other environmental parameters such as temperature and humidity and many invertebrate species seek out a particular part of the threshold in which to live or as part of their life cycle (subtroglophiles).

Tracer testing: used to study groundwater flow paths, this involves introducing a tracer (either a brightly coloured dye or bacteria) into a stream (above or below ground) and monitoring its movement and concentration over time and distance.

Troglobiont: Strongly bound to subterranean habitats (troglobite, stygobite). British examples: amphipods in the genus *Niphargus*, a few species of Collembola (springtails), the spider *Porrhomma rosenhaueri*.

Trogloxene: Species occurring sporadically in subterranean habitats but unable to establish permanent subterranean populations (accidental trogloxene, accidental); includes many species across a variety of animal groups.

Underfit stream: a stream in a cave passage that has undergone successive phases of collapse, such that the stream now flows beneath a layer of boulders and debris and is inaccessible for much of its length.

Vadose: Beneath the surface this is the zone in caves, fissures and conduits that is mostly filled with air and lays above the water-filled phreatic zone, where groundwater is at atmospheric pressure. Pore spaces in rock and soil are partially filled with air and water, whilst bigger vadose passages in cave systems can be either completely dry or hold water as pools and streams.

Data Archive Appendix

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

~~[B] A full set of maps produced in JPEG format~~.

~~[C] A series of GIS layers on which the maps in the report are based with a series of word documents detailing the data processing and structure of the GIS layers~~.

~~[D] A set of raster files in ESRI and ASCII grid formats~~.

~~[E] A database named [name] in Microsoft Access 2000 format with metadata described in a Microsoft Word document [name.doc]~~.

[F] A full set of images produced in [jpg/tiff].

[G] Species records held in Welsh Invertebrate Database (WID).

Metadata for this project is publicly accessible through Natural Resources Wales' Data Discovery Service https://metadata.naturalresources.wales/geonetwork/srv (English version) and https://metadata.cyfoethnaturiol.cymru/geonetwork/cym/ (Welsh Version). The metadata is held as record no. **NRW_DS161353**.