A survey of tufa-forming (petrifying) springs in the Slieve Bloom, Ireland

By

Stephen Heery

Neil Warner

A Report for Offaly & Laois County Councils

2007

Part 1

Main report

SUMMARY

A survey was undertaken in 2007 to locate, map and describe tufa-forming (petrifying) springs in the Slieve Bloom mountains, Counties Offaly and Laois. Twenty sites, in eight valleys, were given site reports (with maps and aerial photographs) and described in terms of types of formation, the vascular plant species present, surrounding habitats and conservation prospects. A collection of digital photographs was made of each site and this is on the CD version of the report. Bryophytes were collected and stored, and some were identified. All the sites described had actively forming tufa accumulations, inextricably associated with bryophyte species (mosses and liverworts), usually *Palustriella commutata* var. *commutata* but also *Conocephalum conicum* and others, including common woodland species. Most of the formations can be described as 'cascades' (formed by water flowing or trickling down a slope) and associated formations. A list of molluscs collected from five sites was considered to represent a very significant addition to the biodiversity of the wider Slieve Bloom. The source of most of the calcium is almost certainly Carboniferous Limestone glacial drift but calcareous strata within the Old Red Sandstone are directly involved at a few sites. Fallow deer have access to all sites but trampling damage is not significant at present. The factors affecting the locations of the springs were not determined and the wider hydrology of the springs was not considered. There is probably scope for finding other tufa-forming springs in valleys, and stretches of valleys, not covered in this survey. This is a habitat that is listed in Annex 1 of the E.U. Habitats Directive. A tentative suggestion is made to include six sites in one new and one extended SAC.

6-3

CONTENTS

PART 1.

1. INTRODUCTION – A REVIEW

1.1.What is tufa?

In nature, tufa is a white to straw-coloured deposit of calcium carbonate (lime). It is formed when groundwater receives carbon dioxide from the soil (or from volcanic sources) and becomes a very weak carbonic acid. When this makes contact with calcium-rich rock or sediments it chemically corrodes (dissolves) some calcium and carries it away in solution. When the water emerges at the surface it loses the carbon dioxide, and the dissolved calcium is reformed as calcium carbonate or tufa deposits.

H_2O water + CO_2 carbon dioxide + $CaCO_3$ calcium carbonate (limestone)

>>>> $CaH_2C_2O_6$ calcium bicarbonate (soluble, carried away in solution)

>>>> H_2O water + CO_2 carbon dioxide (lost to the air) + $CaCO_3$ (insoluble, deposited as tufa)

A loss of carbon dioxide from calcium-saturated groundwater ('hard water'), causing tufa deposition, can occur in four situations in nature:

- When the groundwater emerges at the surface and carbon dioxide is lost on contact with the air and/or subsequent release of pressure.
- When hard water is agitated, as in small or large waterfalls.
- When a thin film of hard water remains in contact with the air in the form of drips or dries out. A classic example is the *stalactite/stalagmite* formations of caves. This can also occur above ground.
- When carbon dioxide is taken from the water by plants during photosynthesis. Some bryophyte species (mosses and liverworts) and perhaps algae perform this task at tufa springs.

Relevance to present survey:

All these processes are apparent in the **Slieve Bloom** tufa springs except possibly loss of carbon dioxide purely due to loss of pressure.

To summarise (after Pentecost, 2005): for a tufa-forming spring to develop it is necessary to have the required combination of **geology** (lime-rich deposits as the source of calcium, and perhaps to direct the route of the groundwater); **water chemistry** (the presence of 'attacking' carbon dioxide-rich water, the carrier of calcium in solution); and **aquifer** characteristics and **topography** (controlling the location of the emerging spring and the rates of flow, which can be very low but need to be constant).

Groundwater probably needs to have travelled a considerable distance to achieve an even flow and to gather sufficient quantities of calcium.

1.2 Synonyms and terminology

Tufa has also been called **calcite**, **spring limestone, spring chalk, calc, stream tufas, calc-sinter** (Praeger, 1904 - an early description) or **bryoliths** (when consisting mainly of petrified bryophytes – mosses and liverworts). Fossil (inactive) tufa deposits (from 1,000s to 100,000s of years old) have been called **calcrete** or **travertine**. Another term, **caliche** is used for a calcium carbonate soil or 'hardpan' formed by evaporation at the surface of an arid landscape. There are no fossilised remains of plant and animal life in a caliche, in contrast to tufa deposits, which often have them in abundance.

- *Relevance to the present survey*.
  Both fossil calcrete and caliche strata are present in the **Slieve Bloom** geology.

Tufa-forming springs are also called ***petrifying springs*** (petrify: to become like stone) due to the encrustation of twigs, mosses, leaves etc which over time can either become replaced with calcite, retaining physical structure, or be preserved in a casing of calcite. Water also appears to 'turn to stone' when depositing tufa in waterfalls. '**Cratoneurion**' is the scientific name given to the vegetation of a classic tufa-forming spring. It refers to the moss species *Cratoneuron commutatum* (now named *Palustriella commutata*) that, along with only a few other species, is usually abundant at these sites. These mosses encourage the precipitation of tufa on their leaves and continue to grow away from it. However, it must be noted that *Palustriella commutata* etc are not confined to tufa-forming situations and can occur in more normal base-rich springs and seepages.

This moss cover is the basis for the development of complex and specialised biological habitat on what was originally a completely inorganic substrate (i.e. the tufa). The habitat often remains lacking in soil or peat development.

1.3. E.U.Habitats Directive

The E.U. Habitats Directive lists habitats that are rare in Europe as a whole and for which Special Areas of Conservation SAC can be designated in order to aid their conservation. **'Petrifying springs with tufa formation (*Cratoneurion*)*'** is a habitat listed in the Directive. The * indicates that its conservation is considered a priority. Unlike other listed habitats, active tufa-forming springs are generally small (sometimes only point or linear formations). The formations in Ireland are said to be small compared to those found in Europe, where some active sites reach up to 1 ha and complexes of dams and cascades are very much larger, for instance in Croatia (Pentecost, 1995).

Active tufa-forming springs occur throughout Europe where the annual mean air temperature is > 5 degrees Celsius. Pentecost (1995) has briefly reviewed 320 published travertine sites in Europe, 156 of which are still active in some form.

The remaining ones are inactive - fossil travertines - and range in area from 650km^2 to just a few square metres and in thickness from 300m to a few cms. Fossil travertine is often quarried - a grey to coral red stone with natural holes and troughs (caused by the mode of origin) giving a 'rustic' look.

1.4. Why are tufa-forming springs of particular interest?

These springs, and the deposits and vegetation associated with them, are of both geological and biological interest.

1.4.1. Geological

The (relatively) rapidly accreting tufa tends to overwhelm the remains of flora and fauna, fossilising them. Quarries in travertine in Germany (for instance, the Ilm Valley), deposited during the Pleistocene (in temporary warm periods during the Ice Age, 100,000 to 225,000 years ago), have yielded a comprehensive fossil record, from invertebrates to mammals, including human remains (references are cited in Pentecost, 1995). Nearer to home, on the border of Offaly and Tipperary, two deposits of fossil tufa have yielded very many species of molluscs (snails) and ostracods (tiny, shelled organisms related to lobsters and crabs) (Preece and Robinson, 1982). The sites are at Millpark (S119 909) and nearby Gloster. The sequence of fossils records a changing series of tufa-forming environments that lasted 5,000 years (starting c 8,000 years ago) and included lakes, pools, seepages, swamps, streams and fens. At Millpark, tufa is still being deposited in waterfalls and dams created where the stream passes over the fossil deposit. Unfortunately, the Gloster site seems to have been destroyed during land reclamation.

Tufa rapids and dams at Millpark.

Examination of carbon chemistry preserved in the calcium carbonate of tufa and travertines has been giving information of past environments including former atmospheric composition (Pentecost, 2005).

- *Relevance to the present survey*:

  Petrification is on-going in the **Slieve Bloom** tufa deposits. Evidence of petrified leaves, plant debris, hazel nut-shaped cavities and greater horsetails *Equisetum telmateia* are testament to the continuation of the process today. Moorkens found a rich assemblage of living molluscs on sampling five **Slieve Bloom** sites for this survey (see Appendix IV).

3-6, Petrified plant remains.

1.4.2. Biological

The unusual nature of this habitat for both flora and fauna has fascinated biologists for more than two centuries and is widely accepted today:

> "Larger petrifying springs form tufa cones that constitute singular habitats with several interacting plant and animal communities" (CORINE, 1994)

> "It was soon established that the specialised physio-chemical environment was home to a great diversity of plants and animals with some peculiar adaptations to a rapidly depositing environment. Rocky, soil free surfaces are not usually recognised for their richness of the biota. Plants have few opportunities to root. But few rocks match travertine in the range of hardness and texture, and the source of water is chemically diverse. Consequently, active travertine surfaces often support a surprising biota which in turn influence the deposition" (from Pentecost, 2005).

Tufa-forming springs are known be a habitat for a specialised fauna – tufobiont species- adapted to an environment that has very many unusual features compared to surrounding habitats, but this aspect has not been considered in detail in this survey. In simple terms, among the most immediately apparent special conditions are: a constant, but often low, water flow of even temperature; a constantly wet, but essentially terrestrial, open mossy substrate; almost complete lack of peat or soil development; an (over) abundance of accreting calcium and other water chemistry aspects. Organisms with non-emergent life styles such as crustaceans (ostracods) and molluscs are said to be more at home here than insects. Crustaceans have an obvious use for excess calcium in shell building, and constant temperatures mean the possibility of year round reproduction. There are, however, some insect species adapted to these places. Caddis fly larvae, chironomids (non-biting midges) and beetles were sampled at Pollardstown Fen tufa springs (Murray, 1996 quoted in Otte, 2003). Furthermore, these species, which are relatively high on the food chain, are living off myriad lower forms that also need to be specially adapted.

1.4.3. Types of tufa formation

Foss (2007) gives the accepted definition of a petrifying spring:

> "Petrifying springs are permanently irrigated and kept moist by water that is calcareous and oligotrophic (i.e. poor in nutrients) in nature. The water supply may be from upwelling groundwater sources, or from seepage sources or sometimes from geo-thermal sources. Petrifying springs may be closely associated with Alkaline fens but with less fluctuations in water table…. A key requirement is a steady flow of water, though this may dry up periodically.

Because of the different combinations of situations that can cause tufa formation, the resulting habitat can take different forms. Pentecost (1995) gives a terminology for eight types of travertine (tufa) formations (see Fig 1.). Mounds form where the emerging water is upwelling onto flat ground; similarly, fissure ridges, in limestone bedrock. Cascades are formed by falling water; stream encrustations form around stones, debris and other sedentary objects in a stream; a lake crust develops where a spring emerges into a shallow lake; paludal deposits build up around marsh and fen plants. Tufa can build up in cascades or streams to form dams. A cemented rudite is equivalent to a calcareous 'hardpan', cementing sand and loose stones together.

It is useful to differentiate these types in the field, as each is likely to be a slightly different habitat for organisms. One site can, of course, contain more than one type, and there will be gradations.

- *Relevance to the present survey*:

  With reference to Fig.1, below, the present **Slieve Bloom** survey found mostly types **c** and **e**, with occasional **d** (see Results).

2-5,Tufa dam formation.

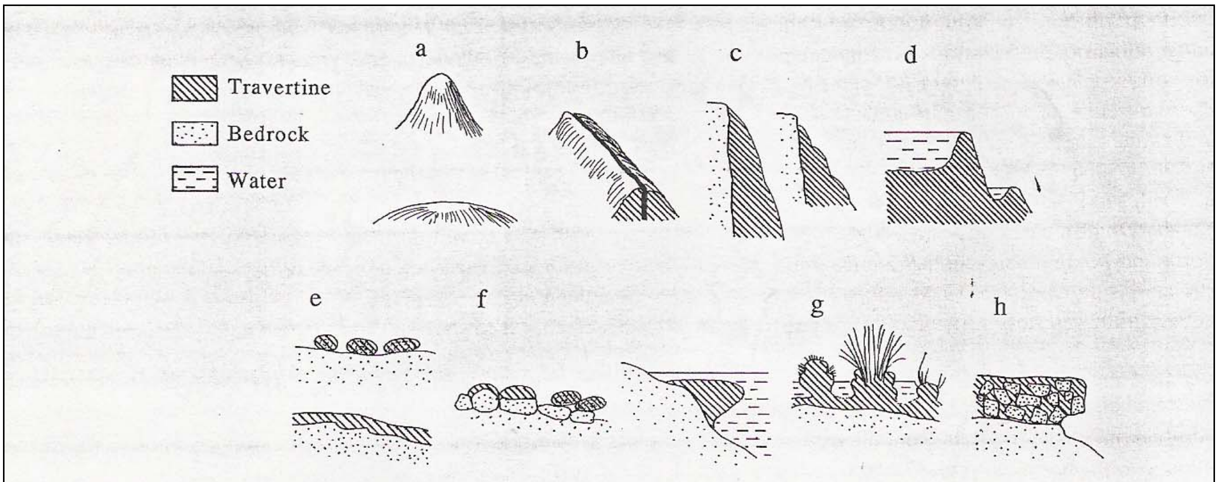


FIG. 1. The main travertine morphologies. (a) mounds; (b) fissure ridge; (c) cascades; (d) dam; (e) stream crust with oncoids; (f) lake crust with oncoids; (g) paludal deposit; (h) cemented rudite (not to scale).

Fig.1. Types of travertine (tufa) formation (from Pentecost, 1995).

2. TUFA-FORMING SPRINGS IN IRELAND and OFFALY/LAOIS

Tufa-forming (or petrifying) springs are reported have a wide range in Ireland (Foss, 2007). This is due to the widespread occurrence of limestone bedrock and its derived glacial drift, coupled with an annual mean air temperature well above the 5 degrees Celsius and a relatively high and constant precipitation rate. These are the factors involved in a location's 'travertine-forming potential' described by Pentecost (1995). A similar conclusion was reached by Foss using the distribution of known petrifying springs together with the distribution of character species and of bryophytes known to be capable of tufa formation.

After an exhaustive review of Irish data, Foss (2007) listed 109 NHA/SACs in Ireland that contain the habitat (covering about 36ha). Six sites (covering 2.67ha) are in Co. Offaly and three sites (covering 1.12ha) are in Co. Laois. These are listed in Table 1, below. The types of tufa formations that these represent are not given in Foss's report.

Table 1. NHA/SAC that contain petrifying spring habitat, in Offaly and Laois (after Foss, 2007).

No.	Name	Sub-site	General Grid Ref.	
000412	SLIEVE BLOOM MOUNTAIN Laois	GLENLAHAN RIVER VALLEY	N330	080
000859	CLONASLEE ESKERS Laois		N270	120
000881	THE GREAT HEATH OF PORTLAOISE Laois		N530	020
000216	RIVER SHANNON CALLOWS Offaly		N025	171*
000576	FIN LOUGH (OFFALY) Offaly		N030	290
000900	DRUMAKEENAN, EAGLE HILL Offaly		S107	917
002147	LISDUFF FEN Offaly		N082	005
002236	ISLAND FEN Offaly		N123	011
002712	PIGEONSTOWN FEN Offaly		N216	068

*site of petrifying spring (personal observation);

Descriptions of four Irish sites, the first three taken from their SAC Conservation Management Plans, NP&WS, illustrate the variation in topographical situations of tufa formation in Ireland.

1. At Pollardstown Fen, in Co. Kildare, a flat lowland site at around 100m in altitude, mounds of tufa with *Cratoneuron*, up to one metre high, have built up at the locations of up-welling groundwater within the fen and associated ash woodland.
2. Around Ben Bulben, in Co. Sligo, springs emerge at around 200m in altitude at the base of Carboniferous Limestone slopes and cliffs. “Large amounts of calcareous sediments have built up, in some cases forming large outcrops”.
3. At Knocksink Woods, near Enniskerry, Co. Wicklow, the springs occur within semi-natural woodland and their streams “are fast flowing, up to 1.5m wide with rocky substrate covered in tufa film and mosses”.
4. At Glenasmole on the sides of the lower reservoir on the upper Dodder River, Co. Wicklow, the tufa springs occur along the contact line between permeable, lime-rich glacial sands and gravels and the relatively impermeable boulder clay below. “The stream flows down the steeply inclined (approx 25 degrees) axis of a landslide scar over the till (i.e. boulder clay) for a distance of 100m before entering the reservoir. Throughout its length Stream 9 is depositing tufa, although the greatest accumulations occur close to the rising. The tufa forms irregular banks and mounds up to 1m high, and these occasionally resemble the rimstone pools commonly found in caves” (Statham, 1977). These are open habitats. Many other streams have encrusted debris only.

3. THE VEGETATION ASSOCIATED WITH TUFA FORMATION

There has not been a systematic study of the vegetation of tufa-forming springs in Ireland, unlike other freshwater-terrestrial habitats, such as fens. The very common feature of various (brief) accounts is the abundance and dominance of bryophytes (mosses and liverworts) at the point at which tufa is most actively forming. This may be as much to do with the constantly wet, spongy nature of the substrate as with the extremely calcareous nature of the water and the tufa itself. There is often an associated fen below or around the spring.

Rodwell's (1995) National Vegetation Classification (NVC), for Britain, includes two categories of vegetation that are associated with tufa formation:

1. M37 *Cratoneuron commutatum–Festuca rubra* springs. These are 'classic' tufa springs with the *Cratoneuron* moss dominant "in large swelling masses". Although there are 41 vascular herbs listed, each individual site was poor in species, which often occurred as a few scattered individuals. Interestingly, *Equisetum telmateia* was not recorded.
2. M38 *Cratoneuron commutatum–Carex nigra* springs. These are richer in both bryophytes and vascular plants, and may sometimes come to resemble a rich fen. They are usually found on gently sloping firmer ground than M37 and are grazed by sheep and deer.

Kelly and Cross (2003) describe a wet woodland category – C3 Alder-ash woodland with giant horsetail (Equiseto-telmatejae-Fraxinetum association). They describe it as:

> "…rather open woodland, on slopes flushed with calcareous groundwater, characterised by beds of giant horsetail *Equisetum telmateia,* which grow up to 1m high but collapse and die down in winter. Trickles and runnels support swards of a golden-green moss with feather-like branching, *Cratoneuron commutatum.* Old shoots of this moss frequently become covered by a whitish crust of calcium carbonate – literally petrified! Soils are constantly wet and are saturated with lime (pH 7.7-8.2); sometimes a hard crust of tufa covers the soft mud beneath".

White and Doyle (1982) also cite the presence of greater horsetail *Equisetum telmateia* as indicating a calcareous spring (Cratoneurion). *Equisetum telmateia* was also included in the CORINE description of hard water springs Cratoneuron (tufa and calcareous), quoted in Foss (2007). The CORINE habitat list (1994) was a precursor to the habitat list of the E.U. Habitats Directive.

- *Relevance to the present survey*:

  In the present **Slieve Bloom** survey, most sites conform to M37 above, with one or two conforming to M38. *Equisetum telmateia* was present at most of the sites. Classic C3 woodland was also found.

The moss species most commonly given as being associated with tufa formation are *Palustriella commutata* (this is the new name for *Cratoneuron commutatum*), *Cratoneuron filicinum* and *Eucladium verticillatum*, but Pentecost and Zhahoui (2002) have listed 22 bryophytes (mosses and liverworts) from five travertine-depositing sites in England (see Appendix III).

11-6. *Palustriella commutata* var. *commutata.*

4. The Slieve Bloom tufa-forming springs survey 2007.

4.1. Aims

The main aim of the survey was a greater understanding of the tufa-forming springs in the Slieve Bloom. Objectives were four-fold. The main two objectives were:

1. To search for tufa-forming springs in the Slieve Bloom and to map their locations.

2. To describe each tufa-forming spring, in terms of physical features and flora (including bryophytes) and to assess their conservation prospects.

Two further objectives were:

3. To conduct a limited literature review to aid the understanding of the habitat in the Slieve Bloom.

4. To indicate, briefly, the potential of these sites for biodiversity conservation in the Slieve Bloom.

4.2. THE GEOLOGICAL BASIS FOR THE SURVEY

Geologically, the mountains of the Slieve Bloom (with summits of around 1,500m) consist of Devonian Old Red Sandstone (13-14 in Fig.2, below) resting unconformably upon (older) Silurian strata (11, below). 'Uncomformably' in this case means that the Silurian strata had already experienced millions of years of folding and erosion and had become a dry, arid landscape before the Old Red Sandstone layers were deposited on top (schematically indicated in Fig.2.). Ancient anticlynal (up) folding and subsequent erosion has caused these rocks to be upstanding (i.e. forming an inlier), surrounded by the younger Carboniferous Limestone (15-16, below) of the Central Plain (see also Map 1).

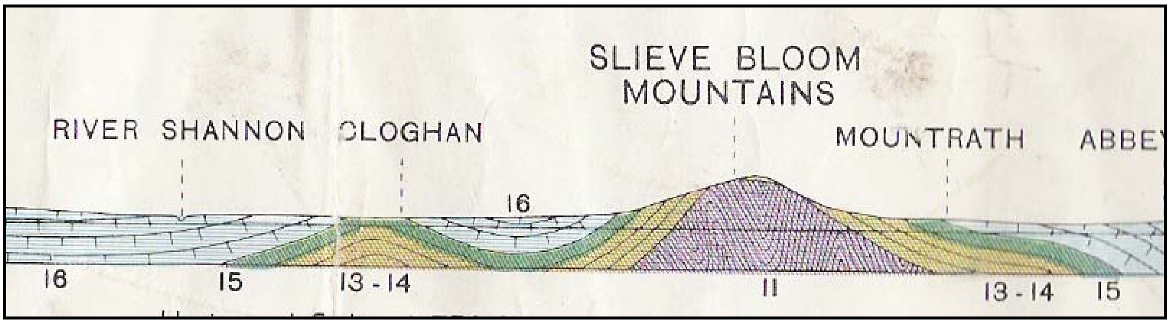


Fig.2. A geological cross-section across the Slieve Bloom, showing anticlynal folding (from O'Brien, 1962). Note: the small 'cap' of ORS on the summit.

All the sites in the present study are underlain by Silurian or Old Red Sandstone strata.

4.2.1. Sources of calcium

The presence of calcareous material as a source of calcium for tufa deposition is self-evidently necessary as indicated in Section 1.1. The Silurian strata themselves are not calcareous. Old Red Sandstone generally consists of coarse to fine-grained sandstones; and the study area did not include the Carboniferous Limestone. However, highly calcareous material does occur within the study area in three situations:

1. **Glacial drift**. This is material ground down and transported by ice movements during the Ice Age, and pushed up against the slopes of the Slieve Bloom. The many valleys of the Slieve Bloom are cut into this drift, their rivers now flowing over bedrock. Much of this drift is material derived from the surrounding Carboniferous Limestone.

Limestone-derived glacial drift.

2. Basal **Caliche**. The Silurian surface on which the desert-like deposits of ORS were laid down is, in many places, highly calcified. This is 'caliche' (see Section 1.2), first described by Wynne in 1862 as "a brecciated slate, the interstices of which were filled with a carbonate of lime" (quoted in Feehan, 1982).

3. **Caliche** deposits also occur within the main Old Red Sandstone sequences. They occur in vertical cracks (or pipes) within the sandstone; as calcareous nodules (from tiny to cobble-sized); and as calcareous conglomerates and sandstones, called 'cornstones'.

4.2.2. Previously known tufa springs in the Slieve Bloom - the rationale for the survey.

The presence of some tufa-forming springs in the Slieve Bloom had been known about before the survey began, but none had been described. The Camcor Wood SAC was known to contain such springs; a survey of Coillte properties in 2000 (Heery 2001) located another on the Camcor, outside the SAC (site 1, in this survey); an ecological survey in 2006 for a Native Woodland Scheme on behalf of Coillte located another two on the Camcor, outside the SAC (site 15 and site 18 in this survey). Dr John Feehan (pers com) knew of a major complex of tufa formation on the Silver River (site 10 in this survey). In addition, Feehan had noted down evidence of tufa formation and stones and blocks of calcrete in the rivers at several other locations in field notebooks during fieldwork for his 1982 paper, although he did not usually mention tufa-forming springs specifically. He kindly made these available for the present survey. A fen with tufa at Pigeonstown had been described as part of an undergraduate thesis from Trinity College Dublin (site G).

The rationale for the present survey was based on:

1. The fact that some tufa springs were already known (but not described);
2. Elements of the geology showed potential for the presence of others;
3. Tufa springs are known to support a specialised flora and fauna, quite unlike the acid blanket bog for which the Slieve Bloom are best known.

4.3. METHODS

The mountains of the Slieve Bloom cover very roughly 200 kms^2 and there are at least 20 valleys amounting to very many kilometres, emanating from the summits. Tufa springs are often very small in area, sometimes just a few square metres. It was decided to concentrate a search on the river valleys, as these were the situations where all but one known sites occurred and where springs (of any kind) were most likely to occur.

Search methods

Most of the rivers of the Slieve Bloom are enclosed in semi-natural woodland or scrub (even those within the extensive coniferous plantations), making them very significant ecological corridors from the mountain summits to the lowlands. The width of the valley floor can range from a few metres to (rarely) 250 metres. In general, therefore, when searching a river valley for tufa springs a route was taken close to the river, or very frequently along the riverbed itself. The valley slopes and potential spring locations were often visible in this way. Three natural features often pointed the way to the presence of a tufa-forming spring when walking up a valley in this way:

1. A small flow of water into the stream, often with slight encrustations of lime;
2. The bright green-orange-yellow colour of the dominant *Cratoneuron* mosses;
3. The presence of conspicuous and impressive greater horsetails *Equisetum telmateia*.

1-3 Greater horsetail *Equisetum telmateia* with *Palustriella commutata* moss cover.

Site reports

Time was spent searching the valleys and locating the springs. Most of the springs found were then revisited, and the following data recorded/collected:

GPS Grid Reference;

Physical description (location of springs in relation to the valley);

Types of tufa formation (categories referred to in Table 2);

Vascular plant species listed;

Bryophyte species collected and preserved at home in envelopes;

Surrounding habitats;

Damage or threats observed and conservation prospects;

A sketch map of the site was drawn.

A collection of photos was made showing many aspects of the sites, including some images of specific bryophyte species. *Photos are labelled with the site number followed by photo number* (e.g. 10-1). They are stored on the CD version of this report.

A two-page description of each site was written in a standard format and the location of each indicated on a Discovery Map, a 6-inch scale map and a colour aerial photograph. A sketch map was drawn (Part 2 of this report).

To keep the data specific to the habitat, vascular plants and bryophyte species were only collected from areas of active tufa formation, or from among mosses growing on such tufa (with one exception, site 3). Only presence and absence of species at a site was recorded. The habitat is often too fragile for the inevitable trampling involved in releve recording. Bryophyte species were collected, but not identified, from most of the sites and were allowed to dry in labelled envelopes at home. Some species were readily identified by the author. These, and the others, were given to an expert (J.Conaghan) for confirmation or identification.

In order to fulfil objective 4 (see section 4.1.) Evelyn Moorkens, a national expert on molluscs, was commissioned to sample and list mollusc species from five sites.

4.4. RESULTS

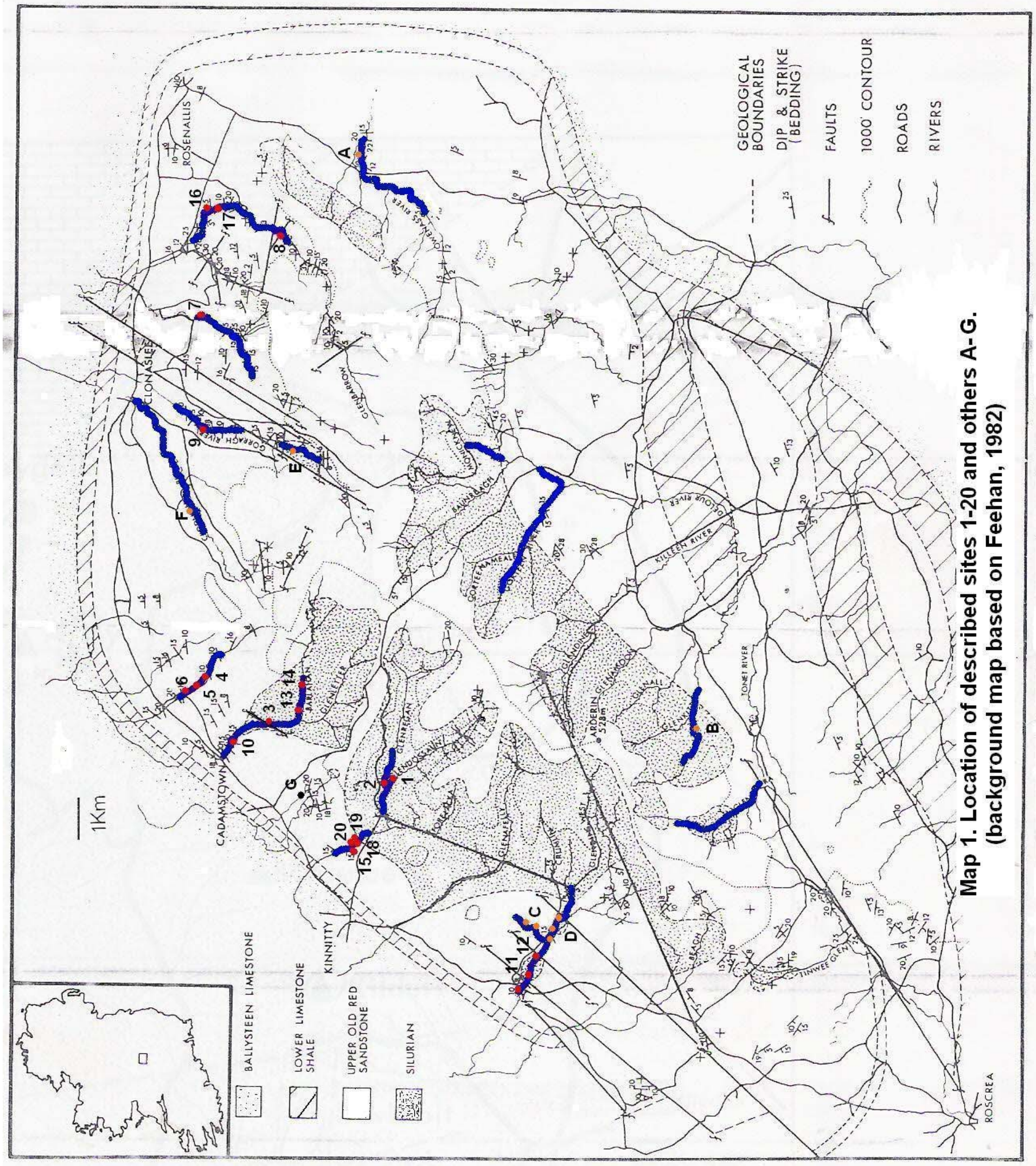
4.4.1. Coverage and locations of sites

Map 1 shows the stretches of river valleys that were searched and the locations of the sites found. More accurate versions of this information are shown on the 1:50,000 Discovery Map (Appendix I) and in the site reports (Part 2). 40 kilometres within 13 valleys, were searched. Active tufa deposition was found in 10 valleys. Eight valleys contained the 20 major tufa-forming springs described in this report. Map 1 also shows tufa-forming sites that were found but not specifically described. The altitude of the sites ranged from about 120m to 240m above sea level. There was however a bias in searching the lower parts of the valleys so this is not to say that others at a higher altitude will not be found in the future.

4.4.2. Types of tufa formation and site characteristics

Table 2 indicates the types (or categories) of active tufa formations found at the Slieve Bloom sites. Photos that illustrate these types are referenced. All the sites described had actively forming tufa accumulations, inextricably associated with bryophyte species, usually *Palustriella commutata* (*Cratoneuron commutatum*), but also *Conocephalum conicum* and others. The five major types described in the survey can all be termed ‘cascades’ (sensu Pentecost 1995, see Fig.1, above). That is, based on water flowing, or trickling, down a steep or gentle slope, rather than an upwelling of water from flat ground, which forms tufa mounds in fens. Although flow was not measured, at most sites it was probably permanent and steady, but two sites (site 12 and site 15) exhibited areas of both permanent and intermittent flow.

The sites were usually covered with tufa-forming bryophytes but bare tufa also occurred. Clear water rivulets encrusting twigs, leaves and stones and, occasionally, dams (‘stream crusts’, and ‘dams’, sensu Pentecost, 1995) were commonly associated with the cascades. Two other categories, not described by Pentecost, also occurred. One was ‘fen grassland with tufa’. The other might be termed a *Conocephalum* crust on a vertical rock face (after the dominant calcified liverwort of the same name). There was also a ‘cemented rudite’ within the glacial drift in the vicinity of site 2, indicating interglacial deposition of calcium carbonate probably by inorganic means rather than by living bryophytes.

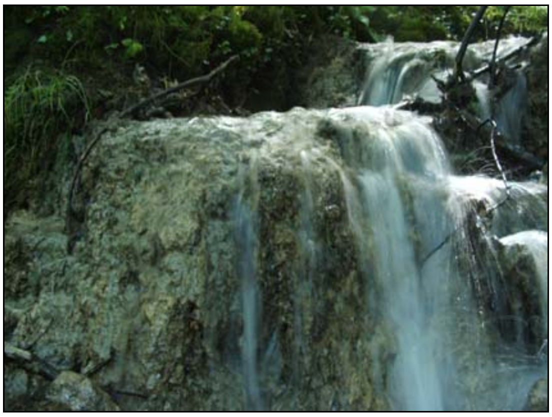


Map 1. Location of described sites 1-20 and others A-G.
(background map based on Feehan, 1982)

7-1. A trickle cascade tufa formation (left) with *Cratoneuron* moss.

4-2. Calcified *Conocephalum* crust.

2-11. Hanging *Cratoneuron* formation



10-3. Waterfall cascade.

Table 3 summarises the locations of the sites, the surrounding habitats and the types of tufa formations found at each site.

Table 2. Types of active tufa formation found during this survey (with references to photographic examples).

Category	**Survey description**	**Description after Pentecost, 1995**
1	Classic *Palustriella* (*Cratoneuron*) ‘mounds’. A relatively thin layer of living moss, soon becoming calcified beneath. Water emerging at some point or points among the moss (flowing, trickling or dripping).	A cascade
	1a: on steep slope **e.g. photo 11-9** **1b:** on gentle slope **e.g. photo 2-8**	
2	Hanging trails of calcified moss, sometimes forming ‘stalactites’ or columns of calcified moss **e.g. photo 2-11, 10-5**	A cascade
3	Deep cushions of *Palustriella* (*Cratoneuron*) under *Equisetum telmateia* (and sometimes other vascular species), tufa forms deep inside the cushions **e.g. photo 1-3**	A cascade
4	Fall of water over mostly bare tufa	A cascade
	4a: a concentrated fall of water (a waterfall) **e.g. photo 10-3, 10-5** **4b:** a more diffuse fall of water (sometimes intermittent) **e.g. photo 15-1**	
5	Rivulets of moss-free, flowing water, encrusting twigs, stones etc **e.g. photo 7-8** (including small dams **photo 2-5**)	Stream encrustations and dams
6	Fen (or fen grassland) with tufa **e.g. photo 14-5**	Not described
7	Thick vertical sheets of active tufa, no flowing water, generally comprising calcified and living *Conocephalum* bryophyte **e.g. photo 4-2**	Not described

Table 3. Summary of site locations and characteristics.

Final number	River valley	County	Tufa formation types (see Table 2 for explanation)	Altitude	Surrounding habitats
1	Camcor	Offaly	1a, 2, 3	180-190 m	WN4, (GA1), WS5
2	Camcor	Offaly	1a, 1b, 4b, 5 (incl. dams)	180-190 m	WD4, WS5, WN6
3	Silver	Offaly	1b (difficult to classify)	190-200 m	(GS4), WN6, WN2, PF1
4	County	Laois	7	190-200 m	WN2, (GA1)
5	County	Offaly	1a, 2	180-190 m	(GS4), WN2
6	County	Laois	7	170-180 m	PF1, WN2, GS4
7	Glenlahan	Laois	1a, 1b, 5	140-150 m	WN2, (GA1)
8	Barrow	Laois	1b, 4b (between stones)	230-240 m	WN6, WD4, WN1
9	Gorragh	Laois	1a, 3, 5	160-170 m	(GA1), WN4, WN2
10	Silver	Offaly	1a, 2, 4a, 4b, 5, 6, 7	160-170 m	WN2, GS1, (GA1)
11	Aghagurty	Offaly	1a, 1b, 2, 5 (above inflow)	120-130 m	WN6, WN2, (GA1)
12	Aghagurty	Offaly	1a, 2, 4b, 6	120-130 m	PF1, WN2, GA1
13	Silver	Offaly	1a, 3	210-220 m	(GS4), WN2
14	Silver	Offaly	4b (very small), 6	220-230 m	WS1, PF1, GS1
15	Camcor	Offaly	1b, 2, 3, 4b, 5	140-150 m	WS5, WD1
16	Barrow	Laois	2	140-150 m	
17	Barrow	Laois	3 (but similar to site 3)	140-150 m	WN2, WN4, (GA1)
18	Camcor	Offaly	1a, 1b, 2, 4a, 5	140-150 m	WN4, WD1
19	Camcor	Offaly	1a, 5	140-150 m	WD4, WD1
20	Camcor	Offaly	2, 4a, 5	140-150 m	WD4

In addition, sites (A – E) were discovered but not fully described. These, and site G, are also shown on Map 1 and have the following characteristics:

A – Cathole, Owenass River. This is a very small ‘trickle’ cascade, with *Palustriella commutata*, down a narrow runnel, just below the sloping waterfall.

B – Glenkitt tributary. This is sloping fen grassland, c 100 m length and 10m wide, along a low valley side with some minor tufa formation. *Eriophorum latifolium* is present in the fen.

C - Aghagurty tributary (Ballymac House). There are a few small, but well developed ‘trickle’ cascade’ and former waterfall tufa formations with *Palustriella*.

D - There are further small formations along the main Aghagurty river, plus patches of fen grassland with tufa on gently sloping fields.

E – Gorragh River. There are two locations. One is a flushed site with abundant *Equisetum telmateia*, and minor tufa deposition. This is inaccessible due to fallen and felled conifers. The other is c 200m upstream and is a calcareous stony flush very similar to site 8. Note the faulted presence of the unconformity here (Map 1).

F - Clodiagh River. This is a steeply sloping *Molinia careulea*-dominated site on terraces of calcrete and tufa. There is only minor tufa deposition at present. Stonewort *Chara* sp. occurs.

G – Pigeonstown Fen (Springs) (see Table 1.) Fen and *Salix* willow carr with tufa formation at ground level. This is NHA 2712 (NP&WS files), and has been described by R.Edge in a Trinity College, Dublin Botany Department final year thesis (no details to hand).

4.4.3. Vascular plant species

Table 4 (Appendix II) shows the 42 vascular plant species recorded at 14 sites. Only vascular plant species that were very closely associated with active tufa formation were recorded. Only five species occurred at seven to nine sites. There was a very species rich fen associated with site 3. A species list from this fen is also given in Appendix II.

4.4.4. Bryophyte species (mosses and liverworts)

Table 5 lists the species that have been identified by a specialist. The method of collecting and identifying during this survey meant that not every species present at a site was collected nor was every species collected has been identified (to date). The list can be considered a good representation of part of the suite of the main bryophytes that inhabit the tufa-forming habitats of the Slieve Bloom.

Table 5. Bryophytes identified during the survey.

Species	Site where ‘type’ was collected
Palustriella commutata var. *commutata**	11
*Eucladium verticillatum**	2
*Plagiomnium rostratum**	10
*Plagiomnium undulatum**	2
*Plagiomnium ellipticum** cf	10
*Fissidens adianthoides**	2
*Bryum pseudotriquetrum**	13
*Plagiocilla asplenioides**	2
Conocephalum conicum	4
*Thamnobryum alopecurum**	28
Pellia endiviifolia	15
*Scorpidium revolvens**	8

* specimens identified by J.Conaghan

4.4.5. Snail survey

Moorkens listed snail species from five sites and this can only be considered a brief sampling. Her report is presented in Appendix IV. 31 snail species were recorded, including common species and "a number of rare and one legally protected species". The numbers of species found ranged from 6 – 18 (a control sample in beech litter away from any tufa spring influence, yielded 10 'common' species). The largest site (site 11, Moorkens no. 5) yielded the least (6 species) and the smallest site (site 13, Moorkens no. 2) yielded the most (18 species).

4.4.6. Surrounding habitats

The habitats surrounding the tufa-forming springs were recorded. Habitat codes follow Fossitt (2000). Most sites were found within what were essentially semi-natural habitats. Although they were free of trees, many of the springs were surrounded by semi-natural oak-ash-hazel woodland WN2 in which ash and hazel were predominant. While most of the sites did not occur within grassland (the exceptions were part of site 10 and site 14, fen grassland sites), the woodland slopes in which the springs were located were usually adjacent to grassland (often improved grassland GA1) at their upper edges, for instance site 11. Significantly, site 3 was associated with an extensive area of a special type of wet grassland GS4, namely *Molinia* meadow, an Annex 1 habitat, at its upper edge. Most sites did not have fens PF1 associated with them. At many sites the excess water flowed along a (natural) channel (with minor lime encrustations) to the river. At site 3, however, a well-developed species-rich fen was an integral part of the site. Two sites were situated in recently clearfelled conifer plantation WS5.

4.4.7.Conservation prospects

Table 6, summarises the information in this regard (see the site reports for more detail). The table ***does not*** address the issue of threats to, or changes in, the hydrological regimes that maintain the springs. Moreover, the possibility of damage due to trampling, sampling and alteration of local hydrology by visitors, *including ecologists*, can be a real threat to these fragile habitats.

'Conservation prospects' are the author's brief assessment of the prospects of the tufa-forming habitat continuing to function at least moderately well *under present conditions*. 'Good prospects' therefore does not guarantee conservation into the future, if conditions change.


12-2. Part drying out of tufa formation


11-8. Deer tracks across tufa formation

Table 6. Summary of conservation prospects assessments of tufa-forming habitat at each site *under present conditions.* Hydrology has not been considered.

Final site number	Summary of Threats and Conservation prospects
1	Almost vertical slope; no threats; prospects are good.
2	Heavily visited by deer at present but part of a Native Woodland Scheme, to be deer fenced, in which case prospects are good.
3	Some deer trampling on the slopes; cattle have access to the fen but apparently use it little; the site would be very vulnerable to drainage attempts. Prospects good under present conditions.
4	Rock outcrop. No apparent threats.
5	Some evidence of deer trampling; vertical slopes; prospects good.
6	Rock outcrop, but would be vulnerable to drainage of swampy fen above. Prospects good under present conditions.
7	Deer damage is moderate. May benefit from some protection.
8	No apparent threat, except a natural occurrence of landslip.
9	Visited by deer but prospects are good.
10	Fen above is vulnerable to increase in grazing pressure; waterfall cascades would be vulnerable to changes in supply stream; deer trampling has occurred on the wet lime-encrusting habitat in places. Prospects are quite good.
11	Deer visit the wood, but access appears difficult. For the suite of springs as a whole, the prospects are good but there is possible evidence of pollution.
12	Already damaged by drainage; good active habitat remains; probably little to be done.
13	Vulnerable to investigation by walkers on the Offaly Way; prospects are good.
14	Vulnerable to an increase of grazing pressure; prospects are good at present.
15	Intermittent water supply; vulnerable to insensitive laurel and beech clearance as part of Native Woodland Scheme; heavily visited by deer at present but it is to be deer fenced, in which case prospects are good.
16	Rock outcrop. Prospects are good.
17	No deer pressure seen, prospects are good.
18	Visited by deer at present but part of a Native Woodland Scheme to be deer fenced; vulnerable to insensitive laurel and beech clearance. Prospects are good.
19	If surrounding conifers are harvested sensitively, then prospects are good.
20	Vulnerable if conifers are harvested insensitively. Prospects are good.

5.0. DISCUSSION

5.1. Geographical and geological distribution of springs

Tufa deposition was found at sites that were widely distributed in the lower parts of the valleys of the Slieve Bloom. It can probably be said that in the stretches of valleys shown as having been searched (Map 1.) the chances of major tufa-forming springs having been missed is low. A few valleys were not searched through lack of time. The possibility of tufa-forming sites being found in at least some of these is fairly high considering that the valleys that were 'cold-searched' (i.e. without any knowledge of the presence of tufa springs there – the Barrow, Glenlahan, Gorragh and Clodiagh) all yielded springs. Most sites were quite restricted in their extent, sometimes with adjacent springs within 10 m or so on the same slope showing no sign of tufa formation. Two exceptions were: the Silver River valley sites (sites 3, 10, 13 and 14) which showed evidence of a more widespread occurrence of minor tufa-forming sites in their vicinities; and Aghagurty (sites 11 and 12) where several large tufa-forming springs occurred closely spaced along a 300 m stretch as well as a more widespread occurrence of minor formations, similar to the Silver River valley.

Some sites were close to, or included, outcrops of hard dry, completely inactive tufa (still recognisable with obvious calcified plant remains). These were outcrops of more widespread tufa deposits formed during a peak of post-glacial tufa deposition several thousand years ago. The present day active tufa springs are probably a continuation of this process having contracted and moved in response to changing hydrology and other environmental conditions.

The geological factors determining the location of the springs are not obvious, and can only be speculation. Feehan (pers com) suggests that the unconformity (or junction) between the (apparently) impervious Silurian and ORS (permeable along cracks) appears to be the cause of some general spring activity. The fact that a calcified layer or caliche occurs at the unconformity may possibly add to the likelihood of a spring at the unconformity being tufa-forming but this is speculation. Although some springs occur close to the mapped unconformity (e.g. site 11; site E; site 10; site 18), others do not (e.g. site 7). Similarly, fault lines (known faults are shown on Map 1) can be conduits of groundwater to a spring location but similar uncertainty exists as to their role.

The concentration of sites on the north and northwest sides is probably a good reflection of the main distribution around the Slieve Bloom. With the exception of the *Conocephalum* crust, the source of calcium-rich groundwater for the springs can probably be said to be glacial drift derived from Carboniferous Limestone. The streams have subsequently cut through this drift and now flow on bedrock once more. With this in mind, the proximity of the lower slopes of the Slieve Bloom in the north and northwest to the Carboniferous Limestone probably accounts for the widespread presence of tufa-forming springs on that side of the mountain. Conversely, the south and southeast slopes are further away for the Limestone and the drift may be composed more of Old Red Sandstone.

5.2. Biodiversity

Vascular plants

The distribution of vascular plant species shown on Table 4 (Appendix II) conforms to Rodwell's (1995) NVC Vegetation Type M37 in that there is considerable variation of associated vascular flora from site to site. Four of the five commonest species are woodland plants (greater horsetail *Equisetum telmateia,* ash *Fraxinus excelsior* seedlings, ivy *Hedera helix* and herb Robert *Geranium robertianum*) reflecting the fact that in the Slieve Bloom most of these sites are, although open, surrounded by woodland habitat. No rare plants were found. The study area is outside the very limited (Co. Sligo) range of the rare species *Saxifraga aizoides*, often cited as a character species for the habitat, but site 8 is a wet stony calcareous mountain flush, typical habitat for the species. The horsetail *Equisetum variegatum*, a relatively scarce species in Ireland, a calcareous species and a poor competitor, found a habitat on the cushions of mosses at several sites. Marsh arrowgrass *Triglochin palustris* is a common coloniser of a wide range of wet habitats in Ireland (including industrially cut-away bogs). At site 2 it is densely colonising the recently exposed encrusting calcareous flushes (accompanied by articulated rush *Juncus articulatus*). At site 14 it has persisted to form a significant part of fen grassland accompanied by co-dominants common sedge *Carex nigra*, marsh horsetail *Equisetum palustre* and red fescue grass *Festuca rubra* (a typical grazed M38 community).

Bryophytes (mosses and liverworts)

Bryophytes are the dominant plants of the tufa-forming springs (in the Slieve Bloom and elsewhere) and the list of species that can grow in the rather specialised conditions has been fairly well described in Europe and is evidently quite limited. Tufa collects around most of the species listed in Table 5, but only very few species can be said to be 'tufa formers'. To be thus they have to be abundant, or at least locally dominant, and be seen to be providing bulk to the tufa deposits with their calcified remains. *Palustriella commutata* var. *commutata* was by far the commonest in this regard. It was present at every site and abundant at most. It presented different forms or 'habits' depending on the particular formation. *Eucladium verticillatum* was another, probably ubiquitous species. *Conocephalum conicum* was a third, forming tufa on certain vertical wet calcareous rock faces. Each of these species forms a tufa deposit of a different texture because of their different physical forms. Thus, the large 'feathery' leaves of *Palustriella* are likely to form a deposit of high volume but full of cavities, whereas the very short, crowded stems of *Eucladium* form a dense compact tufa. It is often mentioned in relation to the habitat that these mosses actually promote tufa deposition around their leaves. This process was seen at site 18 where the cushions of *Palustriella* in a flow of clear water were the only locations where tufa was accumulating.

Most of the other species in Table 5 can be said to be 'tufa collectors'. These are species that can grow with the tufa but are not abundant or ubiquitous in that habitat. They are often common in surrounding habitats. The list is longer than tufa formers but still very limited by the conditions. In this survey, the woodland bryophytes *Fissidens adianthoides*, *Plagiomnium rostratum* (which forms an impressive tufa column with its long trailing stems, photo 10-6 below) *Plagiomnium ellipticum* and *Thamnobryum alopecurum* fulfilled this role at several sites. Interestingly, *P. rostratum* and *P. ellipticum* are listed by Pentecost and Zhaohui (2002) as occurring on waterfall cascades in England and France, respectively. *Bryum pseudotriquetrum* was present at several sites, but was neither tufa-forming nor tufa collecting. Instead it grew on the cushions of tufa-forming mosses (sparsely, on *Eucladium* at site 12 and abundantly on *Palustriella* on wet flushed scree at site 8).


10-6. A column of calcified *Plagiomnium rostratum*

Tufa-forming springs are known be a habitat for a specialised fauna – tufobiont species-adapted to an environment that has very many unusual features compared to surrounding habitats. A constant, but often low, water flow; a constantly wet, but essentially terrestrial open mossy substrate; an almost complete lack of peat or soil development; an (over) abundance of accreting calcium; and other water chemistry aspects all contribute to the specialised conditions. Towards the top of the food chain are molluscs or snails. Although faunal biodiversity was not a main part of this survey, Moorkens' conclusion from her brief survey of snail species is worth noting:

"There was a remarkable diversity of molluscan species found during this short survey, including a number of rare and one legally protected species…It is highly likely that surveys of other taxonomic groups would also lead to equally interesting results. Each of the sites had its own unique habitat, depending on its comparative openness, slope and aspect. As a series of sites these tufa springs provide a remarkable addition to the biodiversity of the larger areas within which they are found, and they deserve the utmost level of conservation protection".

None of the species (even the more notable ones) in the list are restricted to tufa-forming habitats (*Vertigo geyeri* is a fen species, and *Spermodea lamellata* is a wet woodland species) but their survival is probably enhanced by the lack of normal predators and abundance of calcium. One of the sites with the most species (site 13, Moorkens no.2) was a small site, isolated as a tufa spring but present in a valley with a widespread presence of wet ash-alder woodland with greater horsetail *Equisetum telmateia* (sensu Kelly and Cross 2003). This site had as many species as site 3 (Moorkens no.3) whose sampling included the species rich fen and which was regarded by Moorkens as being a 'hot spot' for snail diversity and therefore a potential hot spot for other taxonomic groups.

Chironomids are non-biting midges whose larvae construct silk and silt--lined tubes in soft substrate of lakes and ponds. At site 6 the calcified remains of the tubes of chironomid larvae on the soft wet tufa face is evidence of another of the myriad life forms that dwell at tufa springs.

6-4. Calcified chironomid larval tubes.

5.3. Surrounding habitats

Kelly and Cross's (2003) wet ash-alder woodland with greater horsetail *Equisetum telmateia* is a recognised woodland type in central Europe and was newly described for Ireland from Knocksink Woods, Co. Wicklow by Kelly and Iremonger (1997). It is very local in occurrence in Ireland and occupies small areas. It has obvious affinities with tufa-forming springs (Section 3 above) and site 1, site 3, site 8 and site 11 are situated within good examples. *Molinia* meadow is an Annex 1 habitat in the E.U. Habitats Directive. An unusually extensive area of *Molinia* meadow occurs behind site 3. The exact limits to the habitat were not surveyed but it extends over at least 24 ha. This is a substantial area of previously unrecorded Annex 1 grassland habitat.

The fact that highly improved grassland occurs directly above six of the sites may have implications for pollution of the groundwater source but without more knowledge of the hydrology at each site it is impossible to say. The thick *Cladophora*-like strands in the water flowing into site 11 (photo 11-4) may or may not be of significance in this regard.

5.5. Conservation prospects

Generally, the main physical threats to tufa-forming habitats are said to be: land drainage; land reclamation; over-grazing; excessive trampling (by animals or humans); water abstraction from the aquifer supply; and changes in flow rates.

The main chemical threats to tufa-forming habitats are said to be: eutrophication (sensitive to nitrogen levels due to absence of peat to buffer the effect); deoxygenation of the groundwater source due to organic pollution.

In general, these are the threats that could potentially affect all the sites in the Slieve Bloom. Only physical threats could be assessed in this survey and they are summarised in Table 6.

In particular, local land drainage has evidently adversely affected one site (site 12), drying out the small feeder alkaline fen above. The species rich fen supplied by a tufa-forming habitat (site 3), with *Vertigo geyeri*, *Eriophorum latifolium* and *Epipactis palustris* is very vulnerable to drainage should this ever be attempted. The causes of intermittent flow at site 15 are not obvious and may be historical. Possible signs of eutrophication of water supply were seen at site 11.

Fallow deer have access to all the sites surveyed. In general, deer trampling does not seem to be causing significant damage to sites and in any case would be difficult to mitigate. Proposed deer fences, as part of wider woodland conservation projects, will eliminate (hopefully) the animals from three sites (site 2, site 15 and site 18), at least in the short to medium term. Moderate deer trampling and breaking up of tufa occurs at site 7, maybe because the animals need to cross the habitat to pass up the valley. This site may benefit from effective deer fencing which would direct the deer to the other side of the river but this would need to be considered further.

Insensitive survey and over-sampling by ecologists must be considered a threat. “The stable, specialised conditions of tufa springs offer opportunities for rarities to survive, but sampling of these very restricted habitats runs a real risk of causing extinctions” (Reynolds, 2003). Some snails, for instance, *Vertigo geyeri*, are minute and a whole population can exist in $5cm^2$ moss litter.

In summary, the conservation prospects of the tufa forming habitats found during this survey appear to generally good, under present physical conditions. However, threats from hydrological and chemical conditions have not been considered and may be important.

CONCLUDING REMARKS

The valleys or dingles of the Slieve Bloom contain a series of tufa-forming (petrifying) springs that show the classic moss-tufa associations found in the best examples of the habitat elsewhere. It follows that elements of the specialised ecosystem, described for this habitat elsewhere, occurs here also. For the author, searching for this habitat has reinforced the notion that that these dingles and their streams are ecologically valuable wild corridors extending from the summits to the lowlands, and that the presence of tufa-forming habitats adds an unexpected diversity to these places.

All the sites in this survey are part of a unique suite of tufa forming habitats and each is a significant part of the whole. The complex around Site 10 is the most diverse in terms of types of tufa formations. Site 3 is poor in this regard but is associated with a species-rich fen with rare and scarce species. The complex around Site 11 has the largest surface area of tufa forming habitat. Site 7 is the largest in Co. Laois found during this survey. Site 2 is young, and has good potential to be large and diverse.

6.0. SITES IN RELATION TO SACs

'Petrifying springs with tufa formation' is an Annex 1 habitat in the E.U.Habitats Directive and as such Member States can designate Special Areas of Conservation in order to conserve the habitat. Map 2 shows the relation of selected sites to the SACs in the area.

Site 2 is situated within a newly extended Camcor Wood SAC; site 1 is situated just outside the boundary. Site 7 is situated in the Glenlahan valley extension of the Slieve Bloom SAC, although a small boundary change may be necessary to fully protect the site.

This report suggests that the Silver River valley (to Cadamstown) be considered as an extension to the Slieve Bloom SAC. This could incorporate: excellent quality oak-ash woodland with a tufa-forming complex (site 10); a tufa-forming spring with a species-rich fen with *Vertigo geyeri* (site 3) and at least 24 ha of *Molinia* meadow associated with it; another tufa spring (site 13) and a fen grassland with tufa (site 14); several other minor tufa seepages and wet woodland with *Equisetum telmateia*; and calcareous grassland.

It is also suggested that the suite of tufa springs in the Aghagurty valley (site 11 complex and site 12) could also be considered for SAC designation in its own right.

11-1. The largest tufa spring in the Aghagurty complex.

7.0 FURTHER WORK and RECOMMENDATIONS

The tufa springs described in this survey are well-developed examples of a rare and localised habitat in Ireland. Further work could concentrate on two main aspects: conservation and research.

7.1. Conservation

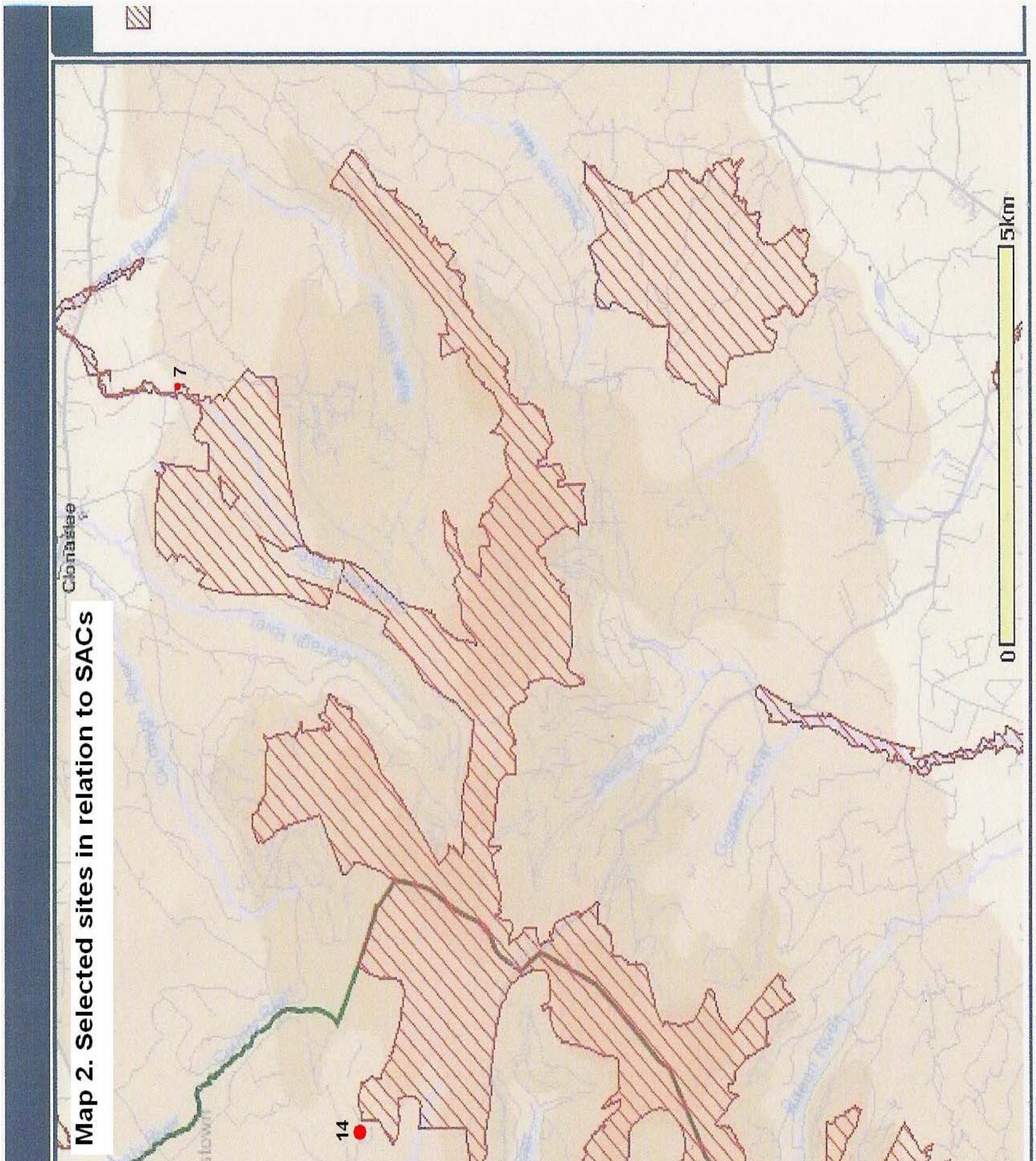
1. To take account of these tufa forming springs in planning decisions in the county.
2. To search further for tufa springs in order to complete their distribution in the Slieve Bloom. To consider the conservation prospects of other sites in Offaly and Laois.
3. To consider the interpretation of one accessible site (namely, site 13) to passing walkers on the Offaly Way.
4. To consider the suggestions made in section 6.0. with regard to SACs.
5. To monitor the sites regularly for deer damage or changes in hydrology. To consider the *practicalities* of protecting site 7 from deer.
6. To consider the wider hydrology of some of the sites in relation to sustaining the habitat

7.2. Research.

1. To sample significant taxonomic groups of fauna in order to add to the knowledge of biodiversity in the Slieve Bloom and to an understanding of the habitat in general. Account should be taken of the fragile nature of the habitat in any sampling.
2. To record the ecological progress of all aspects of the LIFE site (site 2), now that it has been cleared of conifer plantation.
3. To record hydrological measurements with regard to item 7.1 (6) above. This would involve rates of flow, temperature of water and water chemistry (including pollution) and may involve investigations of the whole aquifers.

8.0 ACKNOWLEDGEMENTS

This survey was undertaken with financial support from Laois Co. Co. (and the Heritage Council) and Offaly Co. Co. I gratefully acknowledge this, and the assistance of the respective Heritage Officers, Catherine Casey and Amanda Pedlow, in this regard. I thank John Feehan for sharing his knowledge of the Slieve Bloom and making his field notebooks available to me. I thank Evelyn Moorkens for her snail survey and John Conaghan for identification of bryophytes.


Map 2. Selected sites in relation to SACs
Clonaslee
Cadamstown
1
2
3
7
10
13
14
0
5km

9.0 REFERENCES

Anon, 1994 *Use of Corine biotopes database for the interpretation of the Directive on the conservation of natural habitats of wild fauna and flora (92/43/EEC).* European Commission

Feehan, J. 1982 Old Red Sandstone Rocks of the Slieve Bloom and Northeastern Devil's Bit Mountains, Counties Laois, Offaly and Tipperary. *Journal of Earth Science, Royal Dublin Society*, **5**, 11-30

Foss, P. 2007 *Study of the extent and conservation status of springs, fens and flushes in Ireland 2007* (including *Petrifying springs with tufa formation (Cratoneurion) (7220) Conservation Status Assessment Report*). Report to the National Parks & Wildlife Service, Dublin.

Fossitt, J. 2000 *A guide to habitats in Ireland.* The Heritage Council.

Heery, S. 2001 The Selection of Biodiversity Areas in the Slieve Bloom Forest Management Unit – A pilot survey. Report to Coillte, Newtownmountkennedy.

Kelly, D.L., Iremonger, S.F. 1997 Irish Wet Woodlands: the plant communities and their ecology. *Biology and Environment: Proceedings of the Royal Irish Academy* **97B**, 1-32.

Kelly, D.L., Cross, J. 2003. Wet woodlands. In: Otte, M. (ed) *Wetlands of Ireland.* UCD Press.

Murray, D.A. 1996 *Freshwater resources, systems and habitats in Ireland.* Quoted in: Reynolds, 2003, below.

O'Brien, M.V. 1962. *Geological Map of Ireland, 1:750,000 scale.* Ordnance Survey of Ireland.

Pentecost, A. 1995 The Quaternary Travertine Deposits of Europe and Asia Minor. *Quaternary Science Reviews* **Vol. 14**, 1005-1028.

Pentecost, A. 2005 *Travertine*. Springer-Verlag.

Pentecost, A., Zhaohui, Z. 2002. Bryophytes from some travertine-depositing sites in France and the UK: relationships with climate and water chemistry. *Journal of Bryology* **24**, 233-241.

Praeger, R.L. 1904 Note on Plate 12. *Irish Naturalist* **XIII**, 213.

Preece, R.C., Robinson, J.E. 1982. Molluscan and ostracod faunas from post-glacial tufaceous deposits in Co. Offaly. *Proceedings of the Royal Irish Academy* **82b**, 115-131.

Reynolds, J. 2003 Fauna of turloughs and other wetlands. In: Otte, M. (ed) *Wetlands of Ireland.* UCD Press

Rodwell, J. 1995 British Plant communities **4**: Aquatic communities, swamps and tall herbs. *Cambridge University Press.*

Statham, I. 1977 A note on the tufa depositing springs in Glenasmole, Co. Dublin. *Irish Geographer* **10,** 14-18.

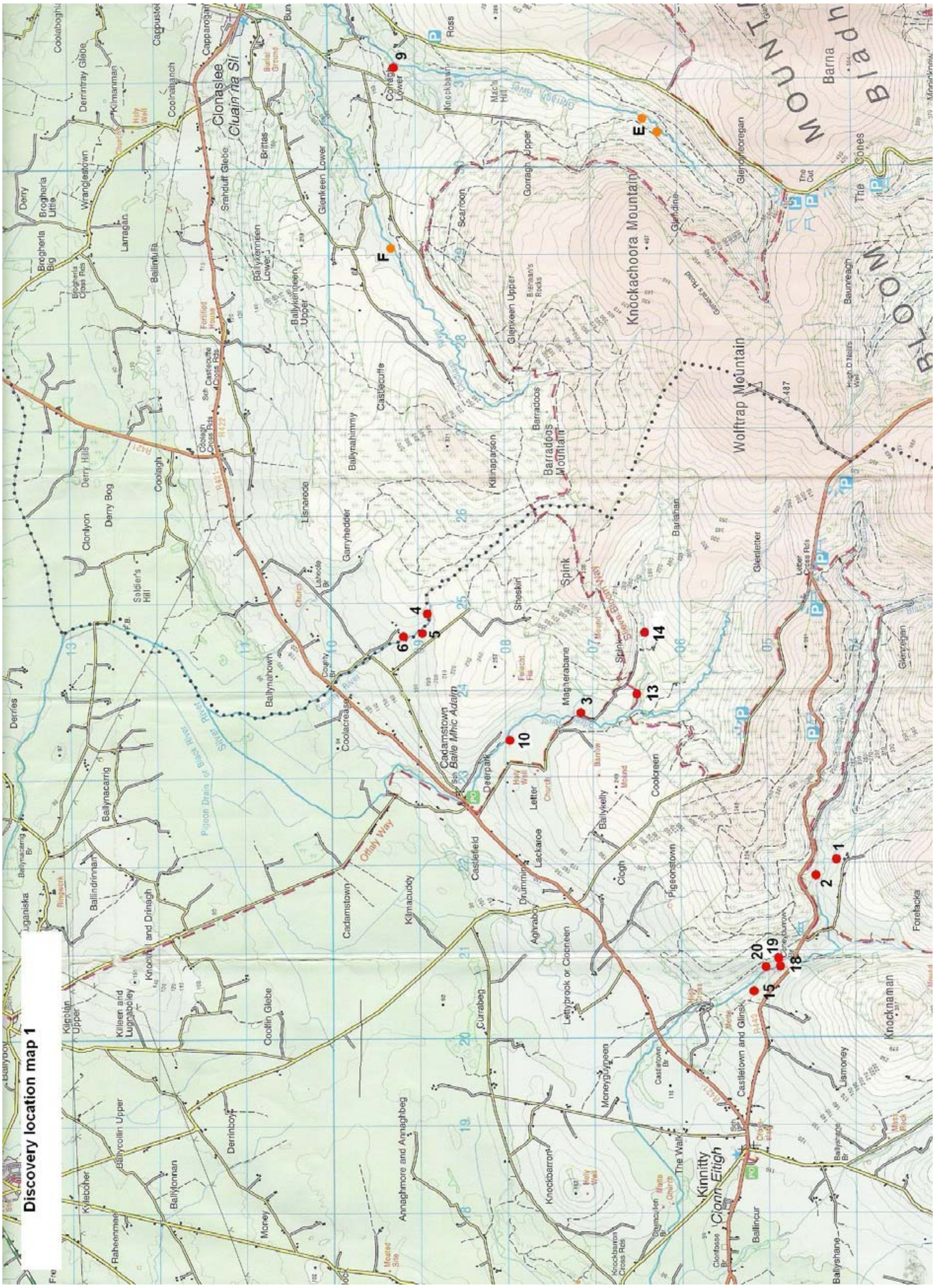
White, J. Doyle, G. 1982 The Vegetation of Ireland – a catalogue raisonné. *Journal of Life Sciences, Royal Dublin Society,* **3**, 289-368.

Wynne, A.B. 1862 *Explanations to accompany Sheet 126 of the Geological Survey of Ireland, comprising parts of County Tipperary and the King's and Queen's Counties.*

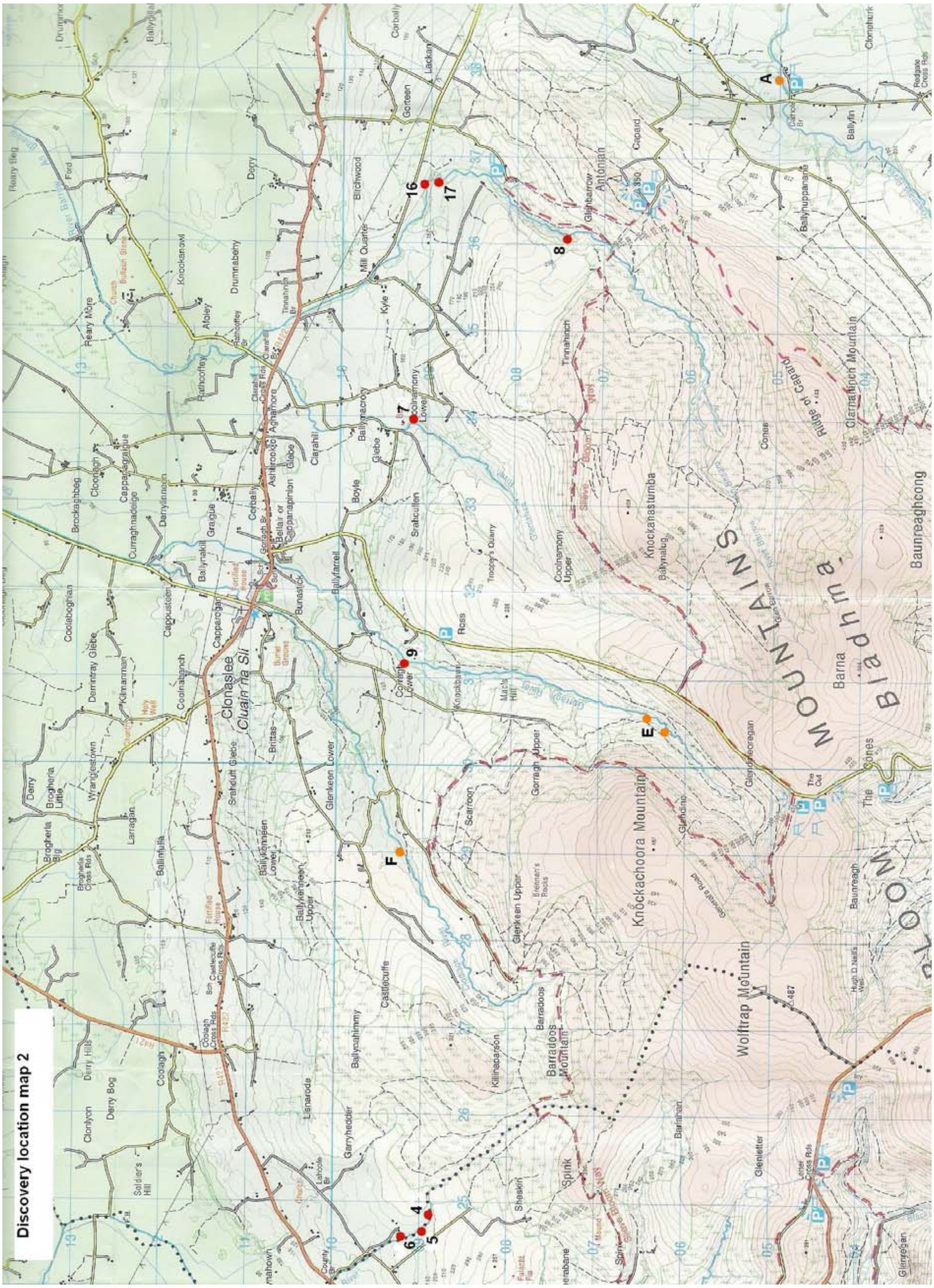
Appendix I

Location of sites on 1:50,000 Discovery maps.

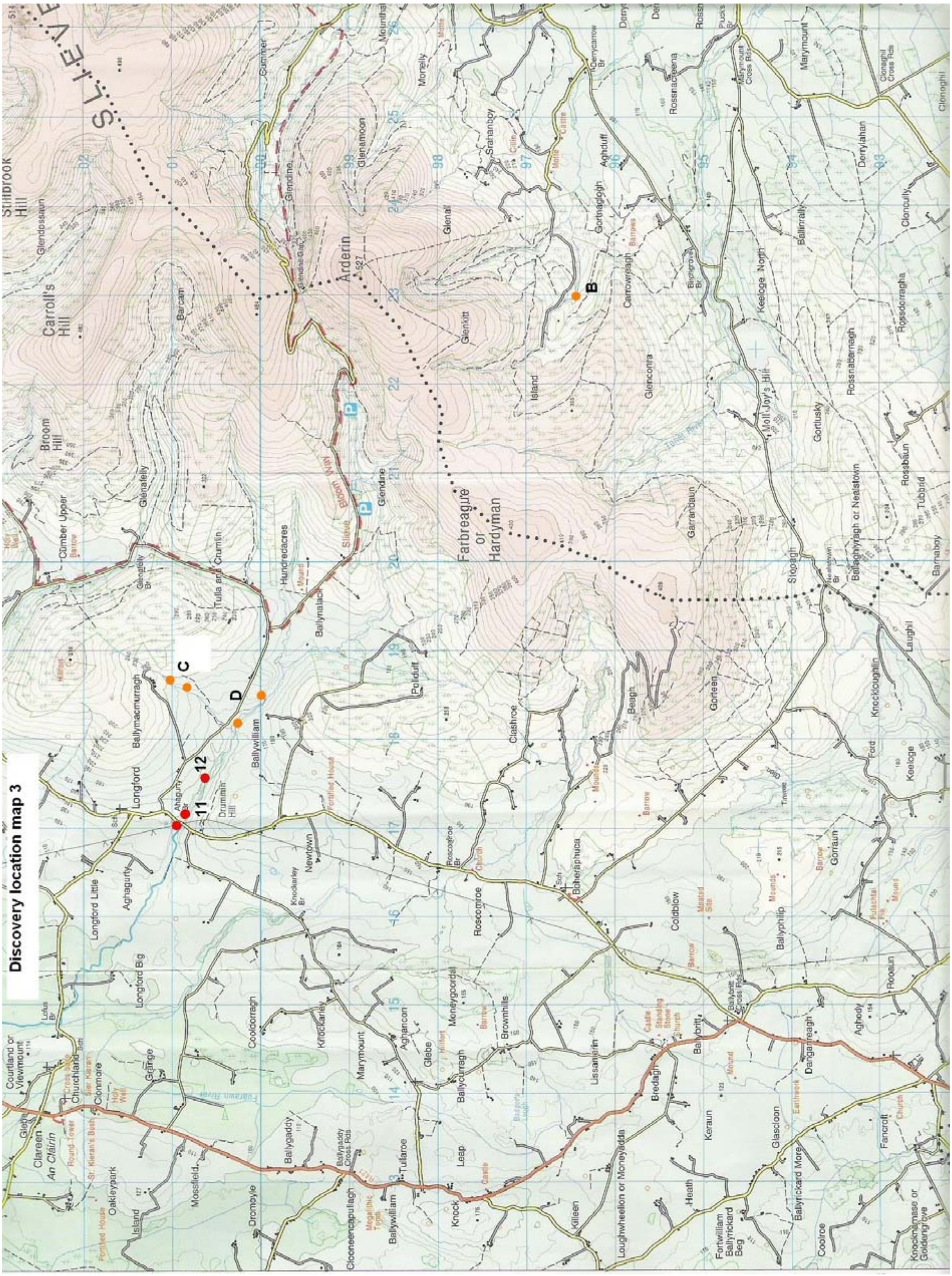
Location Map 1



Location Map 2



Location Map 3



Appendix II

Vascular plant species

Table 4. Vascular plant species found at two or more sites (EXCEL format), overleaf.

1. Vascular plant species present in only one site (see also Table 4.)
(species name is followed by site in which it was recorded)
Lysimachia nemorum, 2; *Cardamine flexuosa*, 2; *Carex strigosa*, 2; *Urtica dioica*, 2; *Potentilla erecta*, 3; *Lotus corniculatus*, 3; *Festuca arundinacea*, 3; *Carex pulicaris*, 3; *Selaginella selaginoides*, 3; *Vicia cracca*, 3; *Heracleum sphondylium*, 3; *Pedicularis palustris*, 3; *Juncus acutiformis*, 3; *Carex panicea*, 3; *Danthonia decumbens*, 3; *Eriophorum latifolium*, 3; *Trifolium pratense*, 3; *Juncus conglomeratus*, 8; *Dactylorhiza* sp, 8; *Gymnadenia conopsea*, 8; *Potentilla repens*, 8; *Carex paniculata*, 10; *Carex panicea*, 10; *Galium uliginosum*, 10; *Geum rivale*, 10; *Betula pubescens* (trees), 11; *Glyceria fluitans*, 11; *Eupatorium cannabinum*, 12; *Schoenus nigricans*, 12; *Arrhenatherum elatius*, 13; *Ajuga repens*, 13; *Juncus effusus*, 13; *Festuca arundinacea*, 13; *Juncus inflexus*, 14; *Caltha palustris*, 14; *Plantago lanceolata*, 14; *Linum catharticum*, 14; *Carex sylvatica*, 15; *Nasturtium* sp, 18; *Filipendula ulmaria*, 18.

2. Vascular plant species present in the species rich fen at site 3.
Briza media *Anagallis tenella* *Arrhenatherum elatius* *Caltha palustris* *Carex flacca* *Carex nigra* *Carex panacea* *Carex rostrata* *Carex viridula* *Cynosurus cristatus* *Dactylorhiza fuschii* *Epipactis palustris* *Equisetum arvense* *Equisetum fluviatile* *Equisetum palustre* *Equisetum telmateia* *Equisetum variegatum* *Eriophorum angustifolium* *Eriophorum latifolium* *Festuca arundinacea* *Festuca rubra* *Galium palustre* *Holcus lanatus* *Juncus acutiflorus* *Lathyrus pratensis* *Lotus corniculatus* *Lychnis flos-cuculi* *Mentha aquatica* *Parnassia palustris* *Pedicularis palustris* *Ranunculus acris* *Ranunculus flammula* *Rhinanthus minor* *Succisa pratensis* *Trifolium pratense* *Trifolium repens* *Valeriana officinalis* *Vicia cracca*

38 species, note: five *Equisetum* sp.

Table 4. Vascular plant species present at more than 2 sites

																			43	44	
SITE NO.	1	2	3	15	5	18	7	8	9	10	11	12	13	14	15	40	17	18	19	20	**no. of sites**
SPECIES																					
Equisetum telmateia		**p**	**p**				**p**	**p**	**p**	**p**	**p**		**p**				**p**				**9**
Agrostis stolonifera			**p**				**p**		**p**	**p**			**p**	**p**	**p**		**p**	**p**			**9**
Fraxinus excelsior (seedlings)		**p**			**p**		**p**		**p**		**p**	**p**	**p**								**7**
Hedera helix		**p**					**p**		**p**	**p**	**p**	**p**			**p**						**7**
Geranium robertianum					**p**		**p**		**p**	**p**	**p**		**p**				**p**				**7**
Carex flacca			**p**				**p**	**p**			**p**		**p**				**p**				**6**
Festuca rubra			**p**					**p**		**p**			**p**	**p**			**p**				**6**
Mentha aquatica									**p**	**p**			**p**	**p**			**p**				**5**
Molinia careulea			**p**					**p**		**p**			**p**	**p**							**5**
Juncus articulatus		**p**							**p**	**p**			**p**	**p**							**5**
Ranunculus repens.		**p**							**p**						**p**		**p**				**4**
Carex remota		**p**					**p**								**p**		**p**				**4**
Equisetum palustre									**p**	**p**			**p**	**p**							**4**
Succissa pratensis			**p**					**p**		**p**				**p**							**4**
Cirsium palustre			**p**					**p**						**p**	**p**						**4**
Holcus lanatus					**p**			**p**					**p**	**p**							**4**
Equisetum variegatum					**p**			**p**	**p**	**p**											**4**
Angelica sylvestris								**p**		**p**			**p**	**p**							**4**
Rubus fruticosus									**p**		**p**		**p**		**p**						**4**
Triglochin palustris		**p**								**p**				**p**							**3**
Juncus bufonius		**p**						**p**	**p**												**3**
Phyllitis scolopendrium		**p**									**p**							**p**			**3**
Descampsia cespitosa		**p**					**p**			**p**											**3**
Equisetum arvense			**p**					**p**													**3**
Pinguicula vulgaris			**p**					**p**						**p**							**3**
Briza media			**p**					**p**						**p**							**3**
Prunella vulgaris			**p**					**p**	**p**												**3**
Lathyrus pratensis			**p**					**p**					**p**								**3**
Parnassia palustris								**p**		**p**				**p**							**3**
Veronica beccabunga		**p**													**p**		**p**				**3**
FINAL SITE NO.	**1**	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

Species present at 2 sites
Tussilago farfara
Salix cinerea
Betula pubescens
Lychnis flos-cuculi
Salix aurita
Epilobium palustre
Hypericum androseamum
Carex viridula
Eriophorum angustifolium
Carex nigra
Agrostis capillaris
Carex pendula

Appendix III

Bryophytes present at five travertine formations in England
(from Pentecost and Zhahoui, 2002)

Mosses	**Liverworts**
Bryum pseudotriquetrum	*Aneura pinguis*
Brachythecium rivulare	*Pellia endiviifolia*
Cinclidotus fontiniodes	*Marchantia polymorpha*
Cratoneuron filicinum	*Conocephalum conicum*
Dichodontium pellucidum	*Jungomannia atrivirons*
Didymodon tofaceous	*Southbya tophacea* (a rarer species)
Eucladium verticillatum	
Fissidens viridulus	
Eurhynchium hians	
Hymenostylium recurvirostrum	
Palustriella commutata var. *commutata*	
Palustriella commutata var. *viresc.*	
Palustriella commutata var. *falcata*	
Philonotis calcarea	
Plagiomnium rostratum	
Rhynchostegium riparioides	

Fissidens sp, Silver River

Appendix IV

A MOLLUSCAN SURVEY OF TUFA SPRING SITES, COUNTIES LAOIS AND OFFALY

Evelyn A. Moorkens

A MOLLUSCAN SURVEY OF TUFA SPRING SITES, COUNTIES LAOIS AND OFFALY

October 2007

Evelyn A. Moorkens

Dr Evelyn Moorkens B.Sc. H.Dip. M.Sc. Ph.D.
Environmental Consultant
53, Charleville Square, Rathfarnham, Dublin 14.
Tel / Fax: 01 4948500 Mobile: 086 8211385
E-mail: emoorkens@eircom.net

Client: Stephen Heery, Laurencetown, Ballinasloe, Co. Galway

1.0 Introduction

A molluscan survey was undertaken at five different tufa spring sites, as identified by Stephen Heery as part of a contract undertaken for the County Councils of Counties Laois and Offaly. The purpose of this one-day survey was to provide information on the importance of the invertebrate biodiversity of the sites by visiting a subset of the sites and looking at the molluscan fauna present. Although these sites are already clearly of very high importance as Annex I Habitats (petrifying springs with tufa formation), this survey should provide an overall indication of the ecological importance that the sites provide for invertebrates.

The survey was carried out on 18th September 2007.

2.0 Methodology

At each site the main habitats of molluscan interest were investigated by hand, e.g. by searching vegetation, stones and the underside of timber by eye. Fringe vegetation was sampled by banging leaves onto a white tray.

As well as observing snails in the field, molluscs were sampled by collecting litter samples. Approximately 2 litres of litter was taken from appropriate habitat at each sampling site, air dried in the laboratory and then sieved through two mesh sizes, 3mm and 0.5mm. The contents of each sieve were examined for snails. An Olympus 40X binocular microscope was used to examine the smaller species.

3.0 Results

The Sites visited are shown in Table 1, and Photos of the areas sampled are given (Photos 1-8). The molluscan faunas are shown in Table 2.

NB: photographs are included in the CD version of the whole Slieve Bloom report (S.Heery)

Table 1. Location of study sites.

Molluscan Site Number	Tufa Spring Number	Location	Site Name	County	Habitat
1	7	N 3391 0921	Glenlahan River Valley	Laois	Hard mossy tufa mounds sloping down to river with *Equisetum telmateia* below
2	13	N 2399 0651	Silver River Valley by Offaly Way route	Offaly	Strongly sloping river valley with more open mossy spring head and *Equisetum telmateia* below
3	3	N 2372 0715	Slopes above Silver River Valley	Offaly	Sloping tufa springs leading to open fen with *Parnassia palustris, Eriophorum latifolium, Scabious pratensis* and *Equisetum telmateia*
4	18	N 2079 0492	Camcor River Valley at Coneyburrow Wood	Offaly	Sloping dendritic tufa within native woodland scheme area. Dendritic flow with mounds and waterfalls and wider fen habitat with *Equisetum telmateia* and some *Carex pendula* tussocks
5	11	N 1712 0086	River Valley below Drummin Hill at Aghagurty Bridge	Offaly	Large slope with *Cratoneuron commutatum*. Fanning from a high springhead area within river valley with *Equisetum telmateia* below
Control	Next to 18	N 2079 0492	Camcor River Valley at Coneyburrow Wood	Offaly	Dry Beech litter

Table 2. Molluscan Species found in survey
(nomenclature follows Anderson, 2005). + Size range

							Sites
	Size	1	2	3	4	5	C
Terrestrial species							
Acicula fusca*	**1**	**X**	**X**		**X**	**X**	**X**
Carychium minimum	**1**	**X**		**X**	**X**		
Carychium tridentatum	**1**		**X**	**X**	**X**		
Oxyloma pfeifferi	**2**			**X**			
Cochlicopa lubrica	**2**	**X**	**X**	**X**	**X**	**X**	
Columella edentula	**1**	**X**	**X**				
Vertigo antivertigo	**1**			**X**			
Vertigo substriata	**1**		**X**	**X**			
Vertigo geyeri*	**1**			**X**			
Leiostyla anglica	**2**	**X**	**X**	**X**	**X**	**X**	**X**
Vallonia pulchella*	**1**	**X**	**X**	**X**			
Acanthinula aculeate*	**1**			**X**			**X**
Spermodea lamellate*	**1**		**X**				
Punctum pygmaeum	**1**		**X**	**X**			
Discus rotundatus	**2**	**X**	**X**		**X**	**X**	**X**
Vitrea crystalline	**1**		**X**	**X**	**X**		**X**
Nesovitrea hammonis	**2**			**X**		**X**	
Aegopinella pura	**2**	**X**	**X**	**X**	**X**		**X**
Aegopinella nitidula	**2**	**X**					
Oxychilus cellarius	**2**	**X**	**X**		**X**		
Oxychilus alliarius	**2**		**X**		**X**		
Zonitoides nitidus	**2**	**X**					
Euconulus fulvus	**2**						**X**
Euconulus praticola*	**2**	**X**	**X**	**X**			
Clausilia bidentata	**3**					**X**	**X**
Balea perversa*	**2**	**X**	**X**		**X**		**X**
Zenobiella subrufescens*	**2**	**X**					
Trochulus hispidus	**2**		**X**	**X**			
Cepea nemoralis	**4**		**X**		**X**		**X**
Galba truncatula	**1**			**X**			
Pisidium personatum	**1**	**X**		**X**			
Total no. species (31)		15	18	18	12	6	10

Size range (maximum adult height): 1 = < 3mm long; 2 = >3, < 10mm long; 3 = >10, < 14mm long; 4 = >14mm.

*** indicates scarce or notable species.**

4.0 Discussion

There was a remarkable diversity of molluscan species found during this short survey, including a number of rare and one legally protected species. While the last tufa site surveyed had the largest area of *Cratoneuron commutatum*, it had the smallest species diversity. Similarly, the dry beech litter without the influence of the spring had a low species diversity with common species only present. The sites that had the combination of tufa spring with other supporting habitats have yielded both high diversity and high quality indicator species, making them hot-spots of molluscan interest and are very likely to be hot-spots for other invertebrate groups as well.

The shaded spring sites on valley slopes with mixed woodland have an excellent mix of wet woodland mollusc fauna, including two nationally rare species, *Spermodea lamellata* at Site 2 and *Zenobiella subrufescens* from Site 1.

Spermodea lamellata has only had one recent record from County Offaly and has declined considerably in Ireland through loss of wet woodland habitat. Its discovery at a new site is very exciting.

Zenobiella subrufescens is a snail of old broadleaved woodlands in moist sheltered situations on valley sides (Kerney, 1999). This combination of conditions is rare in Ireland and the species is considered to be in retreat (Kerney, 1999). Internationally, the species is restricted to the Atlantic region of Western Europe, and as such is mainly restricted to Britain, Ireland and coastal regions of western France. Remaining populations found in Ireland in recent year have been associated with moist south western areas, so a new site for this rare species in County Laois in this fine spring-fed habitat is particularly satisfying.

While four of the sites were in sloping wooded river valleys, one (Site 3) was in open habitat and sloped to a high quality open fen. Among the 18 species of molluscs found in this small area was *Vertigo geyeri*, the rare fen snail that is protected under Annex II of the Habitat's Directive. This is only the fourth site for the species in County Offaly, and places the site at very high conservation value. *Vertigo geyeri,* as well as being an Annex II species, is considered to be a threatened species in Ireland under the recent review of molluscan species using IUCN threat categories (Moorkens, 2006). The species has highly restricted habitat needs, requiring very even hydrogeology, with surface saturation normally attained by the presence of continuous calcareous seepages. This species can only survive in the long term where there is a penetrable area of occupation that varies between habitat that suits both wet and dry years. All Irish populations of this species are vulnerable, conservation management needs to be ongoing, and grazing levels can be critical. This species is threatened by drainage, flooding, overgrazing, and undergrazing, and by development pressure in scenic sites. Therefore, the discovery of a remote and fully functioning fen driven by an active tufa spring is of immense importance. Two other *Vertigo* species were found at this site, *V. substriata,* which utilizes slightly drier habitat, and *V. antivertigo*, which requires open habitat that is wetter than *V. geyeri*. The wetness range of this fen is therefore varied over space, and yet continuous and even in terms of variation in time. This combination is an indication of excellent quality.

Other species of note that were found during the study were *Acicula fusca, Vallonia puchella, Acanthinula aculeata, Euconulus praticola* and *Balea perversa*, all of which are indicators of high quality, clean, natural habitats. It is highly likely that surveys of other taxonomic groups would also lead to equally interesting results. Each of the sites had its own unique habitat, depending on its comparative openness, slope and aspect. As a series of sites these tufa springs provide a remarkable addition to the biodiversity of the larger areas within which they are found, and they deserve the utmost level of conservation protection.

5.0 References

Anderson, R. (2005) An annotated list of the non-marine mollusca of Britain and Ireland. *Journal of Conchology* **38**, 607-638.

Kerney, M. (1999) *Atlas of the land and freshwater molluscs of Britain and Ireland*. Harley Books, Colchester.

Moorkens, E. A. (2006). “Irish non-marine molluscs – an evaluation of species threat status”. *Bull. Ir. Biogeog. Soc*. **30**, 348-371.