Bulletin of the Irish Biogeographical Society **Number 45** (2021)

PSYCHODIDAE (DIPTERA) AS INDICATORS OF THE EFFECTS OF THE LINED KILDARE BYPASS MOTORWAY ON TUFA SPRING HABITAT AT POLLARDSTOWN FEN, IRELAND

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Dedication

***Phil Withers (1954 - 2020) -** a Dipterist of note* (see tribute below).

Abstract

A baseline survey of tufa spring psychodids was carried out at tufaceous springs and flushes in Pollardstown Fen (Ireland) in 2001-2002, using four emergence traps/location at five locations. Monitoring was continued in 2003-2006 and, at one location, in 2017. There was no difference in the mean species occurrence per trap between the monitoring and baseline data, of the tufa habitat species *Pericoma calcilega* and *Paramormia decipiens,* indicating no effects of the road construction or operation on the sampled tufa spring and flush habitat. However, the most sensitive site, a high-level flush with tufaceous runnels in *Schoenus nigricans*-dominated vegetation, has not been monitored after 2006. Moss-expressed water levels (the water level in *Palustriella* moss when pressed by hand) was also monitored at all trapped locations, and this maybe the most efficient way to regularly monitor the tufa habitat, only using psychodid monitoring after low water levels are detected after dry periods.

Key words: *Pericoma*, Psychodidae, tufa springs, Pollardstown Fen, Kildare Bypass, Ireland, ecological impact assessment.

Introduction

Tufaceous springs (also classed as ambient-temperature hard water or petrifying (tufa) springs) are a habitat type of high conservation importance in Europe (Council of Europe, 2019; European Commission, 2013). The occurrence of tufa springs at Pollardstown Fen (County Kildare, Ireland) is one of the reasons for the designation of the fen as a Biogenetic Reserve and a Special Area of Conservation. Pollardstown Fen, as a whole, is fed by calcareous springs originating from the large Curragh sand and gravel aquifer (Kuczyńska, Johnston and Misstear, 2009). Tufa, a porous concretionary calcite rock, is formed by deposition from spring water oversaturated with calcium carbonate, often around the bases of calcicole mosses such as

Palustriella (=*Cratoneuron*) *commutata* (Hedw.) Ochyra, after degassing of carbon dioxide (Pentecost, 2005). The following example is cited by Boyer and Wheeler (1989):

$$Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3\downarrow + CO_2\uparrow + H_2O$$

$$\text{Aquifer } {}_{P}CO_2 = 8.0 \text{ mAtm} \rightarrow \text{Spring } {}_{P}CO_2 = 0.34 \text{ mAtm}$$

This physical process can be enhanced by various photosynthetic, biochemical and microbiological processes (Cantonati *et al*., 2016). The spring water at Pollardstown Fen has been recorded to have $CaCO_3$ concentrations up to 500mg/l (Reynolds, 2003).

In 2001, construction began on 13.2km of motorway to bypass the town of Kildare, 3.5km of which included a cutting into the Curragh aquifer to avoid impacts on the adjacent equine breeding sites (Coppinger *et al*., 2002; Coppinger and Farrell, 2003). In order to also avoid impacts on the groundwater source for Pollardstown Fen, this section of the motorway was lined ('tanked') with a bituminous liner, so the road surface now lies down to 1.75m below the level of the surface of the aquifer (Coppinger *et al*., 2002; Coppinger and Farrell, 2003).

Moth flies (Diptera: Psychodidae) include a range of species occurring in spring and seepage (flush) habitats (madicolous species), including specialists in springs (crenobiont species) and in tufa habitats (tufobiont species). Of the psychodid flies recorded from the Pollardstown tufa springs, the crenobiont *Atrichobrunnettia angustipennis* (Tonnoir) is a very rare species in Britain and otherwise only recorded in Belgium (Wagner, 2014); this is the only known site for this species in Ireland (Withers and O'Connor, 1992), and specimens collected here formed the basis for the first larval description for this species (Vaillant and Withers, 1990). The tufobiont *Pericoma calcilega* Feuerborn is local in Europe, and no other Irish records exist. The larvae, which have specialised dorsal setae on which calcite is deposited (Dürrenfeldt, 1978; see Fig. 1j in Cantonati *et al*., 2016), were described by Vaillant and Withers (1993) from a sample from a Pollardstown Fen tufa spring. Like *Pericoma* species of the *calcilega*-group, *Paramormia* (=*Phyllotelmatoscopus*) *decipiens* (Eaton) is associated with lime-rich habitats, especially tufa (Vaillant, 1991), and a Pollardstown tufa spring was also the only Irish location from which it had been recorded, and from which larvae were described by Vaillant (1991). *Sycorax* species are also crenobiont psychodids (Vaillant, 1978; Omelková and Ježek, 2012), with *S. feuerborni* Jung only known from Pollardstown Fen in Great Britain and Ireland (Withers, 2002). A number of other rare insect species have been recorded from Pollardstown Fen springs and flushes such as the caddisfly *Limnephilus pati* O'Connor (O'Connor, Good and Wallace, 2019) although not all these are tufa specialists.

Small 'obscure' organisms like psychodid flies are rarely used in biodiversity monitoring often because of perceived difficulties with sampling and identification. The results of a monitoring study using tufa habitat psychodids is reported below, where the sampling design was simplified so that it could be used by non-specialist entomologists (JG and TG), with initial input from a specialist (PW).

Methods

Sampling locations

A baseline survey of tufa spring psychodids was carried out at five locations in Pollardstown Fen in 2001-2002, and monitoring was continued at eight locations in 2003-2006 and, at one location, in 2017. The sampled locations and dates are listed in Table 1, and include a range of tufaceous springs and flushes, as well as non-tufaceous flushes. The main location sampled, the ‘Tufa spring’ (Plate 1), which was the location from which all the rare psychodids mentioned in the introduction were recorded, was a historically excavated spring where the excavation had penetrated down through the upper peat and clay layers (see Kuczyńska, Johnston and Misstear, 2009), resulting in an all-year-round flow of tufa-depositing water from the spring. This location is shown in Plate 1 as it was in 1989, although there has been considerable scrub growth on the margins in the meantime.

Details of the ‘Springbank flush’ (‘Site A’ of Kuczyńska and Moorkens (2010: Fig. 2)) are given in Kuczyńska, Johnston and Misstear (2009) and Kuczyńska and Moorkens (2010). It is an undrained natural location with superficial tufa deposits in runnels between *Schoenus* tussocks; data from 2001 were not collected due to difficulties with obtaining access.

The ‘*Schoenus* field’ (‘Site D’ of Kuczyńska and Moorkens (2010: Fig. 2)) had no visible surface tufa deposition and did not have *Palustriella commutata* present; the mosses *Campyllium stellatum* (Hedw.) Jensen and *Scorpidium cossonii* (Schimp.) Hedenäs occurred frequently (K. Duff, *in litt*.).

The ‘*Homalothecium* fen’ (‘Site C’ of Kuczyńska and Moorkens (2010: Fig. 2)) had only patchy *Schoenus* cover, with *Juncus subnodulosus* dominating a large proportion of the vegetation. Tufa deposition and *Palustriella commutata* were also absent. In contrast to the *Schoenus* field, the mosses *Calliergonella cuspidata* (Hedw.) Loeske and the rare *Tomenthypnum* (= *Homalothecium*) *nitens* (Hedw.) Loeske were more frequent (K. Duff, *in litt*.).

Emergence traps

Sets of four Owen emergence traps (Owen, 1989, 1992; see Plate 2), with their bases removed, were operated at various locations as summarised in Table 1, with the exception of Scarletstown drain and Springbank wood, where sets of only two traps were operated in 2003. The main sampling location, the Tufa spring, was sampled in all six years.

The emergence traps were made of white polyester mesh (the same material used in Malaise traps), with a standard Malaise trap collecting bottle, and covered a surface area of approximately 1.05m^2 (see Plate 2). The traps were originally obtained from Marris House Nets in Bournemouth, U.K., but are still available elsewhere commercially, although with a slightly smaller surface area. Traps were held in place by plastic tent pegs inserted into peat or granular tufa in peat, avoiding the pure tufa deposit wherever possible. Because of their size and the mosaic nature of the tufa shelves and peat soils, the Tufa spring traps also covered areas of fen peat vegetation but most of the cover was *Palustriella* moss.

Identification and nomenclature

Psychodidae from emergence traps in 2001 (Table 1) were determined by PW; indicator psychodids (Plate 3) from all other years were determined by JG, using the keys in Withers (1989) and Vaillant and Withers (1993), and reference material. Psychodid nomenclature follows Chandler, O'Connor and Nash (2008), with the exception of the two indicator species (see below); plant nomenclature follows Stace (1997) and Smith (2004). Reference specimens were retained in the Withers collection.

In 1993, Vaillant and Withers described specimens from Pollardstown Fen, recognised in Withers and O'Connor (1992) as *Pericoma tonnoiri* Vaillant, 1978, as *Pericoma calcilega* Feuerborn, 1923. Both species are tufobiont (Vaillant and Withers, 1993; Kvifte and Ivković, 2018). However, the species remains listed in the Irish checklist (Chandler *et al*., 2008) as *Pericoma tonnoiri* Vaillant. In the current *Fauna Europaea* website (Wagner, 2014), *P. calcilega* is recorded from Great Britain, France and Germany but not south of Slovenia, whereas *P. tonnoiri* is recorded from Ireland, Great Britain and south-east Europe but not north of Austria. Although disjunct distributions are not without precedent in the *calcilega* subgroup of *Pericoma* (*P. pallida* is recorded from the south of Spain and the Czech Republic and Slovakia (Ježek and Omelková, 2012; Vaillant and Withers, 1993), but not from suitable habitats in France (Vaillant and Withers, 1993)), nevertheless they are highly unusual for Irish species. The senior author greatly regrets not clarifying this taxonomic question with Phil Withers before his untimely death, but, for the purposes of this paper, we have followed Vaillant and Withers (1993) and used the name *Pericoma calcilega* Feuerborn.

In 1991, Vaillant described specimens from Pollardstown Fen, recognised in Withers and O'Connor (1992) as *Paramormia decipiens* (Eaton, 1893), as *Phyllotelmatoscopus decipiens* (Eaton 1893). The European species of *Phyllotelmatoscopus* are restricted to calcium-rich and tufaceous springs, unlike the more eurytopic *Paramormia* sensu stricto (Vaillant, 1991; Wagner, 2006). However, there is disagreement whether *Phyllotelmatoscopus* should be of generic or subgeneric status; the species remains listed in the Irish and British checklists (Chandler *et al*., 2008; Chandler, 2021) as *Paramormia decipiens*, which we have followed here.

Water levels

Summer water levels in the sampled habitats were measured in 2003, 2004 and 2006; 2003 was the driest summer in the baseline period (2001-2003). The water level in the *Palustriella commutata* or other mosses was measured by pressing an opened hand with moderate pressure into the moss, and recording the level of water expressed, using the following four-point scale of 0 to 3:

0 - No expressed water visible (Plate 4a);
1 - Expressed water visible but not above interdigital skin folds of hand (Plate 4b);
2 - Expressed water visible above interdigital skin folds of hand but not covering fingers;
3 - Expressed water completely covering fingers (Plate 4c).

This was repeated 25 times in the wettest areas of moss, and the 25 values were added to give an index. For example: 0 (x 0) + 13 (x 1) + 9 (x 2) + 3 (x 3) = **40**. The index varied from 0 (no expressed water throughout) to 75 (expressed water completely covering fingers in all 25 presses).

This index was then used to represent what is referred to below as ‘moss-expressed water level’. On one occasion, at the Tufa spring in 2003, where water cress was attracting rats (*Rattus norvegicus* (Berkenhout)), water level samples were not taken due to the presence of rat faeces on the moss.

Results

The results of emergence trapping in 2001 for all Psychodidae are given in Table 2, and for the two tufa habitat indicator species *Paramormia decipiens* and *Pericoma calcilega* (Plate 3), for all years in Table 3. Both species occurred consistently in emergence traps at both the Tufa spring (six years) and at the Springbank flush with tufaceous runnels (four years) (Table 3). The mean occurrence per trap for these species never declined below 1.75 at both sites. Both species were also recorded at the same occurrence/trap at another flush in cut-away peat with more isolated small tufaceous runnels in 2006 (Entrance flush, Table 3). The rare *Atrichobrunettia angustipennis* was also recorded at the *Schoenus* field location, a new record for the north side of the Fen (Table 2).

Both the 2003 and 2004 (after construction), and 2006 and 2017 (after operation) data (Table 3) indicated no effect of the lined road on these two tufa habitat species, when compared to the baseline data.

The *Homalothecium* fen location, which had no tufa, had neither species in any trap (Table 2), as would be predicted if they were tufobiont. Interestingly, at Pollardstown ponds, the new tufa ledges which occurred between the two ponds created approximately 10 years earlier, also had neither species (Table 3), despite being colonised by *Palustriella commutata*.

However, *P. decipiens* did occur in two traps in the *Schoenus* field, which was calcareous but had no distinct tufa deposits. The soil surface of this location was not recorded as having dried in the late summer as was recorded at the *Homalothecium* fen. In contrast, *P. calcilega* occurred in all traps in the tufa ledges under woodland canopy at Springbank wood, whereas *P. decipiens* was absent from these habitats (Table 3). There was a similar pattern of occurrence at Scarletstown drain, in a tufaceous drain with moss, probably *Bryum pseudotriquetrum* (Hedw.) Gaertn., but without *Palustriella commutata*. However, the latter two locations only had data for two traps in one year.

Moss-expressed water level data for the driest summer (2003) of the three years 2001-2003 are given in Table 5. Data from 2004 and 2006 are given in Table 6. Only at the *Homalothecium* fen was there an indication of drying out (both 2004 and 2006 (Tables 5 and 6)), and this is also the only site where both tufa habitat indicator psychodids were absent (Table 3). Contrariwise, the lowest moss-expressed water level at the Springbank flush (21 on 9 August 2003 (Table 5)) preceded a psychodid (mean occurrence/trap) value of 2.0 the year after (2004) (Table 3).

Moss-expressed water levels were affected by recent rainfall, when pluvial water pools on the surface of the moss. For example, rainfall occurred during 3 August 2006, and moss water levels were recorded before rainfall at Springbank flush and the Entrance flush, and after rainfall at the *Schoenus* field. Moss-expressed water levels had decreased since July at the former two sites, but increased at the latter site (Table 6), correlating with the rainfall event. Also, subjective changes between dates in locating the boundaries of the monitored area may contribute to some variation in water level data.

Discussion

A simplified monitoring method, with mean occurrence/trap of two indicator species readily identifiable from male specimens in trap samples (see Plate 3), has given the following understanding of the impacts on tufa spring psychodids at Pollardstown Fen (see Table 3):

(1) The consistent occurrence of both indicator species (*Pericoma calcilega* and *Paramormia decipiens*) year after year, in emergence trap samples at the most frequently monitored sites (Tufa spring and Springbank flush), indicates the reliability of the monitoring results;

(2) Both species occurred in similar frequency in a deeper limnocrene spring with thick tufa (Tufa spring) and in shallower flushed runnels amongst *Schoenus*-dominated vegetation (Springbank flush and Entrance flush) with superficial calcite deposits (very localised at the

Entrance flush), which indicates that runnels were their more likely habitat before fen drainage, and that small patches of habitat can support both species;
(3) Both species were absent from a fen flush without tufa deposition (*Homalothecium* flush) and a tendency to occasionally dry out, indicating their dependency on a continually moist calcite-depositing environment, although *P. decipiens* can occur in calcareous fen soil without visible active tufa deposition (*Schoenus* field);
(4) Only one species (*P. calcilega*) occurred in traps from tufa ledges in drains under *Fraxinus* woodland canopy (Springbank Wood), indicating that *P. decipiens* may require open habitat;
(5) Both species were absent from a newly-formed tufa barrier with *Palustriella commutatum* in the open between two ponds (Pollardstown ponds), which could possibly be explained by lack of tolerance of higher temperatures.
(6) Both species occurred, although in lower frequency, in a drain (Scarletstown drain) with tufa deposition but with moss other than *Palustriella* (probably *Bryum pseudotriquetrum*, a species frequent in peat soil tufa seepages (Pentecost, 2005)).
(7) Some tolerance by both psychodid species of *summer* drying of habitat is indicated by the 2004 results from the Springbank flush, where moss-expressed water levels the previous summer where quite low (index = 21, see Table 5).
(8) Moss-expressed water level data must be collected and interpreted with care. Sampling after rainfall will confound results. Also, the lower values are more reliable for interpretation, as once water levels cover the fingers, the upper index threshold has been reached. Both these factors may explain why there was no significant correlation between moss-expressed water levels and recorded phreatic water levels (T. Gittings, unpublished data).

As with all major road projects, two types of impact, from construction (in this case temporary dewatering) and from operation (in this case liner failure), can be distinguished. The psychodid monitoring during the construction period did not reveal an impact from construction dewatering (2003-2004, Table 3). Neither did psychodid monitoring during operation reveal an impact (2006, 2017, Table 3), nor did moss-expressed water levels change significantly (the lowest value during 2006 being 49 (Table 6), well above the driest 2003 value of 21 (Table 5)).

The 2017 monitoring did not include the Springbank flush (due to time and access constraints), and a question remains concerning an impact at this location. A lowering of groundwater levels feeding the fen was detected near this site, and a contribution of the road construction to this lowering could not be ruled out (Kilroy *et al*., 2009; Moorkens and Killeen, 2011; Johnston *et al*., 2015). Nevertheless, the trapped tufaceous flushes were slightly downslope from the *Vertigo geyeri* Lindholm habitat monitored by Kuczyńska and Moorkens (2010), and potentially less susceptible to drying effects. No change in either psychodid or moss-expressed water levels were recorded here in 2006, but further monitoring would be worthwhile, especially after the effects of recent droughts. Late summer droughts (e.g. 2018) may have less impact than late spring droughts (e.g. 2020) when the more susceptible larval stages occur.

There is also the long-term (measured in decades or centuries) question of deterioration of the bituminous liner, although this is unlikely as the liner is not exposed (one prediction of the lifetime of an unexposed HDPE liner is nearly 450 years (Koerner, Hsuan and Koerner, 2011)), and even exposed liners have shown no leakage after 30 - 40 years (Touze-Foltz and Farcass, 2017; Giroud and Gourc, 2014).

The question of trapping-out of adult *P. decipiens* and *P. calcilega*, due to the intensity of trapping (4 traps/location over several sequential years in a limited spatial habitat) did not arise as a potential confounding factor as there was no decline recorded in frequency of these species over the 2002-2004 period. However, from a conservation perspective, excessive trapping should be avoided. It is possible to reduce the trap size by one half if the back half of the netting is rolled up and clamps used for holding it in place (also the more recent commercially available traps cover a smaller area). Sampling over only one month instead of two is also a possibility, but from the results in Table 4, it is likely that this would reduce mean occurrence/trap to below 1.75. However, it is the consistency in results from year to year, rather than the total value that matters. An option is to discontinue further sampling if the first set of trap bottles contains all positive results; this would require field identification. Finally, there is the option of only carrying out trapping when the moss-expressed water levels are recorded to fall so much as to indicate temporary drying out of some of the moss or runnel surface. This requires water level monitoring in drought periods, especially in spring.

Cairns (1982) defined biological monitoring as "the systematic use of biological responses to evaluate changes in the environment *with the intent to use this information in a quality control program*" (italics added). Vegetation response is likely to be the preferred biological indicator for tufa habitat biological monitoring (Lyons and Kelly, 2016). However, the occasional use of specialised insects as supplementary indicators is worthwhile, if quality control refers to biodiversity as a whole.

Acknowledgements

The authors are particularly grateful for the encouragement, hospitality and guidance of Dr Martin Speight and Professor François Vaillant during this project. We are also particularly grateful to Katherine Duff for information on bryophytes, and to Evelyn Moorkens, Jim Ryan, Fidelma Butler, Teri Hayes and Paul Johnston for their assistance in various ways. The work was funded by Kildare County Council, with the exception of the 2017 monitoring at the Tufa spring.

Tribute

This work would not have occurred without a chance encounter between Phil Withers and Jervis Good in 1989, and the mutual introduction to the wonders of Pollardstown Fen tufa springs and of psychodids. Shockingly, Phil died of a heart attack in July 2020 while on a collecting expedition in the Jura. Given his sense of humour, he would not have missed the chance of attributing this to the revenge of some insect (or better still some twentieth century entomologist reincarnated as such). Phil had a deep interest in the Irish fauna, and visited here regularly from the late 1970s to the early 2000s. He was great company, and was a brilliant entomologist whom it was a pleasure and a privilege to have known. Detailed orbituaries have been published by Claude (2020) and Chandler *et al.* (2021).

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TABLE 1. Details of emergence trap sampling locations and dates for Psychodidae at Pollardstown Fen. Location names were devised for the purposes of this survey only.

Location (grid ref.)	**Habitat**	**Sampling dates**
Tufa spring (N77761526)	Tufaceous *Palustriella commutata*/ *Carex acutiformis* or *Rorippa nasturtium-aquaticum* dominated spring	30 May – 25 July 2001 15 May – 27 July 2002 22 May – 31 July 2003 20 May - 29 July 2004 21 May - 24 July 2006 25 May - 26 July 2017
Springbank flush (N76421590)	Tufa runnels with *P. commutata* under *Schoenus nigricans* tussocks	15 May – 27 July 2002 22 May – 31 July 2003 20 May - 29 July 2004 21 May - 24 July 2006
Schoenus field (N77391662)	*Schoenus nigricans* / *Molinia caerulea*-dominated fen flush	5 June - 25 July 2001
Homalothecium fen (N77531632)	*Juncus subnodulosus* / *Schoenus nigricans*-dominated fen	5 June - 25 July 2001
Pollardstown ponds (N76211597)	Tufaceous *Palustriella commutata* spillway between two new ponds	15 May – 27 July 2002
Entrance flush (N77381543)	Tufaceous runnels between *Molinia caerulea* / *Schoenus nigricans* flush	21 May - 24 July 2006
Springbank wood (N76681579) (n = 2 traps)	Tufa spring under woodland canopy with *Palustriella commutata*	22 May – 31 July 2003
Scarletstown tufa drain (N77101678) (n = 2 traps)	Old tufaceous drain colonised by patches of moss (?-*Bryum pseudotriquetrum*)	22 May – 31 July 2003

TABLE 2. Occurence/trap of Psychodidae (determined P. Withers) from emergence traps at three locations (see Table 1) in Pollardstown Fen in 2001 (n = 4 traps/location).

Species	**Tufa spring**	***Schoenus* field**	***Homalothecium* fen**
Tufobiont species			
Paramormia decipiens (Eaton)	4	2	-
Pericoma calcilega Feuerborn	4	-	-
Crenobiont species			
Atrichobrunettia angustipennis (Tonnoir)	1	1	-
Sycorax feuerborni Jung ♂	1	-	-
Sycorax silacea Haliday *in* Curtis ♂	-	1	-
Other species			
Feuerborniella obscura (Tonnoir)	-	2	1
Panimerus albifacies (Tonnoir)	4	4	4
Panimerus denticulatus Krek	2	1	-
Panimerus maynei (Tonnoir) / *goodi* Vaillant & Withers	3	4	4
Pericoma fuliginosa (Meigen)	2	-	-
Pericoma nubila (Meigen)	2	-	-
Peripsychoda auriculata (Haliday *in* Curtis)	2	1	-
Psychoda albipennis Zetterstedt	1	-	-
Psychoda phalaenoides (Linnaeus)	1	-	1
Psychoda crassipenis Tonnoir	1	-	-
Telmatoscopus labeculosus (Eaton)	1	1	2
Threticus lucifugus (Hailday *in* Walker)	3	-	-
Tinearia lativentris (Berdén)	-	-	1
Tonnoiriella anchoriformis Salamanna	-	-	1
Tonnoiriella pulchra (Eaton)	3	-	-

TABLE 3. Frequency of occurrence of ♂ tufobiont psychodids *Paramormia decipiens* and *Pericoma calcilega* in emergence traps. 'Mean occ.' = mean occurrence.

Location	**Year**	**No. traps**	***Paramormia decipiens***	***Pericoma calcilega***	**Mean occ./trap**
Tufa spring	2001	4	4	4	2.0
	2002	4	3	4	1.75
	2003	4	4	4	2.0
	2004	4	4	4	2.0
	2006	4	4	4	2.0
	2017	4	4	4	2.0
Springbank flush	2002	4	4	3	1.75
	2003	4	3	4	1.75
	2004	4	4	4	2.0
	2006	4	4	3	1.75
Entrance flush	2006	4	4	3	1.75
Schoenus field	2001	4	2	0	0.5
Homalothecium fen	2001	4	0	0	0.0
Pollardstown ponds	2002	4	0	0	0.0
Scarletstown drain	2003	2	1	2	1.5
Springbank wood	2003	2	0	2	1.0

TABLE 4. Frequency of occurrence of ♂ tufobiont psychodids *Paramormia decipiens* and *Pericoma calcilega* in individual emergence traps. Abbreviations: SW - southwest, SE - southeast, NW - northwest, NE - northeast, MW - mid-west, ME - mid-east.

Species								
Tufa spring	**27 June 2002**				**30 June 2003**			
	SW	SE	NW	NE	SW	SE	NW	NE
Paramormia decipiens	+	-	+	+	+	+	+	+
Pericoma calcilega	+	+	+	+	+	+	+	+
	27 July 2002							
	SW	SE	NW	NE				
Paramormia decipiens	+	+	+	+				
Pericoma calcilega	-	+	-	-				
Springbank flush	**27 June 2002**				**30 June 2003**			
	SW	SE	NW	NE	W	MW	ME	E
Paramormia decipiens	-	-	-	-	+	-	-	+
Pericoma calcilega	+	-	+	-	+	+	+	+

TABLE 5. Moss-expressed water levels (see methods) recorded from moss/soil surface at the emergence trap locations at emergence trap locations during late summer and autumn 2003, the driest baseline year for these seasons. Water levels were taken from 25 subsamples at each location, summarised as a cumulative index (see methods).

Location	**Date**		
	9 August	**13 September**	**19 October**
Tufa spring: north traps	40	n.d.	38
Tufa spring: south traps	60	n.d.	52
Tufa spring: untrapped areas	53	n.d.	46
Springbank flush	21	26	44
Schoenus field	22	29	44
Homalothecium fen	35	0	16
Springbank Wood	44	45	41
Scarletstown drain	70	n.d.	67

TABLE 6. Moss-expressed water levels indices (see methods) recorded from moss/soil surface at the emergence trap locations at several locations during summer 2004 and 2006.

Location	**Date**			
2004				
	5 June	**26 June**	**17 July**	**29 July**
Tufa spring (north traps)	73	75	75	75
Tufa spring (untrapped tufa)	75	67	75	75
Springbank flush	46	54	61	58
Schoenus field	55	60	61	65
Homalothecium fen	75	75	75	36
2006				
	11 June	**3 July**	**24 July**	**3 August**
Tufa spring (north traps)	75	75	75	75
Tufa spring (untrapped tufa)	75	75	75	75
Springbank flush	64	75	60	49
Schoenus field	75	75	25	49
Homalothecium fen	75	54	0	0
Entrance flush	50	75	64	61
Springbank wood	75	n.d.	75	n.d.
Pollardstown ponds	75	n.d.	75	n.d.

PLATE 1. The Tufa Spring at Pollardstown Fen, facing south (from a 1989 photograph). Photograph: Jervis Good.

PLATE 2. Emergence trap on *Palustriella*-covered tufa deposit. Photograph: Jervis Good.

PLATE 3. Above: *Paramormia* (*Phyllotelmatoscopus*) *decipiens* ♂. Below: *Pericoma calcilega* ♂. Both as seen in emergence trap samples. Photographs: Jervis Good.

4A.

4B.

4C.

PLATE 4. Moss-expressed water level categories: 0 - no water visible (4A); 1- water visible but not covering all inter-digit webbing (4B); 2 - covering all inter-digit webbing but not covering fingers (not shown); 3 - covering fingers (4C). Photographs: Jervis Good.