Cyfoeth Naturiol Cymru
Natural Resources Wales

An assessment of the condition of the Narrow-mouthed Whorl Snail *Vertigo angustior* at Whiteford Burrows NNR, October 2018

M.J. Willing

NRW Evidence Report No. 395

Figure 1. View looking north-west towards Whiteford Burrows from near Cheriton.

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1. Crynodeb gweithredol

Cafodd *Vertigo angustior*, rhywogaeth sydd wedi'i rhestru yn Atodiad IIa Cyfarwyddeb Cynefinoedd a Rhywogaethau'r Gymuned Ewropeaidd, ei chanfod yn gyntaf yn Nhwyni Whiteford ym mis Mai 1983. Mae'r adroddiad hwn yn adolygu ac yn trafod yr holl waith sydd wedi'i wneud yn flaenorol yn Nhwyni Whiteford ar *V. angustior* rhwng 1993 a 2016, gan gynnwys y gwaith a wnaed ym 1993 a arolygodd llawer o'r parth trawsnewid rhwng y twyni tywod a'r morfeydd heli (ond nid yr holl barth) a saif ar ffiniau dwyreiniol y twyni. Dangosodd hwn bresenoldeb y falwen yn hanner deheuol y parth hwn ar hyd darn o dir tua 0.9 km o hyd. Rhwng 1994 a 2016, cynhaliwyd deg sesiwn fonitro ac un astudiaeth ymchwil awtecolegol, â'r cyfan yn canolbwyntio ar y darn o'r parth trawsnewid rhwng y twyni tywod a'r morfeydd heli ar yr ochr ddeheuol, lle y cofnodwyd nifer o falwod ym 1993.

Yn gyffredinol, daw holl ganlyniadau monitro *V. angustior* rhwng 1994 a 2012 i'r casgliad fod y falwen a'i chynefin cysylltiedig, *Iris pseudacorus*, mewn cyflwr ffafriol ar y cyfan. Ychydig iawn o falwod a gofnodwyd mewn cyfres o bedwar ymweliad monitro â'r safleoedd monitro a astudiwyd yn flaenorol rhwng mis Chwefror a mis Medi 2016, hyd yn oed yn yr ardal graidd ganolog, sy'n awgrymu bod poblogaeth y falwen wedi dirywio'n sylweddol. Mewn ymateb i'r dirywiad amlwg hwn, cynhaliwyd ymweliad asesu un diwrnod ym mis Hydref 2018. Gwnaeth hyn alluogi arolwg trosolwg o'r safle, ynghyd â dadansoddiad swmpsampl oddi ar y safle, er mwyn asesu'r rhan helaeth o'r parth trawsnewid rhwng y twyni tywod a'r morfeydd heli a galluogi asesiad maes o'r falwen ar 11 o safleoedd, a oedd hefyd yn cynnwys cymryd swmpsamplau o lystyfiant oddi ar y safleoedd i bennu presenoldeb y falwen. Datgelodd y canlyniadau fod *V. angustior* yn bresennol ar saith safle, gan gynnwys nifer yn y parth trawsnewid gogleddol, ardal lle na chofnodwyd y falwen ynghynt ac a ddiystyriwyd i'w hastudio er arolwg 1993. **Dangosodd canlyniadau 2018 fod y falwen yn bresennol dros bellter llinol o 1.9 km, sef 1.2 km yn fwy na'r ystod a gofnodwyd ynghynt, a oedd yn gynnydd o 171%.** Er mawr syndod, roedd rhai o'r cyfrifiadau isaf yn 2018 yn yr ardal 'boblogaidd' flaenorol ar ben deheuol y parth trawsnewid. Darganfuwyd nifer bychan o *V. angustior* ar safle twyni tywod hefyd, sef ardal a samplwyd yn flaenorol gan J. Harper yn 2006 a lle y cynhaliwyd chwiliadau anffurfiol yn 2016, gan gofnodi niferoedd isel yn y ddau achos (K. Wilkinson, gohebiaeth bersonol). Yr argraff gyffredinol a chymharol oddrychol a gafwyd o lystyfiant y parth trawsnewid pan yr edrychwyd arno yn 2018 (o'i gymharu ag ymweliadau blaenorol) oedd bod y llystyfiant yn fras a heb ei bori'n ddigonol ar hyd y mwyafrif o'i hyd. Ym 1983, roedd y llystyfiant yn llawer byrrach o ganlyniad i fwy o bori yn ôl pob tebyg ac roedd mwy o ardaloedd amlwg o dir llwm.

Gan fod arolwg 2018 wedi datgelu fod gan *V. angustior* bresenoldeb llawer uwch nag y tybiwyd yn flaenorol, mae angen arolwg llawn o Dwyni Whiteford er mwyn (1) mapio presenoldeb y falwen yn y parth trawsnewid yn fwy trylwyr, (2) cynnwys arolwg ar droed o brif gorff y twyni am y tro cyntaf er mwyn canolbwyntio ar laciau twyni mewn ardaloedd lle y credir bod y lefel trwythiad yn agos i'r arwyneb, a (3) cynnal arolwg o Gors Cwm Ivy gan fod yr ardal bellach yn destun mewnlif llanwol yn sgil creu parth trawsnewid morol/daearol. Awgrymir y dylid ailymweld â'r strategaeth fonitro a ddisgrifiwyd yn Fowles a Guest (2006) a'i symleiddio er mwyn gwneud y gwaith o ailadrodd arolygon cyflwr yn fwy syml yn y dyfodol. Awgrymir hefyd y dylid ategu'r ddibyniaeth ar asesiadau maes yn unig i ddangos presenoldeb V. *angustior* trwy gymryd swmpsamplau. Gwelwyd yn 2018 fod yr hen dechneg yn diystyru presenoldeb y falwen pan oedd dim ond nifer bychan o boblogaethau'n bresennol.

2. Executive summary

Vertigo angustior, a species listed on the EC Habitats & Species Directive Annex IIa was first found at Whiteford Burrows in May 1983. This report reviews and discusses all previous *V. angustior* work undertaken at Whiteford Burrows from 1993 to 2016, including work undertaken in 1993 that surveyed much (but not all) of the sand dune/salt marsh transition zone lying on the eastern margins of the burrows. This demonstrated the presence of the snail in the southern half of this zone along a length of about 0.9km. Between 1994 and 2016, ten monitoring episodes and a single autecological research study were undertaken, all focussing upon the stretch of sand dune/salt marsh transition zone at the southern end where numerous snails were recorded in 1993.

V. angustior monitoring results from 1994 to 2012 all broadly concluded that the snail and its associated *Iris pseudacorus* habitat were mainly in favourable condition. A series of four monitoring visits to the previously studied monitoring sites between February and September 2016 recorded very few snails, even in the central core area, suggesting that the population of the snail had declined significantly. In response to this apparent decline, a single day assessment visit was undertaken in October 2018. This allowed an overview site-survey, combined with off-site bulk sample analysis, to assess most of the sand dune/salt marsh transition zone and allowing the field assessment of the snail at 11 sites, which also involved the removal of bulk vegetation samples for off-site determination of snail presence. The results revealed *V. angustior* to be present at seven sites including several in the northern transition zone, an area in which the snail had not been recorded previously and which had been overlooked for study since the 1993 survey. **The 2018 results demonstrated the presence of the snail over a linear distance of 1.9km extending the previously recorded range by 1.2 km, a 171% increase**. Surprisingly, some of the lowest 2018 counts were in the previous 'hotspot' area at the southern end of the transition zone. *V. angustior* was also recovered in low numbers from a sand dune site, an area previously sampled by J. Harper in 2006 and casual searches in 2016, both of which recorded low numbers (K. Wilkinson, pers. comm.). A general and somewhat subjective impression of the transition zone vegetation when observed in 2018 (when compared to previous visits) was that, along most of its length, the vegetation was rank and under-grazed. In 1983, the vegetation was much shorter as a result of presumably heavier grazing and areas of bare ground were more frequent and obvious.

As the 2018 survey revealed the far more extensive presence of *V. angustior* than previously suspected, a full survey of Whiteford Burrows is required to (1) more thoroughly map the snail's presence in the transition zone, (2) include for the first time a walk-over survey of the main dune body to focus upon dune slacks in areas where the water table is judged to be close to the surface and (3) undertake a survey of Cwm Ivy Marsh now that the area is subject to tidal inflow with the creation of a marine/terrestrial transition zone. It is suggested that the monitoring strategy described in Fowles & Guest (2006) be revisited and simplified to make future repeat condition surveys more straightforward to undertake. It is also suggested that the reliance of field assessment alone to demonstrate V. *angustior* presence be supplemented by the removal of bulk samples. The former technique was shown in 2018 to overlook the presence of the snail where populations are present in low numbers.

3. Introduction

3.1. General information

The Narrow-mouthed Whorl Snail *Vertigo angustior* (Jeffreys, 1830) is a small snail restricted to base-rich, free-draining moist places which are rarely affected by periodic desiccation or flooding. It lives in open, short vegetation of grasses, mosses and low herbs which are typically quickly warmed by the sun. In Britain it occurs in a variety of habitats ranging from salt-marsh transition zones (Killeen, 1983; Preece & Willing, 1984), limestone pavements (Marriott & Marriott, 1982), inland marshy grassland (Killeen, 1997; Norris & Colville, 1974) and sand dune maritime grassland (Colville, 1994). Due to its rarity, it was categorised as Endangered (RDB category 1) in the UK Red Data Books (Bratton, 1991) and more recently as Vulnerable on the IUCN-based UK status review (Seddon *et al.*, 2014). The snail is listed on Annex IIa of the European Community Habitats and Species Directive (92/43/EEC) and is also a Welsh Section 42 'Species of Principal Importance'.

The first records of *V. angustior* in Wales were all of dead shells. Thus, in 1830, Jeffreys found shells in flood debris near Swansea (*Trans. Linn. Soc. Lond*. 16 p.362) with further shells found by him near Tenby (Jeffreys, 1862). On the Gower peninsula in 1924, Quick reported fresh dead shells from sand dunes at Oxwich Bay (Quick, 1924) but despite extensive surveys in following years (Quick, 1926, 1927) he failed to locate live specimens. The first live *V. angustior* in Wales (and indeed in western Britain) were found on a single day in May 1983 when populations of the snail were located at both Oxwich Bay and Whiteford Burrows on the southern and north western Gower coastlines respectively (Preece & Willing, 1984). A third live Welsh population was discovered in Pembrey Forest, Carmarthenshire (lying immediately north of the Gower Peninsula) by John Harper in 2005 (Harper, 2007, 2014).

In England, *V. angustior* specimens found at Aldeburgh, Suffolk by J.E. Cooper in 1903 have been confirmed to have been living when collected following examination of museum specimens (Killeen, 1992). More recently, live shells were first found in Norfolk at Flordon Common in 1972 (Norris & Colville, 1974) and in Suffolk at Martlesham Creek and Fritton by I. Killeen in 1982 (Killeen, 1983) and 1988 (Killeen, 1991, 1992, 2001) respectively. Since those initial discoveries, at least a further six populations have been located at coastal and inland sites in Norfolk (Howlett & Baker, 2004, 2006; Willing, 2011). Since the initial two confirmed live populations, numerous additional ones have been reported in Suffolk. Thus in 2003, an extensive study of the Blyth Estuary (Killeen & Moorkens, 2011) demonstrated the presence of the snail at numerous sites there, with an estimation that a linear 25km of occupied habitat (mostly 'grassy' artificial sea defence embankments) may have supported about 156 million *V. angustior,* making this the most significant area for the snail in the UK and also of international importance. The study also noted the presence of the snail elsewhere in Suffolk associated with other estuary embankments of the rivers Deben, Alde and Waveney. In 2008, a further study (Abrehart, 2008) surveyed existing and some new sites in the county, reporting the presence of the snail from 43 1km squares (32 tetrads), a further confirmation of the importance of Suffolk for the species.

The first live *V. angustior* in Scotland were found at a sand dune site on the Solway coast in the south-west of the country by B. Colville in 1992 (Colville 1994); dead shells had previously been reported from the site by Chris Paul. In 2000, *V. angustior* was found in the north-east of the country at Garron Point near Aberdeen (Marriott, 2004). A study in 2017 (Killeen *et al*., 2019) undertook monitoring of all these Scottish *V. angustior* populations, documenting the loss of the population previously living on sand dune margins at Whiteport on the Solway coast, this being the first documented loss of a population due to maritime coastal erosion.

3.2. Studies on *Vertigo angustior* on Whiteford Burrows

Whiteford Burrows is a dune system lying on the north-west coast of the Gower Peninsula and is part of the much larger Carmarthen Bay Dunes/Twyni Bae Caerfyrddin SAC. Following the initial discovery of *V. angustior* at Whiteford Burrows in 1983 (Preece & Willing, 1984), a more detailed survey was undertaken there in 1993 (Killeen, 1993) confirming the presence of the snail along a narrow length of salt marsh/sand dune 'transition zone' extending for nearly 1km. Following this survey, regular monitoring and condition assessment has been undertaken of the southern area of the transition zone in 1994 (Fowles & Hurford, 1995), 1995 (Fowles, 1998; Fowles & Hurford, 1996), 1996 (Fowles *et al*., 1997), 1997 (Fowles, Painter & Woodman, unpublished), 2001 (Fowles & Guest, 2006), 2006 (K. Wilkinson, 2007 unpublished [pers. comm.]), 2012 (K. Wilkinson, 2012 unpublished [pers. comm.]) and 2016 (K. Wilkinson, in prep.). In 2006, two areas were sampled to trial a vacuum sampler (Harper, 2007). In addition to this monitoring, a survey of Cwm Ivy Marsh was undertaken in 1998 (Holyoak & Willing, 1999) and an autecological study of *V. angustior* was undertaken in the southern area of the transition zone from 1998 to 1999 (Cameron, 2003; Sharland, 2000).

3.3. 2018 Survey objective

In February, May, August and September 2016, Karen Wilkinson and others (Wilkinson, in prep.) sampled the six monitoring plots used by Fowles & Guest (2006) to assess population condition. As very few *V. angustior* were recovered (Appendix 10.4), there was concern that the Whiteford population of the snail had declined sharply. Following molluscan surveys undertaken at Llangennith Marsh in October 2018, the author was asked to spend a day visiting Whiteford Burrows in order to observe and then comment upon the state of the habitat there (based upon previous experience of the site and of other *V. angustior* sites elsewhere in Britain). A site visit on 17th October 2018 provided an opportunity to inspect the entire sand dune/salt marsh transition zone, undertake field sampling for the snail and to remove bulk vegetation and litter samples for later off-site processing.

4. Methods

Survey work was undertaken on 17th October 2018 with the assistance of NRW staff Karen Wilkinson and Dan Guest. The sites chosen for sampling were areas judged to be potentially the most suitable for *V. angustior* in terms of plant community (for hierarchy of plant community 'suitability' see Appendix 10.4, Tables 3 and 4). Site survey involved:

1. visual examination of vegetation and ground litter;
2. beating vegetation onto a white gridded tray and examining debris with a X6 magnifier;
3. shaking dry moss and low growing fresh and dead plant material through a two-tier 2mm and 0.5mm sieve stack.

At all survey sites, bulk vegetation and vegetation litter samples were removed for later laboratory processing. These consisted of approximately 2-3 litres (when lightly compressed) of material chiefly consisting of ground litter, moss and low plants (living and dead) cut near ground level using a serrated 'Kitchen Devil' knife. Material was gathered over an area of about $1m^2$ and probably amounted to what might approximately have been obtained from a 0.25m x 0.25m [$0.0625m^2$] quadrat frame as employed by Sharland (2000). Removed samples were later air-dried (in suspended muslin bags) to constant mass. Material was then sieved through a 2mm/0.5mm sieve nest and sievings examined on a lipped, gridded white tray with finer fractions examined using a X10 – X60 binocular microscope.

Ground moisture levels: Ground water conditions are also of major importance when assessing site suitability for many *Vertigo* species and these have been given for each survey site. The list below (extracted from Killeen & Moorkens, 2003) describes five levels of ground moisture:

1. DRY – no visible moisture on ground surface or detected if touched;
2. DAMP – ground visibly damp but water does not rise if pressed;
3. WET – water appears under light pressure;
4. VERY WET – pools of water present but < 5cm in depth;
5. SUBMERGED – whole sample site under water > 5cm in depth.

Open ground & site shading: The approximate percentage of bare ground was noted at each survey site as was the degree of ground shading resulting from rank herbaceous vegetation and over-shading by bushes and trees.

Plant associates: At each site the dominant plant species were identified and recorded with assessment chiefly undertaken by Dan Guest. All sites were digitally photographed, and GPS 10-fig. OS grid references recorded.

5. Results

Molluscan results, dominant plants and brief habitat descriptions from the Whiteford Burrows survey of 17th October 2018 are displayed in Appendices 10.1, 10.2 and 10.3 respectively. *Vertigo angustior* was found living (or very freshly dead) at 7 of 11 survey stations (Figure 2). Distribution of the snail extended from Cwm Ivy Marsh at the south (a single *V. angustior* at Station 11) in a fragmented pattern along the salt marsh/sand dune 'transition zone' to near the north-eastern margins of the Whiteford Burrows (a single *V. angustior* at Station 5), a linear distance of approximately 1.9km. The last extended survey of Whiteford Burrows, undertaken in January 1993 (Killeen, 1993), surveyed nearly as extensively in the same zone but only recorded the snail along a linear distance of approximately 0.7 km (Figure 3). The 2018 survey therefore extends the known Whiteford *V. angustior* range by x 2.7 (a 171% range increase). Table 1 compares the results from the 1993 and 2018 surveys. Previous surveys all stress the importance of *Iris* as at least one key plant component for 'good' *V. angustior* habitat at Whiteford (e.g. Fowles & Guest, 2006; Fowles & Hurford, 1995; Sharland, 2000). The 2018 botanical assessment noted the presence of *Iris* at four *V. angustior* sites but did record the snail at a further three sites where the plant was absent.

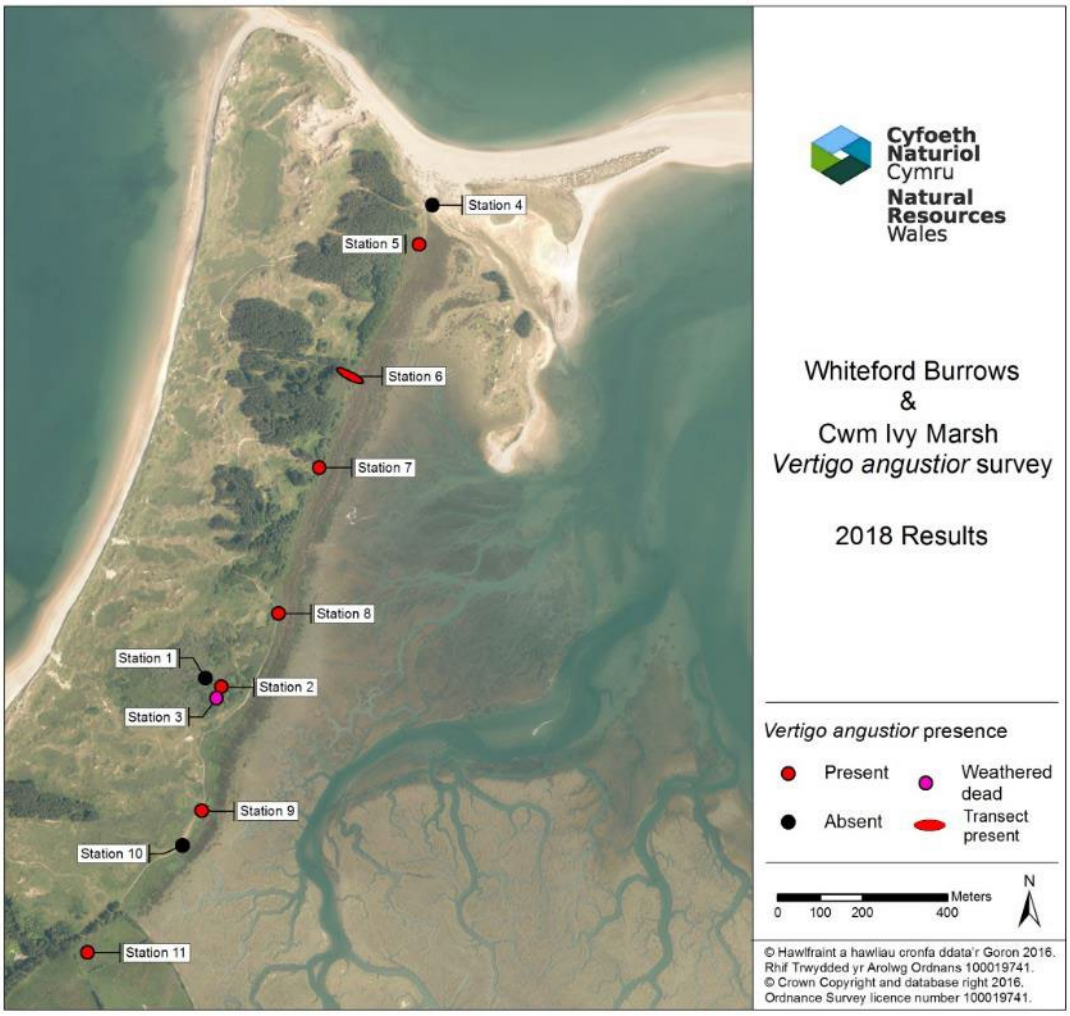

Figure 2. Distribution of survey stations at Whiteford Burrows showing *Vertigo angustior* presence in October 2018.

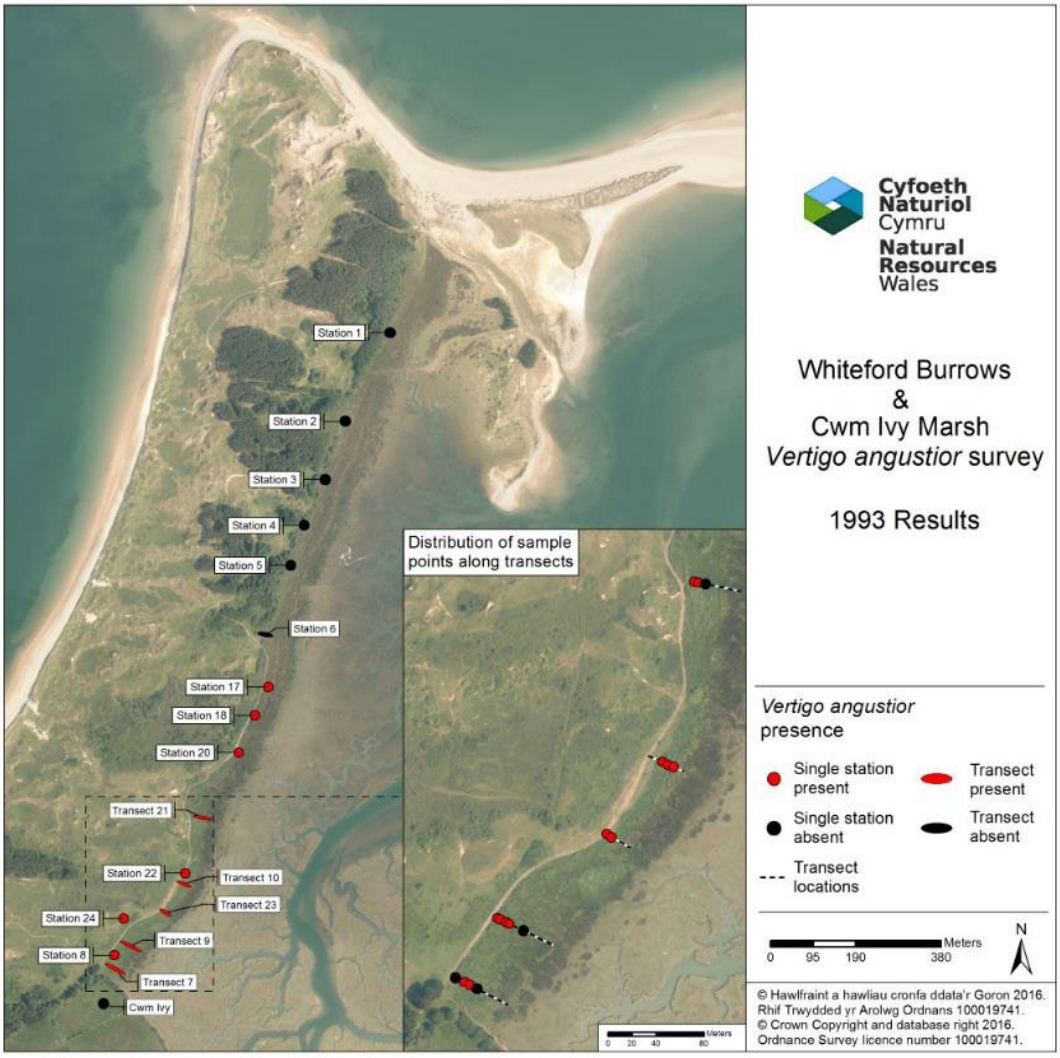

Figure 3. Distribution of survey stations at Whiteford Burrows showing *Vertigo angustior* presence in 1993.

The numbers of *V. angustior* collected from the bulk samples probably give an impression of the abundance of the snail at various survey points but the sampling technique used, being less intense and thorough than in previous surveys (to ensure as many sampling points were covered as possible in the day available for survey), probably 'underestimates' population abundance.

Associated Mollusca recorded have all been reported in previous surveys. Previous reports note the antipathetic relationship between *V. angustior* and *V. antivertigo,* a significant presence of the latter species tending to correspond to lower numbers or an absence of the former. This is because *V. antivertigo* tends to favour much wetter conditions than *V. angustior*. This pattern was clearly seen at several of the 2018 sites. Thus, at Station 6 sampling points 6a and 6b were only about 5m apart; 6a was damper with the bulk sampling producing 30 *V. antivertigo,* but only two *V. angustior*. By contrast, at the drier and less rank Station 6b only 7 *V. antivertigo* individuals were counted with *V. angustior* numbers rising to 28.

Large numbers of *Pupilla muscorum* were found in the relatively dry sand dune marginal Station 4, but a few *Pupilla* were also found in the much wetter habitat sampled at Stations 8 and 9 which had rather larger, more elongate shells. It is possible that these few individuals maybe *Pupilla pratensis,* a rare species in the UK and only recently recognised as distinct from *P. muscorum*. *P. pratensis* tends to live, as with this habitat association at Whiteford, in wetter conditions than *P. muscorum*. The possible *P. pratensis* specimens have been sent to a national expert with familiarity of the species for further study; further discussion is given in Appendix 10.6.

Table 1. A comparison of 2018 Whiteford Burrows surveys with approximately equivalent points from the 1993 survey (Killeen, 1993).

2018 survey stations	*V. angustior* (*Va*) presence ✓ or absence × (& other notes)
1	× (dunes west of footpath)
2	✓ (dunes west of footpath)
3	✓ (dunes west of footpath)
4	× (further north than 1993 survey)
5	✓ (single specimen - further north than 1993 survey)
6 (three samples)	✓ (in all samples but majority west of footpath)
7	✓ (*Va* present in abundance)
8	✓ (*Va* plentiful)
9	✓ (*Va* present in low numbers)
10	× (No *Va* & few other Mollusca)
11	✓ (single fresh dead shell)

1993 survey stations	*V. angustior* (*Va*) presence ✓ or absence × (& other notes)
No equivalent	West of footpath; not surveyed in 1993
No equivalent	West of footpath; not surveyed in 1993
No equivalent	West of footpath; not surveyed in 1993
No equivalent	Station further north of any 1993 surveys
No equivalent	Station further north of any 1993 surveys
2	× (survey only to east of footpath where low nos. of *Va* present in 2018)
4	× (surveyed but negative)
6	× (surveyed but negative)
22	✓ (*Va* plentiful)
23	✓ (*Va* plentiful)
Sampled but no station number given	×

6. Discussion

There were fears, following repeated surveys of Whiteford Burrows in 2016 (Appendix 10.4), that *V. angustior* had undergone a marked decline since the snail was assessed as being in favourable condition in 2012. The brief 2018 'snapshot' survey reassuringly demonstrates that the snail is still present and widespread there, occurring in a probably discontinuous series of sub-populations, over a length of about 1.9km of salt marsh/transition zone, considerably extending the range from the previous documented extent of about 0.7km (Killeen, 1993). The 2018 visit surveyed a greater length of Whiteford Burrows than any previous survey. In 1993, *V. angustior* was not found in the northern half of the zone whereas in 2018 it was recorded at four stations there, occurring in large numbers at three of these (Stations 6, 7 & 8). The failure to record the snail there in 1993 raises several questions; it is not known if the failure to record it was due to its absence or whether survey locations happened to occur at points where the snail was absent. Killeen (1993) only sampled sites to the east of the north-south footpath; although the snail was recorded on this side in 2018, it may be significant that a large number were recorded on the western side of the path (Station 6b & 7) - areas not sampled in 1993. Has it colonised northwards in the last 25 years or was it previously overlooked? The previous failure to record *V. angustior* in this northern sector subsequently led to a lack of any further surveys of this area. *V. angustior* distribution at Whiteford is patchy and numbers of the snail can vary considerably over short distances (Sharland, 2000). Killeen (1993) suggested that the absence of *V. angustior* in the northern sector may have been due to the narrowness of the transition zone as well as the vegetation being too rank and wet. It does however seem unlikely that the habitat in this sector was less suitable in 1993 than in 2018, as at that time grazing pressure seems to have been greater with much shorter vegetation in the transition zone. With greater grazing pressure and a less rank transition zone in 1993 then, if anything, the overall *V. angustior* suitability of *Iris*-dominated transition zone there may be worse now than 25 years before. It is suggested (D. Guest, pers. comm.) that there have been significant changes to the hydrology of the dunes since 1993, with a significant fall in the water-table, especially in the middle and northern sections. Therefore, it may be that these areas have become drier and so more suitable for the
snail. Conversely, more intense grazing and shorter marginal vegetation may have offset the wetter conditions with the optimum ground moisture levels occurring slightly further from the saltmarsh than is now the case.

It seems surprising that only low numbers or a complete absence of *V. angustior* was recorded in 2018 at Stations 9 and 10 as in 1993 and indeed later surveys, this 'key' southern area produced large numbers of *V. angustior*; reasons for a possible decline in 2018 are unclear.

As with earlier surveys (Preece & Willing, 1984; Killeen, 1993; Sharland, 2000), the 2018 survey found an antipathetic relationship between *V. angustior* and *V. antivertigo,* the latter species tending to be found in wetter and sometimes more shaded conditions less suited to the former. This relationship was clearly seen at Stations 6a and 6b; at the former, 30 *V. antivertigo* were found together with 1 *V. angustior* whereas at the drier Station 6b (lying

only about 3 m from 6a), 22 live *V. angustior* were recovered in association with 7 *V. antivertigo.*

It is believed that the relatively quick method of gathering bulk sample material employed in 2018 probably collected fewer *V. angustior* at each location than if the more systematic removal of all dead vegetation and moss as used by Killeen (1993) and Fowles & Hurford (1995, 1996) had been used and even fewer than Sharland's (2000) technique of cutting down and removal of all living and dead vegetation to ground level.

In their monitoring methodology, Fowles & Guest (2006) proposed that *V. angustior* presence at monitoring sites is established solely by trained personnel using field sieving to avoid the need to collect and later laboratory-process bulk samples. In the 2018 survey, *V. angustior* was only detected in the field at two stations (Table 2) and yet it was confirmed from bulk samples at seven stations. Despite the field searches of three surveyors (all with previous experience locating the snail in the field), the snail's presence was overlooked at five sites. If the Fowles/Guest recommendation had been adopted for site assessment, then the presence of the snail would have been overlooked at these sites. It is therefore suggested that in future monitoring for the snail returns to a combination of field searches and the removal of bulk samples.

It is difficult to judge the overall state of the habitat at Whiteford Burrows based upon a single day visit. A relatively quick, subjective assessment suggested that the habitat at most sites was rather rank and under-grazed. Except for the relatively recently scrub-cleared dune Stations 1-3 and the northern sand dune margin (Station 4), bare ground was not present at the remaining sites (Stations 5–11) where the rank state of the vegetation suggested under-grazing. Written site descriptions and images from 1983 (Figure 4) and those included in Killeen (1993) and Sharland (2000) all display sites that appear to be more closely grazed with a short, close-cropped sward. Grazing pressure by commoners' ponies now seems less intense and it may be that increased grazing will improve the site for *V. angustior* perhaps promoting an increase in numbers and allowing a spread of the snail in the transition zone.

Another feature of previous reports (e.g. Fowles & Guest, 2006; Killeen 1993; Sharland, 2000) is the clear association of *V. angustior* with the presence of *Iris pseudacorus*. Although the 2018 survey found the snail in association with this plant at four stations, it was nevertheless present at a further three stations without it (Table 2). Perhaps the *Iris*-*V. angustior* link at Whiteford has led to a reluctance to survey some other non-*Iris* habits for the snail. *V. angustior* has certainly been recorded in numerous coastal situations elsewhere in the UK in the absence of *Iris* such as on the Solway Firth (Killeen & Colville, 2000) and at coastal sites in Norfolk (Baker *et al*., 2007; Howlett & Baker, 2004, 2006; Willing, 2011). In Suffolk, although *Iris* is an occasional associate with *V. angustior,* the snail is found in large numbers in a variety of plant communities including sea couch *Elytrigia atherica* and in some locations in flotsam associated with saltmarsh plants *Halimione portulacoides* and *Beta vulgaris* and also in *Festuca rubra*-dominated grassland (Killeen & Moorkens, 2011).

Table 2. *V. angustior* detection & *Iris pseudacorus* presence at survey stations in 2018.

2018 Station	*V. angustior* recorded live in bulk sample	*V. angustior* recorded during field survey	*Iris pseudacorus* recorded at site
1	×	×	✓
2	✓	×	✓
3	×	×	×
4	×	×	×
5	✓	×	×
6 (three sub-samples)	✓	✓	✓
7	✓	×	×
8	✓	✓	✓
9	✓	×	×
10	×	×	✓
11	✓	×	✓

7. Future *Vertigo angustior* work at Whiteford Burrows

The continued presence of the internationally-important populations of *V. angustior* at Whiteford Burrows may depend upon direct or indirect habitat management. Ideally, this would maintain the open dynamic nature of the snail's preferred habitat by (1) ensuring that stock levels (especially ponies) are sufficient to maintain the short, free-draining, herb-rich sward with occasional areas of bare ground and (2) that invading scrub (e.g. *Rubus* sp, *Salix* sp) does not over-shade and dessicate otherwise suitable habitat. It is suggested that a further assessment of *V. angustior* presence is undertaken in two parts - (1) further survey and (2) the continued development of a simplified and cost-effective conservation status review (monitoring) mechanism.

(1) **Further survey**: The single survey day in October 2018 demonstrated that the distribution of *V. angustior* at Whiteford Burrows is more extensive than previously understood, occurring in the northern transition zone. The most extensive previous survey of the area occurred in 1993 and since then all work on the snail has focussed on the transition zone at the southern sector of the site. Post-1993 studies have also assumed that *V. angustior* lives almost exclusively at Whiteford in *Iris*-dominated habitat. Although habitats with *Iris* also support the snail elsewhere in the country, there are many coastal locations where the snail lives or lived in large numbers in other plant communities in the absence of *Iris* (e.g. estuary embankments and sand dune sites in Norfolk and Suffolk [Howlett & Baker, 2004, 2006; Killeen & Moorkens, 2011; Willing, 2011] and in a sand dune complex on the Solway coast in south-west Scotland [Killeen & Colville, 2000]). It is also of interest that, about 10 km to the north-west of Whiteford Burrows, the snail is associated with both dune slacks and drier banks on the Pembrey dune system, both on the Aerial Firing Range and within Pembrey Forest (Harper, 2007, 2014). It is therefore suggested that further surveys be undertaken at the far north-east of the transition zone and also throughout the main body of the dune system, focussing upon areas in damp hollows and on the margins of dune slacks where the water table is near the surface. Such surveys might take the form of both field white-tray examination of litter samples and the removal of small bulk samples of

vegetation cut down to ground level for later laboratory processing (the 2018 study demonstrated that *V. angustior* site presence is sometimes only revealed by bulk samples processing). All potentially suitable sites would be photographed, recorded with GPS locations and dominant plant species noted. Additionally, given John Harper's successful use of a vacuum sampler in finding *V. angustior* at both Pembrey and Whiteford Burrows (Harper, 2007, 2014) the potential use of one for future Whiteford Burrows survey should be considered.

(2) Revision of a framework to assess *V. angustior* conservation status at Whiteford Burrows

Fowles & Guest (2006) usefully developed a condition framework intended to allow future monitoring to objectively assess *V. angustior* conservation status. Unfortunately, its future use may be problematic without addressing a number of issues including:

a. The locations of the suggested monitoring survey site blocks (A – F) are difficult to locate because the map is very small, has no scale and lacks any GPS or field markers;
b. The criteria for the 'favourable status' in each sector seem rather arbitrary, have not been clearly explained and are probably difficult to apply;
c. The assessment of *V. angustior* presence relies entirely upon finding the snails in the field during a 15 minute white tray search. Experience in 2018 demonstrated that the snail may be present at a site in such low numbers that it is not detectable in the field (even with three experienced surveyors searching at each site), but is only confirmed by the removal and off-site processing of bulk samples;
d. The procedure is restricted to a portion of the southern transition zone; it is now known that *V. angustior* is far more widely distributed at Whiteford Burrows than previously suspected and that future survey may extend that range still further.

Once the full extent of *V. angustior* presence at Whiteford Burrows is known, then a revised and simplified condition assessment needs to be constructed possibly revising the plant community descriptions and also including (as suggested by Fowles & Guest, 2006) the use of high accuracy GPS to pinpoint individual samples to allow the construction of polygons (sample boundaries) around plant communities assessed as important in supporting *V. angustior* populations. Additional habitat features might include the mean height of vegetation (to assess 'rankness'), % bare ground and a simply measure of soil moisture.

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10. Appendices

Appendix 10.1. Mollusca recorded at Whiteford Burrows on 17th October 2018

X = dead shell only
* = very fresh dead / live (difficult to determine)
** = could be *Pupilla pratensis* (second opinion sought on ID)
✓ = recorded in field near sample site but not in the bulk sample.

Vertigo angustior recorded at survey stations 1-11

Survey station	1	2	3	4	5	6	6a	6b	7	8	9	10	11
Adult (L)	-	1*	-	-	1*	4	1	21	56	33	3	-	-
Juvenile (L)	-	-	-	-	-	1	-	1	7	1	2	-	-
Fresh dead	-	1	-	-	-	-	1	6	5	6	-	-	1
Weathered dead	-	1	1	-	-	2	-	-	-	-	-	-	-

Other species recorded at survey stations 1-11

Survey station	1	2	3	4	5	6	6a	6b	7	8	9	10	11
Aegopinella pura	-	-	-	-	-	-	-	3	-	-	-	-	-
Carychium minimum	-	X	1	1	-	-	-	1	-	-	-	-	-
Cepaea sp	-	1	1	-	-	-	-	-	-	-	-	-	-
Cernuella virgata	-	-	-	✓	-	-	-	-	-	-	-	-	-
Clausilia bidentata	-	-	-	1	22	1	3	-	1	3	-	-	-
Cochlicopa lubrica	3	X	3	1	-	1	3	12	7	4	3	4	4
Columella edentula	-	-	-	-	-	-	-	X	1	-	-	-	-
Euconulus fulvus	-	1	1	-	-	-	-	-	-	-	-	-	-
Nesovitrea hammonis	X	-	-	-	-	-	4	1	3	1	1	1	-
Oxychilus alliarius	-	-	-	-	-	1	-	-	-	1	-	-	-
Pupilla muscorum	-	-	-	22	-	-	-	-	-	2**	1**	-	-
Punctum pygmaeum	-	-	-	-	-	-	-	3	-	-	-	-	-
Trochulus hispidus	1	3	-	-	-	-	-	-	-	-	-	-	-
Vertigo antivertigo	-	-	-	-	-	11	30	7	4	17	4	7	6
Vertigo substriata	X	-	-	-	-	-	-	11	-	-	-	-	-
Vertigo pygmaea	-	X	-	-	-	1	1	-	6	1	4	3	9
Vertigo sp.	-	-	1	-	-	-	-	-	-	-	-	-	-
Vallonia pulchella	-	-	-	-	-	-	-	-	-	2	-	-	-
Vallonia excentrica	-	-	-	-	-	-	-	-	1	-	-	-	-
Zonitoides nitidus	1	1	-	-	-	-	-	-	-	-	-	-	-
*Galba truncatula**	-	-	-	-	-	-	3	1	-	2	-	-	-
*Pisidium personatum**	-	2	-	-	-	-	-	-	-	-	-	-	-

Appendix 10.2. Plants recorded at survey stations 1-11, Whiteford Burrows, on 17th October 2018

Survey station	1	2	3	4 a	4b	4c	5	6	7	8	9	10	11
Agrostis stolonifera	-	X	-	-	X	-	-	-	X	X	-	X	-
Althaea officinalis	-	-	-	-	-	X	X	X	X	-	-	X	-
Angelica sylvestris	X	-	-	-	-	-	-	-	-	-	-	-	-
Carex arenaria	-	-	-	X	X	-	-	-	-	-	-	-	-
Carex panicea	-	X	-	-	-	-	-	-	-	-	-	-	-
Cynosurus cristatus	-	-	-	-	-	-	-	-	-	-	-	X	-
Elytrigia atherica	-	-	-	X	X	X	X	-	-	-	-	-	-
Eupatorium cannabinum	X	X	X	-	-	-	-	-	-	-	-	-	-
Festuca pratensis	-	-	-	-	-	-	-	-	-	X	-	-	-
Festuca rubra	-	-	-	-	X	-	X	X	-	-	-	-	-
Filipendula ulmaria	-	-	X	-	-	-	-	-	-	-	-	X	X
Geranium molle	-	-	-	-	X	-	-	-	-	-	-	-	-
Holcus lanatus	X	-	-	-	-	-	-	-	X	-	-	X	X
Hydrocotyle vulgaris	-	X	-	-	-	-	-	-	-	-	-	-	-
Hypochaeris radicata	-	-	-	-	X	-	-	-	-	-	-	-	-
Iris pseudacorus	X	X	-	-	-	-	-	X	-	X	-	X	X
Juncus acutus	-	-	X	X	-	X	X	-	X	-	-	-	-
Juncus effusus	-	-	-	-	-	-	-	-	-	-	-	-	X
Juncus inflexus	-	-	-	-	-	-	-	-	-	-	-	-	X
Juncus maritimus	X	X	X	-	-	X	X	X	X	X	-	-	-
Juncus subnodulosus	-	-	-	-	-	-	-	-	-	-	-	-	X
Lotus pedunculatus	-	-	-	-	-	-	-	X	X	-	-	-	-
Mentha aquatica	-	X	-	-	-	-	-	X	-	-	-	-	-
Molinia caerulea	-	-	-	-	-	-	-	X	-	-	-	-	-
Phragmites australis	-	-	-	-	-	-	-	-	-	-	-	X	-
Plantago coronopus	-	-	-	-	X	-	-	-	-	-	-	-	-
Plantago lanceolata	X	X	-	-	-	-	X	-	-	-	-	-	-
Potentilla anserina	X	X	-	-	-	-	X	X	X	X	-	-	X
Pulicaria dysenterica	X	X	-	-	-	-	-	X	X	-	-	X	-
Rubus caesius	X	X	X	-	-	-	-	-	-	-	-	X	-
Rumex acetosa	-	-	-	-	-	-	-	-	-	-	-	-	X
Salix repens	X	X	X	-	-	-	-	X	X	X	-	-	-
Scorzoneroides autumnalis	-	-	-	-	-	-	X	-	-	-	-	-	-
Taraxacum officinale agg.	-	-	-	-	X	-	-	-	-	-	-	-	-
Trifolium fragiferum	-	-	-	-	-	-	-	X	-	-	-	-	-
Trifolium repens	-	-	-	-	-	-	-	-	-	-	-	X	-

Appendix 10.3. Whiteford Burrows Habitat descriptions 17th October 2018

Station	Grid. ref	Bare ground, shading & ground moisture	General vegetational description and site management	Figure (Appendix 10.5)
1	**SS 44603 95054**	**Bare ground:** <5% **Ground moisture /5**: 1 - 2 **Shading:** no overhead but moderate sward height	**Near John Harper 2006 location** Sward c. 25 to 50 cm tall on flat area of open slack vegetation. The vegetation is dominated by a mix of *Salix repens*, *Pulicaria dysenterica*, *Rubus caesius* and *Holcus lanatus*. It has been cut recently and the soil is peaty. ***V. angustior:*** None in field searches or bulk samples	Figure 6
2	**SS 44641 95034**	**Bare ground:** <5% **Ground moisture /5**: 1 – 2 **Shading:** no overhead but moderate sward height	**Near John Harper 2006 location** Sward 25-50cm tall. As above, a flat area of open slack vegetation dominated by *Salix repens*, *Potentilla anserina* and *Iris pseudacorus*. *Juncus acutus* tussocks are scattered. It has been cut recently and the soil is peaty. ***V. angustior:*** None in field searches but present in bulk samples	Figure 7
3	**SS 44630 95008**	**Bare ground:** <5% **Ground moisture /5**: 1 - 2 **Shading:** slight lateral from Salix spp; tall (rank) herbaceous	**At the John Harper 2006 GPS location** Tall vegetation with an open canopy of *Salix repens*, *Filipendula ulmaria* and *Eupatorium cannabinum*. The vegetation is 80-120cm tall. There is a dense layer of pleurocarp mosses including *Calliergonella cuspidatum*. ***V. angustior:*** None in field searches but present in bulk samples	Figure 8
4a	**SS 45139 96169**	**Bare ground:** ca. 5% **Ground moisture /5**: 1 - 2 **Shading:** low sward height	**No bulk sample taken. Upper edge of saltmarsh at northern end of Whiteford** Sward height c. 10-15cm. The vegetation is dominated by *Elytrigia atherica* and *Carex arenaria* with scattered tussocks of *Juncus acutus*. ***V. angustior:*** None in field searches or bulk samples	Figure. 9

Station	Grid. ref	Bare ground, shading & ground moisture	General vegetational description and site management	Figure (Appendix 10.5)
4b	**As 4a**	**Bare ground:** ca. 5 – 10% **Ground moisture /5**: 1 **Shading:** low sward height	**low banking rising up from upper edge of saltmarsh at northern end of Whiteford** Short to medium sward c. 5-15cm tall dominated by *Elytrigia atherica*, *Agrostis stolonifera* and *Festuca rubra*, grading up slope into shorter open vegetation with *Syntrichia* sp., P*lantago coronopus*, *Carex arenaria* and *Geranium molle.* ***V. angustior:*** None in field searches or bulk samples	Figure 9
4c	**As 4a**	**Bare ground:** 0% **Ground moisture /5**: 2 **Shading:** high from tall sward	**No bulk sample taken. Upper edge of saltmarsh at northern end of Whiteford** Tall sward c. 100-130cm dominated by *Althaea officinalis*, *Elytrigia atherica* and *Juncus maritimus* with scattered *Juncus acutus* tussocks. Sampling was focussed at the base of *Juncus acutus* tussocks. ***V. angustior:*** None in field searches or bulk samples	Figure 9
5	**SS 45107 96076**	**Bare ground:** 0% **Ground moisture /5**: 2 **Shading:** high from tall sward	Tussocky area of upper saltmarsh with scattered *Juncus acutus* tussocks and low mounds with shorter vegetation. *Juncus maritmus*, *Althaea offincialis* and *Elytrigia atherica* dominate lower lying areas while *Plantago lanceolata*, *Elytrigia*, *Scorzoneroides autumnalis* are more prominent on the mounds. ***V. angustior:*** None in field searches but present in bulk samples	Figure 10

Station	Grid. ref	Bare ground, shading & ground moisture	General vegetational description and site management	Figure (Appendix 10.5)
6 (6a & 6b)	**SS 44944 95766**	**Bare ground:** 0% **Ground moisture /5**: 6a: 2-3; 6b: 1 - 2 **Shading:** moderate sward height	**Bay Area cross by Coastal Path** Tall to medium height sward c. 60-80 cm tall. Co-dominated by *Salix repens* and *Molinia caerulea* to the west of the path. To the east of the path *Juncus maritimus*, *Pulicaria dysenteria* and *Iris pseudacorus* are all prominent and *Molinia* is rare. **Site 6a** – Bulk sample taken from east of the Coastal Path **Site 6b** – Bulk sample taken from west of the Coastal Path ***V. angustior:*** found in field searches and in all bulk samples	Figure. 11
7	**SS 44872 95551**	**Bare ground:** 0% **Ground moisture /5**: 2 **Shading:** moderate sward height	A mixed sward mostly co-dominated by *Juncus maritimus* and *Salix repens* c. 50-80cm tall with scattered tumps/anthills. Scattered *Juncus acutus* and *Althaea officinalis*. ***V. angustior:*** None in field searches but abundant in bulk samples	Figure 12
8	**SS 44776 95207**	**Bare ground:** 0% **Ground moisture /5**: 2 **Shading:** moderate sward	Sample taken either side of track. Sward c. 15-30cm high on the west of the track and 40-80cm to the east of the track. ***V. angustior:*** found in field searches and in bulk sample	Figure 13
9	**SS 44595 94742**	**Bare ground:** 0% **Ground moisture /5**: 2 **Shading:** moderate sward	**NRW Sample Area C overlapping with Sharland permanent plot** No record of the vegetation was made. ***V. angustior:*** None in field searches but present in bulk samples	Figure 14
10	**SS 44549 94661**	**Bare ground:** 0% **Ground moisture /5**: 2 **Shading:** nn	**NRWM Sample Area C overlapping with Fowles/Hurford Plot B** Vegetation here is 30-100cm tall with a shorter, grassy fringe along the track side – the vegetation along this fringe is dry with *Cynosurus cristatus*, *Trifolium repens* and *Rubus caesius*. ***V. angustior:*** None in field searches or bulk sample	Figure 15

Station	Grid. ref	Bare ground, shading & ground moisture	General vegetational description and site management	Figure (Appendix 10.5)
11	**SS 44326 94409**	**Bare ground:** 0% **Ground moisture /5**: 2 - 3 **Shading:** tall rank herbaceous	**Cwm Ivy Marsh** A species list was made but no extra description of the vegetation was taken. ***V. angustior:*** None in field searches but present in bulk sample	Figure 16

Appendix 10.4. Summary of previous *Vertigo angustior* work on Whiteford Burrows

1983 FIRST DISCOVERY**: Preece & Willing (1984):** Following Ian Killeen's discovery of *Vertigo angustior* living in a creek-side saltmarsh/terrestrial transition zone in Suffolk (Killeen, 1983), the author of this report (MJW) decided to visit Whiteford Burrows[1] to investigate the possibility of the snail's presence there. In May 1983 accompanied by Richard Preece the area was visited and a hands and knees search of short vegetation in the salt marsh/sand dune transition zone quickly revealed numerous live *V. angustior* in very short turf in a vegetation community[2] and with associated Mollusca[3] many of which were confirmed by later surveys (see below) to be typical of the snail at this site (Figure 4). It was noted that "*V. angustior never occurred in* ***direct*** *association with V. antivertigo although the two could be found within a metre of each other. The latter species always occurred in wetter conditions*" (Preece & Willing, 1984, p. 340). Snail presence was noted between approximately SS 451958 and SS 439939. The paper did not specifically mention the presence of *V. angustior* on Cwm Ivy Marsh, but a brief visit to this area revealed small numbers of the snail there in short turf close to clumps of *Iris pseudacorus* (Figure 5). Noting the association of *V. angustior* at Whiteford with *Potentilla anserina*,Willing and Preece went the same day to Oxwich Burrows on south Gower and, specifically targeting transition zone habitat lying behind the Oxwich dunes where the plant was evident, again located frequent live *V. angustior*, the first confirmation of the live presence of the species there[4]. The simultaneous discovery of *V. angustior* at Whiteford and Oxwich in 1983 is notable as confirming the live presence of the species on the Gower and as the first live records of the species in Wales and in western mainland Britain.

1993 SURVEY**: Killeen (1993**): Ten years after the initial discovery, a *Vertigo angustior* survey of Whiteford Burrows was undertaken in January 1993. This focussed upon the eastern margins of the burrows, sampling in the saltmarsh – sand dune transition zone. Survey technique involved the removal of moss and vegetation litter for later laboratory drying and snail extraction. The survey sampled 18 locations (Figure 3) with *V. angustior*

[1] MJW was familiar with habitats on the Gower coastline having led field courses there since 1976.

[2] Plants recorded in 1983 included: *Senacio aquaticus, Juncus maritimus, Mentha aquatica, Bidens tripartita, Potentilla anserina, Iris pseudacorus, Cratoneuron filicinum.*

[3] Mollusca found in association with *V. angustior* at various survey locations on Whiteford Burrows in 1983 included*: Carychium minimum, Cochlicopa lubrica, Columella edentula, Vertigo substriata, Vallonia pulchella, Arion ater, A. intermedius, Nesovitrea hammonis, Deroceras reticulatum, D. laeve, Trichia hispida* and *Cepaea nemoralis*.

[4] Knowing of the reports of dead *V. angustior* at Oxwich made by Quick in 1924, 1925 & 1927 MJW had, during the period 1980 – 1982, been collecting samples from numerous wetland areas at Oxwich, but all of these had been in sites which were later discovered to be far too wet to support the snail.

present in 11 of these; all located in the southern half of the transition zone demonstrating that the snail was present in a relatively narrow band along nearly 1km of this zone. The snail was not found in (1) the transition zone in the northern half of the Burrows as it was considered too narrow and damp and /or over-shaded or (2) in Cwm Ivy Marsh judged as being too wet and boggy to support the snail. The report describes the preferred micro-habitat as "*the open marshy dominated by Iris pseudacorus and low growing herbs such as Pulicaria and Potentilla and with little or no standing water*". Results indicated that *V. angustior* was either absent or present in very low numbers where the associated molluscan population was dominated by hygrophilous species such as *Vertigo antivertigo.* The survey identified a particularly '*angustior-rich area (the zone between stations 21 and 23)*". The 1993 survey, whilst surveying most of the saltmarsh – sand dune transition zone, nevertheless did not investigate some potential *V. angustior* areas these being (1) areas at the far north of the Burrows (2) most of Cwm Ivy Marsh and (3) all of the extensive dune areas and associated slacks lying to the west of the investigated salt marsh/ terrestrial transition zone.

1994 MONITORING**: Fowles & Hurford (1995)**: Two 5 m X 5 m monitoring plots[5] were established in February 1994 located in the salt marsh/sand dune transition zone, the lower one located in damper ranker upper salt marsh and the upper in drier, shorter saltmarsh margin vegetation. Random quadrat sampling was undertaken in each. The report states (p 3), "*On arrival at the survey sites, plots were positioned in the centre of the known range established by the baseline survey in 1993 (Killeen 1993)"*. In fact, the monitoring plots were not actually placed in the centre of the 1993 range (Figure 3) but toward the southern end a short distance north of the Cwm Ivy Marsh seawall. It is estimated that the adjoining plots were positioned approximately close to Station 22 and Transects 10 and 23 of the 1993 work.
In sampling each of the quadrats it is claimed that only dead vegetation was removed (both upper surface soil, live plants or moss; perhaps this technique failed to pick up many molluscs including *Vertigo angustior*) within each quadrat. Survey results only located *V. angustior* in the drier short vegetation upper plot. Rather lower numbers of *V. angustior* were recovered in 1994 than found at the 'best' 1993 stations, but this was not interpreted as a population decline as work had taken place a month later, after a cold spell and probably using different sampling methods than adopted in 1993. In any event it is unlikely that the 1994 plots happened to be positioned precisely on one of the 1993 stations.

1995 MONITORING**: Fowles & Hurford (1996)**: The two Whiteford plots established in 1994 were resampled together with an additional new plot ('C') which the report states was situated "*higher up the saltmarsh / dune transition at Whiteford*". In the absence of a sketch map (or grid reference) it is not entirely clear where this plot was situated, but it seems to be adjacent to and slightly higher in the transition zone (i.e. nearer the dunes). Sampling procedures repeated those of 1994 but in 1995 work was undertaken in May, bare ground in each was established after removal of dead vegetation and dipwells and soil moisture meters were used to assess ground hydrological conditions. As in 1994, no *V. angustior* were found in the lower plot (Mollusca again being dominated by an abundance of *V. antivertigo*), but the snail was recorded in the higher two. Compared to 1994, lower numbers of both *V. angustior* and other Mollusca were accounted for by the warm dry weather during the survey, which was believed to have resulted in *V. angustior* 'retreat' into the soil surface (not sampled). Mean vegetation height in all plots was very low and all at <10 cm (discounting *Iris*), possibly due to pony grazing.

[5] They also established another plot at Oxwich dunes on south Gower but that is not discussed here.

1996 MONITORING**: Fowles, Painter & Wilkinson (1997)**: The third Whiteford monitoring year was undertaken in April 1996. Adopting similar survey techniques, compared to the 1995 *V. angustior* results were broadly similar; there was not considered to be any statistical justification to conclude that *V. angustior* population had shown any increase. The report states that, "*sampling was undertaken under climatic conditions which were within the stipulated parameters and were considered favourable for obtaining a representative sample of V. angustior*", but nowhere does it state what these parameters were or how they were measured. There is also some confusion as it is stated that there was a recorded increase in soil moisture, but again no methodology is described, and soil moisture readings are not (as stated) given in the 'Physical characteristics' table. Mean vegetation height was very low. The report concludes with suggestions for the development of a monitoring programme to include the recording of soil moisture and humidity and that, to simplify the monitoring process (to make undertaking monitoring more straightforward and more objective for less experienced surveyors) only adult snails should be recorded. Finally, there is the suggestion that timing of monitoring be best placed in late April.

1997, 1998 & 1999 MONITORING: Monitoring results cannot be discussed as K. Wilkinson (personal communication) states it……"*appears these plots* [those used in previous surveys 1994 – 1996] *were repeated in 1997, 1998 & 1999 (Julian Woodman pers. comm.) but we do not have complete data sets and the results were not written up***".**

1998 SURVEY OF CWM IVY MARSH & GLEBE FARM & PILL HOUSE MARSH**: Holyoak & Willing (1999)**: The first full *Vertigo angustior* survey of Cwm Ivy Marsh and Glebe Farm and Pill House Marsh (lying to the immediately south-east of Cwm Ivy) was undertaken in October 1998. In addition to 'hands and knees' searching, quadrat samples were taken (for later drying and laboratory processing) from areas that were judged to be at least potentially suitable for *V. angustior*. Twenty samples were taken from Cwm Ivy Marsh and six from Glebe Farm & Pill House Marshes. No *V. angustior* (living or dead) were recovered from the Glebe Farm & Pill House samples but 3 dead shells were found in one of the Cwm Ivy samples taken from the north-western corner of the site. Two of these shells were opaque and may have died many years before, but a third shell was of a juvenile snail that was translucent with fresh periostracum and probably died shortly before its discovery. Thus, a small *V. angustior* population may still have been living in a small area of the site and seemingly close to where it was reported in 1983 and where A. Fowles reported finding the snail in 1995. It was noted that the molluscan assemblages on Cwm Ivy Marsh were, in general dominated by a higher proportion of both obligatory wetland species (e.g. *Vertigo antivertigo, Carychium minimum, Succinea putris, Euconulus alderi*) and aquatic species (e.g. *Pisidium personatum, Galba (Lymnaea) truncatula*) and that these suggested conditions on the sites were generally too wet for *V. angustior*. Vegetatioll differences also further indicated the generally wetter conditions on Cwm Ivy Marsh compared to Whiteford Burrows. Thus, the report noted that the predominant grasses on Cwm Ivy Marsh to be those tolerating or preferring wet soils (e.g. *Agrostis stolonifera* and *Holcus lanatus* as distinct from the grasses at Whiteford (e.g. *Festuca rubra*) that imply drier conditions. Similarly, conditions observed at Glebe Farm and Pill House Marsh were also considered too wet to support *V. angustior*.

1998 – 89 Autecological study of *Vertigo angustior*: **Sharland (2000)**:
A two-year study 1998 – 99 of *V. angustior* at Whiteford again focussing upon the relatively small area of transition zone toward the south of the sites encompassing the

previous monitoring plot established by Fowles & Hurford in 1994. Survey focussed upon quadrats (25 x 25 cm^3 & 15 x 15 cm^3) along transects, within the previously established monitoring plot and non-random 'bracketing' quadrats. Survey techniques were trialled finding that numbers of recovered *V. angustior* approximately doubled if samples were cut down to ground level (a further slight increase was also revealed by additionally removing the top 2 cm of soil, but this further step was not adopted) to include living plants within quadrat frames and this is the technique adopted during the survey. The study recognised 8 vegetation 'community types' (Table 3). Of these Type 2 '*Iris* with forbs[6]' and Type 3 '*Iris* with grasses and sedges" produced the most *V. angustior,* but at least small numbers were found in all of the other 6 Types. These two vegetation types closely match NVC: MG11. The study considered that (at least within the relatively small study area) the *V. angustior* population was continuing to be in a favourable condition. Further monitoring of the Whiteford populations of the snail were suggested by:

1. Sampling within the permanent monitoring plot;
2. Using 15 x 15 cm quadrats (samples cut down to ground level);
3. That work be undertaken in October with July as a second preference;
4. Habitat quality is assessed by the extent of the preferred *Iris* dominated vegetation types, noting increases in sub-optimal *Salix* / *Rubus*.

The continuation of grazing by ponies was recommended. It was noted that an area of potentially suitable *Iris* dominated habitat was present lying about 200m north of the study area that was not surveyed, but was suggested as being potentially 'good' *V. angustior* habitat. This area was subsequently surveyed in 2018 and found to support *V. angustior* as Sharland had suspected.

Table 3. Sharland's suggested Whiteford Burrow's transition zone *V. angustior* survey vegetation types.

Vegetation classification 'community types'	Vegetation community
Type 1	*Juncus acuta* tussocks
Type 2	*Iris pseudacorus* with forbs
Type 3	*Iris pseudacorus* with grasses and sedges
Type 4	Flushed neutral grassland
Type 5	Sedge-rich sward with grasses
Type 6	*Salix repens* scrub
Type 7	Dry neutral grassland
Type 8	Co-dominated by *Filipendula ulmaria* and *Iris pseudacorus*

2001 MONITORING**: Fowles & Guest (2006)**:

This publication stressed the importance of maintaining the natural dynamics of dune succession and the importance of grazing to that but expressed concern that grazing intensity had reduced.

In 2000, a habitat survey focussed upon vegetation communities where *Iris* was a key component and outlined a system for dividing such vegetation into five different classes (with a sixth '*Iris* –dominated' vegetation covering some of these – Table 4). These classes

[6] The term 'forbs' means …"are herbaceous (not woody), broadleaf plants other than grasses".

were used to produce a map covering about 0.5 km to show 6 monitoring compartments (A – F: with a central core believed to support the 'core' *V. angustior* population) together with another 5 *Iris* containing habit blocks. Employing distributional information from previous surveys and habitat data from 2000 in May 2001 Fowles, Guest and others developed a condition indicator table. This was proposed as to a means to assess if *V. angustior* populations and associated habitat were in favourable condition at Whiteford. The monitoring assessed the proportion of 'optimum *V. angustior* habitat' within each of 6 monitoring compartments ascribing each with a specific % 'pass-rate' of sites assessed, but without any explanation as to how these specific % benchmarks were derived. The sites are assessed by sampling at 5m intervals along 35m approximately east-west transects running eastwards[7] with the transect lines spaced at 5m intervals. At each sampling point along the transects plants and *V. angustior* status were assessed using a circular area with a 50cm radius. In a break from all previous monitoring, the presence of *V. angustior* was proposed by establishing presence or absence alone and with no value for the snail's abundance. It was argued that due to seasonal variations in snail numbers, gathering abundance data may be difficult to assess in the absence of a pattern of regular population monitoring. It was also suggested that snail presence is assessed solely by a maximum 15 minutes scan of plant litter on a white tray and that searching be undertaken in spring or summer when previous surveys had recorded large numbers of adult snails. Based on these procedures, Fowles and Guest judged *V. angustior* populations to be in favourable condition at Whiteford Burrows in 2001.

[7] The article rather confusingly states that the transects run 'westwards' rather than, as they do, eastwards onto the saltmarsh

Table 4. Fowles and Guest's suggested Whiteford Burrows transition zone *V. angustior* survey vegetation types.

Habitat type	Definitions used in mapping
Iris-dominated vegetation	Any vegetation where *Iris pseudacorus* is present at a density of >5 plants per 50 cm radius
Optimal habitat	Vegetation where within a given 50 cm radius search area the following criteria are met: • >10 plants of *Iris* are present; • Either *Lotus pedunculatus* makes up 10–60% of the vegetation cover, or *Pulicaria dysenterica* and/or *Filipendula ulmaria* are present, the latter at less than 50% cover; • *Juncus subnodulosus* (and other tall rushes) account for less than 50% of the ground cover; and • *Juncus maritimus*, *Samolus valerandii*, *Ranunculus sceleratus*, *Oenanthe lachenalii* and *Schoenoplectus tabernaemontani* are absent.
Brackish	Stands of '*Iris* dominated vegetation' where one or more of the following species are present within any given 50 cm radius search area: *J. maritimus*, *S. valerandii*, *R. sceleratus*, *O. lachenalii* and *S. tabernaemontani*
Filipendula dominated	Stands of '*Iris* dominated vegetation' where *F. ulmaria* accounts >50% of the vegetation cover
Juncus subnodulosus dominated	Stands of '*Iris* dominated vegetation' where *J. subnodulosus* accounts for more than 50% of the vegetation
Species-poor Iris	A 'catch-all' category covering all other forms of '*Iris* dominated vegetation' recorded

2006 TRIAL SAMPLING**: Harper (2007)**:
In September 2006, John Harper trialled the use of a vacuum sampler to test its effectiveness in collecting *V. angustior* at an established monitoring site on Whiteford Burrows where the snail was known to be present; he further confirmed the abundance of the species in the transition zone. Interestingly he also sampled an area of *Salix repens* dominated dune slack lying close by but a habitat not previously surveyed for the snail. He found *V. angustior* in abundance there stating, "*On 28.9.2006 a visit demonstrated V. angustior in large numbers in the Iris fen at the top edge of the salt marsh at SS 4459 9471. Only about 0.5m² was sampled (both long dense vegetation and short) as the species was expected to be numerous and there was no need to collect excessively. 106 adult and 144 juveniles (all live or fresh shells) gives a density for the species of 500/m² and that was without being particularly thorough*". .
This leads to the possibility that the Whiteford sand dune complex may have been overlooked for survey in the past and that the snail may occur more widely that previously suspected by occurring in habitats to the west of the frequently surveyed transition zone.

2006 MONITORING: **No recording report available (notes provided by K. Wilkinson)**
Monitoring followed the methodology outlined by Fowles & Guest (2006). *V. angustior* live presence was confirmed in all 6 monitoring plots but habitat marginally failed on the basis of low presence of *Lotus pedunculatus* (a habitat attribute as described in Fowles & Guest 2006); with the removal of this factor the habitat would have passed in five of the six monitoring compartments.

2012 MONITORING: **No recording report available (notes provided by K. Wilkinson**
Monitoring followed the methodology outlined by Fowles & Guest (2006). *V. angustior* was, as in 2006, confirmed in all 6 monitoring plots but habitat passed in all but one sector. Following experience in 2006 *Lotus pedunculatus* was removed as a habitat attribute. The habitat passed in 5/6 monitoring compartments but as all were required to pass the overall assessment was assessed as unfavourable.

2016 MONITORING: **Report in preparation (K. Wilkinson in prep 2020)**
The monitoring plots were visited on four occasions between February – September 2016. Low numbers of *V. angustior* were recorded with no records at all from two of the monitoring sectors. No habitat quality information is recorded. Table 5 presents available data which seems to suggest a major decline in populations of *V. angustior*.

Table 5. Monitoring followed the methodology outlined by Fowles & Guest (2006).

Fowles & Guest monitoring sectors	Feb. 2016	May 2016	Aug. 2016	Sept. 2016
A	X	X	Not sampled	0
B	X	X	Not sampled	0
C ('core sector')	X (1 dead)	✓ (2 live)	✓ (1 live)	17
D	X	✓ (1 live)	Not sampled	2
E	X	X	✓ (5 live)	0
F	X	✓ (5 live)	Not sampled	Results unknown 1

Appendix 10.5. Selected images of survey sites

Figure 4. A view from a high dune looking eastwards across the Whiteford Burrows salt marsh – sand dune transition zone May 1983 on day of *Vertigo angustior* discovery. Note the close-cropped vegetation indicating significant grazing pressure.

Figure 5. A view looking eastwards across Cwm Ivy Marsh, May 1983. Note the close-cropped vegetation indicating significant grazing pressure and the abundance of *Iris pseudacorus* dominated habitat then found to support low numbers of *V. angustior*.

Figure 6. 2018 survey Station 1.

Figure 7. 2018 survey Station 2.

Figure 8. 2018 survey Station 3.

Figure 9. 2018 survey Station 4.

Figure 10. 2018 survey Station 5.

Figure 11. 2018 survey Station 6 (6a to left of path & 6b to right).

Figure 12. 2018 survey Station 7.

Figure 13. 2018 survey Station 8.

Figure 14. 2018 survey Station 9.

Figure 15. 2018 survey Station 10.

Figure 16. 2018 survey Station 11.

Appendix 10.6. Notes on the presence of *Pupilla pratensis* in Britain

The form of *Pupilla muscorum* now known as *P. pratensis* was first found by B. Colville in wetland sites at Belmaduthy on the Black Isle, Ross and Cromarty (VC 106) in 2005 (Norris, 2014). The species was reconfirmed again at the site by Colville and other workers in 2005, 2008 and most recently in 2012 when an additional site was also located close by (I. Killeen, pers. comm.). In 1983, M. Willing and R. Preece found unusually large '*P. muscorum'* in damp marshy habitat in a sand dune slack at Oxwich, Gower. The recent confirmation of *P. pratensis* presence in the Britain has led them to reappraise this find which seems to be the new species. In the latest UK non-marine status review (Seddon *et al*., 2014), the species was assessed as 'Data Deficient'.

In 2009, a paper was published (Prochwitz *et al*., 2009) confirming that *P. muscorum* and *P. pratensis* are different species rather than simply ecophenotypes. This work was based upon three separate lines of evidence (1) molecular [DNA of mitochondrial cytochrome *c & b* oxidase], (2) ecological and (3) morpohological (shell form).
The possibility that the *Pupilla* found at Whiteford Burrows may be *P.pratensis* is based upon two lines of evidence:

1. The shells are, when compared to samples of *P. muscorum* taken from typical dry grassland sites, noticeably larger;
2. The Whiteford specimens were living in damp salt-marsh transition habit (like the *P. pratensis* from Oxwich described above) rather than in the dry ground on the sea defence embankment. This preference for damper habitat than *P. muscorum* is also noted elsewhere (e.g. Proschwitz *et al*., 2009, Welter-Schultes, 2012).

The shells *P.* cf *pratensis* shells have been sent for more detailed study by Dr. R. Marriott who is familiar with this species.

11. Data Archive Appendix

The data archive contains:

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

[B] Species records, which are held on the NRW Recorder 6 database.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://libcat.naturalresources.wales or http://catllyfr.cyfoethnaturiol.cymru by searching 'Dataset Titles'. The metadata is held as record no. 124694.