Further studies to assess the distribution of the Narrow-mouthed Whorl Snail *Vertigo angustior* on Oxwich Burrows, Whiteford Burrows & Llangennith Burrows in October 2022

(including corrections to NRW Evidence Report No. 698)

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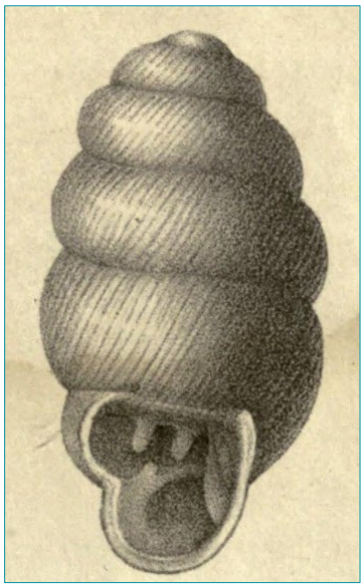

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Contents

About 'Natur am Byth!' 2
About Natural Resources Wales 2
Evidence at Natural Resources Wales 2
Distribution list (core) 3
Distribution list (others) 3
Recommended citation for this volume: 3
Contents 4
List of figures 5
List of tables 6
Crynodeb gweithredol 7
Executive summary 8
1. Introduction 9
1.1 *Vertigo angustior* studies on the Gower Peninsula 10
1.1.1 Oxwich Burrows 10
1.1.2 Whiteford Burrows 10
1.1.3 Llangennith Burrows 11
1.2 Survey objectives 11
1.2.1 Oxwich Burrows 11
1.2.2 Whiteford Burrows 12
1.2.3 Llangennith Burrows 12
2. Methods 12
3. Results 14
3.1 Oxwich Burrows 14
3.2 Whiteford Burrows 15
3.3 Llangennith Burrows 19
4. Discussion 20
4.1 Oxwich Burrows 20
4.2 Whiteford Burrows 25
4.3 Llangennith Burrows 25
4.4 Overall conclusions from the 2022 survey 25
4.5 Conservation considerations 27
4.6 Further work in 2023 28
4.6.1 Oxwich & Nicholaston Burrows 28
4.6.2 Whiteford Burrows 28
4.6.3 Other dune sites on Gower: Three Cliffs Bay, Swansea Dunes & Llangennith Burrows 28
4.6.4 Vacuum sampling trial 28
5. Acknowledgements 29
6. References 29
Appendix 1. Molluscs recorded at Oxwich Burrows from 1st to 4th October 2022 33

Appendix 2. Molluscs recorded at Whiteford Burrows on 4th October 2022 34
Appendix 3. Molluscs recorded at Llangennith Burrows on 3rd and 6th October 2022 35
Appendix 4. NVC plant communities recorded at Oxwich Burrows, Whiteford Burrows and Llangennith Burrows in October 2022 36
Appendix 5. NVC plant communities associated with *Vertigo angustior* locations at Oxwich Burrows and Whiteford Burrows in October 2022 37
Appendix 6. Assessment of plant frequencies and abundance 37
Appendix 7a. Records of prominent plant species from *Vertigo* sampling sites in frontal dune habitats at Oxwich Burrows in 2022 39
Appendix 7b. Records of prominent plant species from *Vertigo* sampling sites in fixed dune habitats at Oxwich Burrows in 2022 40
Appendix 7c. Records of prominent plant species from *Vertigo* sampling sites in upper saltmarsh habitats at Oxwich Burrows in 2022 41
Appendix 7d. Records of prominent plant species from *Vertigo* sampling sites in dune slacks at Oxwich Burrows in 2022 42
Appendix 8. Records of prominent plant species from *Vertigo* sampling sites in dune slacks at Whiteford Burrows in 2022 43
Appendix 9a. Records of prominent plant species from *Vertigo* sampling sites in dune slacks at Llangennith Burrows in 2022 44
Appendix 9b. Records of prominent plant species from *Vertigo* sampling sites in fixed dune grassland at Llangennith Burrows in 2022 45
Appendix 10. Site locations and summary habitat descriptions at Oxwich Burrows 46
Appendix 11. Site locations and summary habitat descriptions at Whiteford Burrows 58
Appendix 12. Site locations and summary habitat descriptions at Llangennith Burrows 62
Appendix 13. Previous *Vertigo angustior* surveys at Oxwich Burrows 67
Appendix 14. Previous *Vertigo angustior* surveys at Whiteford Burrows 72
Appendix 15. Corrections to NRW Evidence Report No. 698. *Vertigo angustior* surveys at Whiteford Burrows 73
Data Archive Appendix 74

List of figures

Figure 1. The location of the 2022 survey areas on the Gower Peninsula 11
Figure 2. The distribution of survey sites on Oxwich Burrows in 2022 14
Figure 3. The distribution of survey sites on Whiteford Burrows 2022 15
Figure 4. The distribution of survey sites on Whiteford Burrows 2018 – 2022 16
Figure 5. The distribution of *Vertigo angustior* sites on Whiteford Burrows 1993 – 2022 17
Figure 6. The distribution of survey sites on Llangennith Burrows 2022 18
Figure 7. 1926 sketch map showing absence of tree cover on northern sector of Oxwich Burrows 20
Figure 8. 1993 image of transition zone showing open nature of the habitat 20
Figure 9. 1996 Image of transition zone showing open nature of the habitat 21
Figure 10. Sand dune 'hummocks' supporting *Vertigo angustior* populations in 2016 but now shaded by *Salix* and *Alnus* lying on the margins of the Oxwich salt marsh 21
Figure 11. General view looking to the east and showing *Betula*, *Alnus* and *Salix* now growing up to the salt marsh margins and shading the former dune transition zone on the northern margins of Oxwich Burrows 22
Figure 12. Survey site locations estimated from Oxwich Burrows 1993 survey and

superimposed onto recent aerial image 22
Figure 13. Summary overview map of Oxwich Burrows *Vertigo angustior* surveys 1983 – 2022 ... 23

List of tables

Table 1. NVC communities found to supporting *V. angustior* at Oxwich Burrows and Whiteford Burrows in surveys from 2018 to 2022 25
Table 2. *Vertigo angustior* recorded in two habitats at Doughmore, Co. Clare 26

Crynodeb gweithredol

Mae'r adroddiad hwn yn disgrifio arolygon ar gyfer math o falwen droellog, *Vertigo angustior*, a gynhaliwyd ddechrau mis Hydref 2022 mewn tair system twyni ym Mhenrhyn Gŵyr – Twyni Oxwich (3.5 diwrnod), Twyni Whiteford (1 diwrnod) a Thwyni Llangynydd (1.5 diwrnod). Yn Nhwyni Oxwich, canolbwyntiwyd yn bennaf ar wneud arolwg manwl o'r forfa heli – parth trosiannol twyni tywod sy'n gorwedd ar ymylon gogleddol y twyni ble darganfuwyd y falwen am y tro cyntaf ym 1983 a ble cynhaliwyd yr holl arolygon dilynol (1993 - 2016). Gan fod y falwen wedi'i darganfod mewn llaciau twyni yn Nhwyni Whiteford yn 2021, ymwelwyd hefyd â detholiad o laciau *Salix repens* ar draws system dwyni Oxwich. Casglwyd un sampl hefyd o safle twyni sefydlog ym mhen gogledd-ddwyreiniol pellaf y twyni. Canolbwyntiodd yr arolwg yn Nhwyni Whiteford ar samplau pellach o laciau twyni penodol yn sector canol gorllewinol y twyni, yn unol ag arolygon a gynhaliwyd yn 2021. Nid oedd yn hysbys bod unrhyw arolwg systematig o folysgiaid wedi'i gynnal yn Nhwyni Llangynydd o'r blaen. Dewisodd yr arolwg presennol gyfres o bantiau twyni a chynefinoedd â nodweddion llaciau ar draws yr ardal.

Yn Nhwyni Oxwich, ni chanfu samplau'r parth trosiannol unrhyw boblogaethau o *V. angustior* yn yr ardal ganolog lle'r oedd y rhan fwyaf o'r arolygon blaenorol wedi cofnodi'r falwen, ond canfuwyd niferoedd bychain mewn dau safle ym mhen dwyreiniol y parth. Priodolir diflaniad y falwen o'r safleoedd blaenorol i ymlediad prysgwydd a choed tua'r gogledd, sydd bellach yn ymestyn i ymylon gogleddol eithaf y forfa heli. Dim ond mewn niferoedd bychain iawn y canfuwyd *V. angustior* mewn un llac twyni (14% o'r rhai a archwiliwyd). Yn annisgwyl, yr un safle hwn o dwyni sefydlog a ddangosodd y nifer fwyaf o falwod *V. angustior* byw*,* y tro cyntaf i'r falwen gael ei chofnodi yn y math hwn o gynefin yn Oxwich. Yn Nhwyni Whiteford, canfuwyd y falwen mewn pedwar llac arall, er na chafodd ei chofnodi mewn nifer debyg o safleoedd eraill a oedd yn ymddangos yn addas. Ni chanfuwyd *V. angustior* yn Nhwyni Llangynydd, gyda'r rhan fwyaf o'r llaciau *Salix repens* a arolygwyd yn rhy sych i gynnal y falwen.

Awgrymir y dylid gwneud arolygon pellach, a hynny yn Nhwyni Oxwich er mwyn ymchwilio ymhellach i'r twyni sefydlog a lled-sefydlog nas arolygwyd o'r blaen, a hefyd yn Nhwyni Whiteford er mwyn canolbwyntio ar gynefinoedd llaciau twyni ym mhen gogleddol a gorllewinol y twyni tywod. Ni argymhellir unrhyw arolygon pellach yn Nhwyni Llangynydd.

Dangoswyd pwysigrwydd casglu samplau mewn swmp i'w dadansoddi yn ddiweddarach oddi ar y safle, er mwyn ategu gwaith hidlo yn y maes ac arsylwadau uniongyrchol ar y tir. Yn Oxwich, ni chofnodwyd unrhyw sbesimenau o *V. angustior* yn y maes o unrhyw un o'r pedwar safle cadarnhaol, tra bo'r rhywogaeth wedi'i chofnodi yn y maes yn Whiteford mewn dim ond un o'r pedwar safle newydd ble daethpwyd o hyd iddi.

Executive summary

This report describes surveys for the Narrow-mouthed Whorl Snail *Vertigo angustior* undertaken in early October 2022 at three dune systems on the Gower Peninsula - Oxwich Burrows (3.5 days), Whiteford Burrows (1 day) and Llangennith Burrows (1.5 days). At Oxwich Burrows, the survey focussed primarily upon a detailed survey of the saltmarsh – sand dune transition zone lying on the northern margins of the dunes where the snail was first found in 1983 and where all subsequent surveys (1993 - 2016) have taken place. As the snail had been found in dune slacks at Whiteford Burrows in 2021, a selection of *Salix repens* slacks was also visited across the Oxwich dune system. Finally, a single sample was collected from a fixed dune site at the extreme north-eastern end of the dunes. At Whiteford Burrows, the survey focussed on the further sampling of selected dune slacks in the centre-western sector of the dunes in line with surveys undertaken in 2021. No known systematic molluscan survey of Llangennith Burrows had been undertaken previously. The current survey selected a series of dune hollows and slack-type habitats across the area.

At Oxwich Burrows, the transition zone sampling did not locate any *V. angustior* populations in the central area where most earlier surveys had recorded the snail, but did find low numbers at two sites at the eastern end of the zone. The disappearance of the snail from former sites is attributed to the northward spread of scrub and trees which now extend north to the extreme margins of the saltmarsh. *V. angustior* was only found in very low numbers in a single dune slack (14% of those surveyed). Unexpectedly, the single fixed dune site produced the largest number of live *V.angustior,* the first time that the snail had been recorded in this habitat type at Oxwich. At Whiteford Burrows, the snail was found in a further four dune slacks although it was not recorded from a similar number of other seemingly suitable sites. *V. angustior* was not found at Llangennith Burrows, with the mostly *Salix repens* slacks surveyed all being too dry to support the snail.

Further surveys are suggested both at Oxwich Burrows, to further investigate the previously un-surveyed fixed and semi-fixed dunes, and at Whiteford Burrows, focussing on dune slack habitats at the northern and western ends of the burrows. No further surveys are recommended at Llangennith Burrows.

The importance of collecting bulk samples for later, off-site analysis to supplement on-site field sieving and direct ground observation was demonstrated. At Oxwich, no *V. angustior* specimens were recorded in the field from any of the four positive sites whilst at Whiteford it was field recorded at only one of the four new sites where it was found.

1. Introduction

The Narrow-mouthed Whorl Snail *Vertigo angustior* (Jeffreys, 1830) is a small species 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 typically are warmed quickly 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; Moorkens & Gaynor, 2003). 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 7 'Species of Principal Importance'.

The first records of *V. angustior* in Wales were all dead shells. Thus, in 1830, Jeffreys found shells in flood debris near Swansea (Jeffreys, 1830) with further shells reported by him found 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 were located at both Oxwich Bay and Whiteford Burrows on the southern and northwestern 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). Thus, in Wales, *V. angustior* is confined to a relatively small area of coastline in Carmarthenshire and West Glamorgan incorporating the Pembrey dune system (Pembrey Aerial Firing Range & Pembrey Forest), Whiteford Burrows (including Cwm Ivy Marsh) and Oxwich Burrows, with historical records from Swansea (its type locality) and Tenby in Pembrokeshire.

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 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.

1.1 *Vertigo angustior* studies on the Gower Peninsula

1.1.1 Oxwich Burrows

Oxwich Burrows is a dune system lying on the central south coast of the Gower Peninsula. It is part of Oxwich National Nature Reserve and Oxwich Bay SSSI. *Vertigo angustior* shells were first found here in 1924 and 1925 (Quick 1924, 1926, 1927) but no live animals were recorded. Live specimens were first found in 1983 (Preece & Willing, 1984), with further surveys and monitoring occurring in 1993 (Killeen, 1993), 1994, 1995, 1996 (Fowles & Hurford, 1995, 1996; Fowles *et al*., 1997 respectively) and 2006 (Harper, 2007), and a short unpublished NRW visit in 2016 (Wilkinson & Howe, pers. comm.). These surveys focussed exclusively on a narrow band of dunes lying as a 'transition zone' immediately parallel to saltmarsh on the northern margins of the dunes. *V. angustior* is not believed to have been surveyed previously in other Oxwich dune locations. In 1995, *V. angustior* was considered to be on the verge of extinction at Oxwich (Fowles & Hurford, 1996) but the following year the snail was recorded at a number of locations at the eastern end of the 'transition zone' (Fowles *et al*., 1997). Despite these encouraging finds, no further surveys were undertaken by NRW until a short visit in 2016 when a few snails were found on dune hummocks close to where the snail was first found in 1983. In 2006, a trial vacuum sampling visit (Harper, 2007) also found live populations in the vicinity of the first finds. This 2022 project is the first since Quick in 1925 to survey *V. angustior* more widely across the Oxwich dunes system. More detailed notes on all previous Oxwich surveys are given in Appendix 13.

1.1.2 Whiteford Burrows

Whiteford Burrows lies 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).

The *V. angustior* monitoring results from 1994 to 2012 (cited above) all broadly concluded that the snail and its associated Yellow Iris *Iris pseudacorus* habitat were mainly in favourable condition. However, a series of four monitoring visits to these 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. The 'crashed' population in the Whiteford transition zone was then assessed as Unfavourable with a decreasing trend (Karen Wilkinson, pers. comm.). This formed the basis of NRW Article 17 reporting for the snail in 2018 – a stable range but all populations under threat (Howe, 2018).

In response to this apparent decline, a single day assessment visit was undertaken in October 2018 (Willing, 2020). 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 along the eastern saltmarsh / sand dune transition zone extending the previously recorded range by 1.2 km, a 171% increase. A survey in 2021 (Willing, 2023) was the first to undertake wide-ranging *V. angustior* surveys within the main body of the dunes. As a result, the snail was found in 32% of the *Salix repens* dominated slacks surveyed, living in different vegetational communities to those present in the sand dune / salt marsh transition zone where the snail had been recorded.

1.1.3 Llangennith Burrows

Llangennith Burrows lies on the extreme central western margins of the Gower peninsula. No systematic molluscan survey of the area had previously been undertaken.

1.2 Survey objectives

1.2.1 Oxwich Burrows

A comprehensive survey of the sand dune / saltmarsh transition zone was planned in 2022 to revisit the central 'core area' where all previous surveys had recorded the snail the last in 2016. The surveys would extend laterally to the east and west of this area to assess the wider transition zone. A further priority was the survey of a selection of *Salix repens* dominated dune slacks across the reserve following the unexpected discovery of *V. angustior* in this habitat at Whiteford Burrows in 2021 (Willing, 2023).

1.2.2 Whiteford Burrows

Following the presence of large *V. angustior* populations in several dune slack habitats in 2021, a wider range of this habitat was planned for the 2022 survey.

1.2.3 Llangennith Burrows

As this extensive dune system lies a relatively short distance south of Whiteford Burrows, a survey for the presence of *V. angustior* seemed appropriate. No previous non-marine molluscan surveys of Llangennith Burrows are known to have taken place.

2. Methods

Survey work was undertaken during a 6-day period from 1st to 6th October 2022.



Figure 1. The location of the 2022 survey areas on the Gower Peninsula.

Oxwich Burrows was visited over a 3½ period on 1st, 2nd, 3rd (half day) and 4th October 2022. MJW was joined by Dan Guest and Catherine Hammond (both from Natural Resources Wales [NRW]) for part of this time. The survey focus was to:

- resurvey the length of the sand dune - saltmarsh 'transition zone lying at the north of the reserve, an area where survey work has been undertaken between 1983 and 2016 and where all previous *V. angustior* finds originate;
- to survey a selection of dune slacks across the reserve, a habitat not previously surveyed for the snail at Oxwich.

A total of 23 sites on Oxwich Burrows was surveyed.

Whiteford Burrows was visited on 5th October 2022. MJW was accompanied by Karen Wilkinson, Sue Westwood, Laura Brooks and Catherine Hammond (all from NRW). The work continued surveys started in 2021 of dune slacks in the central and north-western parts of the reserve. A total of 8 sites was surveyed.

Llangennith Burrows was surveyed for 1.5 days on 3rd (half day) and 6th October 2022. MJW was accompanied by Dan Guest, Catherine Hammond, Karen Wilkinson and Kristina Jenkins (all from NRW). The survey primarily focussed on dune slack habitats. A total of 10 sites were surveyed.

Site surveys 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 also removed for later laboratory processing. These consisted of approximately 2-3 litres of lightly compressed 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.

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 plant species were identified and their frequency recorded, with each attributed to National Vegetation Classification (NVC) by Dan Guest

and Karen Wilkinson. All sites were digitally photographed, and GPS 10-figure OS grid references recorded.

3. Results

Molluscan results from the 2022 surveys of Oxwich Burrows, Whiteford Burrows and Llangenith Burrows are displayed in Appendix 1 to 3 and species naming throughout follows that of Anderson & Rowson (2020). Absolute counts of each species equate to numbers recovered from each of the approximately comparable sized bulk samples. Plant records appear in Appendix 7.2 and are preceded by an explanation of (A) National Vegetational Categories (NVC) of communities recorded during the 2022 surveys and (B) dominance assessments. Survey site locations, summarised habitat descriptions and site images are given in Appendix 10 to 12.

3.1 Oxwich Burrows

23 sites were surveyed across Oxwich Burrows (Figure 2). Of these, 12 sites (Sites 2, 3, 5, 6/6a, 7, 8, 9, 10, 11, 21/21b, 22 and 23) were situated at or close to the sand dune / saltmarsh transition zone lying at the northern margins of the reserve, a region where all previous *V. angustior* surveys at Oxwich (1983 – 2016) had taken place. The snail was not found at or close to locations where it was recorded in 1983, 1993, 2006 or 2016. However, it was recorded at Sites 3 and 21 in NVC SD8 (*Festuca rubra – Galium verum* fixed dune community) and at Site 21 in a transition with NVC SM18 (*Juncus maritimus* salt marsh community). The snail may have been recorded close to these sites in 1996 (Fowles *et al*., 1997) whilst Site 3 lies close to a sand dune 'island' where Fowles recorded about 50 live *V. angustior* in 1996 (A. Fowles, pers. comm. in 2023). *V. angustior* was also unexpectedly recorded in relatively large numbers at Site 1 in dry fixed dunes NVC SD7d (*Ammophila arenaria-Festuca rubra* semi-fixed dune community [*Tortula ruraliformis* subcommunity]), lying well to the east of any previous Oxwich records (Figure 2; Site OB1 in Appendix 10).

Elsewhere at Oxwich, eight *Salix repens* dominated dune slacks were surveyed (Sites 12, 13, 14, 15, 16, 17,18, 19/19a) but *V. angustior* was only recorded in one, Site 16 an NVC SD15b community (*Salix repens-Calliergon cuspidatum* dune-slack [*Equisetum variegatum* subcommunity]). At the four sites where it was recorded *V. angustior* was not located in the field but from laboratory processed bulk samples and, in all cases, live individuals were recorded in low numbers. This may, at least in part, be a consequence of the 2022 survey taking place following a summer of prolonged drought and record high temperatures both of which are likely to have negatively impacted the snail. A combined total of 16 terrestrial mollusc species were recorded from the Oxwich sites the majority of which had been recorded previously (e.g. Preece & Willing 1984, Killeen 1993). The presence of the

shade-loving, typically woodland *Acanthinuella aculeata* from three sites may indicate an increase in scrub and rank vegetation at many sites.

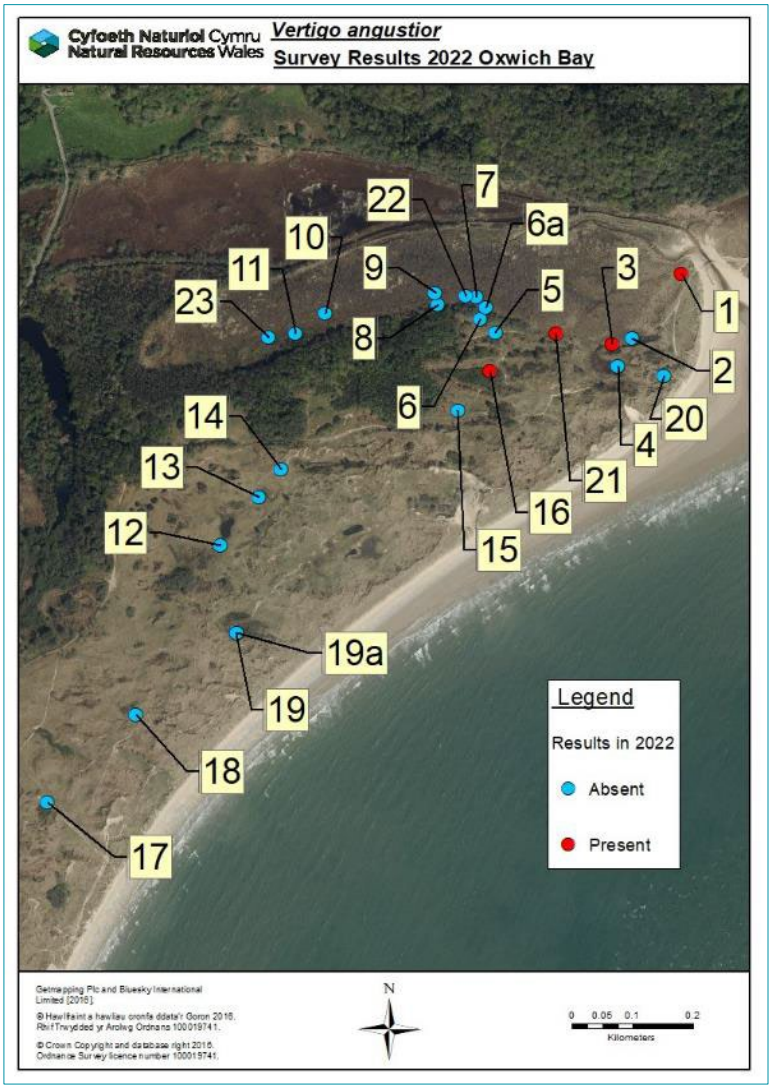

Figure 2. The distribution of survey sites on Oxwich Burrows in 2022 (indicating those sites where *Vertigo angustior* was recorded).

3.2 Whiteford Burrows

Eight further sites were surveyed in the centre and centre-west of Whiteford Burrows (Figure 3). All were in *Salix repens* dominated dune slacks and *V. angustior* was recorded in four; at Site 4a in NVC SD14b (*Salix repens-Campylium stellatum* dune-slack) and Sites 6, 7 and 8 all in SD16 (*Salix repens-Holcus lanatus* dune-slack). The snail was only recorded in the field at Site 7, confirmation of its presence at the other three sites resulting from later bulk sample examination. A combined total of 15 terrestrial mollusc species were recorded from the sites, all having been recorded previously at Whiteford Burrows (e.g. Willing, 2020, 2023).

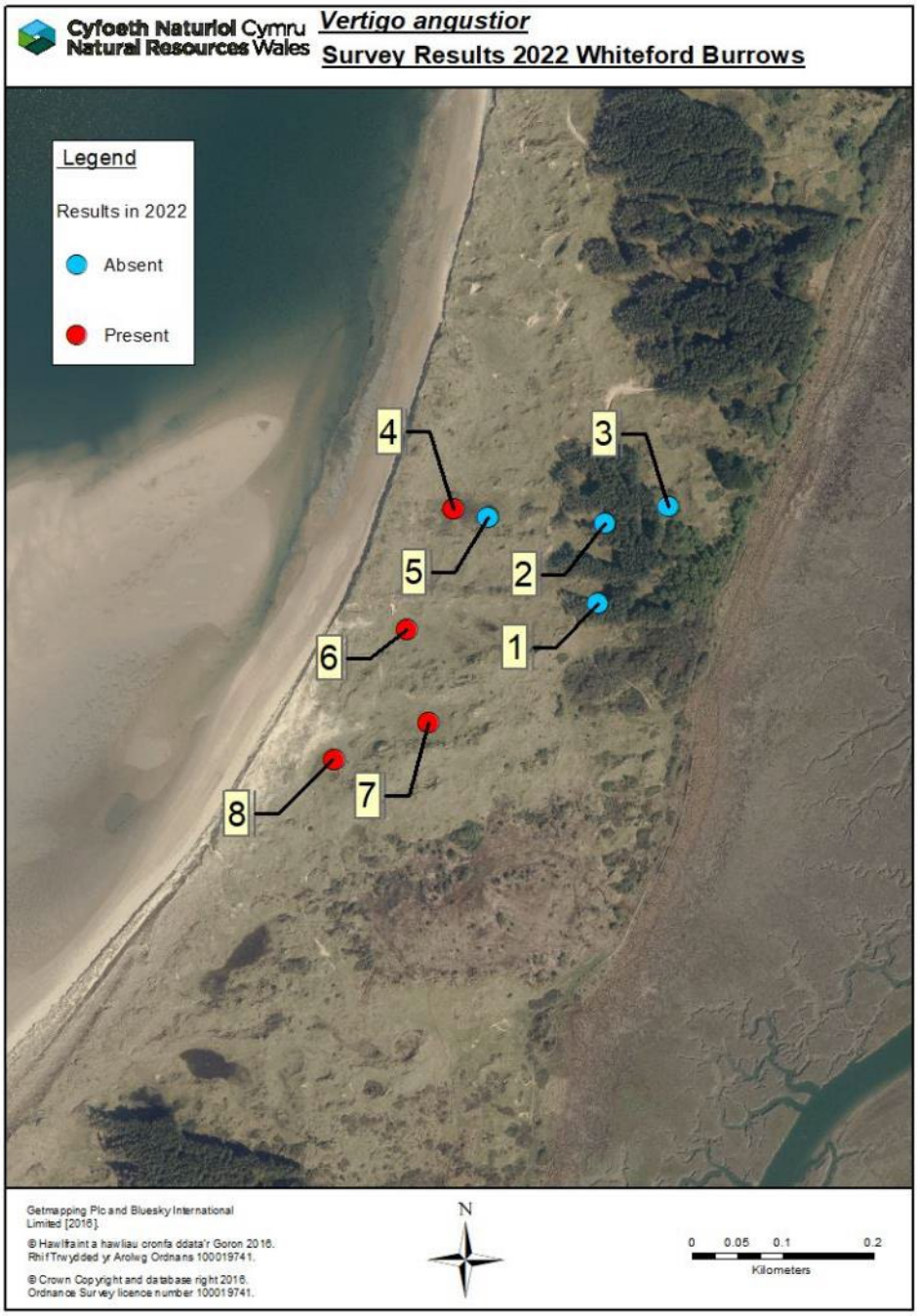

Figure 3. The distribution of survey sites on Whiteford Burrows 2022 (indicating those sites where *Vertigo angustior* was recorded).

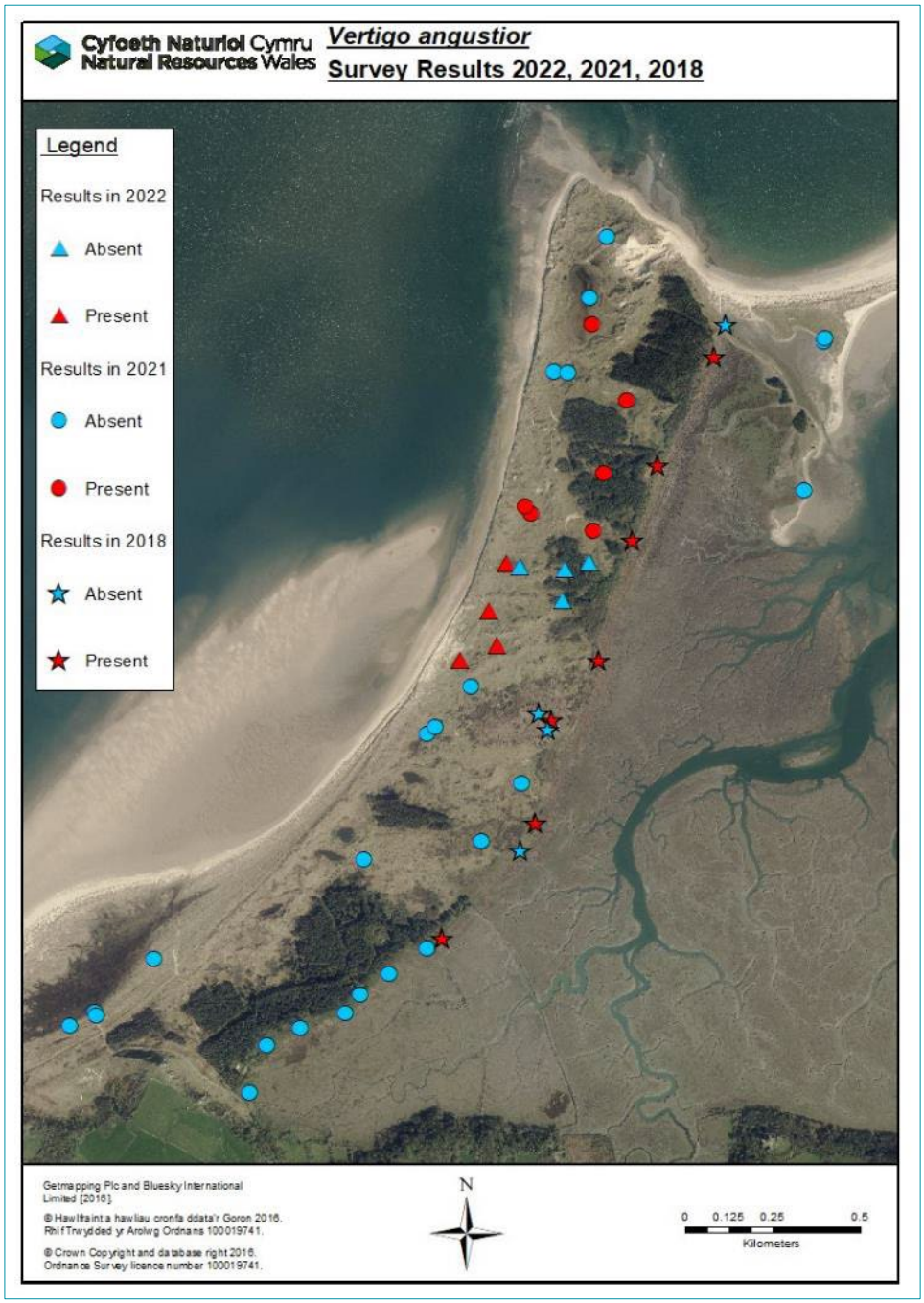

Figure 4. The distribution of survey sites on Whiteford Burrows 2018 - 2022 showing presence and absence of *Vertigo angustior.*

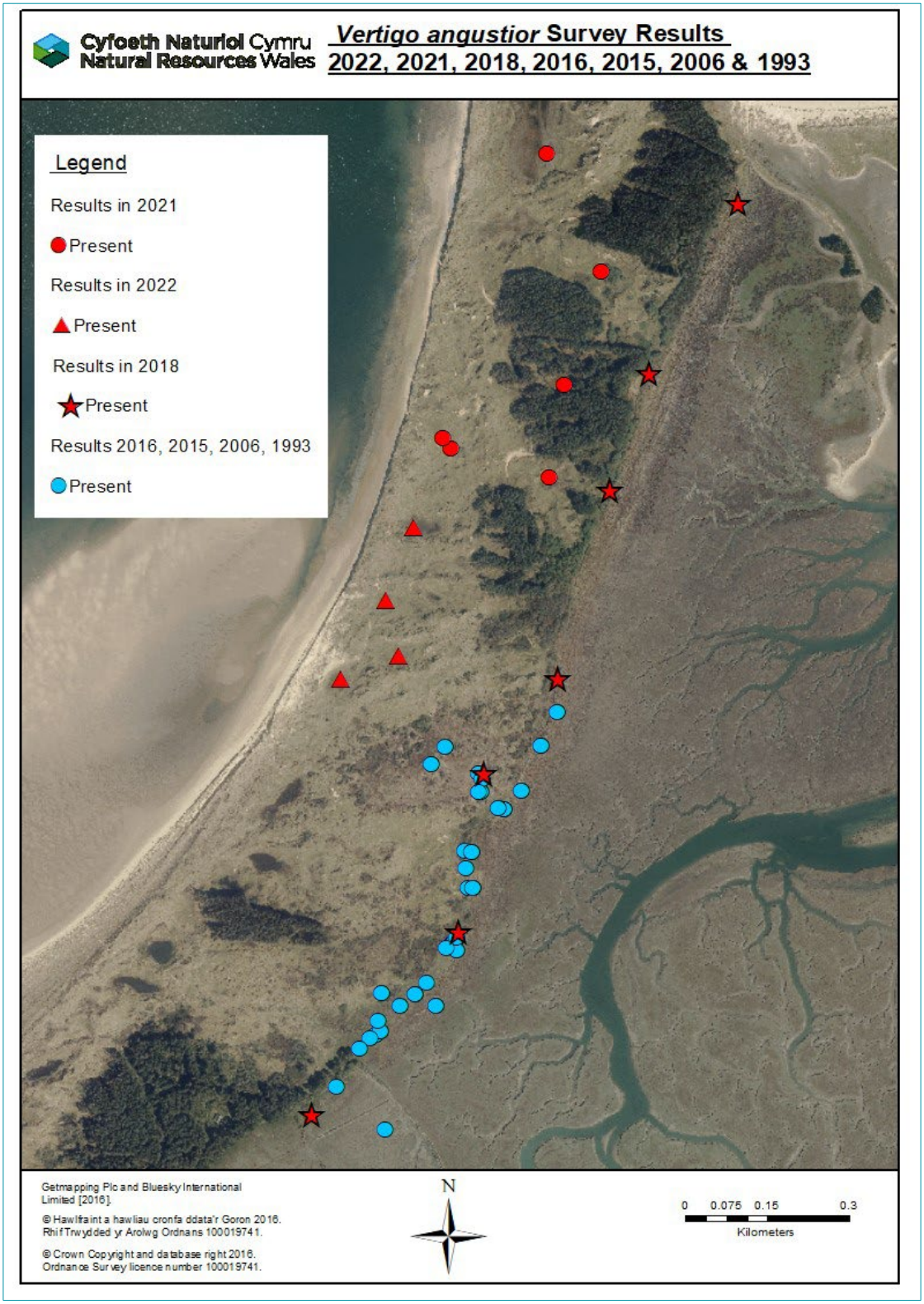

Figure 5. The distribution of *Vertigo angustior* sites on Whiteford Burrows 1993 – 2022.

3.3 Llangennith Burrows

Ten sites were visited across the extensive Llangennith Burrows (Figure 6), with bulk samples taken from eight. All were *Salix repens* dominated dune slacks and *V. angustior* was not recorded. Believed to be the first systematic molluscan survey of Llangennith Burrows, a total of 15 terrestrial mollusc species were recorded. The absence of wetland / humid habitat species such as *Vertigo antivertigo* and *Vallonia pulchella* reflects the consistently dry nature of the survey sites. The widespread presence of the non-native *Cochlicella barbara* is of note. This Mediterranean species was first recorded on Llangennith Burrows by T. Lewis in 1999 and is also known from six other Welsh coastal sites (NBN Atlas, accessed August 2023).

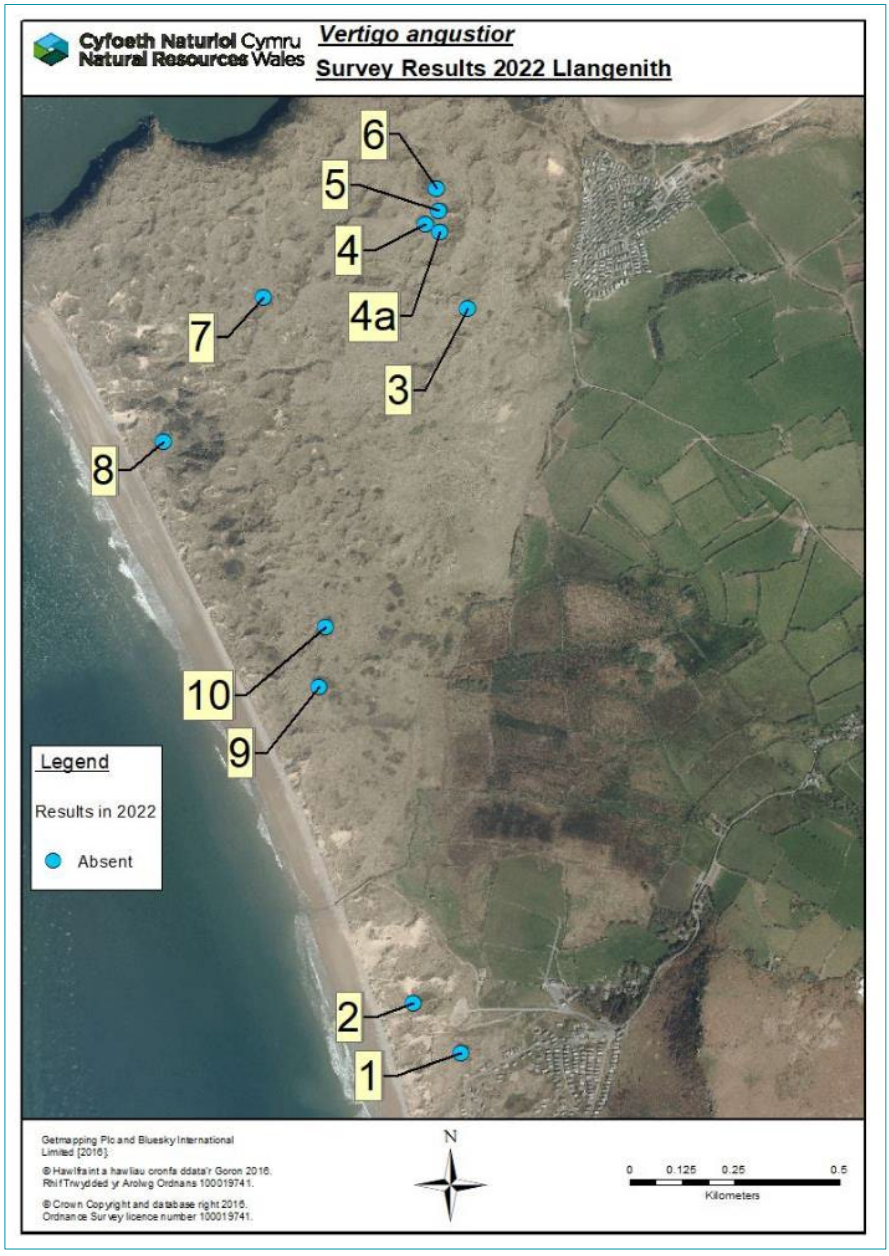

Figure 6. The distribution of survey sites on Llangennith Burrows 2022.

4. Discussion

4.1 Oxwich Burrows

The 2022 survey of 23 sites on Oxwich Burrows is the most detailed *Vertigo angustior* study of the area. Previously, the most extensive survey of 9 sites across the reserve was undertaken by Quick in 1925 (Quick, 1926; Figure A in Appendix 13). By contrast, the 1993 survey of 17 sites (Killeen, 1993) focussed exclusively on the central region of the northern sand dune – saltmarsh transition zone (Figure 12). All previous Oxwich Burrows *V. angustior* records are in the narrow saltmarsh – sand dune transition zone lying on the northern margins of the reserve (Figure 12; Figures B & C in Appendix 13). The 2022 survey extensively surveyed of this zone (Figure 2) but *V. angustior* was only located in very low numbers at two sites (Site 3 & Site 21). No populations were found in the 'core area' (2022 Sites 5, 6. 6a, 7, 8, 9 & 22) where the snail was first found in 1983 (Preece & Willing, 1984) and again in 1993 (Killeen, 1993), in 1996 (Fowles *et al*., 1997) in 2006 (Harper, 2007) and 2016 (Karen Wilkinson, pers. comm.). The 2022 Site 21 lies further east than most previous survey locations but Site 3 lies close to where the snail was estimated have been found in large numbers by A. Fowles in 1996 (Fowles *et al*., 1997).

A little further south, the snail was also recorded by D. Painter in 1996 (Harper, 2007) close to 2022 Site 4, but was not re-found there by D. Harper in 2006 or during this survey.

A possible reason for the loss of *V. angustior* from all but the eastern margins of the transition zone is an increase in habitat shading caused by the advance of scrub and tree cover. There is evidence of a gradual eastward spread of tree cover on the northern sector of Oxwich Burrows. Quick (1927) includes a sketch map of Oxwich Burrows showing no tree growth on the northern sector of the dunes (Figure 7).

When *V. angustior* was first discovered at Oxwich Burrows in 1983 (Preece & Willing, 1984), it was found in dune hummocks close to the northern edge of the dunes in a habitat unshaded by trees or scrub (unfortunately no photographs exist). The northern transition zone was still open in 1993 (Killeen, 1993) although the survey report noted with concern the presence of rank vegetation and occasional young trees. It states that "*the encroachment onto the transition zone by scrub appears to be a recent phenomenon, indeed there may have been significant change since 1983*" (Figure 8).

A survey in 1996 (Fowles *et al*., 1997) still shows unshaded conditions although the presence of occasional young trees (Figure 9).

No later habitat descriptions exist until the current study. A short visit by NRW staff Karen Wilkinson and Mike Howe in September 2016 observed live *V. angustior* on dune hummocks close to the 1983 and 1993 sites. Although these lay close to advancing tree cover, they were still apparently unshaded when visited (Mike Howe, pers. comm.).

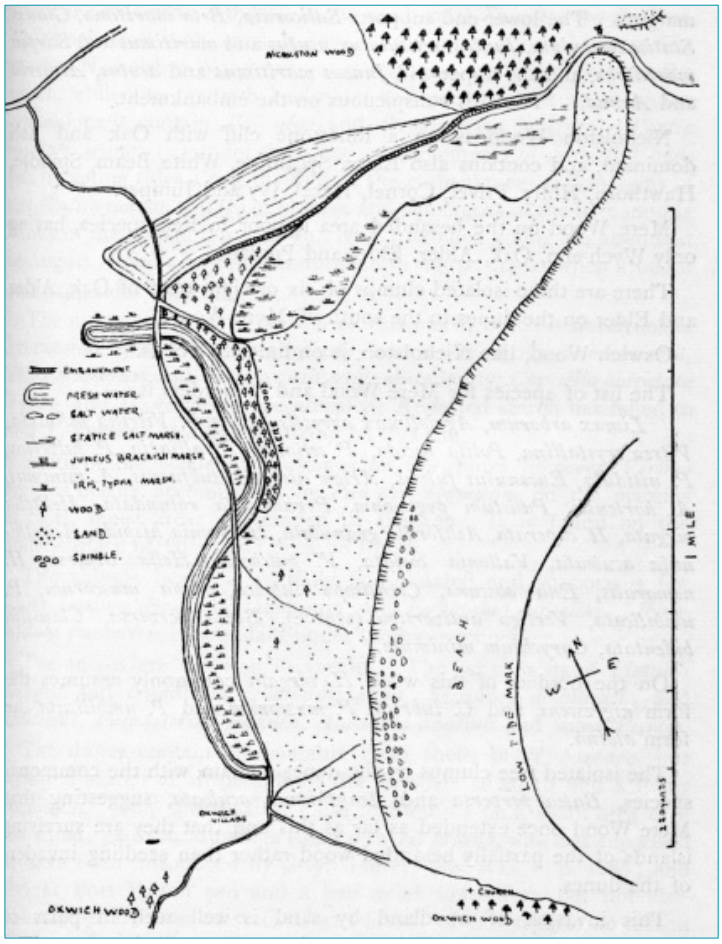

Figure 7. A sketch map drawn in 1926 (Quick, 1927) showing an absence of tree cover on the northern sector of Oxwich Burrows.


Figure 8. Image of the transition zone in 1993 showing the still open nature of the habitat. From Killeen (1993).



Figure 9. Image of the transition zone in 1996 showing the still open nature of the habitat. From Fowles *et al*. (1997).

The 2022 survey revisited this area locating these hummocks which were by then heavily shaded; no *V. angustior* were found in samples taken from the area but these included numerous *Vertigo antivertigo* indicating a saturated and shaded microhabitat. The 2022 survey found that tree and scrub cover now encroach over much of the sand dunes in the central and western transition zone including all of the area where it was initially found in 1983 and 1993. The 2022 survey found that tree cover extends right up to the saltmarsh margins along all but the eastern end of the transition zone (Figures 10 & 11), and it is believed that the replacement of open dune habitat by trees and scrub has led to the loss of the *V. angustior* populations there.



Figure 10. Sand dune 'hummocks' supporting *Vertigo angustior* populations in 2016 but now shaded by *Salix* and *Alnus* lying on the margins of the Oxwich salt marsh (October 2022).



Figure 11. A general view looking to the east and showing *Betula*, *Alnus* and *Salix* now growing up to the salt marsh margins and shading the former dune transition zone on the northern margins of Oxwich Burrows (October 2022).

If the 1993 *V. angustior* locations (Killeen, 1993) are superimposed onto a recent aerial map of the northern sector of Oxwich Burrows, it shows all of the 1983 and 1993 *V. angustior* and other survey locations are now situated in or very close to alder and willow woodland (Figure 12).

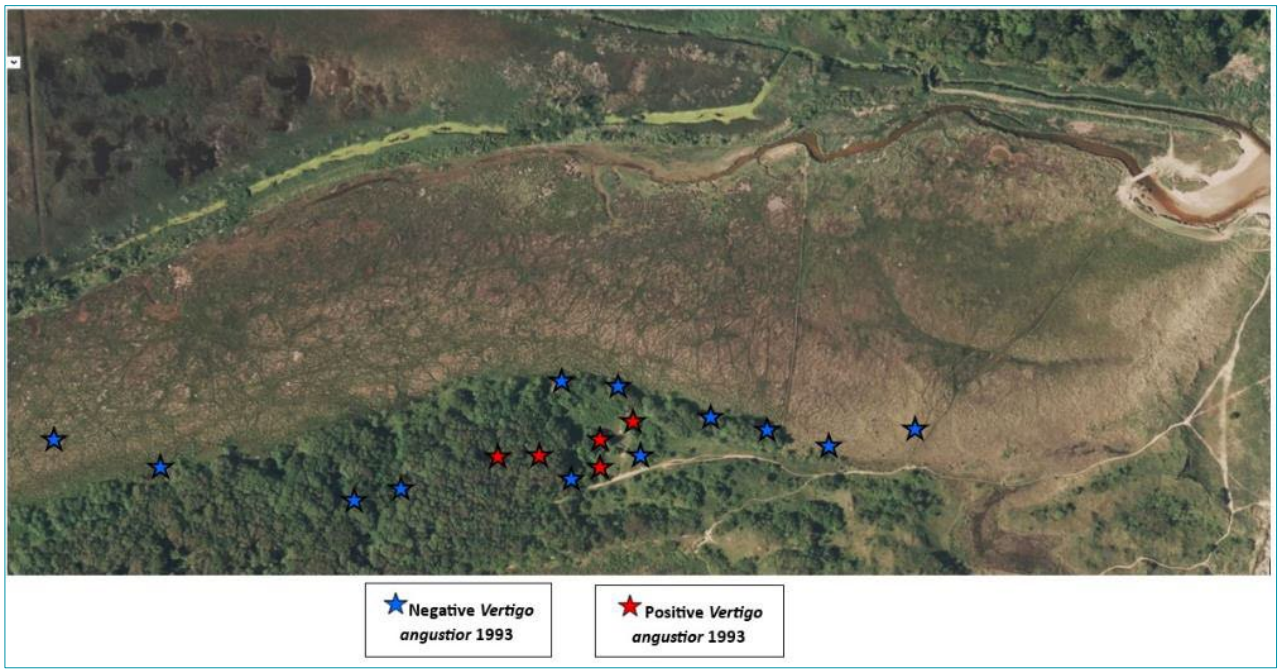

Figure 12. Survey site locations estimated from the Oxwich Burrows 1993 survey (Killeen, 1993) and superimposed onto a recent aerial image. This shows that most previous open, unshaded sites (including those supporting *V. angustior*) now lie within shading woodland and scrub.

Following the unexpected discovery of *V. angustior* in six *Salix repens* dominated dune slacks in the central / northern areas of Whiteford Burrows in 2021 (Willing, 2023), this habitat was also investigated at Oxwich. Eight slacks were surveyed but *V. angustior* was only recorded in low numbers in one (Site 16). It is not clear why the snail was not present more widely but perhaps they were generally drier than those at Whiteford. A dip well study of selected slacks in the two areas might resolve the situation).

Additionally, an opportunistic sample (Site OB1; see image in Appendix 10) taken from fixed dunes at the extreme north-eastern end of the Oxwich dunes unexpectedly produced numerous live *V. angustior* from a *Ammophila arenaria-Festuca rubra* dune site (NVC: SD15b) lying above and away from the salt marsh transition zone.

An overview map (Figure 13) shows the restricted nature of all Oxwich surveys prior to 2022 and the focus on the central northern salt marsh / sand dune transition zone.

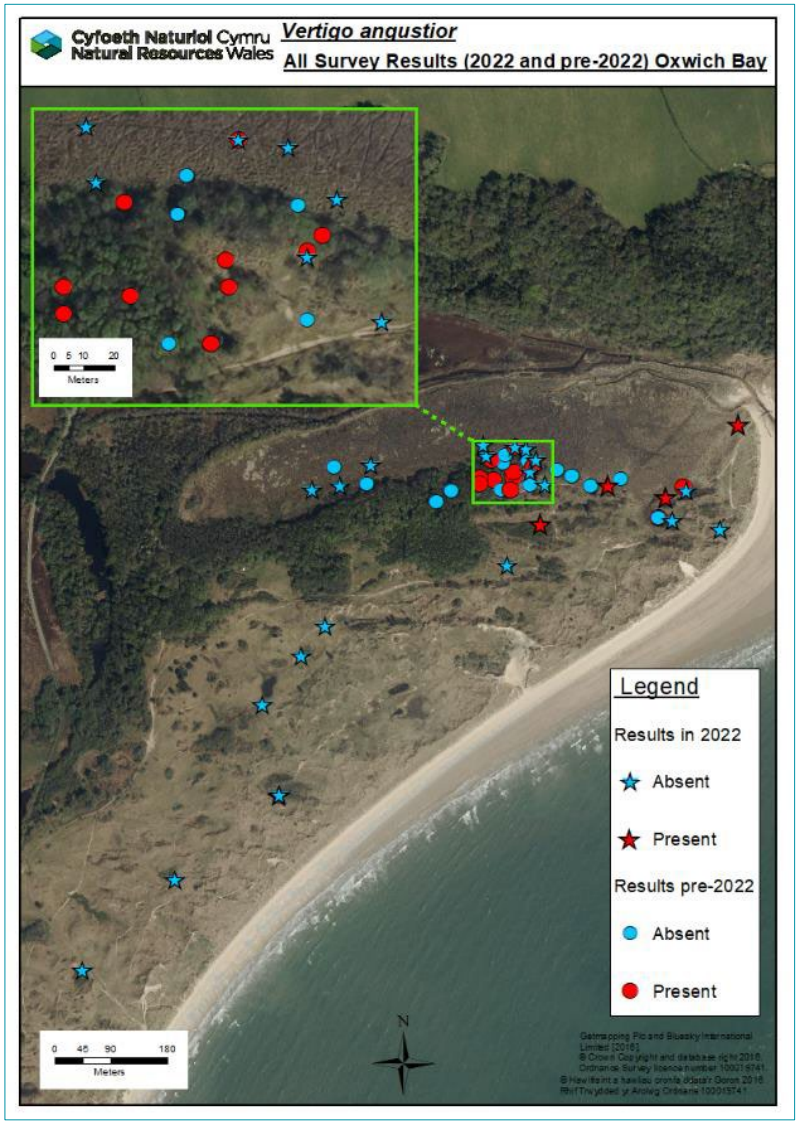

Figure 13. A summary overview map of Oxwich Burrows *Vertigo angustior* surveys 1983 – 2022.

4.2 Whiteford Burrows

The 2022 Whiteford Burrows surveys further sampled dune slack habitats within the main body of the dunes away from the eastern saltmarsh – sand dune transition zone. *V. angustior* was found in an additional four *Salix repens* dominated dune slacks (see images in Appendix 11). Unlike the 2021 Whiteford survey, the snail was not found at three sites lying beneath or close to conifers.

It is unclear why *V. angustior* is present in some Whiteford dune slacks but absent from other, seemingly similar ones close by. It may be that a metapopulation situation exists such that, as conditions fluctuate in particular slacks (often essentially isolated from adjacent slacks) *V. angustior* may die out or numbers fall to very low levels. With improved conditions, populations 'bounce back' either from a very low base or by colonisation from adjacent slacks. Two factors are likely to greatly assist with the latter process. Firstly, these tiny snails are little bigger than a sand grain and so are readily transported by wind, with Whiteford Burrows being exposed to the force of predominantly westerly winds. The transport of *V. angustior* by wind was demonstrated by Quick in 1925 (Quick, 1926) who found all Oxwich specimens of the snail in allochthonous wind-blown pockets of shells in the dunes. Secondly, *V.angustior* is able to self-fertilise so that a single snail blown into a site has the potential to establish a new population.

4.3 Llangennith Burrows

No *V. angustior* specimens were recovered from the ten Llangennith Burrows survey locations. These focussed on dune hollows, most of which were identified as potential survey locations due to the presence of *Salix repens* (see images in Appendix 12). The molluscan communities recorded generally reflect conditions that are probably too dry throughout the year to support *V. angustior.* The survey sites were mostly situated high in the dunes in slacks that may not regularly flood, unlike the low-lying Whiteford Burrows ones which support the snail.

4.4 Overall conclusions from the 2022 survey

The 2022 Whiteford and Oxwich results further demonstrate that in these areas *V. angustior* lives in a wider range of habitats than believed to be the case prior to 2021. Surveys in that year (Willing, 2023) discovered the snail more widely at Whiteford than in the narrow range of typically *Iris* dominated plant communities vegetational communities present in the saltmarsh / sand dune transition zone (e.g. NVC M28 [*Iris pseudacorus - Filipendula ulmaria* mire*, Juncus* spp. sub-community] and MG11 [*Festuca rubra - Agrostis stolonifera – Potentilla anserina* grassland]) as described by Fowles (1998) and Fowles & Guest (2006).

Thus Fowles (1988) states that "*at both of its Welsh sites V. angustior chiefly occupies a narrow transition zone between the saltmarsh and dune biotypes*". This is now known not to be the case. In 2022, *V. angustior* was found at Whiteford as in 2021 (Willing, 2023) in

sand dune slack habitats (NVC communities: SD14b, SD16 & SD16b), whilst at Oxwich as well as presence in a single dune slack (SD15B) it was also found in both fixed and semi-fixed dunes (SD8 & SD7d respectively). Thus, in the period 2018 – 2022, *V. angustior* has been recorded at Whiteford Burrows and Oxwich Burrows in a wide range of community types (Table 1).

Table 1. NVC communities found to supporting *V. angustior* at Oxwich Burrows and Whiteford Burrows in surveys from 2018 to 2022.

Habitat	Approximate no. of sites supporting *V. angustior*
SAND DUNES. **SD7d:** *Ammophila arenaria-Festuca rubra* semi-fixed dune community, *Elymus pycnanthus* sub-community.	1
SAND DUNES. **SD8**: *Festuca rubra-Galium verum* fixed dune grassland (+ sub-community).	4
SAND DUNES. **SD14b**: *Salix repens-Campylium stellatum* dune-slack community, *Rubus caesius-Galium palustre* sub-community.	1
SAND DUNES. **SD15**: *Salix repens-Calliergon cuspidatum* dune-slack community (plus sub-communities).	5
SAND DUNES. **SD16**: *Salix repens-Holcus lanatus* dune-slack community (inc: *Rubus caesius* sub-community).	9
WOODLAND. **W1**: *Salix cinerea-Galium palustre* woodland.	2
MIRE: **M22a**: *Juncus subnodulosus - Cirsium palustre* fen-meadow, typical sub-community.	1
MIRE: **M28a**: *Iris pseudacorus - Filipendula ulmaria* mire*, Juncus* spp. sub-community.	4
SALTMARSH. **SM18**: *Juncus maritimus* salt-marsh community.	4
MESOTROPHIC GRASSLANDS. **MG11**: *Festuca rubra - Agrostis stolonifera – Potentilla anserina* grassland.	Several 2018 & earlier surveys

In many ways, this wider range of Gower habitats found to support the snail is not surprising considering the wide range of habitats supporting the snail elsewhere in Britain and Ireland including dry dune grassland, man-made grassy estuary embankments, limestone pavements, inland grazed fens, saltmarsh / terrestrial transition zones (discussed in greater detail in Willing [2023]). The wide vegetation community tolerance of *V. angustior* can usefully be summarised by a statement written by Robert Cameron (2003) .... "*a review of the literature shows that there are no consistent associations with particular plant communities but rather with a particular combination of environmental*

conditions. These include permanent dampness without inundation, herbaceous or other cover supplying litter and friable refuges, not dense grazed turf with a tough root mat and relative openness rather than heavy shade cast by trees or very dense tall herbs".

4.5 Conservation considerations

The exposed westerly location of the Whiteford dunes closely resemble oceanic sites in western Ireland such as at Doughmore, Co. Clare (Moorkens & Gaynor, 2003) although Oxwich Burrows arguably less so, due to its relatively sheltered easterly-facing situation (lying further east on the relatively more sheltered southern Gower coast). *V. angustior* has been found living in the Doughmore dunes in a wide variety of closely associated habitats including (in decreasing order of *V. angustior* frequency); (1) fixed dunes, (2) 're-shaped' dunes, (3) dune slacks, (4) mown grassland, (5) wetland (with *Iris*), (6) improved dune grassland and (7) mobile dunes. *V. angustior* numbers were monitored by Moorkens & Gaynor in several habitats at Doughmore over the two successive years; in 2000 which experienced unusually dry conditions and then in 2001 which, by contrast, was an exceptionally wet year. They found that in the dry year the largest *V. angustior* numbers were recorded in the 'wet' habitat with proportionately low numbers in the 'dry' habitat. Conversely, in the following 'wet' year results had reversed with proportionately higher numbers of the snail in the 'dry' habitat and lower numbers in the 'wet' (Table 2).

Table 2. *Vertigo angustior* recorded in two habitats at Doughmore, Co. Clare (adapted from Moorkens & Gaynor, 2003). Numbers represent selected examples of shells m^{-2}

YEAR	2000 - 'DRY' YEAR	2001 - 'WET' YEAR
FIXED DUNE (A2)	325	875
FIXED DUNE (B3)	25	75
WETLAND	850	175

Based on this study, Moorkens & Gaynor (2003) suggest that for the successful conservation of *V. angustior* it is important, where possible, to maintain a mosaic of habitats. They state that "*Experiences in this dune system suggest that the wetland areas may be critical to V. angustior, such that in dry years, the snail may find refuge in the wetland areas. Conversely, in very wet years, when the wetland areas are too wet for this species, the dune element becomes essential habitat. Thus, both habitat types may be required to ensure long-term survival of a population in this climate"* (= western, oceanic). The possibly widespread presence of *V. angustior* at Whiteford may, at least in part, be due to the habitat mosaic that exists there including numerous dune slacks, some that regularly flood in winter and steep dry dunes. The dune sides are oriented in different directions; the slopes facing east and north possibly maintaining cooler, more humid conditions (and so better suited to maintain V*. angustior* populations) than on the drier and warmer southerly and westerly facing slopes.

4.6 Further work in 2023

4.6.1 Oxwich & Nicholaston Burrows

Both salt marsh / sand dune transition zone and *Salix repens* dominated dune slacks were adequately surveyed at Oxwich in 2022 making surveys of these habitats a low priority in 2023. As *Vertigo angustior* were found in 2022 in 'good numbers' in a fixed fore dune community at Oxwich, then this habitat (not previously suspected as supporting the snail there) should be more extensively surveyed at Oxwich in 2023. Additionally, as Nicholaston Burrows lies immediately to the east of Oxwich Burrows (only separated from them by a small outflow stream) then a survey of a selection of dune habitats there in 2023 is justified. The western end of Nicholaston Burrows also lies relatively close to the Oxwich Site 1 which produced a large number of *V. angustior* in 2022.

4.6.2 Whiteford Burrows

The further discovery of 'good' populations of *V. angustior* in dune slacks at Whiteford Burrows suggests that this habitat should be more extensively surveyed in 2023, focussing upon areas toward the north of the dunes that have not yet been visited. Additionally, a sequential series of transect samples taken up the southern and northern facing slopes of dunes bordering one of the *V. angustior* occupied dune slacks (such as 2022 Whiteford Site 7) might determine the extent to which the snail lives on the dune slopes bordering occupied slacks.

4.6.3 Other dune sites on Gower: Three Cliffs Bay, Swansea Dunes & Llangennith Burrows

Further to the east of Nicholaston Burrows (although not connected to them) lie a small number of dunes at Three Cliffs Bay which would merit trial sampling; the area has not been investigated previously for the presence of *V. angustior*.

Aerial photographs indicate that a narrow line of dunes lie above the beach immediately to the east of Swansea University, possibly close to where Jeffreys first recorded dead *V. angustior* in 1830 (Jeffreys, 1830) becoming the type locality for the species. As no molluscan survey is believed to been undertaken in this area then one is proposed for 2023.

As a representative series of potential *V. angustior* sites were surveyed in Llangennith Burrows in 2022 all failing to produce the snail, then no further visits to the area are suggested in 2023.

4.6.4 Vacuum sampling trial

John Harper successfully recovered *V. angustior* using a vacuum sampler at Oxwich Burrows, Whiteford Burrows and in Pembrey Forest and open dunes (Harper, 2007, 2014). A comparison of bulk sampling with vacuum sampling is suggested for several sites at

Whiteford Burrows and / or Oxwich Burrows to investigate which, if either, is the more effective *V. angustior* sampling technique.

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Additionally, various NRW staff gave support on some of the survey visits. Thus, Cat Hammond assisted with visits to all three survey areas, Laura Brooks and Sue Westwood attended the Whiteford Burrows day whilst Kristina Jenkins joined the final day of the Llangennith Burrows work. Finally, I am also further indebted to Cat for assistance in constructing survey maps.

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Appendix 1. Molluscs recorded at Oxwich Burrows from 1st to 4th October 2022

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19A	19B	20	21A	21B	22	23
V. angustior Adult (L)	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
V. angustior Juvenile (L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-
V. angustior Fresh dead	5	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V. angustior Weathered dead	2	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthinula aculeata	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-
Aegopinella pura	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-
Carychium minimum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	12	-	51	2	-	-	-	-	-
Carychium tridentatum	-	-	-	-	-	-	-	-	-	-	-	1	-	-	4	4	-	-	-	-	-	-	-	-	-
Cepaea nemoralis	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	1	-	-	-
Cepaea sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-
Clausilia bidentata	2	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	4	-	2	-
Cochlicopa lubrica	7	-	1	-	2	3	-	-	-	-	-	10	1	4	6	4	6	-	10	-	2	2	2	-	-
Euconulus fulvus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nesovitrea hammonis	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Oxychilus alliarius	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Punctum pygmaeum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-
Trochulus hispidus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	2	-	-	-	-	-	-	-	-
Vertigo antivertigo	-	-	-	-	-	3	-	7	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	8	17
Vertigo pygmaea	5	-	8	-	1	-	-	-	-	-	-	2	-	1	-	-	1	1	-	1	4	2	2	-	-
Vitrea sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Xeroplexa intersecta	2	-	3	7	5	1	-	-	-	-	-	-	1	-	-	-	1	-	1	-	2	2	1	-	-

Appendix 2. Molluscs recorded at Whiteford Burrows on 4th October 2022

Species	1	2	3	4A	4B	5	6	7	8
V. angustior Adult (L)	-	-	-	1	-	-	18	20	2
V. angustior Juvenile (L)	-	-	-	-	-	-	-	2	-
V. angustior Fresh dead	-	-	-	2	1	-	1	6	-
V. angustior Weathered dead	-	-	-	-	-	-	-	6	-
Carychium minimum	-	-	-	-	-	-	5	-	1
Cochlicopa lubrica	-	-	-	13	5	5	18	54	13
Columella edentula	2	-	1	4	-	-	-	-	-
Monacha cantiana	-	-	-	2	1	1	1	3	2
Oxychilus alliarius	1	-	-	-	-	-	-	-	-
Punctum pygmaeum	-	-	-	5	11	-	13	4	1
Trochulus hispidus	-	-	-	3	8	-	4	-	6
Vertigo antivertigo	-	-	-	1	-	-	-	-	-
Vertigo pygmaea	-	-	-	1	-	1	3	6	2
Vallonia costata	-	-	-	2	-	-	-	-	-
Vallonia pulchella	-	-	-	5	5	-	9	5	4
Vallonia excentrica	-	-	-	2	-	-	1	-	-
Vallonia sp.	-	-	-	5	7	-	7	1	1
Vitrina pellucida	-	-	-	3	-	-	-	1	-
Xeroplexa intersecta	-	-	-	-	-	-	2	3	-

Appendix 3. Molluscs recorded at Llangennith Burrows on 3rd and 6th October 2022

Species	1	2	5	6	7	8	9	10
Acanthinula aculeata	-	-	1	-	-	-	-	-
Aegopinella nitidula	1	-	-	-	-	-	-	-
Carychium minimum	-	9	-	-	-	-	-	-
Cepaea nemoralis	-	-	5	-	-	-	-	1
Cepaea hortensis	1	-	-	-	-	-	-	-
Cepaea sp	-	-	-	-	-	-	1	-
Cochlicopa lubrica	8	8	9	8	5	-	2	1
Cochlicella acuta	-	-	-	-	3	-	-	-
Cochlicella barbara	-	-	-	-	3	7	3	1
Columella edentula	-	-	2	-	2	-	-	1
Cornu aspersum	-	1	-	-	-	-	-	-
Oxychilus alliarius	1	-	-	-	-	-	-	-
Trochulus hispidus	-	-	-	-	-	-	-	1
Vertigo pygmaea	-	-	4	3	1	-	-	-
Vitrina pellucida	-	-	-	-	-	1	-	-
Xeroplexa intersecta	-	-	1	6	-	-	-	-

Appendix 4. NVC plant communities recorded at Oxwich Burrows, Whiteford Burrows and Llangennith Burrows in October 2022

NVC	NVC description
M27	*Filipendula ulmaria-Angelica sylvestris* tall-herb fen
MG12	*Festuca arundinacea* grassland
SD7	*Ammophila arenaria-Festuca rubra* semi-fixed dune community
SD7d	*Ammophila arenaria-Festuca rubra* semi-fixed dune community (*Tortula ruraliformis* subcommunity)
SD8	*Festuca rubra-Galium verum* fixed dune community
SD14b	*Salix repens-Campylium stellatum* dune-slack (*Rubus caesius-Galium palustre* subcommunity)
SD15b	*Salix repens-Calliergon cuspidatum* dune-slack (*Equisetum variegatum* subcommunity)
SD15c	*Salix repens-Calliergon cuspidatum* dune-slack (*Carex flacca-Pulicaria dysenterica* subcommunity)
SD15d	*Salix repens-Calliergon cuspidatum* dune-slack (*Holcus lanatus-Angelica sylvestris* subcommunity)
SD16	*Salix repens-Holcus lanatus* dune-slack
SD16b	*Salix repens-Holcus lanatus dune*-slack (*Rubus caesius* subcommunity)
SM16	*Festuca rubra* salt-marsh community
SM18	*Juncus maritimus* salt-marsh community
W1	*Salix cinerea-Galium palustre* woodland

Appendix 5. NVC plant communities associated with *Vertigo angustior* locations at Oxwich Burrows and Whiteford Burrows in October 2022

Site	NVC	NVC description
Whiteford Site 4a	SD14b	*Salix repens-Campylium stellatum* dune-slack (*Rubus caesius-Galium palustre* subcommunity)
Whiteford Site 6	SD16b	*Salix repens-Holcus lanatus* dune-slack (*Rubus caesius* subcommunity)
Whiteford Site 7	SD16	*Salix repens-Holcus lanatus* dune-slack
Whiteford Site 8	SD16	*Salix repens-Holcus lanatus* dune-slack
Oxwich Site 1	SD7d	*Ammophila arenaria-Festuca rubra* semi-fixed dune community (*Tortula ruraliformis* subcommunity)
Oxwich Site 3	SD8	*Festuca rubra-Galium verum* fixed dune community
Oxwich Site 16	SD15b	*Salix repens-Calliergon cuspidatum* dune-slack (*Equisetum variegatum* subcommunity)
Oxwich Site 21a	SM18 / SD8	*Juncus maritimus* salt-marsh community (Festuca rubra-Galium verum fixed dune community)

Appendix 6. Assessment of plant frequencies and abundance

Plant frequency and abundance ratings are based upon an approximate DAFOR scale where:

1. Species listed as **Rare** are likely to be present in less than 20% of samples (2m x 2m) within the stand of vegetation;
2. Species listed as **Occasional** are likely to be present in 20-59% of samples within the stand;
3. Species listed as **Frequent** are likely to be present in at least 60% of samples, but are not are not typically at high covers (above 20%);
4. Species listed as **Abundant** make up more than 20% of the cover at, at least, 60% of sample locations but are not prominent enough to be considered **Dominant**;
5. Species listed as **Dominant** make up more than 50% of the cover at least 60% of locations within the stand.

Where a taxon has a particularly uneven distribution or abundance within an otherwise homogeneous stand of vegetation, a second local DAFOR value has been provided after a */*. See Appendices 7 to 9.

Appendix 7a. Records of prominent plant species from *Vertigo* sampling sites in frontal dune habitats at Oxwich Burrows in 2022

D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare.

Species	Site 1	Site 20
Ammophilla arenaria	A/D	F
Carex arenaria	F	F
Elymus cf. junceiformis	A	O/F
Festuca rubra	A/D	A
Oenothera sp.	O	F
Poa humilis	F	F
Rubus caesius	O	A
Avenula pubescens	-	F
Eryngium maritimum	F	-
Homalothecium lutescens	-	A
Hypnum cupressiforme lacunosum	-	O/A
Ononis repens	-	F
Plantago lanceolata	-	F
Polypodium cf. interjectum	-	A
Rosa spinosissima	-	A
Thymus drucei	-	O/A
Sward height range cm	25-40	20-40
Main NVC community	SD7	SD7
Associated NVC types	-	SD8

Appendix 7b. Records of prominent plant species from *Vertigo* sampling sites in fixed dune habitats at Oxwich Burrows in 2022

D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare.

Species	Site 3	Site 4	Site 5	Site 6A	Site 6b
Festuca rubra	F	F	F	F/A	F/A
Leontodon saxatilis	F	F	F	F	-
Plantago lanceolata	F	F	-	F	F
Carex arenaria	F	F	F	-	-
Centaurium erythraea	F	F	-	F	-
Hypochaeris radicata	F	-	F	F	-
Juncus maritimus	F/A	O/A	-	-	O
Poa humilis	-	F	F	-	F
Ranunculus acris	F	-	-	A	F
Anthoxanthum odoratum	-	-	F	F	-
Calliergonella cuspidata	-	-	-	F/A	A
Cerastium fontanum	F	-	-	F	-
Cladonia sp	-	F	F	-	-
Elymus cf. junceiformis	-	A	-	F	-
Euonymus europaeus	O	-	-	A	-
Holcus lanatus	F	-	-	F	-
Hypnum cupressiforme lacunosum	-	A	-	F	-
Jacobaea vulgaris	O	-	F		-
Lotus corniculatus	-	-	-	F	F
Ononis repens	-	F/A	F	-	-
Polygala vulgaris	-	F	-	F	-
Rosa spinosissima	-	O	F/D	-	-
Rubus caesius	-	-	F/A	F	-
Taraxacum officinale agg.	F	-	-	-	F
Trifolium repens	-	-	-	O	F
Agrostis stolonifera	-	-	-	-	F/A
Arenaria serpyllifolia	-	-	F	-	-
Elymus cf. antherica	A/D	-	-	-	-
Geranium sangineum	-	-	-	F	-
Homalothecium lutescens	-	-	D	-	-
Juncus cf. articulatus	-	-	-	-	F
Juncus effusus	-	-	-	-	F
Phleum arenaria	-	-	F	-	-

Species	Site 3	Site 4	Site 5	Site 6A	Site 6b
Pilosella officinarum	-	-	F	-	-
Potentilla anserina	-	-	-	-	F
Pulicaria dysenterica	-	-	-	-	F
Syntrichia ruraliformis	-	-	F/A	-	-
Vulpia fasiculata	-	-	F	-	-
Sward height range cm	10-20	5-15	0-5 (30)	5-10	5-15 (500)
Main NVC community	SD8	SD8/MC9	SD19	SD8	W6
Associated NVC types	SM18	SM18	-	-	SM18/ M23b

Appendix 7c. Records of prominent plant species from *Vertigo* sampling sites in upper saltmarsh habitats at Oxwich Burrows in 2022

D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare.

Species	Site 2	Sites 7, 9 & 10	Site 8	Site 11	Site 21	Site 22	Site 23
Agrostis stolonifera	A	F/A	D	A/D	A	F/A	F/D
Juncus maritimus	A	D	F	F/A	A	D	O/D
Festuca rubra	F	F/A	-	F	A	F/A	-
Elymus antherica	A	F/A	F	-	A	F	-
Oenanthe lachenalii	F	F	-	F	F	F	F
Kindbergia praelongum	F	-	-	F	F	-	-
Potentilla anserina	-	-	-	F	O/F	-	F/A
Iris pseudacorus	-	-	F	F	-	-	F/A
Mentha aquatica	-	-	F	F	-	-	F
Pulicaria dysenterica	-	-	-	F	O/F	-	F/D
Centaurium erythraea	F	-	-	-	F	-	-
Elymus junceiformis	-	-	-	F	-	-	F
Holcus lanatus	-	-	-	F	F	-	-
Samolus valerandii	-	-	-	F	-	-	F
Phragmites australis	-	-	-	-	-	F	F
Lotus pedunculatus	-	-	-	F/A	-	-	F/A
Lythrum salicaria	-	-	-	F	-	-	F
Carex extensa	-	F	-	-	-	F	-
Juncus gerardii	-	-	-	-	-	F	O/A
Lysimachia maritima	-	F/A	-	-	-	F/A	-
Sward height range cm	30-40	50-70	2-5 (40)	4-10 (60)	50-60	40-70	50-60 (1-3)
Main NVC community	SM18	SM18	SM18	SM18	SM18	SM18	MG12

Species	Site 2	Sites 7, 9 & 10	Site 8	Site 11	Site 21	Site 22	Site 23
Associated NVC types	-	-	-	-	SD8	-	SM18, SM16

Appendix 7d. Records of prominent plant species from *Vertigo* sampling sites in dune slacks at Oxwich Burrows in 2022

D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare.

Species	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19
Rubus caesius	A	A	A	D	A	A	A	F
Salix repens	D	A/D	D	A	D	A	D	A
Agrostis stolonifera	F	O/F	-	F/A	F	A	A	F
Festuca rubra	F/A	F/A	A	F/A	F	F	-	F
Lotus corniculatus	F	F	F	-	O/F	F	F	F
Carex flacca	F	F	-	-	F	F	F	F
Pseudoscleropodium purum	F	F	F	-	F	F	F	-
Betula pubescens	O/F	-	F	F/A	F	-	F/A	-
Danthonia decumbens	F	F	F	-	-	F	-	F
Holcus lanatus	-	F	F	F/A	F	-	-	F
Plantago lanceolata	F	F	F	F	-	F	-	-
Ranunculus acris	F	F	-	-	-	F	F	F
Anthoxanthum odoratum	F	F	F	-	F	-	-	-
Calliergonella cuspidata	F	-	-	-	F/A	F	A	-
Carex arenaria	-	-	-	O/F	O/F	F	F	-
Agrimonia sp.	-	F	F	-	F	-	-	-
Brachythecium rutabulum	F	-	-	F	F	-	-	-
Euphrasia officinale agg.	F	-	-	F	-	-	-	F
Juncus maritimus	-	O/F	-	F/A	F/R	-	-	-
Linum catharticum	F	F	-	-	-	-	P	-
Quercus sp. sapling	O/F	-	-	F	F	-	-	-
Rhinanthus minor	F	-	-	-	-	-	F	F
Taraxacum officinale agg.	-	F	-	-	-	F	-	F
Trifolium pratense	F	F	-	-	-	-	F	-
Geranium sangineum	-	-	O/F	F/A	-	-	-	-
Filipendula ulmaria	-	-	-	A/D	-	-	-	-
Sward height range cm	5-20	10-20	10-60	30-70	30-70	10-15	20-40	5-40
Main NVC community	SD16b	SD16b	SD16b	SD16b	SD15b	SD15b	SD15b	SD15b
Associated NVC types	-	-	-	M27	-	-	-	-

Appendix 8. Records of prominent plant species from *Vertigo* sampling sites in dune slacks at Whiteford Burrows in 2022

D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare.

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Lotus corniculatus	O/F	F	-	F	O/F	O/F	F	F
Salix repens	F	A	F	A/D	A/D	A/D	A	A/D
Festuca rubra	-	F	F	F	A	F/A	A	F/A
Rubus caesius	F/A	A	A	F/A	F	F	F	-
Pseudoscleropodium purum	F	F/A	F/A	-	F	F/A	F	-
Holcus lanatus	-	-	-	O/F	F	F	F	F
Anthoxanthum odoratum	-	F	O/F	-	F	F	-	-
Calliergonella cuspidata	-	-	-	O/F	F	-	F	-
Plantago lanceolata	F	-	-	O/F	-	-	-	F
Potentilla anserina	-	-	-	F	F	O/F	-	-
Brachythecium rutabulum	-	F	-	-	-	F	-	-
Danthonia decumbens	-	-	-	-	-	F	-	F
Kindbergia praelongum	A	F	-	-	-	-	-	-
Trifolium pratense	-	-	-	R/O	-	-	-	F
Equisetum variegatum	-	-	-	-	O/F	-	-	-
Juncus maritimus	-	-	-	-	-	-	-	R/A
Ligustrum vulgare	F/D	-	-	-	-	-	-	-
Salix cinerea	O/D	O	-	-	0	-	-	-
Scorzoneroides autumnalis	-	-	-	O/F	-	-	-	-
Sward height range cm	50-100 (250)	2-60 (200)	15-40 (250)	8-25 (50)	2-30 (250)	20-35	?	10 - 30
Main NVC community	SD16b	SD16b	SD16b	SD14b	SD14b	SD16b	SD16	SD16
Associated NVC types/other mosaic components	W1	SD8	W1:SD8	SD16:W1	SD16:W1	-	SD8	-

Appendix 9a. Records of prominent plant species from *Vertigo* sampling sites in dune slacks at Llangennith Burrows in 2022

D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare.

Species	Site 1	Site 2	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Rubus caesius	D	A	F	A/D	F/A	A/D	A	A
Carex arenaria	F	F	F	F	O/F	R/F	O/F	-
Salix repens	D	D	D	-	A	R/D	D	D
Festuca rubra	F	-	A	-	F/A	O/F	O/F	F/A
Agrostis stolonifera	A	-	-	A/D	F	F	-	A
Ammophilla arenaria	F	-	F/R	-	O/F	R/F	-	-
Salix cinerea	O/D	O/D	R/D	F	-	-	-	-
Dactylis glomerata	-	-	-	F	F	-	-	-
Holcus lanatus	-	-	-	-	F	F/A	-	-
Phragmites australis	-	F	-	-	-	-	-	F/A
Poa trivialis	-	-	F	-	-	F	-	-
Plantago lanceolata	-	-	-	-	F	F	-	-
Hydrocotyle vulgaris	-	F	-	-	-	-	-	F
Pulicaria dysenterica	-	-	-	-	F	F/A	-	-
Calliergonella cuspidata	-	-	-	F	-	-	-	D
Mentha aquatica	-	-	-	-	-	-	F	-
Carex flacca	-	-	-	-	-	-	-	F
Eupatorium cannabinum	-	-	-	O/D	-	-	-	-
Hippophae rhamnoides	-	-	-	O/D	-	-	-	-
Iris pseudacorus	-	-	-	-	-	O/A	-	-
Juncus maritimus	-	-	-	-	-	-	O/A	-
Potentilla anserina	-	-	-	-	-	-	-	F
Sward height range/ cm	30-40 (150-300)	50-70	20-30 (130)	40-50 (500)	30-50 (350)	30-50	50-90	15-30
Main NVC community	SD16b	SD15d	SD16b	W1	SD16	Cut scrub	SD16b	SD15c
Associated NVC types/other mosaic components	W1	W1	W1	SD16	W1 & SD8	-	-	-

Appendix 9b. Records of prominent plant species from *Vertigo* sampling sites in fixed dune grassland at Llangennith Burrows in 2022

D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare.

Species	Site 3	Site 4
Carex arenaria	F	F
Festuca rubra	A	F
Geranium sangineum	D	F
Lotus corniculatus	F	F
Agrostis stolonifera	F	-
Anthylis vulneraria	F	-
Dactylis glomerata	-	A
Galium verum	F	-
Hypochaeris radicata	F	-
Kindbergia praelongum	F	-
Plantago lanceolata	-	F
Poa humilis	F	-
Polygala vulgaris	F	-
Pseudoscleropodium purum	A	-
Ranunculus acris	-	F
Ranunculus bulbosus	-	F
Rhinanthus minor	F	-
Rosa spinosissima	-	F/A
Rubus caesius	-	A
Taraxacum officinale agg.	F	-
Veronica chamaedrys	-	F
Vicia sativa	-	F
Main NVC community	SD8	SD8
Sward height range cm	5-15	5 -30

Appendix 10. Site locations and summary habitat descriptions at Oxwich Burrows

Site OB1. SS 51387 87799
Yellow dune dominated by mixtures of *Ammophila*, *Festuca rubra* and *Elymus* cf. *junceiformis*. *Carex arenaria*, *Eryngium maritimum*, *Ononis repens* are among a limited range of vascular associates. The sward is roughly 25-40cm tall and relatively closed with only very local patches of shorter turf and/or bare sand visible and little or no bryophyte cover. Site NVC: SD7d. *Vertigo angustior* present.



Site OB2. SS 51308 87698
Upper saltmarsh vegetation in which *Juncus maritimus*, *Agrostis solonifera*, *Festuca rubra*, *Elymus repens* and *Elymus* cf. *athericus* are the most prominent species forming a mostly closed sward around 30-40cm tall. *Oenanthe lachenalii*, *Centaurium erythraea* and *Blackstonia perfoliata* are among the more frequent forbs. There is little or no exposed bare ground and *Kindbergia praelongum* is the only frequent bryophyte. Site NVC: SM18.



Site OB3. SS 51269 87691
A grassy tump on the upper edge of the saltmarsh. *Elymus* cf. *antherica*, *Festuca rubra*, *Carex arenaria* and to a lesser extent *Taraxacum*, *Leontodon saxatilis* and *Plantago lanceolata* are among the most prominent species in a mostly closed sward, roughly 10-20cm tall. *Juncus maritimus* is also locally abundant where the drier ground grades into the saltmarsh. Bryophytes including *Kindbergia* and *Brachythecium* cf. *rutabulum* are frequent at low covers and bareground is rare.
Site NVC: SD8 with SM18 associate. *Vertigo angustior* present.



Site OB4. SS 51284 87651
The bulk sample was collected from a dry bank in the transition zone between the upper saltmarsh and sand dune. The vegetation here is short (5-15cm tall) and relatively open with relatively high covers of mosses and lichens (notably *Hypnum lacunosum* and *Cladonia* spp.). Prominent vascular plants include, *Festuca rubra*, *Elymus* cf. *junceiformis*, *Poa humilis*, *Ononis repens*, *Centaurium erythraea*, *Sedum acre* and *Sagina nodosa*.
Site NVC: SD8/MC9 with SM18 associate.



Site OB5. SS 51086 87706
A sandy bank with patchy bare-ground and high covers of mosses (most prominently *Homalothecium lutescens* and *Syntrichia ruraliformis*) in a mostly short sward (less than 5 cm tall). Annuals including *Phleum arenarium*, *Arenaria serpyllifolia* and *Vulpia faciculata* are frequent alongside a range of other vascular associates including *Festuca rubra*, *Carex arenaria*, *Ononis repens* and *Pilosella officinarum*, while bulkier plants of *Rosa spinosissima* and *Rubus caesius* become dominant in taller less open vegetation away from the main bank. Site NVC: SD19.



Site OB6. SS 51065 87743
A dry bank which is part shaded by taller *Rhamnus* and *Euonymus europaeus* scrub. *Rubus caesius*, *Geranium sangineum* and *Dactylis glomerata* are among the more frequent species alongside a range of less bulky grasses and forbs (including *Festuca rubra*, *Anthoxanthum odoratum*, *Lotus corniculatus*, *Linum catharticum*, *Polygala vulgaris* and *Rhinanthus minor*) in an ankle high turf (5-10cm). Bryophytes are reasonably well represented with *Calliergonella cuspidata*, *Hypnum* and *Scleropodium purum* frequent and locally abundant. Site NVC: SD8.



Site OB6b. SS 51053 87729
The bulk sample was collected from a damp sward beneath a tall, mostly closed, canopy of *Salix cinerea* and *Alnus glutinosa*. Rushes (*Juncus* cf. *acutiflorus*, *Juncus effusus* and more locally *Juncus maritimus*) are frequent alongside a range of other marshy grassland taxa including *Lythrum salicaria, Mentha aquatica, Pulicaria dysenterica* and *Potentilla anserina*. *Festuca rubra*, *Agrostis stolonifera* and *Poa humilis* are the most frequent grasses while *Calliergonella cuspidata* is prominent in a patchy bryophyte layer.
Site NVC: W6 with SM18/M23b associates.

Site OB7. SS 51051 87763. (and Site 9 - SS 50982 87764 and Site 10 - SS 50803 87736). These three samples were all collected from similar areas of upper saltmarsh vegetation dominated by *Juncus martimus*. *Oenanthe lachenalii, Festuca rubra, Agrostis stolonifera, Lysimachia* (*Glaux*) *maritima* and *Samolus valerandii* are among a small suite of frequent associates in a thigh high sward. Site NVC: SM18.



Site OB8. SS 50990 87755
The bulk sample was collected from an area on the upper edge of the saltmarsh on the margins of a stand of dense *Salix cinerea*. The sward here is mostly short grazed (c 2.5cm tall) dominated by *Agrostis stolonifera* with scattered clumps of taller (c.40cm) *Juncus maritimus* and *Iris pseudacorus* and the occasional tussock of *Juncus acutus*. Poor-fen forbs including *Mentha aquatica, Potentilla anserina* and *Samolus valerandii* are scattered thinly throughout. Site NVC: SM18.



Site OB9. SS 50982 87764
Details: see site 7 above.



Site OB10. SS 50803 87736
Details: see site 7 above.



Site OB11. SS 50754 87707
Variable sward featuring shorter areas dominated by *Agrostis stolonifera* and *Festuca rubra* (mostly 4-10cm tall) and taller more tussocky patches with high covers of *Juncus maritimus* and taller wetland forbs (typically around 60cm high). *Pulicaria dysenterica, Lotus pedunculatus, Lythrum salicaria, Iris pseudacorus, Mentha aquatica* and *Potentilla anserina* are among the prominent herbs. There is patchy scrub (mostly *Salix cinerea* and *S. caprea*) and scattered *Phragmite*s in this area.
Site NVC: SM18.



Site OB12. SS 50625 87356
Slack vegetation in which *Salix repens* and *Rubus caesius* co-dominate, forming a mostly sward at around 5-20cm. *Ranunculus acris*, *Carex panicea*, *C. flacca, Lotus corniculatus, Festuca rubra* and *Danthonia decumbens* are among the more frequent vascular associates, while *Scleropodium purum*, *Bracythecium rutabulum* and *Calliergonella cuspidata* promiment in a patchy bryophyte carpet. The slack includes areas that have recently been cleared of mature scrub and patches of taller more closed *Salix repens*, as well as shorter grass-dominated areas. Site NVC: SD16b.



Site OB13. SS 50706 87445
The sample was collected from a a small rather variable slack. The centre of the slack has been recently cleared of scrub and is now strongly dominated by *Salix repens* and *Rubus caesius* and there are high covers of woody debris and scattered regrowth of *Betula*, *Quercus* and *Salix cinerea*. *Salix repens* and *Rubus caesius* remain abundant around the margins of the slack, but are accompanied by a more diverse mix of associates including *Agrimonia eupatoria*, *Ranunculus acris, Lotus corniculatus, Taraxacum officinale, Festuca rubra* and *Danthonia decumbens*. Bryophytes are generally sparce with only *Scleropodium purum* occurring at high frequency. Site NVC:SD16b.



Site OB14. SS 50732 87478
A small, relatively dry dune hollow, dominated by *Salix repens* in association with abundant *Rubus caesius* and *Festuca rubra*. *Lotus corniculatus, Hypochoeris radicata, Agrimonia eupatoria* and more locally *Geranium sangineum* are among the more frequent herbs, while commoner grasses include *Anthoxanthum odoratum, Danthonia decumbens* and *Holcus lanatus*. Moderate levels of leaf litter are present and *Scleropodium purum* is the only prominent bryophyte. Site NVC: SD16b.



Site OB15. SS 51022 87583
Damp slack with significant scrub (mostly *Betula pubescens*) invasion. *Filipendula ulmaria* and *Juncus maritimus* are locally abundant/dominant alongside *Salix repens* and *Rubus caesius* in a sward that is mostly between knee and thigh high (30-70cm tall). *Agrostis stolonifera, Festuca rubra* and Hocus lanatus are the most prominent grasses while *Lysimachia vulgaris, Eupatorium cannabinum* and *Geranium sangineum* are among the most frequent herbs. Bryophytes are generally sparce. Site NVC: SD16b.



Site OB16. SS 51081 87644
The sample was collected from the margins of a slack which has recently been cleared of dense, but relatively young scrub and regrowth is now abundant from the cut stem bases. The slack is dominated by dense *Salix repens*, with *Rubus caesius* abundant throughout. Tall herbs, most notably *Cirsium palustre* and *Agrimonia eupatoria* and more locally *Angelica sylvestris* are locally prominent alongside a range of shorter grasses and sedges including *Agrostis stolonifera, Festuca rubra, Holcus lanatus* and *Carex flacca*. *Calliergonella cuspidata* is the most prominent bryophyte in an patchy moss carpet. Site NVC: SD15b. *Vertigo angustior* present.



Site OB17. SS 50342 86925
A closed mature dune slack, which appears to have been cleared of scrub and mown leaving a sward at around ankle height (10-15cm tall) dominated by *Salix repens* and to a lesser extent *Rubus caesius*. More frequent associates include a range of grasses, sedges and herbs among them *Festuca rubra, Agrostis stolonifera, Danthonia decumbens, Carex arenaria, Carex flacca, Lotus corniculatus, Leontodon autumnalis* and *Ranunculus acris*. *Scleropodium purum* and *Calliergonella cuspidata* are the most frequent mosses in a patchy bryophyte layer. Site NVC: SD15b.



Site OB18. SS 50488 87083
The bulk sample was collected from the southern margin of a large mature, slack, co-dominated by mixtures of *Salix repens, Rubus caesius* and *Agrostis stolonifera,* which together form a canopy at around calf to knee height (20-40cm). More frequent associates again include a range of grasses sedges and forbs, notably *Agrostis stolonifera, Poa humilis, Carex arenaria, Carex flacca, Lotus corniculatus,Trifolium pratense, Rhinanthus minor, Leontodon autumnalis, Ranunculus acris* and *Agrimonia eupatoria*. *Calliergonella cuspidata* and *Scleropodium purum* are prominent in a reasonably well developed bryophyte layer. The area has recently been cleared of scrub, but again significant regrowth is apparent from cut stumps/stems. Site NVC: SD15b.



Site OB19. SS 50664 87220
A second sample from within the same slack as Site 18. This sample was collected from a more central area in the slack with a more variable sward height ranging from 5-40cm tall. The overall floristic composition is very similar to that described in sample O18 although the cover of *Salix repens* and *Rubus caesius* is less here and shorter growing plants including *Equisetum varigatum* are at least locally frequent. Site NVC: SD15b.



Site OB20. SS 51358 87631
A steeply sloping dune bank supporting vegetation between 20 and 40cm tall. The sward here is co-dominated by mixtures of *Polypodium* cf. *interjectum*, *Rubus caesius*, *Rosa spinosissima* and *Festuca rubra*. Other prominent associates include *Ammophilla arenaria*, *Poa humilis*, *Ononis repens*, *Oenothera* sp. and more locally *Thymus drucei*. Bryophytes are also prominent with *Homalothecium lutescens* and *Hypnum lacunosum* forming a relatively dense under layer, with little or no bare sand visible.
Site NVC: SD7 with SD8 associate.



SiteOB 21. SS 51180 87701
This sample falls in an area of upper, *Juncus maritimus*-dominated, saltmarsh where it grades into shorter, drier sand dune habitat. *Agrostis stolonifera*, *Festuca rubra*, *Elymus* cf. *antherica* and *Oenanthe lachenallii* are among the more prominent species in the taller (50-60cm) *J. maritimus*-dominated areas, while *Scorzoneroides autumnalis*, *Ononis repens* and *Thymus praecox* become more prevalent in areas of shorter drier turf on the edge of the dunes.
Site NVC: SM18 with SD8 associate. *Vertigo angustior* present.



Site OB22. SS 51032 87763
Juncus maritimus dominates this area of saltmarsh vegetation, forming a level canopy at thigh level (50-60cm*). Agrostis stolonifera*, *Festuca rubra*, *Juncus gerardii* and *Lysymachia martima* are prominent in a marked understory alongside scattered plants of *Oenanthe lachenallii* and *Carex elongata*.
Site NVC: SM18.



Site OB23: SS 50707 87695
The bulk sample was collected from an intergrading patchwork of vegetation types on the upper edge of the saltmarsh. Patches of very short (1-3cm tall) vegetation dominated by mixtures of *Agrostis stolonifera* and *Juncus gerardii* intersperse stands of taller vegetation (50-80cm) in which robust herbs (including *Pulicaria dysenterica*, *Iris pseudacorus*, *Potentilla anserina*, *Lythrum salicaria* and *Mentha aquatica*) and sprawlers (most commonly *Lotus pedunculatus* and *Calystegia sepium*) are abundant. *Juncus maritimus* is abundant or even dominant in some of the taller patches and there is some local encroachment by *Alnus glutinosa* and *Phragmites.*
Site NVC: MG12 with SM18 & SM16 associates.



Appendix 11. Site locations and summary habitat descriptions at Whiteford Burrows

Site WB1. SS 44667 95389
A small, dry, over mature slack within an open area in one of the conifer plantations. Some brash/branches and stems of the dead conifers lies within the slack (I think these have just naturally fallen here, rather than being piled up, but can't be absolutely sure). The vegetation grades into dry dune grassland around the edges of the slack, and the bulk sample included material collected from these drier sections. *Ligustrum vulgare* and *Salix cinerea* (typically around 1m but up to 2.5 m tall) are dominant over half of the slack. *Salix repens* and *Rubus caesius* are abundant over the remaining areas.
Site NVC: SD16b with W1 associate.



Site WB2. SS 44681 95477
A small, dry, mature slack dominated by *Salix repens*. It is split in two by a low dune ridge which supports drier dune grassland. The vegetation is quite closed, and ranges from 2 to 30cm (excluding inflorences) in the smaller section of this slack, and is taller 5 to 60 cm.
Site NVC: SD16b with SD8 associate.



Site WB3. SS 44767 95494
20 to 30 mins search time. Small sized slack dominated by *Rubus caesius* with *Salix repens*, in a small hollow. Scattered *Salix cinerea* and *Betula* trees, which dominate the southern end of the slack. The vegetation on the edge of the slack is drier and *Rubus caesius* is more dominant, alongside grasses (rather than *Salix repens*), *Galium verum*, and F/A *Scleropodium purum* (this area was also included in Martin's bulk sample). Other associates in this dry edge vegetation include *Frageria vesca*, *Ononis repens* (R), *Carex flacca* (O/R) and *Holcus lanatus* (O/R). The vegetation height is up to c. 40cm in the slack (several metres where there are trees), with the drier slack sides around 15cm.
Site NVC: SD16b with W1 & SD8 associates.



Site WB4. (western end of Slack 22) SS 44512 95491
This slack is dominated by *Salix repens* with scattered *Rubus caesius* and *Potentilla anserina*. The vegetation is typically 8 to 25cm but occasionally up to 50cm. The very western end is scrubby with short *Salix cinerea*. Bulk sample taken from main body of the slack but also in the shade of the scrub. Site NVC: SD14b with SD16 & W1 associates.
Vertigo angustior present - found in bulk sample but not in the field.



Site WB5. (eastern end of Slack 22) SS 44565 95475
This is slack 22 on the NRW slack map. (See SW notes which are taken from the same slack). This slack is fenced to ensure better control of the grazing here. The vegetation is predominantly referable to short, closed slack vegetation across the bulk of the slack, and is typically dominated by *Salix repens*. There is a fringe of taller, rank vegetation around the edges. The ground is dry (could just be due to drought this year). *Festuca rubra*, *Potentialla anserina* and *Holcus lanatus* are Frequent. At the southern end there is a fringe of *Salix cinerea* with *Juncus acutus*. The bulk sample includes material collected from underneath these. There is a scatter of *Hippophae* in the north-eastern part of the slack, and on the slope outside of the fenceline. The vegetation height is 2cm to 30 cm (or up to 2.5m along the line of scattered scrub). Site NVC: SD14b with SD16 & W1 associates.

Site WB6. (Slack 25a) SS 44465 95356
The slack was very dry in 2022. The vegetation here consists of a closed sward with no bare ground. It used to be much more open and was where Emma and I recorded *Petalophyllum ralfsii* in the past. The cover of *Festuca rubra* is more prominent here than in Slack 22; this and Salix repens are abundant The vegetation is typically 20 to 35cm tall (excluding inflorescences). Site NVC: SD16b.
Vertigo angustior present - found in bulk sample but not in the field.



Site WB7. (Slack 27) SS 44489 95251
This mature slack was very dry in 2022. The vegetation here consists of a closed sward with no bare ground. The cover of *Festuca rubra* is high (but not as high as where sample 6 was collected). There are a number of small dry hummocks, one of which is where angustior was located in the field. The slack vegetation grades into dry fixed dune grassland moving up the sides of the slack, and *angustior* was also found in a location along this transition. Site NVC: SD16 with SD8 associate.
Vertigo angustior present - found in bulk sample and in the field.



Site WB8. SS 44380 95214
A slack with abundant/dominant by short *Saliex repens* (5 to 10cm) in the central area. Here the vegetation is closed and reasonably species-poor. *Festuca rubra* cover is high around the edges. There are large *Juncus acutus* tussocks along the eastern edge. Site NVC: SD16. *Vertigo angustior* present - found in bulk sample but not in the field.



Appendix 12. Site locations and summary habitat descriptions at Llangennith Burrows

Site LB1. SS 41383 90799
A small, steep sided slack the centre of which is over-topped by a tall, closed canopy of *Salix cinerea*. *Salix repens* and *Rubus caesius* are scattered throughout, dominating on the margins of the slack. *Iris pseudacorus* and *Agrostis stolonifera* are locally frequent under the scrub canopy. Site NVC: SD16b with W1 associates.



Site LB2. SS 41265 90914
A rank ungrazed slack, the margins of which are overtopped by a 2-3m tall canopy of *Salix cinerea* and *Alnus glutinosa*. A dense stand of *Salix repens* and *Rubus caesius* dominates the centre of the slack with an open canopy of *Phragmites* and scattered *Carex* cf. *riparia.* The bulk sample was collected from both the centre and scrubby margins of the slack. Site NVC: SD15d with W1 associates.



Site LB3. SS 41381 92578
A dry dune hollow with abundant *Geranium sanguineum*. *Ammophila arenaria* is occasional alongside a range of other grasses and herbs typical of fixed dune grasslands including *Poa humilis*, *Festuca rubra*, *Agrostis stolonifera*, *Lotus corniculatus*, *Anthylis vulneraria*, *Galium verum* and *Rhinanthus minor*. The sward is fairly short and rather open with a patchy litter layer and abundant *Scleropodium purum*. Samples from this location were sieved and checked by eye on site, but no bulk sample was collected.
Site NVC: SD8.



Site LB4. SS 41327 92749 & SS 41292 92765
A dry depression (not really a slack) with closed, mid-calf dry vegetation (range 5 to 30cm) dominated by coarse grasses with *Rubus caesius* and *Rosa spinissima* and two large *Juncus acutus* tussocks. This site was sieved only, no bulk sample was taken.
Site NVC: SD8.

Site LB5. SS 41323 92900
A steep-sided and relatively dry slack/dune hollow with tall rank *Salix repens* dominated vegetation at one end and dense *Prunus spinosa*, *Salix cinerea* scrub at the other. The slack margins feature locally abundant *Geranium sanguineum* and *Festuca rubra*, with *Rubus caesius* frequent and locally prominent here and in the areas dominated by *Salix repens*. The bulk sample combined material from both the margins and the *Salix repens* dominated areas of the slack. Site NVC: SD16b with W1 associate.



Site LB6. SS 41318 92858
An over-mature slack with tall (c.5m) *Salix cinerea* shrubs covering around one third to half of the slack. The remaining area is a mix of *Hippophae* and *Salix cinerea* (low growing and up to 2.5m), *Chamaenerion*, *Epilobium hirsutum*, *Rubus caesius* and *R. fruticosus*, and *Agrostis stolonifera*. The vegetation across this section is closed and typically 40-50cm tall. Material was also collected vegetation from the surrounding dry grassland, which was largely short, *Festuca rubra* turf with *Thymus*, *Carex arenaria*, *Pilosella*, *Galium verum* and *Scleropodium purum*; there was a fringe of *Salix repens* along the edge of the slack that was also sampled. Site NVC: W1 with SD16 associate.



Site LB7. SS 40909 92601
A mature slack with a small stand of *Salix cinerea* (c.3.5m tall) surrounded by a fringe of *Salix repens* (c. 50cm tall), with *Rubus caesius* and *Festuca rubra*. Here there was a reasonable cover of leaf litter, which was sampled. This grades into areas of drier dune grassland dominated by *Festuca rubra* and *Rubus caesius* c. 30cm tall, with a reasonable list of associated species. Site NVC: SD16 with W1 & SD8 ssociates.



Site LB8. SS 40671 92252
The bulk sample was mostly collected from the margin of a larger slack, targeting an area that appeared to have been recently cleared of taller scrub. *Rubus caesius* is the most abundant species here, with *Iris pseudacorus* and *Pulicaria dysenterica* locally prominent alongside frequent *Holcus lanatus*, *Poa humilis* and *Agrostis stolonifera*. Some material was also collected from an area of closed, dry slack dominated by *Salix repens* and *Rubus caesius*, in which *Festuca rubra*, *Ammophilla* and *Carex arenaria* are among the few frequent associates. Site NVC: non-description as cleared scrub.



Site LB9. SS 41040 91672
A steep-sided slack the center of which is dominated by tall (50-70cm) *Salix repens*. *Rubus caesius* is also abundant and *Juncus maritimus* and *Jucus acutus* are locally prominent while bare-ground and bryophytes are scarce or absent.
The slack margins are dominated by *Salix cinerea* scrub with *Geranium sanguineum*, *Festuca rubra* and *Carex arenaria* becoming prominent on the drier edges.
Site NVC: SD16b.



Site LB10. SS 41057 91815
A closed slack dominated by calf to knee high (30-40cm) *Salix repens*, with *Rubus caesius* and *Phragmites autralis* also prominent. The ground is damper here with *Hydrocotyle vulgaris*, *Potentilla anserina*, *Carex panicea* and *C. flacca* among the more frequent associates, while *Calliergonella cuspidata* forms a lush carpet under the creeping willow canopy. Site NVC: SD15c.



Appendix 13. Previous *Vertigo angustior* surveys at Oxwich Burrows

1924 – 1927: FIRST OXWICH SHELL RECORDS: (Quick 1924, 1925 & 1927).
In 1924, Dr. H.E. Quick found a single freshly dead *V. angustior* shell in a sand dune pocket in association with a mixture of other dead terrestrial, brackish and marine shells including *Vertigo pygmaea, Pupilla muscorum*, *Phytia* (now *Myosotella*) *myosotis* and *Rissoa* sp. (Quick, 1924). The range of habitats suggest a wind-blown mixture. A more detailed survey in 1925 (Quick, 1926) took dead shell samples from 7 sites approximately running north – south through Oxwich Burrows and a total of 9 dead *V. angustior* were recovered from 3 sites (Figure A) where they were associated with a diverse range of shells representing a range of terrestrial and brackish habitats suggesting a wind-blown assemblage including *Pupa muscorum* (= *Pupilla*) *muscorum*, *Pupa* (= *Lauria*) *cylindracea*, *Vertigo antivertigo*, *V. pygmaea*, *Punctum pygmaeum*, *Cochlicella lubrica*, *Vallonia* spp, *Phytia* (= *Myosotella*) *myosotis*, *Helicella caperata* (= *Xeroplexa intersecta*) , *Helicella* (= *Cernuella*) *virgata* and *Helicella barbara* (= *Cochlicella acuta*).

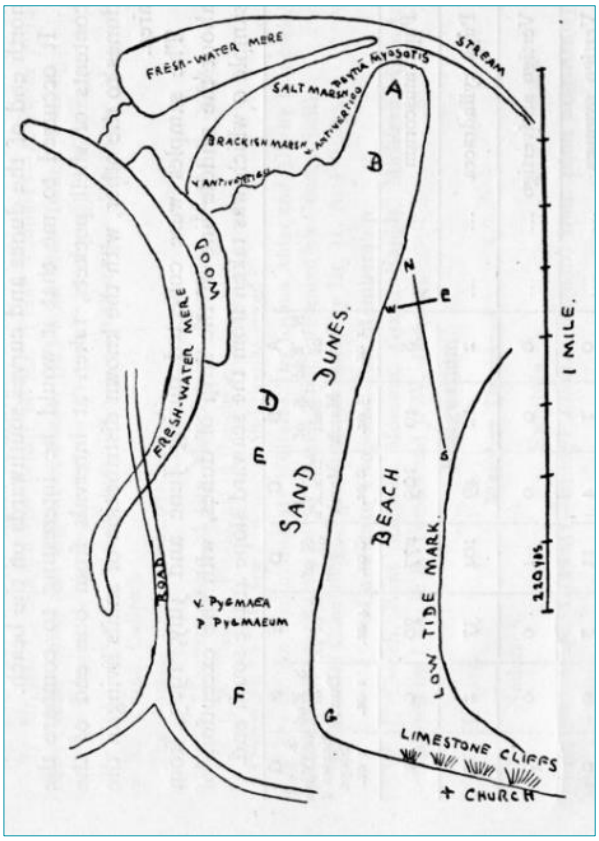

Figure A. Map drawn of a survey in 1925 (Quick, 1926) showing molluscan collection points across Oxwich Burrows. Note that Quick appears to have omitted 'Site C' which presumably lay between sites B and D.

Another detailed survey of the area in 1927 again failed to find *V. angustior* (Quick, 1927). A detailed map accompanying the last paper shows the northern areas of Oxwich Burrows bordering the saltmarsh to be open and devoid of the extensive tree cover now present in the area (Figure 7).

1983 FIRST LIVE DISCOVERY: Preece & Willing (1984)

In May 1983, the author of this report accompanied by Richard Preece discovered numerous live *Vertigo angustior* living on the eastern margins of Whiteford Burrows in a saltmarsh – sand dune transition zone (Preece & Willing, 1984). Noting the habitat type and association with *Potentilla anserina*, they went the same day to Oxwich Burrows NNR on the south Gower coast to search for similar habitat. As a result, numerous *V. angustior* were found living in a relatively small area of unshaded open marshy ground lying on the north of the sand dune complex where it borders onto a salt marsh at approximately SS 511 877 (Note: this Ordnance Survey grid reference was only estimated from a map and not obtained using a modern GPS device). Flood debris found close by indicated that the habitat was subject to occasional tidal flooding. Dominant vegetation recorded at the site included *Senecio aquaticus*, Juncus maritimus, *Mentha aquatica, Bidens tripartita, Potentilla anserina, Iris pseudacorus,* and *Cratoneuron filicinum*. The associated Mollusca were a predominantly 'catholic' community including *Carychium minimum, Cochlicopa lubrica, Columella edentula, Vallonia pulchella, Punctum pygmaeum, Arion ater, A. intermedius, Nesovitrea hammonis, Deroceras reticulatum*, *D. laeve*, *Euconulus fulvus*, *Clausilia bidentata*, *Trichia hispida* and *Cepaea nemoralis*.

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 survey of Whiteford Burrows (results summarised in Willing, 2020) and Oxwich Burrows was undertaken in January 1993 commissioned by the Countryside Council for Wales. The Oxwich survey focussed upon the northern margins of the burrows adjoining the saltmarsh, 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 17 locations (Figure 12) along the saltmarsh / northern sand dune transition zone. *V. angustior* was not recorded in the field but a total of 12 live snails were recovered from five of the bulk samples, all in an area close to where the species had been recorded in 1983 (Figure B). It was observed that the sites were relatively open and characterised by the presence of herbs such as *Pulicaria* and *Iris*. A consistent feature of 1993 samples containing *V. angustior* was the presence of *Clausilia bidentata* which was associated with a suspected increased shading of the site;

the other associated molluscs were all observed to be catholic species and non-indicative of open marshland.

It was stated that "*V. angustior* is restricted to parts of the saltmarsh/dune transition zone where the vegetation is predominantly short and there is a variable proportion of bare, friable soils covered by sparse litter."

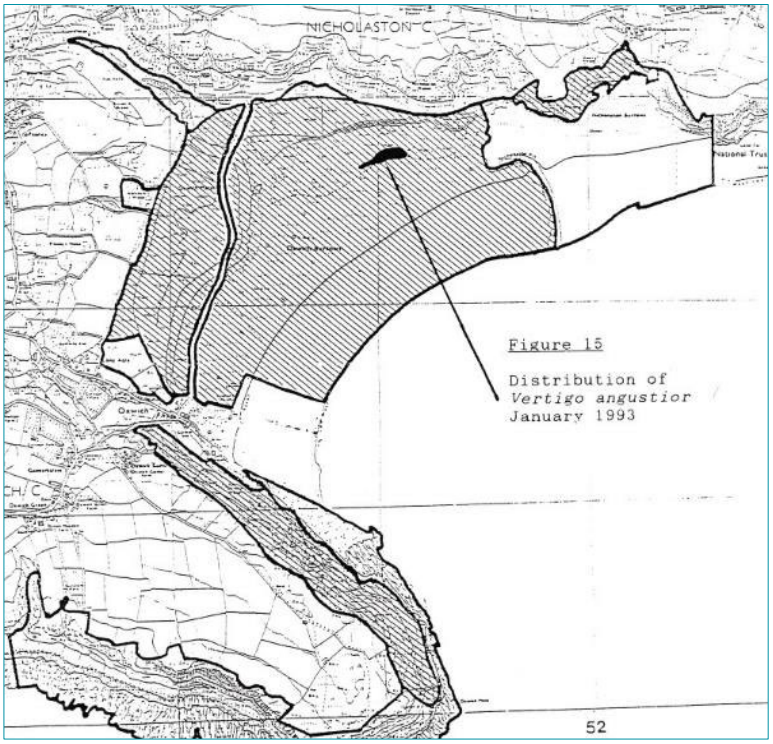

Figure B. The assumed distribution of *Vertigo angustior* in January 1993 (map extract from Killeen, 1993).

Killeen notes that "*the encroachment onto the transition zone by scrub appears to be a recent phenomenon, indeed there may have been a significant change since 1983*". The field notes record the frequent presence of *Salix* saplings in the surveyed area although photographs from the report do not show the now tree-covered nature of the area surveyed by Killeen (Figure 8). "Without imminent management the continued survival of *V. angustior* at this site may be under threat". The report concludes that the Oxwich site has experienced vegetation changes since 1983 making it taller and shadier; the controlled grazing of the transition zone by ponies is recommended.

1994 MONITORING: Fowles & Hurford (1995)

A limited survey in 1994 attempted to resurvey the approximate area where Killeen had recorded the snail a year before. A single dead *V. angustior* was recovered. The report concluded that "Habitats suitable for maintaining a population of *V. angustior* at Oxwich must certainly be very limited". A 5m x 5m monitoring plot was established (described as

'Oxwich Plot C') with a location described in the report text and shown on a sketch map but rather unhelpfully not including a grid reference.

1995 MONITORING: Fowles & Hurford (1996)
No sampling was undertaken but there were several statements in the report noting the requirement for a full Oxwich survey - "*However what is really required at Oxwich is a detailed survey of the entire fringe of the saltmarsh to determine whether any suitable habitat survives and whether V. angustior is still present".* It was also stated that "*The population (of V. angustior) maybe on the verge of extinction*". Although it was not monitored, the 'Oxwich Plot C' established in 1994 was renamed 'Oxwich Plot Z'.

1996 MONITORING: Fowles, Painter & Wilkinson (1997)
In April 1996, spot sieve-sampling was undertaken along the transition zone on the southern margins of the saltmarsh – sand dune transition zone. *V. angustior* is reported to have been found at 'several locations' to the east of a 'monitoring plot Z' although sampling within the plot itself is not recorded. Unhelpfully the location of these sites is not given as grid references or displayed on any map. The report states that "sampling on top of the low ridge of fossil dunes at the east end of Oxwich saltmarsh revealed *V. angustior* to be present locally in abundance. On two of these dune islands *V. angustior* occurred c. 1m above the saltmarsh amongst rank grassland vegetation consisting of: *Festuca arundinacea*, *Elymus farctus*, *Taraxacum officinale* (agg), *Festuca rubra*, *Eurynchium praelongum*, *Juncus maritimus* and *Carex arenaria*. One sample from this habitat contained 48 adult *V. angustior* – juveniles were not counted in the field". Although the grid reference of this site is not given in the report, it may lie close to SS 513 877 (A. Fowles, pers. comm., March 2023). Additional spot sampling was undertaken for about 150m to the west of 'monitoring plot Z' but the snail was not found in the wetter, ranker and scrubbed habitat present there. It is noted that in the winter of 1995/6 two trial mown management plots were undertaken (presumably close to established 'monitoring plot Z') to improve the *V. angustior* habitat. Although they were not sampled as the *V. angustior* population there was presumed to be too small, it was suggested that the plots be monitored in 1998 and subsequently on an annual basis. There is no documented evidence of any further NRW survey / monitoring work being undertaken at Oxwich until twenty years later in 2016. Considering the discovery of live *V. angustior* in 1996 and in 'good numbers' in at least one location, it is surprising that a more detailed survey of the transition zone was not undertaken (as indeed was suggested in Fowles & Hurford [1996]. Habitat images included in the report show rank vegetation and some scrub at survey sites but the tree growth that now covers much of this area in 2023 is not present (Figure 9).

2006 TRIAL SAMPLING: Harper (2007)
Following a further 10-year survey hiatus, in September 2006, John Harper (accompanied by David Painter who had sampled the area with A. Fowles in 1996) trialled the use of a vacuum sampler to test its effectiveness in collecting *V. angustior*. He sampled four sites:

1. At SS 50994 87742: a dry dune site adjoining a salt marsh ‘salient’. This was sampled as D. Painter had recorded the snail here in 1996 but it was not recovered in 2006.
2. At three closely adjoining sites, all seemingly lying close to the ‘Oxwich Plot Z’ monitoring site established in 1994 (and enlarged in 1995). At SS 50994 87742, 50 live adult and juvenile *V. angustior* were collected in ‘rich fen’ supporting *Iris pseudacorus*. Very close by, the snail was not recovered in rather similar fen (although noted as lacking *I. pseudacorus*) at SS 51015 87751. A short distance to the east at SS 51060 87731, four live *V. angustior* were found in 2 “a dry bank with long grass, 1 – 2m above the level of the fen”.

So, Harper had again confirmed the presence of the snail close to where they were found in both 1983 and 1993; he makes no mention of tree shading.

2016 (unpublished site visit)

A brief field visit by NRW staff Karen Wilkinson and Mike Howe on 27th September 2016 observed live *V. angustior* in the field on sand dune hummocks close to an estimated point of SS 50990 8775. The site was reported not to be shaded by trees when visited although close to the dune - scrub boundary. Similar hummocks were located at this location in 2023 and are now heavily shaded by willow and alder trees.

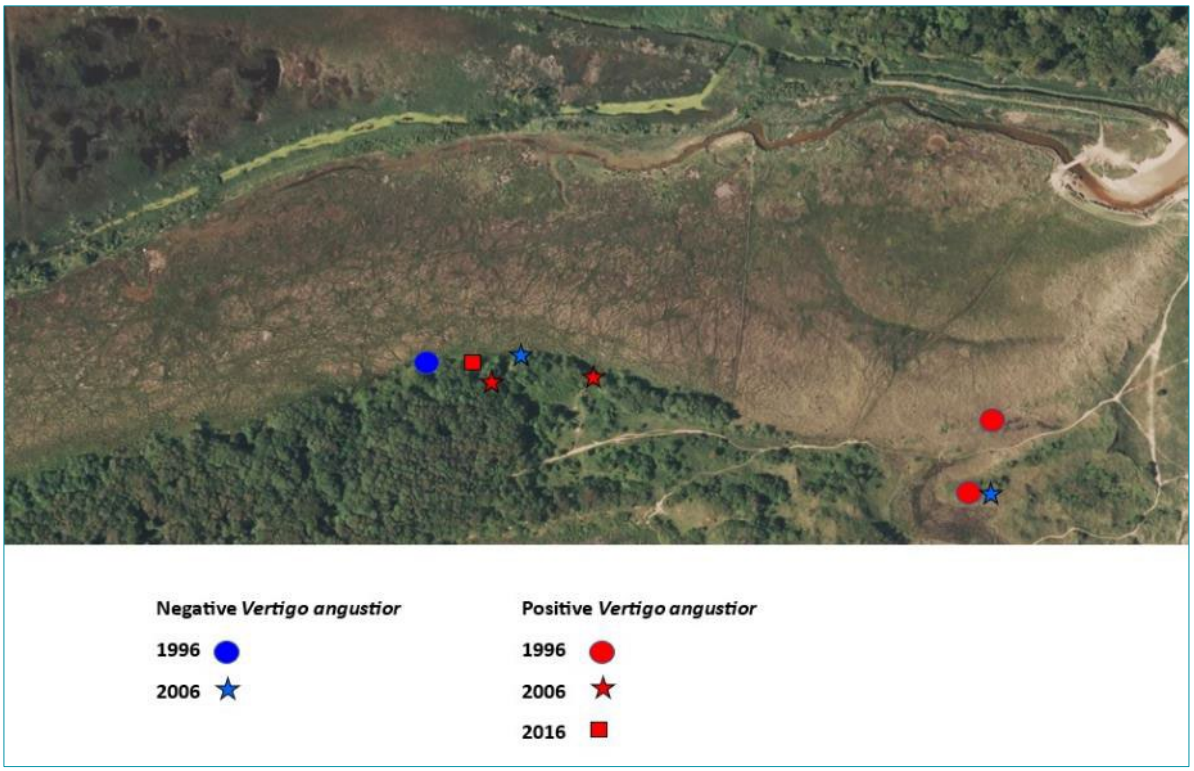

Figure C. Survey sites at Oxwich Burrows from 1996 to 2016 showing presence and absence of *Vertigo angustior*.

Appendix 14. Previous *Vertigo angustior* surveys at Whiteford Burrows

Willing (2020; Appendix 10.4) provided a detailed summary of previous *Vertigo angustior* work undertaken on Whiteford Burrows between 1983 and 2016. Since then, two further surveys have taken place in 2018 (Willing, 2020) and 2021 (Willing, 2023).

In 2018, 11 sites were surveyed all lying on the eastern margins in the saltmarsh / sand dune transition zone. 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.

In 2021, a further 29 sites were surveyed with a focus on (a) the extreme north of the reserve, (b) inland areas in the centre and west of the area and (c) Cwm Ivy Marsh (following the recent tidal inundation of much of this area). *V. angustior* was not found at the extreme north-eastern end of the Burrows or in the narrow, marshy transition zone of Cwm Ivy Marsh, but was located in six *Salix repens* dominated dune slacks (NVC communities SD 15 & 16) in northern areas of the dune system. Except for a single find in 2006, these are the first *V. angustior* records in the main body of Whiteford dunes showing that the snail was far more widespread than previously suspected and living in much drier habitat than in the transition zone. They also demonstrated that, at Whiteford, the snail is not, as previous surveys have suggested, primarily restricted to *Iris pseudacorus* dominated transition zone habitat. Further details appear in Willing (2023). Although all the new *V. angustior* populations were found in *S. repens* dune slacks, only a proportion of such habitat surveyed at Whiteford in 2021 was found to support the snail; it was not located in seemingly similar sites situated in the more southerly areas reserve.

Appendix 15. Corrections to NRW Evidence Report No. 698. *Vertigo angustior* surveys at Whiteford Burrows

NRW Evidence Report No. 698. page & erratum item.	Error	Correction
p. 33 Figure 6 (site 2)	SS 43334 9420	SS 43334 94204
p.34 Figure 7 (site 3)	As above	As above
p. 34 Figure 8 (Site 4)	SS 43504 34351	SS 43504 94351
p. 41 Figure 21 (Site 21)	SS 45423 9612	SS 45423 96123
p. 43 Figure 24	Details of a second Figure 24 are a repeat from p. 42.	Should be Figure 25 Site 21 SS 44756 96172
p. 46	All details for Site 28 are missing	See details below:



Figure 31B. Site 28 (SS 44563 95650)

Sample collected from area of short, but closed dune slack habitat dominated by *Salix repens*. *Lotus corniculatus*, *Carex flacca*, *C. viridula*, *Euphrasia officinalis* agg., *Leontodon saxatilis*, *Scorzoneroides autumnalis* and *Danthonia* are among the more frequent vascular

associates, while *Hypnum lacunosum*, *Pseudoscleropodium purum* are prominent in a well-developed moss layer.

Data Archive Appendix

The data archive contains:

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

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

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

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

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

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

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

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue https://libcat.naturalresources.wales (English Version) and https://catllyfr.cyfoethnaturiol.cymru (Welsh Version) by searching 'Dataset Titles'. The metadata is held as record no. XXXXXX.

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