A survey to determine the status of the Depressed River Mussel *Pseudanodonta complanata* at eight monitoring stations within the River Wye (Lower Wye) SSSI in 2022

NRW Evidence Report No. 846

Author Name: M.J. Willing

Depressed River Mussels recorded at River Wye, Dixton in August 2022

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Cynhaliwyd arolwg o gregyn gleision *Pseudanodonta complanata* ar SoDdGA Afon Gwy (Gwy Isaf) dros gyfnod o 3 diwrnod rhwng 17 ac 19 Awst 2022. Roedd y fethodoleg samplu yn dilyn y fethodoleg a sefydlwyd yn yr arolwg blaenorol yn 2007, ac ymwelwyd ag wyth safle monitro o Gomin Backney (i'r gogledd o'r Rhosan ar Wy) i lawr yr afon i Bigsweir, gan gwmpasu darn 50km o Afon Gwy. Ym mhob safle, cynhaliwyd arolygon gweledol 60 munud o hyd yn yr afon gan ddefnyddio bathysgop i weld cregyn gleision wedi'u claddu mewn gwaddodion neu wedi'u symud o'r gwaddodion gan ddefnyddio rhaca fforchiog. Cafodd nifer y cregyn gleision a ddarganfuwyd yn ystod y cyfnod hwnnw eu cyfrif a'u mesur; yna tynnwyd lluniau ohonynt a chawsant eu dychwelyd i'r afon.

Cofnodwyd cyfanswm o 52 *P. complanata* byw o chwe safle; ni chofnodwyd y cregyn gleision yn Kerne Bridge (i lawr yr afon o'r Rhosan ar Wy) a Bigsweir, yr orsaf fonitro bellaf i lawr yr afon. Mae hyn yn cymharu ag 81 o gregyn gleision yn 2007, gyda phob un o'r wyth safle yn cefnogi *P. complanata*. Roedd niferoedd cregyn gleision yn 2007 a 2022 fwy neu lai'n debyg ar ddau safle (Comin Backney a'r Rhosan ar Wy), yn is yn 2022 ar dri safle (Huntsham Bridge, Trefynwy a Redbrook, yn uwch ar un safle (Dixton) ac ni chawsant eu cofnodi yn Kerne Bridge a Bigsweir yn 2022. Mae astudiaeth o led mesuredig cyfunol y cregyn gleision (sy'n rhoi syniad o'u hoedran) yn awgrymu, o gymharu â data tebyg yn 2007, fod strwythur poblogaeth 2022 yn cynnwys ychydig iawn o gregyn gleision bach (iau) a nifer fawr o gregyn gleision mwy (hŷn). Gall hyn fod yn arwydd o boblogaeth *P. complanata* heneiddiol sydd â chyfradd recriwtio isel.

Tra derbynnir nad yw'n hawdd priodoli achosion i'r newidiadau ym mhoblogaethau'r cregyn gleision, awgrymir y gallai dirywiad yn ansawdd dŵr yr afon fel yr awgrymir gan y cynnydd yn nhwf algâu fod wrth wraidd dirywiad cregyn gleision, o leiaf mewn pedwar safle - Kerne Bridge, Huntsham Bridge, Trefynwy a Redbrook. Mae'n bosibl bod y nifer uwch o gregyn gleision a gofnodwyd yn Dixton yn 2022 yn ganlyniad i ailffocysu ar ardaloedd ymylol o'r afon yn absenoldeb cregyn gleision wedi'u symud o'r graean sydd ymhellach allan yn y sianel. Awgrymir mai achos y golled ymddangosiadol yn y boblogaeth yn Bigsweir yw'r dŵr lled hallt llanwol sy'n cyrraedd yn achlysurol ac o bosibl y dyddodiad cysylltiedig o silt ar dywod a graean yr afon, a oedd gynt yn lân.

Gan gymhwyso Monitro Safonau Cyffredin fel y manylir yn Amcan Cadwraeth 2007, asesir *P. complanata* a'i gynefin fel rhai sydd mewn **cyflwr anffafriol** yn Afon Gwy (Gwy Isaf) yn 2022 ar sail (1) colli'r gragen las o Bigsweir a (2) dirywiad helaeth yn y cynefin, a welwyd yn y rhan fwyaf o'r safleoedd monitro. Er gwaethaf hyn, mae poblogaethau *P. complanata* yn Afon Gwy yn cynnal rhywfaint o bresenoldeb cryf yn lleol ond mae cyfradd recriwtio isel y cregyn gleision yn bryder a chaiff ei hasesu wrth fonitro yn y dyfodol.

Gyda cholled barhaol debygol *P. complanata* o Bigsweir, awgrymir y dylid symud y safle monitro hwn, sef yr un pellaf i lawr yr afon, i fyny'r afon i bwynt lle mae'r cregyn gleision yn dal yn bresennol a lle nad ydynt dan fygythiad ar hyn o bryd gan ddylanwadau'r llanw; ystyrir Cadora Woods yn safle addas.

Trafodir sawl cynnig arall o ran arolygon monitro ac ymchwil a allai, o'u gweithredu, wella ein dealltwriaeth o boblogaethau *P. complanata* sy'n byw yn Afon Gwy ac a allai felly gynorthwyo gyda'u gwarchod.

Executive summary

A survey of Depressed River Mussel *Pseudanodonta complanata* on the River Wye (Lower Wye) SSSI was undertaken over a 3-day period from 17th to 19th August 2022. Sampling methodology followed that established in the previous survey in 2007, with eight monitoring sites visited from Backney Common (north of Ross-on-Wye) downstream to Bigsweir covering a 50km stretch of the River Wye. At each site, 60-minute visual surveys were undertaken in the river using a bathyscope to spot mussels buried in sediments or dislodged from them using a pronged rake. The number of mussels located during that period were counted, measured, photographed and then returned to the river.

In total, 52 live *P. complanata* were recorded from six sites, the mussel not being recorded at Kerne Bridge (downstream of Ross-on-Wye) and Bigsweir, the furthest downstream monitoring station. This compares to 81 mussels in 2007, with all eight sites supporting *P. complanata*. Mussel numbers in 2007 and 2022 were approximately similar at two sites (Backney Common and Ross-on-Wye), lower in 2022 at three sites (Huntsham Bridge, Monmouth and Redbrook, higher at one site (Dixton) and were not recorded at Kerne Bridge and Bigsweir in 2022. A study of the combined measured widths of the mussels (providing an indication of age) suggests that, in comparison with similar 2007 data, the 2022 population structure includes very few small (younger) mussels and a predominance of larger (older) mussels. This may indicate a senescent *P. complanata* population with low recruitment.

Whilst accepting the difficulties of attributing causes to the changes in mussel populations, it is suggested that a deterioration in river water quality as suggested by increased algal growth may be the cause of mussel declines, at least at four sites - Kerne Bridge, Huntsham Bridge, Monmouth and Redbrook. The higher number of mussels recorded at Dixton in 2022 may be due to a refocus on marginal areas of the river in the absence of mussels dislodged from gravels situated further out into the channel. The apparent loss of the population at Bigsweir is suggested because of occasional intrusions of tidal brackish water and possibly the associated deposition of silt onto formerly clean river sands and gravel.

Applying Common Standards Monitoring as detailed in the 2007 Conservation Objective, *P. complanata* and its habitat are assessed as being in **unfavourable condition** in the River Wye (Lower Wye) in 2022 based upon (1) the loss of the mussel from Bigsweir and (2) a widespread habitat deterioration observed at most monitoring sites. Despite this, *P. complanata* populations in the River Wye are nevertheless maintaining some locally strong presence but low mussel recruitment is a concern and will be assessed as a part of future monitoring.

With the probable permanent loss of *P. complanata* from Bigsweir, it is suggested that this most downstream monitoring site is moved upstream to a point still populated by the mussel and not currently threatened by tidal influences, with Cadora Woods being a suitable candidate.

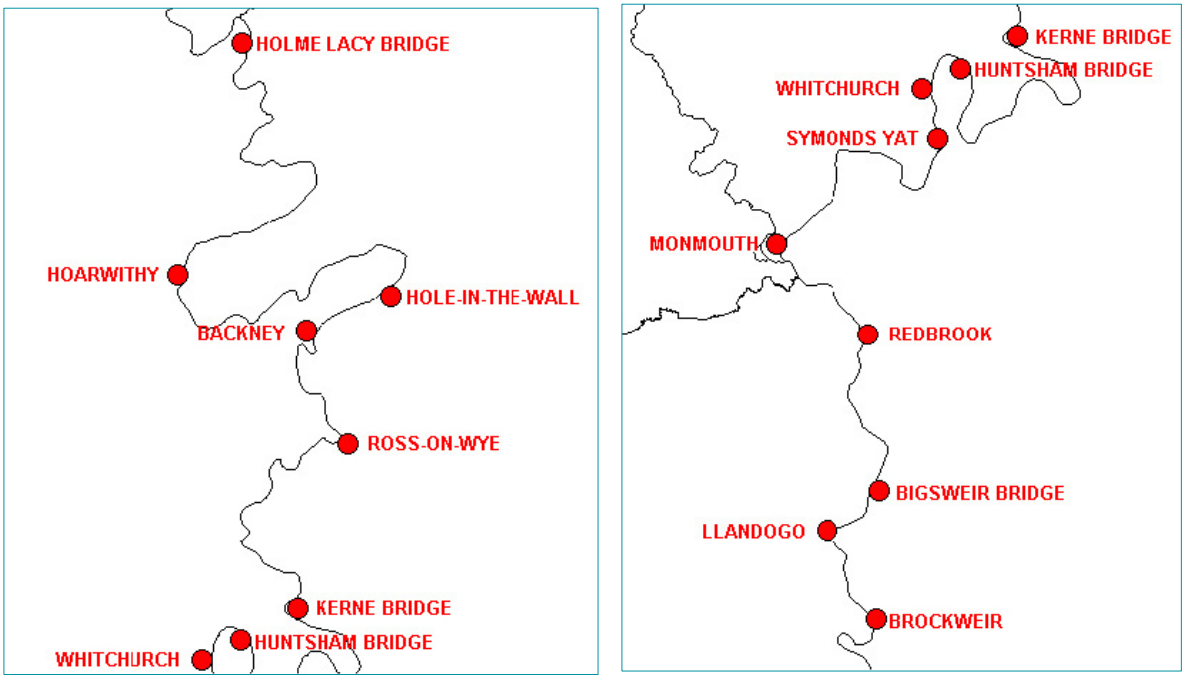
Several further monitoring survey and research proposals are discussed which, if implemented, might improve our understanding of *P. complanata* populations living in the River Wye and so assist in their conservation.

1. Introduction

The Depressed (Compressed) River Mussel *Pseudanodonta complanata* (Rossmässler, 1835) is widespread in Europe, occurring in the lowlands between south Scandinavia and the Alps and living in medium to slow-flowing hard water, lowland rivers and occasionally canals with a substrate of fine clays and mud. It is considered to be local or regionally rare throughout its range (Kerney, 1999; McIvor & Aldridge, 2007) and is classed as Near Threatened in Europe (Cuttelod *et al*., 2011) and appearing on the EU Red List (IUCN, 2008). Welter-Schultes (2012) states that in Europe it has become locally extinct due to habitat destruction and pollution. In Britain *P. complanata* was made a UK Biodiversity Steering Group (BAP) Priority Species in 1995 (Anon, 1995) and an action plan for the mussel was published in 1997 (Willing, 1997). In the most recent non-marine status review (Seddon *et al*., 2014), the species was given a GB IUCN Status of 'Least Concern' and a spatial status of Nationally Scarce although the report notes that the species has been the subject of misidentifications and confusion with *Anodonta anatina* and hence some of the historical records are in doubt. The mussel is a Welsh Section 7 'Species of Principal Importance'.

P. complanata is locally distributed throughout England (Kerney, 1999) in lowland rivers and canals as far north as Yorkshire where it has been recorded from at least 65 hectads, and important waterways include the River Waveney and River Yare in the Norfolk Broads (Baker *et al*., 1996,1998), the Somerset Levels, River Arun in Sussex and the Old West River in Cambridgeshire. Close to the Welsh border, it was found in the Shropshire Union Canal in the 1930s (Boycott & Oldham, 1936) and recorded at seven sites on the Llangollen Canal in Shropshire in February 2009 although no Welsh stretches of canal were surveyed (Willing, 2009a).

In Wales, *P. complanata* is restricted to the lower reaches of the River Wye where it comprises as much as 80% of the mussel fauna, but occurs only at low densities (Killeen *et al*., 2004). During a survey in the early 1990s for the Freshwater Pearl Mussel *Margaritifera margaritifera*, it was found at three stations within the Wye Valley Gorge – The Biblins, Redbrook and Bigsweir (Oliver *et al*., 1993). Studies of UK populations in the late 1990s recorded good numbers of the mussel at Dixton Church, Monmouth where they were found with the Duck Mussel *Anodonta anatina* (Müller, 1998, 1999). A Countryside Council for Wales-funded survey in autumn 2007 recorded a total of 81 live and one freshly dead *P. complanata* from 11 sites over a channel distance of 64.5km of the Wye, extending from Hoarwithy in Herefordshire (the freshly dead shell) to Llandogo in Monmouthshire (Willing, 2009b). This survey extended the previous known range of the mussel in the river from 19.5 km, a 330% increase from the previous recorded limits. At all sites, mussels were found in fast-flowing water buried in mixtures of sand, gravel and cobbles, atypically avoiding the fine clay and mud sediments which it inhabits in most other UK rivers. A Conservation Objective (monitoring protocol) was developed during the same survey (Appendix 1A) and this selected 8 monitoring sites covering the mussel's newly discovered range in the river.



Figures 1 & 2. River Wye sampling sites for *Pseudanodonta complanata* in 2007. From: Willing (2009b).

The survey in 2022 was to determine the status of the populations of *Pseudanodonta complanata* in the Lower Wye following the protocols established in 2007. Ideally, the survey should be undertaken every five years as a 15-year gap is too long to react to any population declines.

2. Methods

Surveys were undertaken over the three-day period from 17th to 19th August 2022. These dates were chosen as they were preceded by a period of low river flows that were predicted (by NRW and the Environment Agency) to remain low during the survey period (Appendix 6). The river levels (as monitored at gauging stations at Ross-on-Wye or Monmouth) needed to be below levels set out in the Lower Wye *Pseudanodonta complanata* Conservation Objective to allow standardised surveys at the eight selected monitoring stations. Low water levels were required because surveys require the surveyor to wade in the river and visually search for mussels. Monitoring surveys were undertaken at the eight sites detailed in the Conservation Objective, these being (in downstream order) - (1) Backney Common, (2) Ross-on-Wye (Bridstow Bridge), (3) Kerne Bridge, (4) Huntsham Bridge, (5) Dixton, (6) Monmouth, (7) Redbrook and (8) Bigsweir (Table 1; Figure 3). This covers a 50km stretch of the River Wye.

Table 1. The eight monitoring stations on the River Wye.

Site	Site name	Approximate grid reference
1	Backney Common	SO5847327128
2	Ross-on-Wye (Bridstow Bridge)	SO5957624505

Site	Site name	Approximate grid reference
3	Kerne Bridge	SO5813719213
4	Huntsham Bridge	SO5690517533
5	Dixton	SO5226313746
6	Monmouth (Monmouth School)	SO5124112835
7	Redbrook	SO5346810145
8	Bigsweir	SO5400905532

Experience gained by the contractor during the 2007 *P. complanata* survey were adopted to take account of the particular behaviours of the mussel in the Lower Wye. These included their relative scarcity, patchy distribution and habit of living deeply buried (often in small groups) in coarse sand between gravel and cobbles. Search technique involved the use of a bathyscope ('glass-bottomed bucket') to visually search the riverbed whilst wading in water depths to about 1.2m whilst wearing chest waders and a flotation aid (Figure 4).

Buried mussels were often difficult to see in the channel floor, which typically consisted of gravel and cobbles set in sand and less frequently silt and clay. In 2007, many mussels were uncovered by gently agitating sediments by either dragging a rake across the riverbed or by drawing a foot backwards and forwards across the bottom to a sediment depth of about 10 cm (dislodged mussels could then be collected for examination using a net held just downstream from their position). This technique was again trialled during the 2022 survey but found to be less effective. A second and more successful approach involved visually spotting the buried mussels in shallower marginal water (mostly depths < 0.5m). Each survey station was searched for a period of 60 minutes, timed by a H&S assistant situated on the riverbank close by. The mussels were then retrieved by hand or, at greater depths, dislodged and lifted with an expanding rake (Figure 4). In some areas (e.g. Dixton, Monmouth and Redbrook), the rake was also used to scrape away filamentous algal blankets where these were obscuring river sediments (Figure 8). Almost all *P. complanata* and other unionid mussels recovered in 2022 were found living in slower flowing, marginal areas of the river; few mussels were located further than 4m from the bank. Recovered unionid mussels were examined on the bank, and all *P. complanata* photographed and their length measured (anterior – posterior shell width) using digital vernier calipers (Figure 5). All living mussels were then returned to the river close to the point of capture and gently eased into patches of soft sand to assist their re-settlement. Sampling sites were photographed, and locations logged using a Garmin 'E-Trex' GPS device.

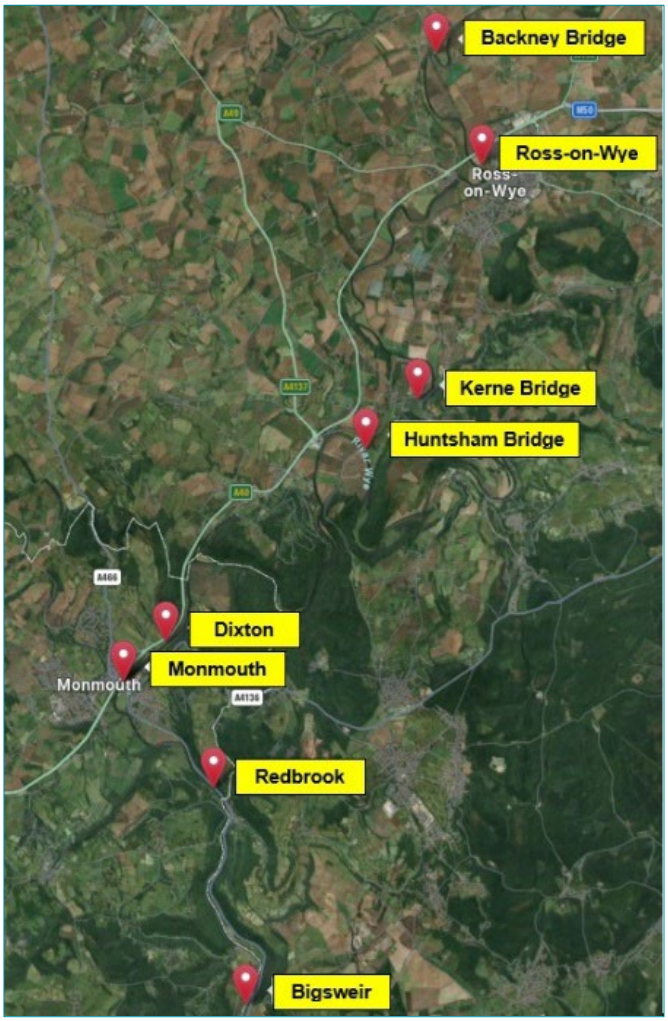


Figure 3. Monitoring sites on the River Wye.


Figure 4. Surveying for *Pseudanodonta complanata* at Ross-on-Wye. Visual inspection of the river sediments involved using a bathyscope and extendable pronged rake.

Figure 5. Measuring mussels using digital calipers.

3. Results

Survey results are given in Appendix 2 and summarised in Table 2, and site descriptions and locations provided in Appendix 5. Site survey images and recorded *P. complanata* (and selected other unionid mussels) are in Appendix 7, the measurements of individual *P. complanata* mussels are given in Appendix 3 and an associated cumulative size chart in Appendix 4.

In summary, a total of 52 live *P. complanata* was recorded at 6 of the 8 monitoring stations, the mussel not being recorded at sites 3 (Kerne Bridge) and 8 (Bigsweir). Other unionid mussels recorded included 27 *Anodonta anatina* found at 7 of the monitoring sites, and Swan Mussel *Anodonta cygnea* and Painter's Mussel *Unio pictorum* both found at a single site. A comparison of results in 2007 and 2022 is given in Table 3.

Table 2. Unionid mussels recorded on the River Wye during the August 2022 survey.

Site	*P. complanata*	*A. anatina*	*A. cygnea*	*U. pictorum*
1. Backney Common	2	1	2	1
2. Ross-on-Wye (Bridstow Bridge)	4 (+1 post timed survey)	7	0	0
3. Kerne Bridge	0	0	0	0
4. Huntsham Bridge	3	7	0	0
5. Dixton	32	3	0	0
6. Monmouth (Monmouth School)	10	5	0	0
7. Redbrook	1	2	0	0
8. Bigsweir	0	2	0	0
Total counts with 1 hour per site:	**52**	**27**	**2**	**1**

Table 3. Counts of *Pseudanodonta complanata* in 2007 and 2022. Note that Hoarwithy Bridge, Old Forge Bridge and Llandogo are not included as monitoring stations and were not surveyed (N/S) in 2022. 1* = freshly dead shell

Site	2007	2022
Hoarwithy Bridge (SO5480629111)	1*	N/S
1. Backney Common	2	2
2. Ross-on-Wye	4	4
3. Kerne Bridge	11	0
4. Huntsham Bridge	15	3
Old Forge Bridge (SO5632118419)	7	N/S
5. Dixton	14	32
6. Monmouth School	18	10
7. Redbrook	5	1
8. Bigsweir	4	0
Llandogo (SO5267403927)	1	N/S
Total	**81**	**52**

Habitat deterioration was noted at most sites in the form of blankets of filamentous algae. Algal and 'sewage fungus' cover of river sediment details are described in Appendix 5.

4. Discussion

The 2022 survey on the Lower Wye demonstrated that *P. complanata* has maintained much of its previous 2007 range, extending from the upstream site at Backney Bridge down to Redbrook, albeit with an absence at Kerne Bridge and Bigsweir, the latter being the most downstream station on the river. As in 2007, *P. complanata* was the most frequently recorded mussel outnumbering all other unionid mussels and forming 63% of the combined mussel total (Table 2). Although the total number of 52 mussels recorded comfortably exceeds the lower Conservation Objective criterion of 40 mussels a (total from all 8 sites), 42 of these came from just sites, Dixton and Monmouth. The high total of 32 mussels from Dixton exceeded the 14 found in 2007 and may have been the result of switching to focus on more marginal areas of the river and the chance find of several large mussel 'clusters'. The mussel count in 2022 was lower than in 2007, the most pronounced decline being at Kerne Bridge and Huntsham Bridge (Table 3).

A study of the combined measured widths of the mussels (an indication of age) suggests that, in comparison with similar 2007 data, the 2022 population structure includes very few small (younger) mussels and a predominance of large (older) mussels. This may indicate a senescent *P. complanata* population with low recruitment. Such a situation has been observed in numerous Freshwater Pearl Mussel *Margaritifera margaritifera* populations in England and Wales including the upper River Wye (Oliver, 2001; Oliver *et al*., 1993). If this situation is shown to exist, then future *P. complanata* monitoring may record population declines with the death of the older mussels not being replaced by a younger cohort.

The other most frequently recorded mussel species was the common and widespread *A. anatina*. As in 2007, although *A. anatina* was present at all of the current *P. complanata* sites, the two species were not living sympatrically; *P. complanata* being present in clean sand and gravel with *A. anatina* generally found in muddy, silty sediments.

Much has been reported concerning the relatively recent issue of eutrophication in the River Wye widely attributed to an increase in intensive poultry rearing in the upper Wye catchment (see The State of the Wye | Save the Wye). If this were the sole/main pollution source, one might expect to see the upstream monitoring sites being affected most, with a decreasing impact on sites further downstream as water quality improves. This expected sequential decrease in pollution impacts was not observed at the 2022 monitoring sites. The degree to which the eight monitoring sites were affected by aquatic pollution in 2022 was rather subjectively assessed by this surveyor by observations of algal growth - blankets of filamentous algae and the algal encrustation of macrophytes and river sediments. The water quality observed at the monitoring stations did not display the expected downstream improvement but, rather surprisingly, something of a downstream deterioration. The situation during the current survey was markedly different from that observed in 2007 (Willing, 2009b) when the only observation of algal impact was at the upstream Hoarwithy site (upstream of all 2022 monitoring stations). No other observations of significant algal presence or other water quality issues were noted at other 2007 survey sites, when river water was clear and filamentous algae was not observed. During the intervening 15 years, conditions in 2022 are noticeably different at most monitoring sites. At upstream Backney Common, only relatively slight algal growth was only observed, partially covering sediments beneath the slow flowing waters of a pool lying to one side of the main channel (Figure 6).

Similarly at Ross-on-Wye, only very small amounts of algae growth were noticed in a few, very slow flowing marginal pools, most of the sand and gravel sediments there being algal free across the channel. By contrast, a relatively short distance downstream from Ross-on-Wye at Kerne Bridge (where no unionid mussels were recorded) the water-crowfoot *Ranunculus* sp observed in 2007 was not seen and river sediments in all but the fastest flowing stretches were covered in algae and ‘sewage fungus’. Further downstream site at Huntsham Bridge, and again in marked contrast to 2007, water-crowfoot and other macrophytes were mostly smothered in blankets of filamentous algae and the relatively slow-flowing river water was noticeably turbid. Downstream again at Dixton, the conditions were slightly improved but nevertheless filamentous algal mats partially blanketed sand and gravel sediments in the slower flowing marginal areas and additionally partially covered the frequent clumps of water-crowfoot (Figure 7).

Yet further downstream at Monmouth and Redbrook, filamentous algal blankets were more widespread covering both macrophytes and bottom sediments, even in faster flowing water towards the central river channel. At both sites, a metal pronged rake was needed to scrape algal mats from the riverbed to undertake mussel searches of the sediments bellow (Figure 8).

Surprisingly very little algal growth was observed at the downstream Bigsweir site, although fine silty clay sediments were observed to have infilled spaces between the

previously clean gravel and cobbles, possibly the result of upstream tidal intrusions. A summary of the water quality situation at the eight monitoring stations suggests that conditions were least polluted at the two uppermost sites of Backney Bridge and Ross-on-Wye but deteriorated downstream, with the heaviest presence of filamentous algae at Huntsham Bridge, Monmouth and Redbrook. These observations do not suggest a single upstream pollution source but perhaps a series of diffuse pollution inputs, a situation requiring further investigation.

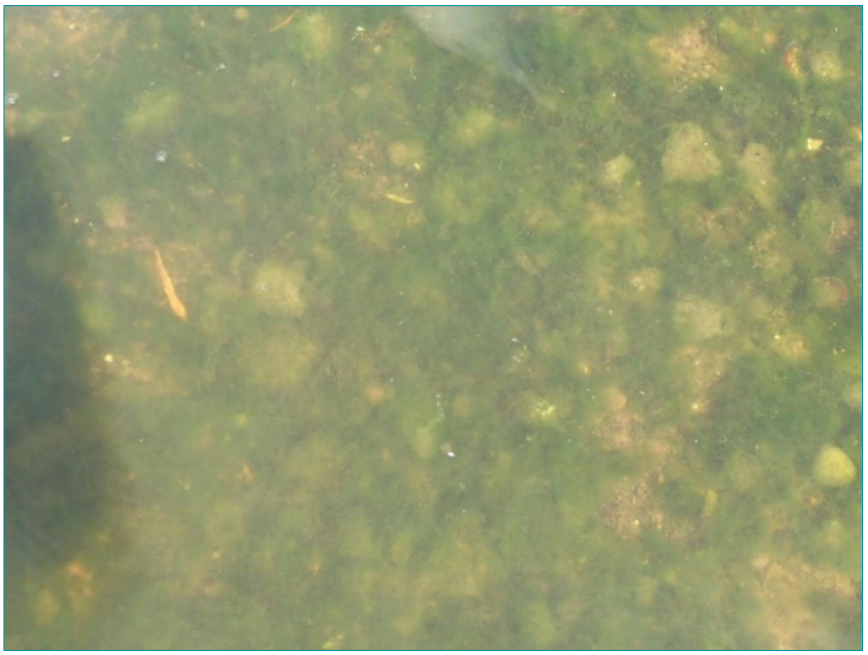


Figure 6. Slight algal growth covering sediments in a sheltered river backwater pool at Backney Common in August 2022.

Figure 7. Filamentous algae partially smothering water- crowfoot at Dixton in August 2022.

Figure 8. Filamentous algae scraped from the riverbed at Monmouth in August 2022.

It is difficult to relate observed water quality to *P. complanata* presence. The mussel was absent or significantly reduced at the Kerne Bridge and Huntsham Bridge sites, but numbers were high at Dixton and 'reasonable' in Monmouth. So, although *P. complanata* numbers were reduced overall compared to 2007 the mussel is, nevertheless, maintaining a reasonable presence in at least some locations in the Lower Wye although low mussel recruitment is a concern.

The apparent loss of *P. complanata* at Bigsweir may be associated with either occasional intrusions of tidal brackish water and/or the deposition of tidal silt onto formerly clean river sands and gravel. This survey site lies a relatively short distance upstream from Bigsweir Bridge, shown by the Ordnance Survey (2020) to be the Normal Tidal Limit (NTL) for the river. It is possible that since the 2007 surveys the tidal waters may have extended further upstream. It is likely that the lower *P. complanata* limit on the Wye is determined by occasional saline intrusions. This issue was discussed in the 2007 report (Willing, 2009b) where it was written: "*Godfrey (2007) noted that that the freshwater shrimps Gammarus pulex and Crangonyx pseudogracilis, recorded in the river at Dixton, were replaced with the brackish water species Gammarus zaddachi at Bigsweir and Brockweir. Godfrey states that the "very poor species richness at Brockweir was attributed to the brackish-water conditions here, which could clearly not be tolerated by most of the freshwater invertebrates found further upstream". Increased salinity is also considered to account for the observed lowest P. complanata limits on other rivers such as the Waveney and Arun (Müller, 1999; Willing, unpublished data). Gittenberger et al. (1998) in summarising the salinity tolerances of all Dutch fresh and brackish water Mollusca indicate that P. complanata has no brackish tolerance, although Anodonta anatina, a frequent associate, tolerates oligohaline conditions (chloride content of 0.3 - 3‰)*."

It may therefore be significant that *A. anatina* was still found living at Bigsweir in 2022 whereas only a few dead corroded *P. complanata* valves were found. A similar situation

has been observed elsewhere such as on the tidal River Arun in West Sussex where *A. anatina* is found living much further downstream than *P. complanata* (Willing, 2006).

4.1. Conservation Objective

Judged by the *P. complanata* Conservation Objective produced for the River Wye (Lower Wye) SSSI (Appendix 1A), the mussel was, in August 2022, assessed as having **unfavourable conservation status** because:

- it was found living at 6 of the 8 monitoring sites (lower limit criterion is 6 of the 8 sites but this was to include stations at either end of the 2007 known distributional range. The mussel was not recorded at Bigsweir, the lowest station on the river;

- a combined total of 52 mussels were found at 6 of the 8 monitoring stations (lower limit criterion is 40 mussels based upon 1 hour search per site);

- in relation to habitat condition, although some areas had 'good quality' habitat with predominantly clean gravel, cobbles and small boulders with sand between there was significant filamentous and other algal growth at 5 monitoring sites (particularly affecting those marginal stretches of the river typically occupied by *P. complanata* in the lower Wye). Favourable status would require that 'Stones were largely free from encrusting algal growths and 'sewage fungus' and were not smothered in mud, silt and clay (lower criterion limit is that 50% – 75% of the sampling patches display these 'good quality' characteristics)'. This criterion was not achieved in 2022.

Whilst the lower limit of mussels found was exceeded, an absence from Bigsweir and poor habitat quality results in **Unfavourable Condition**. Given the apparent unsuitability of Bigsweir, it is recommended that the Conservation Objective is adjusted (see Section 5 below & Appendix 1B) to include a site slightly further upstream.

5. Further work

The Favourable Conservation Status (FCS) of *P. complanata* in the River Wye (Lower Wye) SSSI is judged by criteria outlined in a pre-determined Conservation Objective (CO). Results from the 2022 Lower Wye *P. complanata* monitoring programme suggest that the Conservation Objective written for the mussel in 2007 (Willing, 2009b) and used for the assessment in 2022 is no longer fully appropriate for future monitoring programmes. Adjustments are justified for four reasons:

- It is probable that the mussel has been lost from the Wye at Bigsweir due to tidal saline and or silt intrusions. This means that future monitoring efforts at this site will always prove negative meaning that one of key CO criteria cannot be met. To remove this problem, it is suggested that the CO is modified to move this most downstream site approximately 1km upstream to Cadora Woods Nature Reserve (approximately SO5323608258) where any mussel population is not threatened by

tidal influences. Relocation to this site depends upon confirmation of the mussel's presence there.

- The 2007 CO stipulated that, to reach FCS, the minimum total number of *P. complanata* recorded from the monitoring sites is 40. It is suggested that this number be increased to 60 mussels as, in 2022, this 40 total was achieved and slightly exceeded (with 42 mussels) with the counts from just the two sites, Dixton and Monmouth School (with mussel counts of 32 and 10 respectively), the remaining 6 monitoring sites only accounting for a further ten mussels.

- In comparison to the 2007 survey, the 2022 data revealed an apparent decline of small, younger mussels. This change suggests that there may be a marked future decline in mussel recruitment in the Lower Wye leading to a gradual fall in *P. complanata* numbers as old adults die. To monitor this situation, the revised CO now requires that, to achieve FCS, 30% of the monitored mussel cohort are <50mm shell width. This baseline was chosen as this was proportion of smaller mussels recorded during the 2007 surveys when the river was not noticeably impacted by the effects of eutrophication.

- The current CO places Backney Common as the upper monitoring site because this was the furthest upstream point where live *P. complanata* were recorded in 2007. In that survey, freshly dead articulated valves were also found three sites further upstream at Hoarwithy, demonstrating that the mussel must have been living there or close by at that time. To record any possible additional upstream population, it is suggested that Hoarwithy is included as a ninth monitoring site, but that Backney Common still remains as the CO's fixed upper limit for live mussel presence. These four suggested changes appear in a revised CO (see Appendix 1B).

The 2007 report suggested that the monitoring programme is undertaken every five years. In view of the recent concerns relating to the habitat deterioration of the Wye, it is further suggested that this programme be restored to allow a more regular status assessment of the nationally important *P. complanata* populations living in the Wye.

The 2007 studies only undertook surveys upstream to Holme Lacey (just downstream of Hereford). The resulting survey report (Willing, 2009b) suggested that further surveys are planned to answer the question, '*Is Hoarwithy the upper limit of P. complanata distribution on the Wye or is the mussel present further upstream*'. This work was not undertaken and so it is still not known if the mussel occupies the river upstream of Hereford.

Attempts should be made to link the results of the 2022 survey to water quality data that has been gathered in recent years by a number governmental and NGO organisations also monitoring the reported deterioration of the Wye's waters. Such data may be available via liaison with the Natural Resources Wales, Natural England and the Environment Agency.

6. References

Anon. 1995. Biodiversity: *The UK Steering Group Report. Vol. 2 Action Plans.* HMSO, London.

Baker, R., Clarke, K. & Howlett, D. 1996. Norfolk Biodiversity Action Plan for *Pseudanodonta complanata* Rossmäller. The Ted Ellis Trust. An unpublished report to English Nature.

Baker, R., Clarke, K. & Howlett, D. 1998. A survey of *Pseudanodonta complanata* Rossmaller in Norfolk. English Nature Research Report No. **293**.

Boycott, A.E. & Oldham, C. 1936. The Mollusca of the western parts of the Shropshire Union Canal. *North Western Naturalist*. **11**: 217-227.

Cuttelod, A., Seddon, M. & Neubert, E. 2011. *European Red List of Non-marine Molluscs.* Luxembourg: Publications Office of the European Union.

Gittenberger, E., Janssen, A.W., Kuijper, W.J., Kuiper, J.G.J., Meijer, T., Van der Velde, G., de Vries, J.N. & Peeters, G.A. 1998. *De Nederlandse zoetwatermollusken. Recente en fossieleweekdieren uit zoet en brak water.* Nederlandse Fauna 2. Nationaal Natuurhistorisch Museum Naturalis, KNNV Uitgeverij & EIS-Nederland, Leiden.

Godfrey, A. 2007. Monitoring invertebrate features on SSSIs: Depressed river mussel in the lower Wye. Unpublished report to the Countryside Council for Wales.

IUCN. 2008. IUCN Red List of Threatened Species. http://www.iucnredlist.org

Kerney, M.P. 1999. *Atlas of the Land and Freshwater Molluscs of Britain and Ireland.* Harley Books, Colchester.

Killeen, I.J., Aldridge, D. & Oliver, O. 2004. *Freshwater Bivalves of Britain & Ireland.* Field Studies Council, Shrewsbury.

McIvor, A.L. & Aldridge, D.C. 2007. The reproductive biology of the depressed river mussel, *Pseudanodonta complanata* (Bivalvia: Unionidae), with implications for its conservation. *Journal of Molluscan Studies.* **73**: 259-266.

Müller, S.J. 1998. Population genetics, ecology and waterway management in the conservation of *Pseudanodonta complanata.* M.Phil. dissertation, University of Cambridge.

Müller, S.J. 1999. Population genetics, ecology and waterway management in the conservation of the depressed River Mussel (*Pseudanodonta complanata*). Unpublished report for the Environment Agency.

Oliver, G. 2001. The freshwater pearl mussel in Wales - a terminal decline? *Natur Cymru*. **1**: 18-22.

Oliver, P.G., Meechan, C.J. & Trew, A. 1993. Report on the 1992/93 survey of the freshwater pearl mussel (*Margaritifera margaritifera* L., 1758) in the River Wye. CCW Contract Science Report No. **30**. Countryside Council for Wales, Bangor.

Ordnance Survey. 2020. Wye Valley & Forest of Dean / Dyffryn Gwy a Fforest y Ddena. OS Explorer map **OL14**.
Seddon, M.B., Killeen, I.J. & Fowles, A.P. 2014. A review of the Non-marine Mollusca of Great Britain. Species Status No.**17**. NRW Evidence Report No. **14**. Natural Resources Wales, Bangor.

Welter-Schultes, F. 2012*. European non-marine molluscs, a guide for species identification.* Planet Poster Editions, Göttingen.

Willing, M.J. 1997. Environment Agency Species Action Plan for England and Wales: compressed river mussel *Pseudanodonta complanata.* In Mainstone, C.P. (ed.) (1998). *Species Management in Aquatic Habitats – Compendium of Project Outputs: Species Action Plans and Management Guidelines.* Environment Agency R & D Project Record **W1/i640/3/M**.

Willing, M.J. 2006. *River Arun Scoping Study: Further surveys for the Compressed River Mussel (Pseudanodonta complanata) July – October 2006*. An unpublished report to Atkins PLC.

Willing, M.J. 2009a. A survey to determine the presence of the depressed river mussel *Pseudanodonta complanata* at selected locations on the Shropshire Union and Llangollen Canals (February & March 2009). Environment Agency Contract No. **30226743**.

Willing, M. J. 2009b. A survey to determine the current status and distribution of the Depressed River Mussel *Pseudanodonta complanata* on the River Wye and a condition assessment of the mussel on the River Wye (Lower Wye) SSSI. Contract Science Report No. **869**. Countryside Council for Wales, Bangor.

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Appendix 1A. 2007 Conservation Objective for the Depressed River Mussel *Pseudanodonta complanata* in the River Wye.

The 2007 report (Willing, 2009b) outlined a common standards monitoring Conservation Objective preceded by a set of survey guidelines. These are reproduced below:

"*The sampling procedure should take place as follows:*

- *At each sampling station mussel counting should take place for 1 hour.*
- *During the survey time searches should take place in water depths between 0.2 – 1.2m in a zone extending approximately 8 – 10m from the river margin.*
- *Sediments to be sampled should ideally be a cobbles / gravel mix embedded in sand. Areas of predominantly gravel produce fewer mussels and, in the Wye, Pseudanodonta avoids thick mud, clay and silty sediments, which are occasionally present in sheltered marginal areas of the river.*
- *Mussel searching can be (1) by the visual detection of mussel siphons where they are buried in sand between larger cobbles or boulders; (2) hand searching by turning cobbles and small boulders in water depths >0.5m or (3) mussels can be revealed by gently agitating the gravel / cobbles by drawing a foot backwards and forwards to a depth of about 10cm across the bottom. Mussels so dislodged lie flat on the bottom and can, after disturbed fine sediment has cleared, be collected for identification by placing a net just downstream of the animals to allow water currents to carry them into the mesh. In place of a foot, a small rake might be substituted. During the sampling period it should be possible to survey a length of river channel approximately 20 – 30m, examining sediments in a variety of locations so that between 15 – 20 separate 0.5m^2 areas have been searched.*
- *Survey sites should be digitally photographed and precise locations recorded with a GPS device. Ideally (although this is not a component of the CSM) live mussels should be measured (length of valves) with vernier calipers, photographed and returned to the river.*
- *Surveyors should wear chest waders and a brightly coloured flotation aid (to increase their visibility to canoe and boat traffic) or alternatively a dry suit made more visible with yellow or orange tape. For reasons of health and safety and also for data recording, another member of the survey team should be located on the river bank, equipped with a suitable throw rope in case of surveyor difficulty whilst in the river."*

The 2007 Conservation Objective:

Conservation objective (for when the feature is in favourable condition)	To maintain the Depressed (Compressed) River Mussel *Pseudanodonta complanata* in the River Wye (Lower Wye) SSSI in favourable condition where:
Lower limit	The combined total of *Pseudanodonta complanata* present at the 8 monitoring sites is 40 (counting 1 hour per site);
Lower limit	and where: The mussel is recorded at 6 of the 8 monitoring sites (see site map);
Lower limit	and where: Occupied stations include Backney Common and Bigsweir in order to maintain current distributional range.
Habitat extent: lower limit	In the survey zone (extending 8 – 12m from river margin) 10 X 0.5m^2 sampling patches (of the 15 – 20 to be sampled per site) should consist of predominantly clean gravel, cobbles and small boulders with sand between. Stones in these patches should be largely free of silt and mud, encrusting algal growth and 'sewage fungus'. If water crowfoot (*Ranunculus* spp) is present at the site, then this is deemed a positive habitat attribute.
Definition of suitable *Pseudanodonta complanata* habitat	In water depths 0.2 – 1.2m (with river levels at or below 1.04m for sites near Monmouth and 0.44m for sites near to Ross-on-Wye) the river floor consists predominantly of clean gravel, cobbles and small boulders with sand between. These rocks are largely free from encrusting algal growths, sewage fungus and are (except in a few sheltered marginal locations) not smothered with mud, silt and clay. River water (at river levels defined) has good clarity such that the river floor can be clearly seen to a depth of at least 1.5m. Water is (at the river levels defined) not turbid due to silt, organic detritus or algal blooms.

Recovery target (for when the feature is in unfavourable condition)	To restore the Depressed (Compressed) River Mussel *Pseudanodonta complanata* in the River Wye (Lower Wye) SSSI to a favourable condition where:
Lower limit	The combined total of *Pseudanodonta complanata* present (counting 1 hour per site) at the 8 monitoring sites is 58 (numbers to restore estimated 2007 'survey period' mussel levels);
Lower limit	and where: the mussel is recorded at 7 of the 8 monitoring sites (see site map);
Lower limit	and where: Occupied stations include Backney Common and Bigsweir in order to maintain current distributional range.
Habitat extent: lower limit	In the survey zone (extending 8 – 12m from river margin) 12 X 0.5m^2 sampling patches (of the 15 – 20 to be sampled per site) should consist of predominantly clean gravel, cobbles and small boulders with sand between. Stones in these patches should be largely free of silt and mud, encrusting algal growth and 'sewage fungus'. If growths of water crowfoot (*Ranunculus* spp) are present at the site, then this is deemed a positive habitat attribute.
Definition of suitable *Pseudanodonta complanata* habitat	In water depths 0.2 – 1.2m (with river levels at or below 1.04m for sites near Monmouth and 0.44m for sites near to Ross-on-Wye) the river floor consists predominantly of clean gravel, cobbles and small boulders with sand between. These rocks are largely free from encrusting algal growths, sewage fungus and are (except in a few sheltered marginal locations) not smothered with mud, silt and clay. River water (at river levels defined) has good clarity such that the river floor can be clearly seen to a depth of at least 1.5m. Water is (at the river levels defined) not turbid due to silt, organic detritus or algal blooms.

Appendix 1B. Revised Conservation Objective for the Depressed River Mussel *Pseudanodonta complanata* in the River Wye following 2022 Survey.

Conservation objective (for when the feature is in favourable condition)	To maintain the Depressed (Compressed) River Mussel *Pseudanodonta complanata* in the River Wye (Lower Wye) SSSI in favourable condition where:
Lower limit	The combined total of *Pseudanodonta complanata* present at the 9 monitoring sites is 60 (counting 1 hour per site);
Lower limit	where: The mussel is recorded at 6 of the 9 monitoring sites (see site map and newly including Hoarwithy at extreme upper limit);
Lower limit	and where: Occupied stations include Backney Common and Cadora Woods Nature Reserve (if shown to support *P. complanata*) to maintain current live distributional range;
Lower limit	and where: 30% of mussels recorded should be in a size cohort of <50mm shell width as an indication of continued population recruitment.
Habitat extent: lower limit	In the survey zone (extending 8 - 12m from river margin) 10 X 0.5m^2 sampling patches (of the 15 - 20 to be sampled per site) should consist of predominantly clean gravel, cobbles and small boulders with sand between. Stones in these patches should be largely free of silt and mud, encrusting algal growth and 'sewage fungus'. If water crowfoot (*Ranunculus* spp) is present at the site, then this is deemed a positive habitat attribute.
Definition of suitable *Pseudanodonta complanata* habitat	In water depths 0.2 - 1.2m (with river levels at or below 1.04m for sites near Monmouth and 0.44m for sites near to Ross-on-Wye) the river floor consists predominantly of clean gravel, cobbles and small boulders with sand between. These rocks are largely free from encrusting algal growths, sewage fungus and are (except in a few sheltered marginal locations) not smothered with mud, silt and clay. River water (at river levels defined) has good clarity such that the river floor can be clearly seen to a depth of at least 1.5m. Water is (at the river levels defined) not turbid due to silt, organic detritus or algal blooms.

Recovery target (for when the feature is in unfavourable condition)	To restore the Depressed (Compressed) River Mussel *Pseudanodonta complanata* in the River Wye (Lower Wye) SSSI to a favourable condition where:
Lower limit	The combined total of *Pseudanodonta complanata* present (counting 1 hour per site) at the 9 monitoring sites is 65 (numbers to restore estimated 2022 'survey period' mussel levels);
Lower limit	where: the mussel is recorded at 7 of the 9 monitoring sites (see site map and newly including Hoarwithy at extreme upper limit);
Lower limit	and where: Occupied stations include Backney Common and Cadora Woods Nature Reserve (if shown to support *P. complanata*) in order to maintain current distributional range;
Lower limit	and where: 35% of mussels recorded should be in a size cohort of <50mm shell width as an indication of recovered population recruitment.
Habitat extent: lower limit	In the survey zone (extending 8 - 12m from river margin) 12 X 0.5m^2 sampling patches (of the 15 - 20 to be sampled per site) should consist of predominantly clean gravel, cobbles and small boulders with sand between. Stones in these patches should be largely free of silt and mud, encrusting algal growth and 'sewage fungus'. If growths of water crowfoot (*Ranunculus* spp) are present at the site, then this is deemed a positive habitat attribute.
Definition of suitable *Pseudanodonta complanata* habitat	In water depths 0.2 - 1.2m (with river levels at or below 1.04m for sites near Monmouth and 0.44m for sites near to Ross-on-Wye) the river floor consists predominantly of clean gravel, cobbles and small boulders with sand between. These rocks are largely free from encrusting algal growths, sewage fungus and are (except in a few sheltered marginal locations) not smothered with mud, silt and clay. River water (at river levels defined) has good clarity such that the river floor can be clearly seen to a depth of at least 1.5m. Water is (at the river levels defined) not turbid due to silt, organic detritus or algal blooms.

Appendix 2. River Wye 2022 survey results.

Site name & number, grid ref. & vice county	Survey date	*Pseudanodonta complanata* in 2007 (live)	*Pseudanodonta complanata* (live / fresh dead [FD]) in 2022 per hour	*Anodonta anatina* (& other unionids)	Summary of changes 2007 to 2022
1. Backney Common SO5853127064 (VC 36)	18.8.2022	2 (in 1.5 hours)	2	*Anodonta anatina* x1 *Anodonta cygnea* x2 *Unio pictorum* x1	Seemingly similar to 2007 (although slight habitat deterioration)
2. Ross-on-Wye (below Bridstow Bridge) SO5953824497 (VC 36)	18.8.2022	4 (in 1.5 hours)	4 (+ 1 recorded beyond the 1 hour survey period)	*Anodonta anatina* x7	Seemingly similar to 2007 (although slight habitat deterioration)
3. Kerne Bridge SO5803019195 (VC 36)	18.8.2022	11 (in 1 hour)	0	No other unionids living or dead	Significant habitat deterioration. Apparent disappearance of *P. complanata* and other unionid mussels.
4. Huntsham Bridge SO5684218068 (VC 36)	19.9.2022	15 (in 0.75 hour)	3	*Anodonta anatina* x7	Marked habitat deterioration. Decline in mussel presence; only old mature mussels recovered suggesting no or low recruitment.
5. Dixton SO5223513727 (VC 35)	19.9.2022	14 (in 2.5 hours) (but recovered chiefly from central channel not margins)	32 (all from channel margins)	*Anodonta anatina* x3	Noticeable signs of habitat deterioration. *P. complanata* seemingly doing well but all specimens found at river margins and none central channel (see discussion for further details)

Site name & number, grid ref. & vice county	Survey date	*Pseudanodonta complanata* in 2007 (live)	*Pseudanodonta complanata* (live / fresh dead [FD]) in 2022 per hour	*Anodonta anatina* (& other unionids)	Summary of changes 2007 to 2022
6. Monmouth (Monmouth School Rowing Club) SO5125812829 (VC 35)	17.8.2022	18 (in 1.5 hours)	10	*Anodonta anatina* x5	Noticeable signs of habitat deterioration. *P. complanata* population maintained.
7. Redbrook (river above) SO5329610380 (VC 35)	17.8.2022	5 (in 1.5 hours)	1	*Anodonta anatina* x2	Noticeable signs of habitat deterioration. *P. complanata* seemingly scarce and possible decline; 2 fresh dead (tissue remains present) specimens found in shallows
8. Bigsweir SO5397305447 (VC 35)	17.8.2022	4 (2 hours)	0 (1 pair of dead & corroded paired valves) 1.5 hours spent at this site	*Anodonta anatina* x2	Noticeable signs of habitat change. Apparent disappearance of *P. complanata* and decline of other unionid mussels.

Appendix 3. *Pseudanodonata complanata* (measurements: valve length mm (anterior-posterior width).

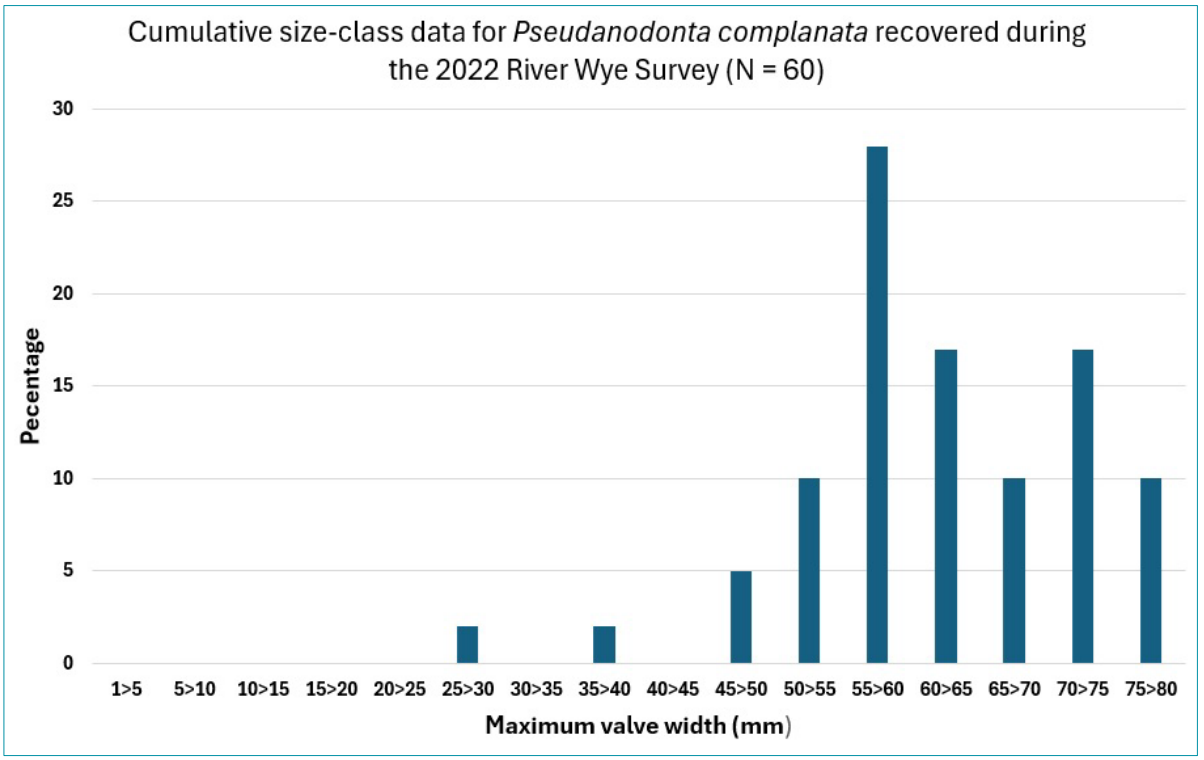
Site name & number	*Pseudanodonta complanata* live or FD (fresh dead) mm
1. Backney Common SO5853127064 (VC 36)	76.8, 64.8 (2 live); 54.3 (1 fresh dead)
2. Ross-on-Wye (below Bridstow Bridge) SO5953824497 (VC 36)	78.1, 77.1, 73.1, 70.0, 55.1 (5 live)

3. Kerne Bridge SO5803019195 (VC 36)	No mussels found
4. Huntsham Bridge SO5684218068 (VC 36)	78.8, 75.5, 73.9 (3 live)
5. Dixton SO5223513727 (VC 35)	77.5, 74.2, 73.2, 72.2, 71.8, 70.4, 70.2, 70.1, 68.1, 66.9, 65.3, 62.7, 62.6, 62.0, 61.9, 60.8, 60.3, 60.2, 59.2, 59.2, 58.7, 58.4, 57.6, 56.4, 56.0, 55.2, 55.0, 55.9, 53.7, 50.8. 48.2, 44.8 (32 live); 58.2, 57.5, 69.0, 56.3 (4 fresh dead)
6. Monmouth (Monmouth School Rowing Club) SO5125812829 (VC 35)	64.5, 61.2, 59.6, 56.7, 55.8, 54.7, 53.8, 49.8, 37.1, 27.5 (10 live)
7. Redbrook (river above) SO5329610380 (VC 35)	51.4 (1 live); 68.0, 65.9 (fresh dead)
8. Bigsweir SO5397305447 (VC 35)	No live mussels found (two dead and corroded paired valves)

Appendix 4. Cumulative size class data for *Pseudanodonta complanata* recovered during the River Wye 2022 survey (N = 60)

The 60 live and freshly dead *Pseudanodonta complanata* recorded on the current survey ranged in size from 27.5mm to 78.8mm shell width. Compared to the 2007 survey, there is a greater proportion of large, older mussels and a smaller proportion of small, younger ones. Thus, in 2007 30% of the mussel cohort was <50mm shell width whereas in 2022 only it was only 9%. By contrast, in 2007 25% of the mussels were >65mm shell width whereas in 2022 this was 37%. Additionally, in 2022 six mussels (9%) exceeded 75mm shell width, but none was recorded in this size range in 2007. Some of the 2022 sites such as Backney Bridge, Ross-on-Wye and Huntsham Bridge only supported cohorts of large, old adults (Figures 6.2, 6.5 & 6.8 respectively). In 2007, 15 mussels were recovered at Huntsham Bridge of which 47% were <50mm shell width. In 2022, only three large,

corroded mussels were found at the site, all exceeding 70mm shell width. This observation indicates a lack of mussel recruitment at the site.



Appendix 5. River Wye site details

Site name & number, grid. ref. & vice county (VC)	Survey date	*Pseudanodonta complanata* (live [L] / fresh dead [FD])	River level when surveyed (from nearest Environment Agency monitoring station (R = Ross-on-Wye; M = Monmouth)	Site description (2007)	Site description (2022) & observed changes since 2007 survey
1. Backney Common SO5853127064 (VC 36)	18.8.2022	2 (L); 1 (FD)	0.182m (R) (Suggested max for survey 0.44 m)	Moderate to very fast flow whole width of channel <1.5 m in depth; clean gravel, cobbles and occasional small clean boulders with sand and silt in sheltered marginal areas, some areas of water crowfoot; fine marginal sediments in sheltered area downstream of willows sampled for *Pisidium* spp. Mussels located in water within 10m of margin at depths 0.3 – 1.2m. Possible to wade across river when surveyed.	Similar to 2007 and sampled at low water levels exposing areas of gravel shore. Small areas of water crowfoot. In marginal pool on west bank some filamentous algal growth producing some slight and partial covering of the bottom and on macrophytic growth. Marginal areas of consolidated fine sand and silt (in slower water flow) produced both live *P. complanata* (and other 3 recorded unionid species).

Site name & number, grid. ref. & vice county (VC)	Survey date	*Pseudanodonta complanata* (live [L] / fresh dead [FD])	River level when surveyed (from nearest Environment Agency monitoring station (R = Ross-on-Wye; M = Monmouth)	Site description (2007)	Site description (2022) & observed changes since 2007 survey
2. Ross-on-Wye (below Bridstow Bridge) SO5953824497 (VC 36)	18.8.2022	5 (L)	0.182m (R) (Suggested max for survey 0.44 m)	Moderate to fast flow whole width of channel <1.3m in depth; clean gravel, cobbles with small areas of finer sediments (silt, sand) in more sheltered marginal areas. Mussels found across channel buried in gravel & between cobbles. Possible to wade across river when surveyed.	Similar to 2007. Most of channel devoid of water crowfoot except immediately downstream of the Ross-on-Wye rowing club. Water clarity good and bottom gravel and sand largely free from filamentous algae and encrusting algae. Small amounts of filamentous algae restricted to a few slow flowing deeper (up to 1 m) water areas on left bank below rowing club.
3. Kerne Bridge SO5803019195 (VC 36)	18.8.2022	Nil	0.182m (R) (Suggested max for survey 0.44 m)	Moderate flow whole width of channel <1.5m in depth; clean cobbles and gravel with sand between; some areas of water crowfoot . Mussels located by hand searching amongst cobble & small boulders located in water depths <0.8m within 5m of margin.	Decline of water crowfoot, in all but fastest water flow gravel covered in filamentous algae and 'sewage fungus' covered gravel and cobbles. Some shaded fine marginal fine sand and clay in the shade of overhanging willows were largely free from algal growth.

Site name & number, grid. ref. & vice county (VC)	Survey date	*Pseudanodonta complanata* (live [L] / fresh dead [FD])	River level when surveyed (from nearest Environment Agency monitoring station (R = Ross-on-Wye; M = Monmouth)	Site description (2007)	Site description (2022) & observed changes since 2007 survey
4. Huntsham Bridge SO5684218068 (VC 36)	19.9.2022	3 (L)	0.712m (M) (Suggested max for survey 1.04m)	Moderate flow across whole channel with water depths >1.3m; mussels located in fine gravel and sand amongst cobbles with plentiful water crowfoot in water depths 0.5 – 1.2m within 6m of margins. Possible to wade across river when surveyed.	Water slightly turbid. Water crowfoot and other macrophytes mostly festooned with blankets of filamentous algae. Areas of coarse sand, gravel and cobbles partially algal free in faster flowing stretches or in shade of marginal willows. No significant algal growth was not noted in 2007.
5. Dixton Upstream of … SO5223513727 (VC 35)	19.9.2022	32 (L); 4 (FD)	0.73m (M) (Suggested max for survey 1.04m)	Moderate to fast flow across whole channel with water depths >1.6m; mussels located in sandy gravel with occasional cobbles and sand amongst cobbles in water depths to 1.2m within 6 – 7m of margins. Possible to wade across river when surveyed.	Moderate to fast flow across whole channel with water depths >1.2m. Some discontinuous filamentous algae presence evident in slower flowing marginal areas (covering bottom sediments and water crowfoot) but not affecting most of the central channel where gravel and cobbles were clean and algal-free; frequent patches of water crowfoot across much of the channel. Filamentous algal presence significantly less that observed immediately downstream at Site 6 in Monmouth.

Site name & number, grid. ref. & vice county (VC)	Survey date	*Pseudanodonta complanata* (live [L] / fresh dead [FD])	River level when surveyed (from nearest Environment Agency monitoring station (R = Ross-on-Wye; M = Monmouth)	Site description (2007)	Site description (2022) & observed changes since 2007 survey
6. Monmouth (Monmouth School Rowing Club) SO5125812829 (VC 35)	17.8.2022	10 (L)	0.712m (M) (Suggested max for survey 1.04m)	Moderate to fast flow; mussels located in gravel and cobbles in one sheltered marginal location overlain with 10cm of clay (allowing mussel siphons to be seen) in water depths to 1.2m within 6 – 7m of margins.	In shallower and more marginal areas bottom sediments were more than 80% covered with blankets of filamentous algae. This only decreased in central, faster flowing areas of the channel. The algal growth significantly impeded bathyscope searches for river mussels. Small areas of water crowfoot were observed; algal cover was noticeably greater than that observed at Dixton a relatively short distance upstream. Blanketing filamentous algae were not observed in this search area in 2007.
7. Redbrook (river above village) SO5329610380 (VC 35)	17.8.2022	1 (L); 2 (FD)	0.722m (M) (Suggested max for survey 1.04m)	Moderate to fast flow; mussels located in sandy gravel in marginal areas within 6m of margins (beyond which water deepened to >2m and presence of larger boulders prevented use of hand net or dredge.	Gravel only free from algal cover in faster flower (mostly shallower) sections of the channel. In slower flowing and deeper water areas, significant ‘blankets’ of filamentous algae were observed to smother the bottom and envelop macrophyte growth e.g. water crowfoot. Bottom sediments were algal free here in 2007.

Site name & number, grid. ref. & vice county (VC)	Survey date	*Pseudanodonta complanata* (live [L] / fresh dead [FD])	River level when surveyed (from nearest Environment Agency monitoring station (R = Ross-on-Wye; M = Monmouth)	Site description (2007)	Site description (2022) & observed changes since 2007 survey
8. Bigsweir SO5397305447 (VC 35)	17.8.2022	No live / fresh dead, 1 paired dead	0.721m (M) (Suggested max for survey 1.04m)	Moderate to fast flow across whole channel with water depths >1.6m; mussels located in sandy gravel with occasional cobbles in water depths to 1.2m within 6 – 7m of margins. Possible to wade across river when surveyed.	Moderate to fast flow across whole channel with water depths >1.2m. No significant algal growth observed even in slower flow marginal areas. Quantities of fine silt and clay present amongst gravel and cobbles noticeable when these were agitated by a foot or mussel search rake. These fine sediments may be deposited from upstream tidal intrusions of silty water (search area lies immediately above the River Wye Upper Tidal Limit) Such fine sediments and were not noted during the 2007 survey.

Appendix 6. River Wye water levels recorded (at NRW & EA gauging stations) during 2022 survey period

Survey site & date	Ross-on-Wye (gauging station) max. river level for survey (m)	Ross-on-Wye (gauging station) River level on survey day	Monmouth (gauging station) max. river level for survey (m)	Monmouth (gauging station) River level on survey day
Monmouth (17.8.22)	-	-	1.04	0.712
Redbrook (17.8.22)	-	-	1.04	0.721
Bigsweir (17.8.22)	-	-	1.04	0.722
Backney Common (18.8.22)	0.44	0.182	-	-
Bridstow Bridge (Ross-on-Wye) (18.8.22)	0.44	0.182	-	-
Kerne Bridge (18.8.22)	0.44	0.182	-	-
Dixton (19.8.22)	-	-	1.04	0.712
Huntsham Bridge (19.8.22)	-	-	1.04	0.73

Appendix 7. Images of monitoring sites and *Pseudanodonta complanata* and other Unionid mussels recorded

Figure 6.1. Site 1 - Backney Common.

Figure 6.2. *Pseudanodonta complanata* recorded at Backney Common.

Figure 6.3. *Anodonta cygnea* (bottom) and *Unio pictorum* (top) recorded at Backney Common.

Figure 6.4. Site 2 – Ross-on-Wye (Bridstow Bridge).

Figure 6.5. *Pseudanodonta complanata* recorded at Ross-on-Wye (Bridstow Bridge).

Figure 6.6. Site 3 - Kerne Bridge (looking upstream).

Figure 6.7. Site 4 - Huntsham Bridge.

Figure 6.8. *Pseudanodonta complanata* recorded at Huntsham Bridge.

Figure 6.9. Site 5 – Dixton.

Figure 6.10. *Pseudanodonta complanata* recorded at Dixton.

Figure 6.11. Site 6 - Monmouth (Monmouth School rowing club).

Figure 6.12. *Pseudanodonta complanata* recorded at Monmouth.

Figure 6.13. Site 7 – Redbrook.

Figure 6.14. *Pseudanodonta complanata* recorded at Redbrook (top two shells fresh dead shells).

Figure 6.15. Site 8 – Bigsweir.

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' Data Discovery Service https://metadata.naturalresources.wales/geonetwork/srv (English version) and https://metadata.cyfoethnaturiol.cymru/geonetwork/cym/ (Welsh Version). The metadata is held as record no. **NRW_DS161313**.