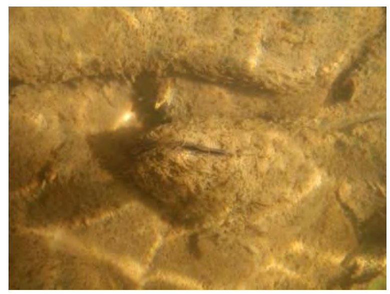
Monitoring substrate and interstitial quality of the River Our, Luxembourg



Study carried as part of EU-Project LIFE05Nat/L/000116
« *Restauration des populations des moules perlières en Ardennes* »

August 2011

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1.0 Introduction

In 2005, a LIFE Nature project, *Restoration of Freshwater Pearl Mussel populations in the Ardennes* (LIFE05Nat/L/000116) commenced on the River Our in Luxembourg. The project, jointly funded by EU, the Luxembourg Government and the Fondation Hellef fir d'Natur, was set up with the primary aims of carrying out restoration measures on the tributaries, to culture juvenile mussels, to monitor the population and its habitat and public awareness. The restoration measures have included felling of non-native spruce forest, planting deciduous forest, fencing to exclude cattle from the river, provision of watering facilities, cattle bridges, addition of gravels to the river, enhancing tributaries for fish migration, release of fish encysted with pearl mussel glochidia, and captive rearing of pearl mussels at Kalborn Mill.

The monitoring program has included chemical and physical water parameter measurements, macro-zoobenthos communitiy analysis, and the fish population, on the tributaries and the main River Our in the tributaries and the river. Part of the monitoring programme also included an assessment of the suitability of the substrate in the River Our for juvenile pearl mussels, in part to determine the most suitable places for release of captive bred juvenile mussels. The interstitial quality of the substrate was determined by redox potential and taking penetrometry measurements. For this purpose, twelve monitoring transects were set up along a section of the River Our from the 3 border conjunction in the north, to Dasburg in the south. These transects were monitored in 2007 and 2009 by Juergen Geist (Geist 2007, 2009). To determine if there has been any change, a further round of monitoring has been carried out at the end of the LIFE project in August 2011.

This report describes the 2011 round of monitoring.

2.0 Site locations

The locations of the 12 transects with Latitude and Longitude co-ordinates are given in Table 2.1 and in Figure 2.1. All of these correspond to those as surveyed by Geist in 2007 and 2009, apart from Transect 2. In 2011 the habitat at the original Transect 2 site was found to be comprised almost entirely of silt covered bedrock and large angular cobble and boulders, with virtually no places where satisfactory redox or penetrometry measurements could be made. Therefore, the transect was relocated further downstream at a location where a few mussels were known to occur. Additional measurements were made at a site between Transect 2 and Transect 3 (labelled Transect 13) to obtain additional information from a site where pearl mussels were known to still live. However, this was not a linear transect and a series of readings were made principally in the habitat where the mussels were living. Measurements of redox potential and penetrometry were also taken in the mill channel at Kalborn Mill to assess the suitability of the habitat as a potential receptor site for captive bred mussels.

Table 1.1: Location of Transect sites

Site No.	Location	Lat/Long co-ordinates	Width of transect (m)
1	100 m below 3 border point	50.128988°N, 6.137655 °E	14.4
2	c. 125 m below confluence with Schelsbaach	50.117557 °N, 6.128683 °E	21.9
3	20 m below dam at the mill of Kalborn	50.105273 °N, 6.134269 °E	11.6
4	20 m above confluence with Selburen "Schankbaach"	50.101728 °N, 6.126072 °E	13.2
5	400 m above sampling site 6 (former mussel area)	50.098427 °N, 6.126175 °E	15.4
6	"Duck cages" former mussel area	50.095971 °N, 6.128313 °E	23.3
7	Grossenauel 20m below former cattle watering place	50.081846 °N, 6.122023 °E	11.7
8	20 m below meadow with former "Lorentz-Millen"	50.074067 °N, 6.122168 °E	16.1
9	50 m above confluence with Kenzelbaach	50.060937 °N, 6.112305 °E	23.3
10	30 m above confluence with Kenzelbaach / 30 m below sampling site 9	50.060775 °N, 6.11258 °E	14.2
11	c. 50 m below confluence with Ruederbaach / River km 38	50.057362 °N, 6.115598 °E	22.2
12	150 m below bridge in Dasburg	50.048388 °N, 6.127016 °E	19.6
13	Hiour – mussel location	50.111341 °N, 6.133977 °E	13.5
14	Kalborn Mill – mill stream		2.5

Figure 1.1: Location of transect sites

3.0 Work carried out

At each Transect location, the following measurements were taken:

Width of transect
Temperature
pH
Depth across transect
Water velocity across transect
Conductivity across transect
Redox measurements across transect
Penetrometry measurements across transect

The redox and penetrometry work was carried out by Ian Killeen, Malacological Services, and all other measurements were made by Frankie Thielen, Fondation Hellef fir d'Natur.

A summary of all of the measurements taken at each site along with photographs is given in the Appendix to this report. Methodologies, results and discussion for individual parameters are given in the following sections.

4.0 Redox Potential Measurements

4.1 Introduction

The key cause of decline in pearl mussel populations in most rivers is lack of recruitment brought about by the habitat for juvenile mussels after they fall off the gills of host salmonids being unsuitable. This stage requires the safety of remaining within the river bed gravels, before growing to a size that allows the emergence of the filtering siphons into the open water body. While the juvenile mussels remain within the river bed gravels, they filter the interstitial water within the gravels. Where the gaps between the gravel stones get clogged with fine silt, the flow of water in the interstices becomes very restricted. Without adequate water movement and replacement, oxygen levels are exhausted and young mussels die. The decline in interstitial water quality in silted gravels has been detailed by Buddensiek (1989), Buddensiek *et al*. (1993). Fine sediments in gravels were shown to increase mortality in juvenile mussels to 100% (Buddensiek, 2001).

Fine silt can become a problem due to excessive loading from various sources. Excessive nutrients in the water body lead to filamentous algal growth, which in turn decays and forms organic silt.

A technique was devised by Geist and Auerswald (2007) measuring differences in the redox potential between the water column and the substrate which correlate with differences in oxygen levels, and thus, the level of clogging of the interstices by fine sediments (silt). These data are of greatest significance for juvenile mussels which require full oxygenation of the sediment. In suitable juvenile mussel habitat, there should be very little loss of redox potential between the open water and the gravels below. There should not be a significant reduction in redox potential to depths to 10cm (Geist & Auerswald 2007).

4.2 Methodology

The equipment comprises a 0.7m long probe fitted with a platinum tipped electrode, a reference electrode and a meter with a millivolt display. A reading was obtained by holding both electrodes in the water column until a stable reading was obtained (typically this would be 400-540mV). With the reference electrode remaining in the water column, the platinum electrode was then inserted into measured depths in the substrate and a reading taken immediately. Separate readings were obtained for substrate depths of 5cm and 10cm. Approximately 10-15 readings were taken at intervals along the transect at each site. The number of intervals depending upon transect width.

Figure 2: Taking redox measurements

4.3 Results

A total of 551 measurements were made on the 12 main monitoring transects at a depth of 5cm and a further 117 measurements made at a depth of 10cm. At the additional site 13, a total of 81 measurements were made (all at 5cm depth, and at Kalborn Mill (site 14), 44 readings were taken at 5cm depth and 34 at 10cm depth.

The results of the redox measurements are summarized in Table 4.1. These are shown as the mean redox potential values for each transect in mV, and the mean loss in redox potential between the open water and the substrate at 5cm and 10cm depth. Figures 4.1 and 4.2 show the results as scatter graphs for the mV readings and %loss in redox respectively.

Table 4.1: Summary of redox results

			Value mV	**% loss in redox potential**
Transect	**Depth (cm)**	**n**	**Mean**	**Mean**
1	water		460	
	5	45	315	31.5
	10	15	277	39.8
2	water		440/450	
	5	71	302	32.2
	10	18	226	49.1
3	water		420/440	
	5	45	319	27.5
	10	12	267	39.3
4	water		450	
	5	53	324	28.0
	10	8	275	38.9
5	water		450	
	5	58	310	31.1
	10	11	270	40.0
6	water		450	
	5	55	289	35.8
	10	25	234	48.0
7	water		440	
	5	30	326	25.6
	10	0	-	-
8	water		440	
	5	45	295	33.0
	10	15	196	55.4
9	water		450	
	5	53	300	33.3
	10	10	233	48.2
10	water		450	
	5	38	314	30.2
	10	3	244	45.8
11	water		450	
	5	58	311	30.9
	10	0	-	-
12	water		450	
	5	52	257	42.9
	10	0	-	-
13	water		440	
	5	81	287	34.8
	10	0	-	-
14	water		450	
	5	44	326	27.6
	10	34	298	33.8

Figure 4.1: Mean redox values (mV) for each transect site

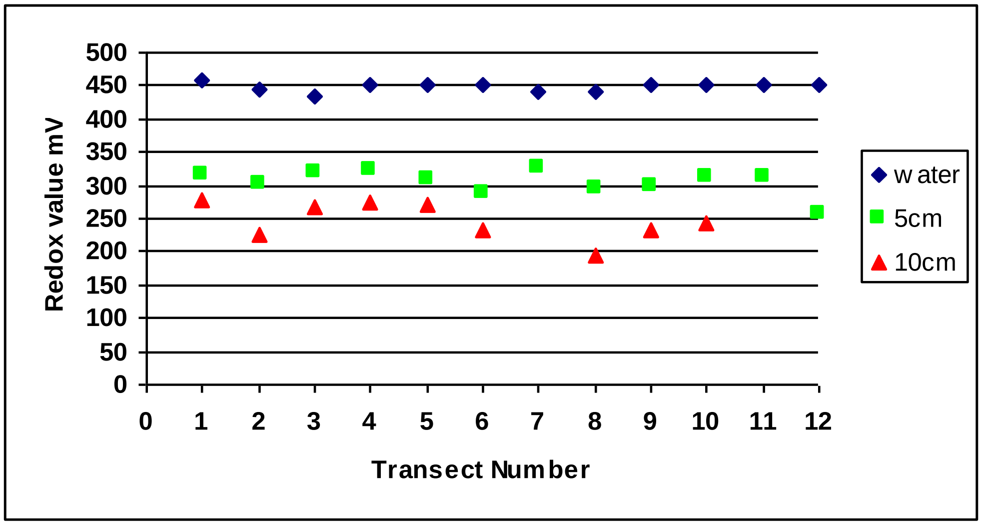
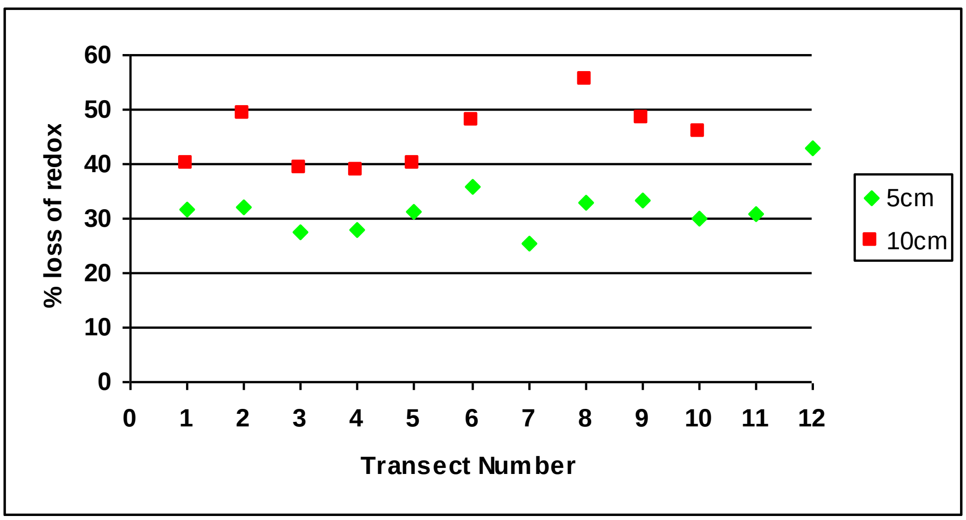


Figure 4.2: Mean %loss in redox between the open water and the substrate at each transect site



4.4 Discussion

The main point of taking redox measurements is to assess the level of oxygen reaching the interstitial habitat of the substrate at depths that are required to support juvenile pearl mussels. This ideally means a good mix of stable material from very fine (1-3mm) gravel to very coarse gravel (30-75mm) (definitions based upon the Udden-Wentworth scale) with additional stabilisation provided by large cobble (75-250 mm) and boulder (250mm+). The redox measurement is a proxy for the ability for oxygen in the interstitial water to exchange with that of the open water.

A major problem at nearly all of the transect sites was the sparsity of habitat in which redox potential measurements could be reliably taken, i.e. lack of pearl mussel habitat. A significant portion of the substrate in the monitored section of the River Our is comprised of bedrock. This was overlain to varying degrees by very coarse gravel and cobble. Much of the coarse material was angular or was lamellar (flattened). In the case of lamellar substrate, mussels cannot bury in such shaped material and it is not possible to insert the redox probe either. Smaller clast size material (i.e. 1 – 30mm) was often restricted to narrow zones at the margins of the river channel, or to runnels and depressions within the bedrock, there were few places where good, stable mussel habitat occurred (parts of Transects 4, 5 and 6 for example) to any extent. Within the runnels and depressions the layer of gravels was frequently very shallow, only a few centimetres in depth. These places are not stable and are easily flushed out in flood events. This shallow depth of gravels also accounts for the difficulty in finding enough places to take redox measurements at a depth of 10cm.

At all of the sites, either parts of the channel or the whole channel width were covered with a layer of fine silty/muddy sediment (see comments and photos in the Appendix). A plume of silt was also released from the substrate when walking across the channel or kicking into the substrate. It is therefore of no surprise that the results from the redox measurements show levels of silt infiltration within the substrate that render the habitat unsuitable for juvenile pearl mussels.

It must be noted that these are only raw data – redox potential (eH) values should be temperature corrected, and therefore the values are comparative rather than exact in this study. However, as there was very little temperature variation between sites during the sampling period, the data are considered to be comparable.

Although not directly comparable, results from a recent survey of the River Ehen in Cumbria (Killeen 2006) show that young mussels and juveniles were present only in the most highly oxygenated riffle areas where the loss in redox value was less than 20% at 5cm depth. Losses at 5cm depth of 25-30% show that the substrate is silted but not severe, whereas anything over 30% is considered severe.

The mean results of loss in redox potential at 5cm depth range from 25.6% (Transect 7), to 42.9% (Transect 12). Only 2 other sites (Transects 3 and 4) had losses of less than 30%. Whilst these results suggest that the substrate is less unsuitable at these locations, it has to be remembered that the often small and shallow patches of gravels in which redox was measured, may have been in unstable, cleaned and scoured. At all of the other transect sites the mean loss of redox at 5cm depth was 30% or greater, showing severe silt infiltration of the substrate. At most of the transects there was a further increase in loss of redox at a depth of 10cm, generally ranging from an additional 10-15% loss.

The 2011 results are less favourable than those recorded by Geist in 2007 and 2009 (Figures 4.3 and 4.4). Geist's graphs do not show % loss but by estimation it can seen that there were several transects with losses of below 20% at 5cm depth and with the exception of Transect 12, all others had losses of less than 30%. The results suggest that the interstitial quality of the River Our substrate has deteriorated such that the majority of the potential mussel habitat is severely infiltrated by silt. However, the Our had been in a low-flow regime for much of the summer and it is therefore possible that this has allowed fine material to build up both on the surface and within the substrate. It is also possible that higher winter flows will disperse a significant amount of this silty material. However, even if the interstices within the gravels are clogged by silt even for a few months each year, it is highly unlikely that juvenile pearl mussels would be able to survive during such low flow periods.

Figure 4.3 Redox potential results (mV) for 2007 (Geist 2007)

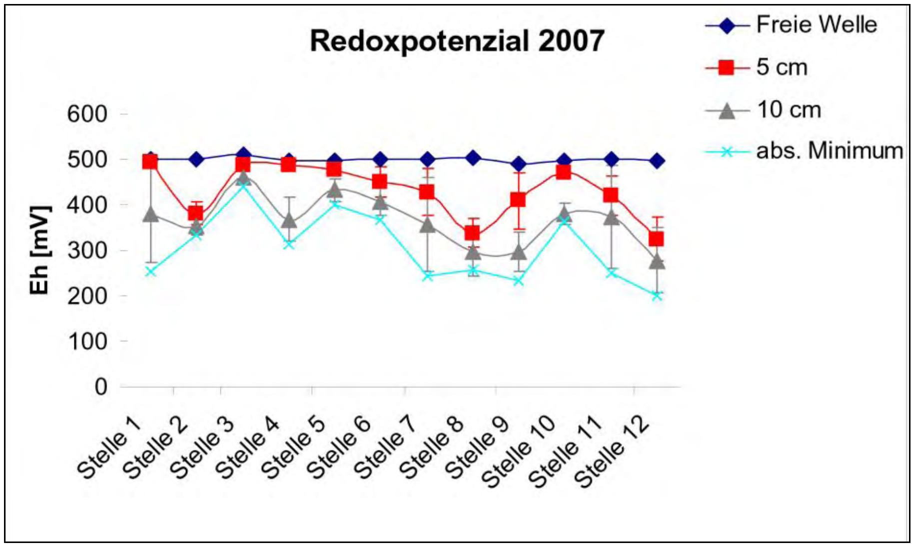
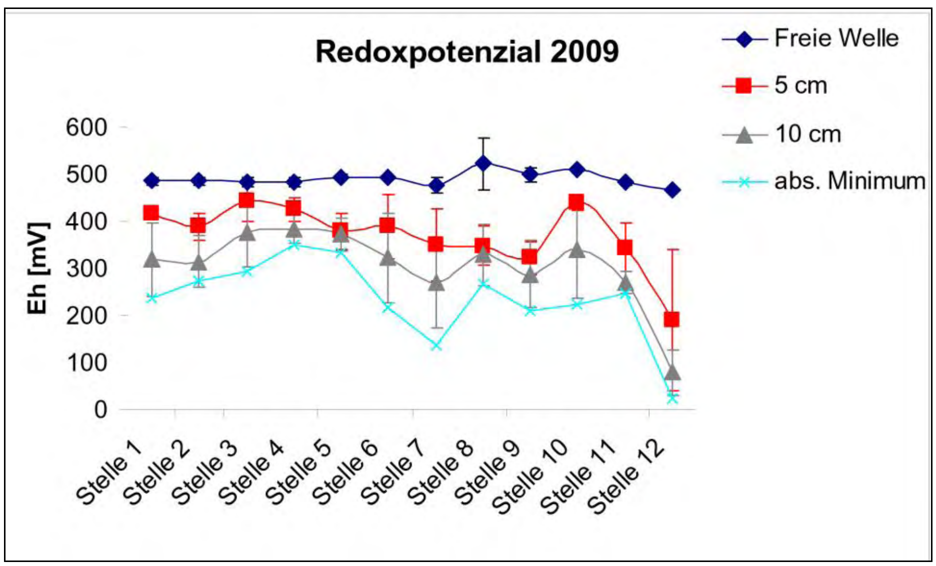


Figure 4.4 Redox potential results (mV) for 2009 (Geist 2009)



5.0 Penetrometry

Freshwater pearl mussels, both adult and juvenile, require an appropriate river bed substrate structure. In areas of river bed with an excess of fine sediments, the bed will not be stable enough to support juvenile mussels, and adult mussels can easily be transported downstream. In areas of river bed where the substrate is too compacted, mussels find it difficult to burrow to an appropriate depth, so a balance is needed where the river bed is stable in nature but not compacted enough to reduce oxygen levels or the ability of mussels to move when needed. The most suitable pearl mussel habitat contains a wide range of substrate size except for extremely fine silt or mud.

While redox potential measurements provide valuable information on the oxygen levels of the sediment, a hand-held penetrometer is used to establish the level of compactness of the river bed substrate. The basis of the measurement is to press a standard cone on a standard spring and measure the resistance provided by the substrate against the cone entering the substrate mix. The technique involved in penetrometry measurement requires an understanding of the substrate one is working with. Obviously the meter cannot enter solid rock, no matter how hard one pushes, therefore solid bedrock is at one extreme of the scale, and a depth of silt or mud is at the other end. Both extremes are consistent with poor mussel habitat, but a value in between is consistent with mixed substrate that is stable but moves under pressure.

The technique described above describes the use of the cone penetrometer, which is a measurement of resistance of the meter versus the substrate. In other meters, a wider disc is used, which looks at the shear stress movement of substrate particles with each other. The latter technique was used in the 2007 and 2009 surveys, and thus is not directly relatable to this survey. The results of cone penetrometry in freshwater pearl mussel habitat have not yet been published, but an example of typical results from good habitat in an English *Margaritifera* river is provided as an example (Figures 5.1, 5.2).

Figure 5.1: Penetrometry results from good *Margaritifera* habitat, River Ehen (England), Station 1 (penetrometry reading between 0 and 7 versus % of readings in each reading class, N= 84)

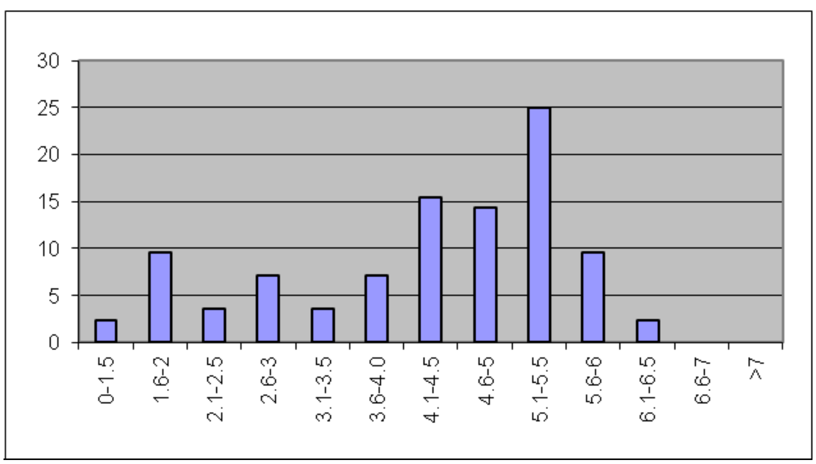
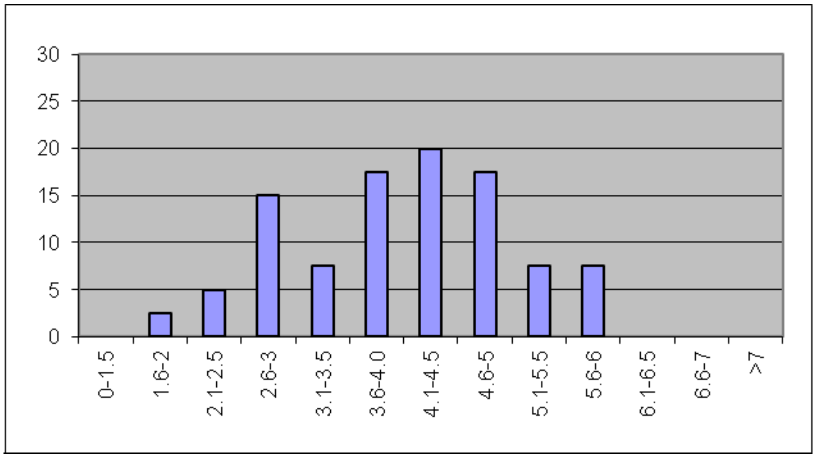


Figure 5.2: Penetrometry results from good *Margaritifera* habitat, River Ehen (England), Station 2 (penetrometry reading between 0 and 7 versus % of readings in each reading class, N= 40)



The results show that good pearl mussel habitat has little or no excessive soft or hard substrate, but has a wide variety of middle values, derived from the fact that no single class size dominates the results.

5.2 Methodology

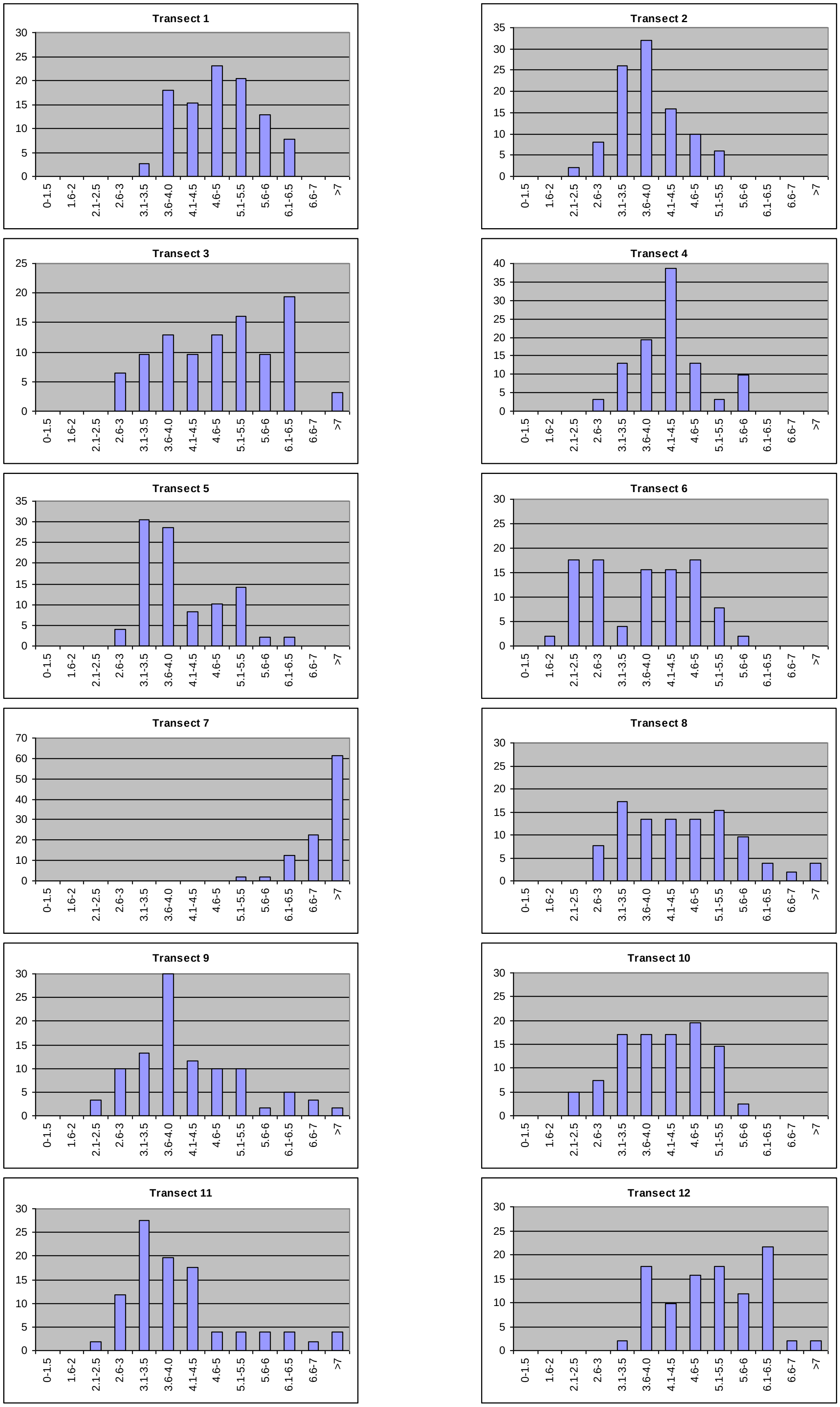
The measurements in the River Our were taken using a Van Walt Hand Penetrometer equipped with a 100N spring and a 8mm diameter cone (= 0.5cm^2 surface area). The scale on the penetrometer is set to zero and then pushed into the substrate with one hand a constant pressure (2cm/sec) until the spring resists or gives. A reading is then taken. This reading may then be converted to cone resistance in kg/cm^2 (for this cone size and spring, the factor is reading x 2).

5.3 Results

The results are summarized in Table 5.1 below and graphs of penetrometry readings between 0 and 7 versus % of readings in each reading class are shown in Figure 5.3.

Transect Number		Reading (cm)		Cone resistance (kg/cm^2)	
	n	Range	Mean	Range	Mean
1	40	3.4-6.2	4.81	6.8-12.4	9.62
2	50	2.4-5.5	3.80	4.8-11.0	7.6
3	30	2.9-7.1	4.79	5.8-14.2	9.58
4	30	2.9-5.6	4.39	5.8-11.2	8.78
5	50	2.8-6.2	3.94	5.6-12.4	7.88
6	50	2.0-5.7	3.79	4.0-11.4	7.58
7	50	5.4-9.2	7.28	10.8-18.4	14.56
8	52	2.6-7.6	4.54	5.2-14.6	9.08
9	60	2.5-7.2	4.14	5.0-14.4	8.28
10	40	2.7-5.9	4.04	5.4-11.8	8.08
11	50	2.2-7.2	4.05	4.4-14.4	8.10
12	50	3.3-7.1	5.10	6.6-14.2	10.2

Figure 5.3: Penetrometry reading between 0 and 7 versus % of readings in each reading class



5.4 Discussion

These results show a very wide range of resistance of the substrate in the River Our. The substrate at Transects 1, 3, 7 and 12 for example, have a high proportion of high readings, whereas the substrate at Transects 6 and 11 have a higher proportion of low readings, and the remaining transects have a wide spread. On this basis, and making comparison with the River Ehen, it might be deduced that the more suitable habitat for mussels is at Transects 2, 5, 6 and 11 where, from field observations, there was better potential habitat and mussels still living or were formerly known. As with the redox measurements, a relatively high proportion of these penetrometry readings are being taken in substrate which is not pearl mussel habitat. The readings taken from coarse, angular or lamellar substrate will inevitably give high penetrometry readings, and low readings will be obtained in the pockets of unstable gravels lying in runnels and depressions in the bedrock

As use of this technique is still in its early stages of use and much more work is required to interpret the results and assess their usefulness. Therefore, the data is given in this relatively raw form, but it should be possible in the future to assess these data in greater detail.

6.0 pH and conductivity

6.1 Results

The results of the pH and Conductivity measurements are summarized in Table 6.1. Figures 6.1 and 6.2 show the results as scatter graphs for the pH and conductivity respectively.

Table 6.1: Mean pH and Conductivity values for each transect site

Transect Number	pH	Conductivity µs/cm
1	8.71	174
2	8.89	176
3	7.81	174
4	8.29	173
5	8.71	171
6	8.89	171
7	7.95	180
8	8.21	180
9	7.85	182
10	8.50	182
11	8.72	181
12	8.53	183
13	8.16	163

Figure 6.1: Mean pH values for each transect site

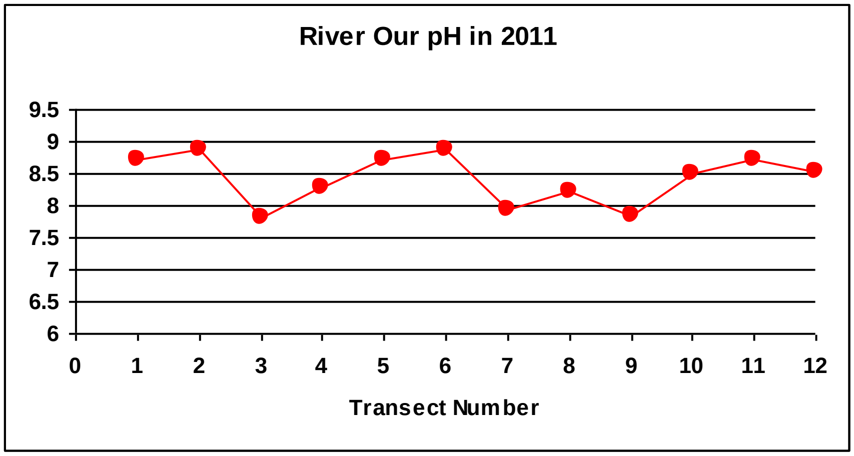
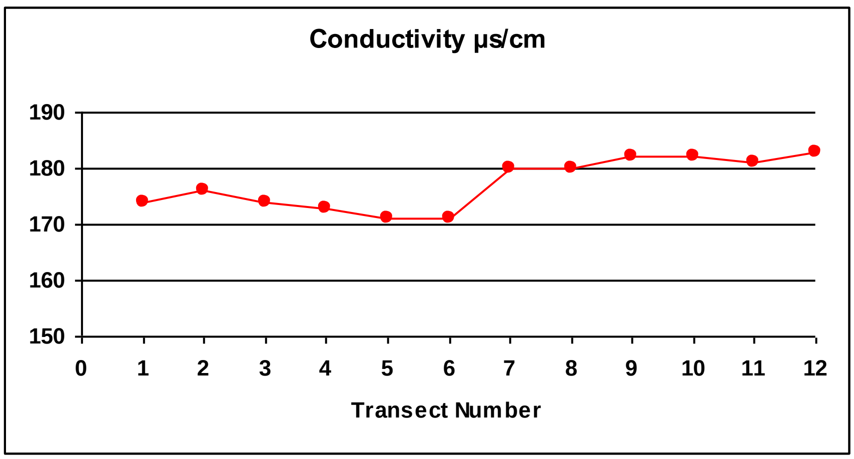


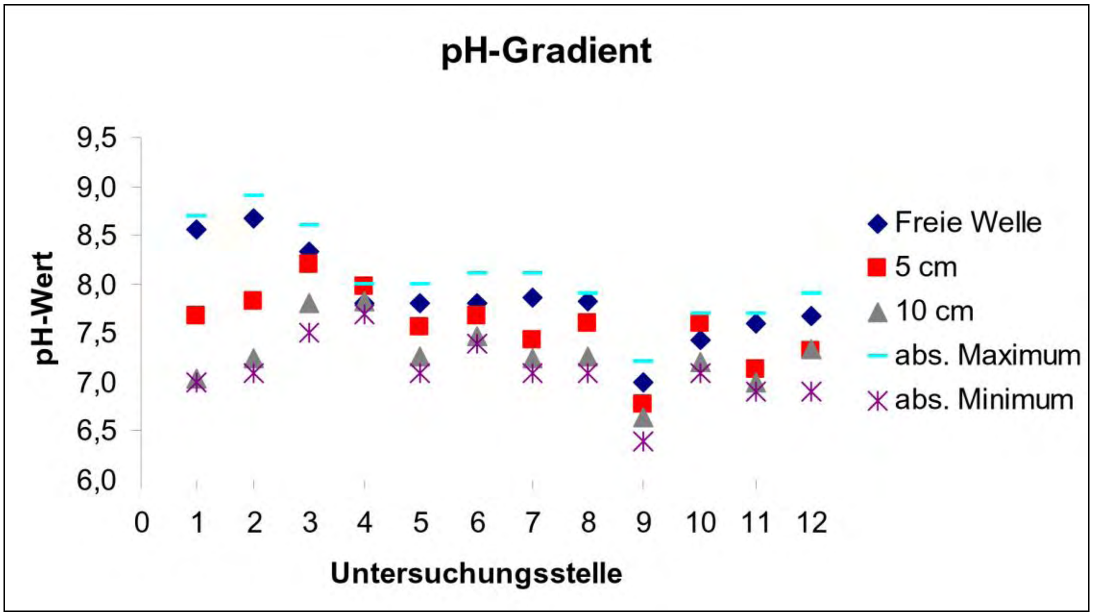
Figure 6.2: Mean Conductivity values for each transect site



6.2 Discussion

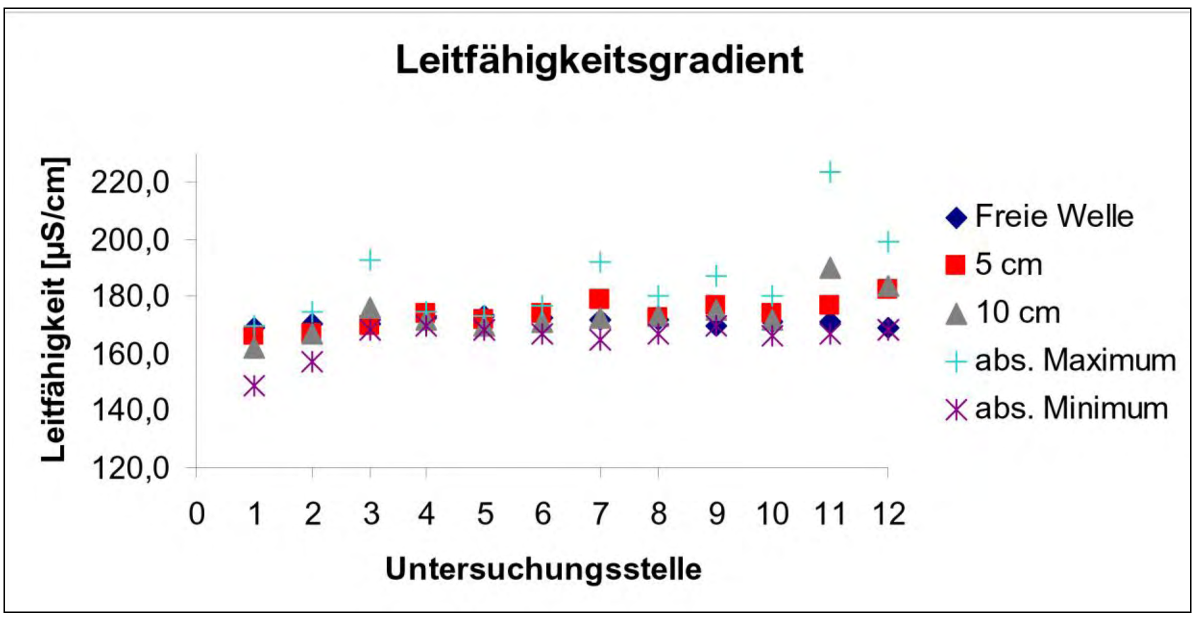
The pH ranged from a low of 7.81 at Transect site 3 to a high of 8.89 at sites 2 and 6. A much greater variation was recorded by Geist in 2009 (Figure 6.3).

Figure 6.3 pH results for 2009 (Geist 2009)



The conductivity barely changed throughout the monitored section of the River Our, ranging from 173 to 183 µs/cm. Geist (2009) recorded a slightly greater range (Figure 6.4) and with a general trend of an increase from upstream to downstream.

Figure 6.4 Conductivity results (µs/cm) for 2009 (Geist 2009)



7.0 Temperature and Oxygen

7.1 Results

Table 7.1: Mean Temperature and Oxygen values for each transect site

		Oxygen O_2	
Transect Number	**Temperature °C**	**mg/l**	**%**
1	13.6	11.36	113.7
2	14.7	11.15	114.8
3	13.0	9.55	93.5
4	13.0	10.13	100.1
5	14.4	10.54	106.6
6	14.6	10.34	104.7
7	11.9	10.21	97
8	12.2	10.15	98.2
9	12.9	10.95	106.2
10	13.0	10.06	96.7
11	13.3	10.82	106.2
12	13.1	10.59	104.3
13	12.8	10.1	98.4

8.0 Conclusions

The pearl mussel population of the River Our is in severe decline such that there are probably less than 200 (aged) adults surviving (Thielen pers. comm.). The survival of the species in the river is now dependent upon the success of the restoration measures to provide a habitat which becomes suitable initially for survival of captive bred juveniles, and in the longer term for habitat in which the mussels could be self-sustaining.

The results of the 2011 monitoring have demonstrated that infiltration of the substrate by silt is a major problem throughout the Luxembourg section of the Our as far downstream as Dasburg. Whilst much of the silt is likely to be of terriginous origin, this physical silt problem is compounded by organic fine silt derived from the decay of filamentous algae, the growth of which has resulted from elevated nutrient levels in the open river water. Whilst these issues can be addressed to a greater or lesser extent through catchment management, the problem is not merely one of good mussel habitat in poor condition, but a major concern is the lack of potential pearl mussel habitat.

As discussed in Section 4.4, there is a marked lack of suitable pearl mussel habitat in the river. During the present survey mussels were found only at sites 2 and 13, and at these, the adults were lodged amongst coarse cobble on bedrock or in very small patches of gravels at the extreme margins of the tree lined banks. This is poor habitat for adult mussels, and very unlikely habitat to support growing juvenile freshwater pearl mussels. A similar habitat was noted at sites 5 and 6 where mussels had been recorded formerly. It seems highly unlikely that this sparsity of habitat would always have prevailed. There is sufficient historical and anecdotal evidence to indicate that there was a good-sized population of pearl mussels in the Our and that they were successfully recruiting in the past. Therefore we can conclude that there was considerable areas with suitable habitat in terms of mixed size coarse substrate and stable gravels (see Section 4.4). The relative abundance of coarse, angular clasts in the river suggests that substrate replenishment is not an issue, but the rarity of material under 30mm especially, suggests that clasts of this size class are being lost from the system. There was evidence at several of the transect locations of large accumulations of gravels high on the river banks. This suggests that river function may have changed, and that catchment management upstream may have intensified drainage into the river channel such that the water has higher energy levels than in former times. It is strongly recommended that an expert fluvio-geomorphologist is consulted in an attempt to understand the processes currently within the river, if the substrate has changed and why, and what measures might be taken to remedy the situation. If changes in the upper catchment are negatively impacting the mussel habitat, remedial measures may need to be employed across a wide area. It may be helpful to provide some medium sized boulders within former mussel habitat, followed by replacement of gravels in order to protect new gravels from being washed away.

It is recommended that monitoring of the River Our continues. Given that juvenile mussels are being successfully reared, it would be desirable in the longer term to return these to the river. Therefore, it is suggested that the monitoring is focused more towards the sections of the river or parts of the channel where 'better' habitat already exists. There is little to be gained from continued work at locations where, even if the nutrient, siltation and fluvial process issues can be resolved, there is little likelihood of the river supporting suitable mussel habitat.

9.0 References

Buddensiek, V. (1989). The pearl mussel *Margaritifera margaritifera* L. in its early postparasitic life. Proc. 10th. Malac. Congress, Tubingen, Germany.

Buddensiek, V., 2001. Okologie der jungen Flussperlmusschel. In: Böttig, E. (Ed.) "The Freshwater pearl mussel in Europe: Population status and conservation strategies". Wasserwirtschaftsamt, Hof.

Buddensiek, V., Engel, H., Fleischauer-Rossing, S. and Wachtler, K., 1993. Studies on the chemistry of interstitial water taken from defined horizons in the fine sediments of bivalve habitats in several northern German lowland waters. II: Microhabitats of *Margaritifera margaritifera* L., *Unio crassus* (Philipson) and *Unio tumidus* Philipsson. *Archiv fur Hydrobiologie* **127**: 151-166.

Geist J, Auerswald K (2007) Physicochemical stream bed characteristics and recruitment of the freshwater pearl mussel (*Margaritifera margaritifera*); *Freshwater Biology* **52**; 2299-2316

Geist J (2007) Untersuchungen zur Substratqualität in der Our (Luxemburg); Gutachten im Rahmen des EU-Projektes LIFE05Nat/L/000116 "Restauration des populations des moules perlières en Ardennes". Unpublished report.

Geist J (2009) Untersuchungen zur Substratqualität in der Our (Luxemburg); Gutachten im Rahmen des EU-Projektes LIFE05Nat/L/000116 "Restauration des populations des moules perlières en Ardennes". Unpublished report.

Killeen, I.J., 2006. The freshwater pearl mussel *Margaritifera margaritifera* (L., 1758) in the River Ehen, Cumbria: Report on the 2006 survey. Unpublished report to the Environment Agency, Penrith.

Killeen, I.J., 2011. The freshwater pearl mussel *Margaritifera margaritifera* (L., 1758) in the River Ehen, Cumbria: RSA Monitoring project Summary of work carried out in 2011. Unpublished report to the Environment Agency, Penrith.

Appendix: Results and photographs from each transect

Transect Sampling site 1   River Our 100 m below 3 border point

Date: 19 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	8	15.558	6.137655°E
Logitude	50	7	44.358	50.12899°N

General description of Transect site

The transect lies within a relatively narrow section of river with a slow-flowing glide upstream, becoming a gentle riffle run downstream. The Left bank is lined by tall trees, whereas the Right bank is open, steep, and with tall herbs and marginal plants such as *Glyceria*. The substrate is very coarse with boulders and cobble, much of which is lamellar (flattened). Patches of gravel were sparse and occurring mostly on the downstream side of boulders. In many places the gravels were only a thin veneer of <5cm over cobble or bedrock. Most of the substrate was covered with a layer of silt and algal flock. Filamentous algae was present but not luxuriant.

Results

River Width at Transect [m]	14.4	Water Depth [cm]	Mean	28	Water Flow [m/s]	Mean	0.3
			Min	10		Min	0
			Max	50		Max	0.6

Conductivity [µS/cm] Centre channel	Water	174.0		Temperature [°C]	13.6
	5 cm depth	171.8		O2 [mg/l]	11.36
	10 cm depth	173.5		O2 [%]	113.7
				pH	8.71
Conductivity [µS/cm]		174.1			

Redox Potential measurements				Value mV		% loss in redox potential	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			460		
a	c. 3m from R bank. Silty gravels on d/s side of boulders, sparse habitat	5	10	291-338	314	26.5-36.7	31.7
		10	4	249-299	277	35.0-45.9	39.8
b	c. 7m from R bank. Silty gravels on d/s side of boulders and bedrock slabs	5	10	299-338	315	26.5-35.0	31.5
		10	0	-	-	-	-
c	c. 11m from R bank. Habitat as above	5	10	313-362	334	21.3-32.0	27.4
		10	4	249-320	282	30.4-45.9	38.7
d	Near edge of L bank. Compacted gravels amongst cobble and lamellar stones	5	15	274-360	296	21.7-40.4	35.6
		10	7	249-302	273	34.3-45.9	40.7
All	All sites combined	5	45	274-362	315	21.3-40.4	**31.5**
		10	15	249-320	277	30.4-45.9	**39.8**

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	c. 3m from R bank.	10	3.7-6.3	5.02	7.4-12.6	10.04
b	c. 7m from R bank	10	3.7-6.5	5.44	7.4-13.0	10.88
c	c. 11m from R bank	10	3.4-5.1	4.10	6.8-10.2	8.20
d	Near edge of L bank	10	3.9-5.3	4.68	7.8-10.6	9.36
All	All sites combined	40	3.4-6.2	4.81	6.8-12.4	**9.62**

Transect location

View upstream from transect

View downstream from transect

View looking across the transect

Pocket of silted gravel amongst boulders

Discussion of results

The redox measurements show that the substrate across the channel was infiltrated by silt. The lowest mean loss of redox at 5cm depth was found in mid-channel (27.4%) but along the Left bank this rose to 35.6 % (overall mean 31.5%). The mean loss at 10cm depth increased to 39.8% but this was based upon very few readings due to the sparsity of habitat with relatively deep gravels.

Transect Sampling site 2: River Our c.125 m below confluence with Schelsbaach

Date: 19 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	7	43.259	6.128683 ^{o}E
Logitude	50	7	5.298	50.11756 ^{o}N

Note: This is not the original Transect site 2 as surveyed by Geist in 2007 and 2009. In 2011 the habitat at the site was found to be comprised almost entirely of silt covered bedrock and large angular cobble and boulders, with virtually no places where satisfactory redox or penetrometry measurements could be made. Therefore, the transect was relocated further downstream at a location where a few mussels were known to occur.

General description of Transect site

The river at the transect location is 21.9m wide and runs across a gentle riffle section. The Left bank is tree lined but on the Right bank, there is a strip of land with a few trees, scrub and tall herbs. The substrate across the transect is dominated by cobble, both angular and lamellar, all with a layer of silt. Patches of gravels were rather sparse but more frequent in a run along the Left bank. Individuals of *Margaritifera margaritifera* and *Unio crassus* were found in the margins along the Left bank.

Results

River Width at Transect [m]	21.9	Water Depth [cm]	Mean	24.33	Water Flow [m/s]	Mean	0.2
			Min	14		Min	0.0
			Max	32		Max	0.4

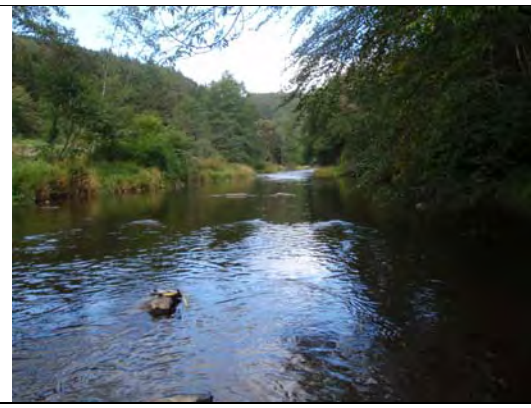
Conductivity [µS/cm] Centre channel	Water	176.4		Temperature [°C]	14.7
	5 cm depth	200		O2 [mg/l]	11.15
	10 cm depth	172.2		O2 [%]	114.8
				pH	8.89
Conductivity [µS/cm]		176.4			

Redox Potential measurements				Value mV		% loss in redox potential	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**440**		
a	2m from R bank.	5	10	249-325	288	26.1-43.4	34.5
		10	5	229-245	236	44.3-47.9	46.4
b	5m from R bank.	5	11	279-339	308	23.0-36.6	30.0
		10	4	214-299	252	32.0-51.4	42.7
c	9m from R bank.	5	12	277-346	310	21.4-37.0	29.5
		10	0	-	-	-	-
		Open water			**450**		
d	15m from R bank.	5	13	267-336	312	25.3-40.7	30.7
		10	5	238-294	259	34.7-47.1	42.4

e	19m from R bank.	5	11	275-338	314	24.9-38.9	30.2
		10	0	-	-	-	-
f	21m from R bank. Muddy gravels	5	14	243-313	278	30.4-46.0	38.2
		10	4	140-178	157	60.4-68.9	65.1
All	All sites combined	5	71	243-346	302	21.4-46.0	**32.2**
		10	18	140-299	226	42.4-65.1	**49.1**

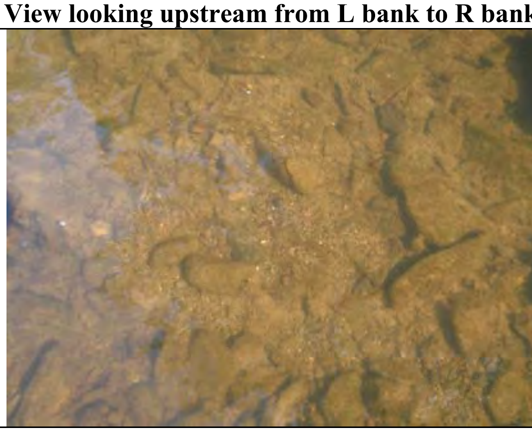
Penetrometry Measurements			**Reading (cm)**		**Cone resistance (kg/cm^2)**	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	2m from R bank.	10	3.3-5.5	3.95	6.6-11.0	7.90
b	5m from R bank.	10	3.0-4.1	3.46	6.0-8.2	6.92
c	9m from R bank.	10	2.9-4.6	3.71	5.8-9.2	7.42
d	15m from R bank.	10	3.6-5.2	4.46	7.2-10.4	8.92
e	19m from R bank.	10	2.4-4.2	3.43	4.8-8.4	6.86
All		50	2.4-5.5	3.80	4.8-11.0	**7.6**

Transect location



View upstream from transect

View downstream from transect

	
View looking upstream from L bank to R bank	**Substrate covered in silt layer**
	
Silty substrate along L bank	**Silt-covered mussel**

Discussion of results

The loss in redox potential at 5cm depth across the channel was generally very similar, with the means at each stop ranging from 29.5% to 34.5%. At the sample site near the Left bank the loss was 38.2%. The overall mean loss at 5cm depth for the transect was 32.2%. At 10cm depth the overall loss was 49.1% with a peak of 65% along the Left bank. These data clearly show that all of the substrate in the channel at this location is very silted, both on the surface and within the interstices.

Transect Sampling site 3: River Our 20 m below dam at the mill of Kalborn

Date: 19 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	8	3.366	6.134269 °E
Logitude	50	6	18.983	50.10527 °N

General description of Transect site

The transect runs across a narrow section of river 20m downstream of the old dam at Kalborn Mill which now comprises a shallow high energy riffle crest with remains of the old rock dam along the Left bank. The banks are generally open with tall herbs, and backed by pasture. The substrate comprises mostly coarse, angular cobble with small pockets of gravels in between. The cobbles are covered in a layer of diatoms, silt, filamentous algae and algal flock. Large plumes of silt were released from the substrate in the lower energy areas (especially in the lee of the old weir.

Results

River Width at Transect [m]	11.6	**Water Depth [cm]**	Mean	41.29	**Water Flow [m/s]**	Mean	0.2
			Min	23		Min	0.0
			Max	50		Max	0.6

Conductivity [µS/cm] Centre channel	Water	172.0		**Temperature [˚C]**	13
	5 cm depth	170.6		**O2 [mg/l]**	9.55
	10 cm depth	179.8		**O2 [%]**	93.5
				pH	7.81
Conductivity [µS/cm]		174.1			

Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**420**		
a	2.5m from R bank, mostly unstable gravel and pebble	5	13	264-340	310	19.0-37.1	26.2
		10	9	225-313	263	25.5-46.3	37.4
		Open water			**440**		
b	Mid channel, patches of gravel d/s of rocks	5	15	289-389	347	11.6-34.3	21.1
		10	0	-	-	-	-
c	2.5m from L bank	5	12	277-342	313	22.3-37.0	28.9
		10	3	266-290	278	34.1-39.5	36.8
d	1m from L bank, silty gravel between rocks	5	5	239-301	271	31.6-45.7	38.6
		10	0	-	-	-	-
All	All sites combined	5	45	239-389	319	19.0-45.7	**27.5**
		10	12	225-313	267	25.5-46.3	**39.3**

Penetrometry Measurements			**Reading (cm)**		**Cone resistance (kg/cm^2)**	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	2.5m from R bank	10	3.6-6.4	5.08	7.2-12.8	10.16
b	Mid channel	10	4.8-7.1	5.73	9.6-14.2	11.46
c	2.5m from L bank	10	2.9-4.1	3.56	5.8-8.2	7.12
All		30	2.9-7.1	4.79	5.8-14.2	**9.58**

Transect location

View upstream from transect

View downstream from transect

Small pockets of gravel amongst boulders

Mixed silty substrate

Discussion of results

There were very few places where redox measurements could be taken, and within those places the depth of gravels was insufficient to permit many readings from a depth of 10cm.

There was considerable variation in the redox values going across the channel. The loss in redox at 5cm depth ranged from 21.1% in the more scoured mid-channel areas to 38.6% near the Left bank. The overall mean loss was 27.5%. At 10cm depth, the overall mean loss in redox was 39.3%. Whilst the centre channel has clean substrate, it is too unstable to support juvenile mussels, whereas in the more stable margins the substrate is highly infiltrated with silt.

Transect Sampling site 4: River Our 20 m above confluence with Selburen "Schankbaach"

Date: 19 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	7	33.858	6.126072 °E
Logitude	50	6	6.222	50.10173 °N

General description of Transect site

The transect lies in a shallow, relatively high energy riffle run, approximately 50m downstream from the riffle crest. The depth increases from ~10cm along the Right bank to ~30cm along the Left bank. The substrate also changes with predominantly pebble and gravel along the R bank with increasing coarser material (cobble, pebble and gravel) along the L bank. The L bank was also very silted in places. Macrophytes (*Elodea* and *Ranunculus*) were present across most of the transect. The substrate in which they were rooted was also highly silted. Filamentous algae was present in the lower flow towards the L bank as was surface silt and algal flock. The channel was generally unshaded with pasture on both sides with marginal tall herbs.

Results

River Width at Transect [m]	13.2	**Water Depth [cm]**	Mean	18.7	**Water Flow [m/s]**	Mean	0.5
			Min	8		Min	0.0
			Max	30		Max	0.75

Conductivity [µS/cm] Centre channel	Water	178.7		**Temperature [˚C]**	13
	5 cm depth	178.8		**O2 [mg/l]**	10.13
	10 cm depth	175.4		**O2 [%]**	100.1
				pH	8.29
Conductivity [µS/cm]		173.4			

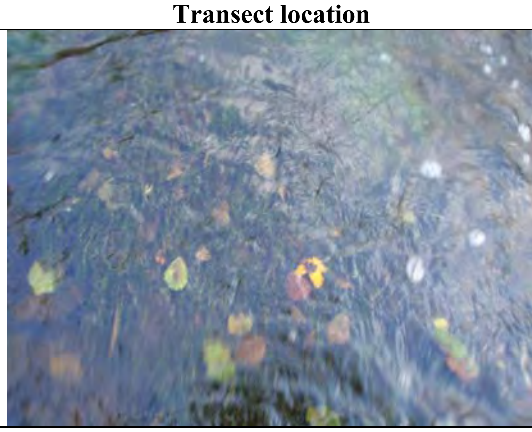
Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
a	c.1m from R bank, silty with gravel/cobble patches and weeds	5	13	288-335	310	25.6-36.0	31.1
		10	3	239-271	258	39.8-46.9	42.7
b	c.3m from R bank, relatively compacted cobble in swift flow	5	10	319-379	345	15.8-29.1	23.3
		10	0	-	-	-	-
c	Mid-channel, cobble & gravel	5	10	308-373	339	17.1-31.6	24.7
		10	0	-	-	-	-
d	c.9m from R bank, cobble with very silty gravels between	5	11	290-363	325	19.3-35.6	27.8
		10	5	259-315	285	30.0-42.4	36.7
e	1m from L bank, very silty	5	9	279-339	307	24.7-38.0	31.8
		10	0	-	-	-	-
All	All sites combined	5	53	279-379	324	15.8-38.0	**28.0**
		10	8	239-315	275	30.0-46.9	**38.9**

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	c.2.5m from R bank	10	3.6-5.6	5.17	7.2-11.2	10.34
b	Mid channel	10	3.3-4.6	4.14	6.6-9.2	8.28
c	c.4m from L bank	10	2.9-4.5	3.86	5.8-9.0	7.72
All		30	2.9-5.6	4.39	5.8-11.2	**8.78**

Transect location

View upstream from transect

View downstream from transect



Habitat near Right bank

Habitat along Left bank

	
Cobble substrate with algae and diatom growths	**Mixed gravel and cobble substrate**

Discussion of results

The redox potential measurements show that the mean loss at 5cm depth across most of the channel was relatively low ranging from 23.3% -27.8%. However, higher losses (31.1-31.8%) were recorded at the 2 marginal sites. Very few (8) readings were obtained at a depth of 10cm but these show an overall increase in the mean loss from 28.0% at 5cm to 38.9% at 10cm depth.

Transect Sampling site 5: River Our 400 m above sampling site 6 (former mussel area)

Date: 19 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	**Degrees**	**Minutes**	**Seconds**	**Decimal**
Latitude	6	7	34.2299	6.126175 °E
Logitude	50	5	54.336	50.09843 °N

General description of Transect site

The transect is within a generally very shallow glide section with an open L bank with a tall herb buffer strip and fenced off from cattle in the adjacent pasture. The Right bank is tree lined. The substrate in the Left half of the channel is predominantly cobble and pebble with good areas of gravels, whereas the Right half of the channel supports a coarser substrate of mostly angular cobble. The entire substrate surface was covered with a veneer of silt.

Results

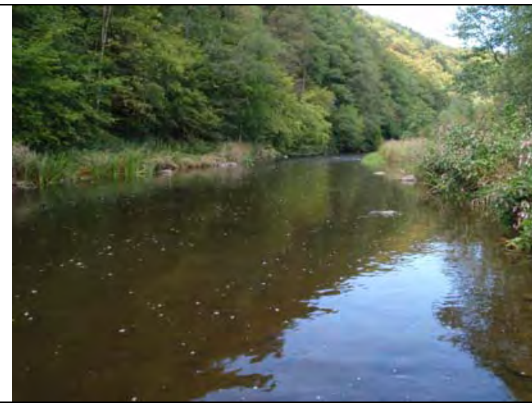
River Width at Transect [m]	15.4	**Water Depth [cm]**	Mean	31.23	**Water Flow [m/s]**	Mean	0.2
			Min	6		Min	0.0
			Max	50		Max	0.4

Conductivity [µS/cm] Centre channel	Water	171.9		**Temperature [˚C]**	14.4
	5 cm depth	169.9		**O2 [mg/l]**	10.54
	10 cm depth	171.7		**O2 [%]**	106.6
				pH	8.71
Conductivity [µS/cm]		170.9			

Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
a	3m from L bank	5	11	289-347	324	22.9-35.8	28.0
		10	6	220-296	268	34.2-51.1	40.4
b	5m from L bank	5	11	307-351	330	22.0-31.8	26.7
		10	5	249-291	272	35.3-44.7	39.6
c	8m from L bank	5	11	269-353	312	21.6-40.2	30.7
		10	0	-	-	-	-
d	12m from L bank. Very small pockets of muddy gravel amongst large slabs	5	13	269-329	299	26.9-40.2	33.6
		10	0	-	-	-	-
e	14m from L bank	5	12	250-321	288	28.7-44.4	36.0
		10	0	-	-	-	-
All	All sites combined	5	58	250-353	310	21.6-44.4	**31.1**
		10	11	220-296	270	34.2-51.1	**40.0**

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	3m from L bank	10	3.1-3.7	3.37	6.2-7.4	7.74
b	5m from L bank	10	3.1-4.7	3.81	6.2-7.62	7.62
c	8m from L bank	10	3.6-5.5	4.66	7.2-11.0	9.32
d	12m from L bank	10	3.3-6.2	4.40	6.6-12.4	8.80
e	14m from L bank	10	2.8-4.2	3.46	5.6-8.4	6.92
All		50	2.8-6.2	3.94	5.6-12.4	7.88

Transect location



View upstream from transect

View downstream from transect

View across transect fro L to R

Coarse, silt-covered substrate

	
Patches of gravels	

Discussion of results

In spite of the larger areas of gravels than at many of the transect sites, there were few places where the gravel was sufficiently deep to permit many readings at a depth of 10cm. The overall mean loss in redox potential at 5cm depth was 31.1%, with the Left half of the channel having a lower loss (26.7-30.7%) than the Right half (33.6-36% loss). The mean loss at a depth of 10cm was 40%.

Transect Sampling site 6: River Our "Duck cages" former mussel area

Date: 19 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	7	41.9279	6.128313 °E
Logitude	50	5	45.4979	50.09597 °N

General description of Transect site

The transect is located c. 200m downstream of Transect site 5, in the same environment with an open L bank with a tall herb buffer strip and fenced off from cattle in the adjacent pasture. The Right bank is tree lined. The river at this point is wider (23.3m) and is within a very shallow riffle/glide run. The substrate changes from fine muddy/sandy gravels along the Left margin to pebble and lamellar cobble towards the mid-channel, and then becoming coarser with angular and lamellar cobble and boulder towards the Right bank. Large patches of *Ranunculus* growing in very silty substrate were growing along the Left half of the channel. Large plumes of silt were released from the substrate just by wading across the river (see photo below). Mussels were formerly known from this section along the Right bank.

Results

River Width at Transect [m]	23.3	**Water Depth [cm]**	Mean	25.93	**Water Flow [m/s]**	Mean	0.2
			Min	17		Min	0.0
			Max	37		Max	0.4

Conductivity [µS/cm] Centre channel	Water	170.6		**Temperature [˚C]**	14.6
	5 cm depth	172.1		**O2 [mg/l]**	10.34
	10 cm depth	172.6		**O2 [%]**	104.7
				pH	8.89
Conductivity [µS/cm]		170.6			

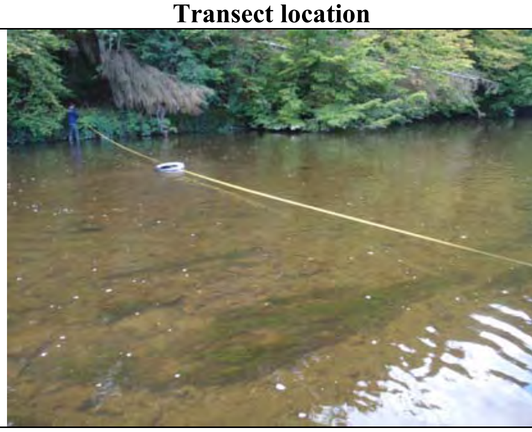
Redox Potential measurements				Value mV		% loss in redox potential	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
a	2m from L bank	5	11	244-317	281	29.6-45.8	37.6
		10	8	207-262	230	41.8-54.0	48.9
b	4m from L bank	5	11	248-320	280	28.9-44.9	37.8
		10	6	207-240	225	46.7-54.0	50.0
c	8m from L bank	5	11	244-324	291	28.0-45.8	35.3
		10	7	228-270	249	40.0-49.3	44.7
d	12-14m from L bank.	5	10	244-333	296	26.0-45.8	34.2
		10	0	-	-	-	-
e	21m from L bank	5	12	249-335	297	25.6-44.7	34.0
		10	4	219-236	227	47.6-51.3	49.5
All	All sites combined	5	55	244-335	289	25.6-45.8	**35.8**
		10	25	207-262	234	41.8-54.0	**48.0**

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	2m from L bank	10	2.1-3.3	2.55	4.2-6.6	5.10
b	5m from L bank	10	2.0-3.0	2.55	4.0-6.0	5.10
c	7m from L bank	10	3.4-4.8	4.08	6.8-9.6	8.16
d	12m from L bank	10	4.2-5.7	4.80	8.4-11.4	9.60
e	20m from L bank	10	3.9-5.2	4.99	7.8-10.4	9.98
All		50	2.0-5.7	3.79	4.0-11.4	7.58

Transect location

View upstream from transect

View downstream from transect



View across transect from L to R

Muddy plumes

	
Substrate with silt, diatoms and dead algal flock	**Substrate with silt, diatoms and dead algal flock**

Discussion of results

The highly silted nature of the substrate is clearly reflected in the redox potential measurements. The overall loss in redox at 5cm depth was 35.8% with very little significant difference across the channel. The more frequent areas of finer sediment allowed more readings (25) to be taken at 10cm depth, but the loss of redox was 48% showing high silt infiltration of the substrate to this depth.

Transect Sampling site 7: River Our, Grossenauel 20m below a former cattle watering place

Date: 20 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	7	19.2839	6.122023 ^{o}E
Logitude	50	4	54.6479	50.08185 ^{o}N

General description of Transect site

Relatively narrow section of river downstream of a natural bedrock riffle crest, and also just downstream of an old cattle watering place on the right bank. The river has steep, tree-covered slopes along the left bank and open pasture along the right bank. From the left bank to c. 7m across, the substrate comprised mostly bedrock with a few loose boulders and very occasional runnels with some coarse gravel. The substrate across the rest of channel comprised mostly flattened or angular cobble. *Ranunculus* was present in places in the open channel.

Upstream of the riffle crest, the river was very shallow, and much of the substrate comprised sheet bedrock with ridges, some of it with discontinuous layer of variable thickness cobble, coarse and finer gravel, most of which was heavily infiltrated by silt.

Results

River Width at Transect [m]	11.7	**Water Depth [cm]**	Mean	21.18	**Water Flow [m/s]**	Mean	0.35
			Min	4		Min	0.0
			Max	50		Max	0.7

Conductivity [µS/cm] Centre channel	Water	179.8		**Temperature [˚C]**	11.9
	5 cm depth	181.1		**O2 [mg/l]**	10.21
	10 cm depth	180.5		**O2 [%]**	97
				pH	7.95
Conductivity [µS/cm]		179.6			

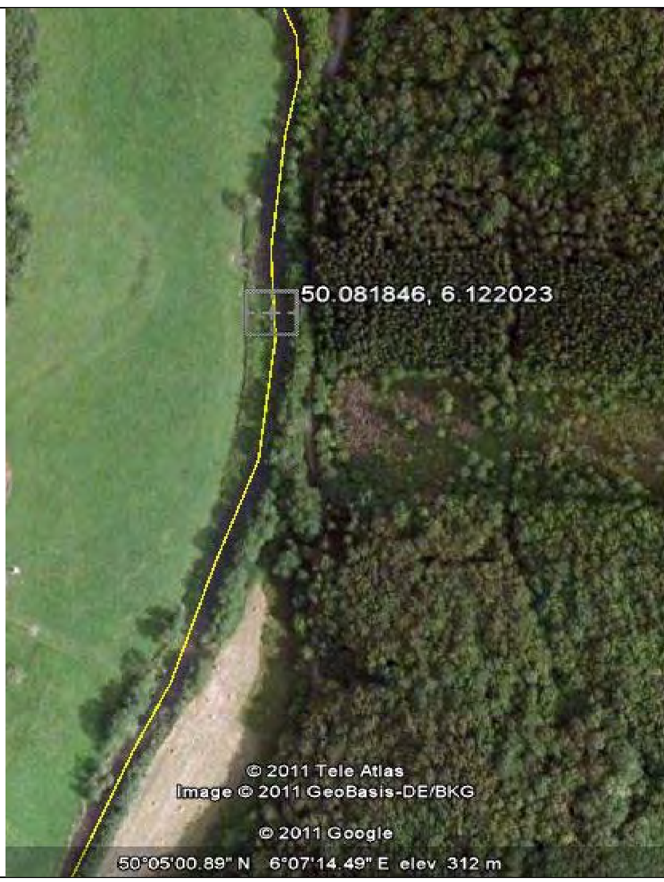
Transect

Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**440**		
a	1m from R bank, scoured angular cobble	5	10	306-372	336	15.5-30.4	23.6
		10	0	-	-	-	-
b	2m from R bank, scoured angular cobble	5	10	321-378	351	14.1-27.0	20.2
		10	0	-	-	-	-
c	3m from R bank, small pocket of gravel on d/s side of large boulder	5	10	294-368	321	16.4-33.2	27.0
		10	0	-	-	-	-
All	All sites combined	5	30	294-378	326	14.1-33.2	**25.6**
		10	0	-	-	-	-

c. 15m upstream of old cattle watering place

				Value mV		% loss in redox potential	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**440**		
a	c. 3m from R bank, silty gravel and cobble	5	13	269-329	296	25.2-38.9	32.7
		10	0	-	-	-	-
b	Near mid-channel, pockets of coarse gravel and cobble lying in hollows on the bedrock	5	8	266-375	318	14.8-39.5	27.7
		10	0	-	-	-	-
c	Further upstream, muddy gravels down R bank	5	9	249-328	286	25.5-43.4	35.0
		10	0	-	-	-	-
All	All sites combined	5	30	249-375	299	14.8-43.4	**32.0**
		10	0	-	-	-	-

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	1m from R bank	10	5.4-7.7	6.50	10.8-15.4	11.0
b	2m from R bank	10	6.4-7.4	6.92	12.8-14.8	13.8
c	3m from R bank	10	6.2-7.2	6.83	12.4-14.4	13.66
d	4m from R bank	10	7.1-8.4	7.84	14.2-16.8	15.68
e	5m from R bank	10	7.4-9.2	8.32	14.8-18.4	16.64
All		50	5.4-9.2	7.28	10.8-18.4	14.56



Transect location


View upstream from transect


View downstream from transect

	
Habitat towards R bank	**Habitat in centre channel**
	
Angular cobble substrate at c.4m from R bank	**Silt plumes from substrate**
	
Habitat u/s of old cattle drink	**Habitat u/s of old cattle drink – ridged bedrock**

Discussion of results

The results from the 3 sets of redox measurements taken along the transect are rather low, with losses ranging from 23.6-27% (mean 25.6%). However, this is misleading as measurements could only be taken in the shallow layer of scoured angular gravels along the R margin of the river. This is not suitable (juvenile) mussel habitat as it is too unstable. Because of the shallow depth of gravels, no measurements could be taken at 10cm depth. Upstream of the transect, the gravels were thicker and in a more stable environment. However, they were more heavily infiltrated by silt as is reflected in the redox data with losses at 5cm depth ranging from 27.7-35% (mean 32%).

Transect Sampling site 8: River Our 20m below meadow with former "Lorentz-Millen"

Date: 20 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	7	19.806	6.122168 ^{o}E
Logitude	50	4	26.64	50.07407 ^{o}N

General description of Transect site

The transect lies in a swift-flowing section between 2 riffle crests. The channel is heavily shaded by trees along both banks and there are large accumulations of gravels along both banks, suggesting that this finer material has been deposited from the river after flood events. Starting from the Left bank, the substrate initially comprises a bedrock ledge, then into coarser angular cobble, before deepening into a U-shaped centre channel which has layers of varying thicknesses of more rounded cobble and gravels. The slope rises towards the left bank through more flattened (lamellar) cobble covered with a thick layer of muddy silt and then into coarser silt infiltrated gravels at the Right margin.

Results

River Width at Transect [m]	16.1	**Water Depth [cm]**	Mean	34.38	**Water Flow [m/s]**	Mean	0.2
			Min	10		Min	0.0
			Max	54		Max	0.6

Conductivity [µS/cm] Centre channel	Water	180.3		**Temperature [˚C]**	12.2
	5 cm depth	182.9		**O2 [mg/l]**	10.15
	10 cm depth	181.1		**O2 [%]**	98.2
				pH	8.21
Conductivity [µS/cm]		180.3			

Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**440**		
a	3.5-4m from L bank	5	11	279-347	318	21.1-36.6	27.7
		10	0	-	-	-	-
b	7m from L bank	5	12	264-341	317	22.5-40.0	27.8
		10	0	-	-	-	-
c	10m from L bank	5	12	241-322	289	26.8-45.2	34.3
		10	8	164-280	209	36.4-62.7	52.5
d	15m from L bank.	5	10	193-311	249	29.3-56.1	43.4
		10	5	143-202	175	54.1-67.5	60.2
All	All sites combined	5	45	193-347	295	21.1-56.1	**33.0**
		10	13	143-280	196	36.4-67.5	**55.4**

Penetrometry Measurements			**Reading (cm)**		**Cone resistance (kg/cm^2)**	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	3.5m from L bank	10	3.9-7.2	5.51	7.8-14.4	11.02
b	7m from L bank	11	3.2-7.3	4.60	6.4-14.6	9.2
c	10m from L bank	10	3.3-5.7	4.18	6.6-11.4	8.36
d	13m from L bank	10	3.1-6.4	4.79	6.2-12.8	9.58
e	15m from L bank	11	2.6-4.8	3.62	5.2-9.6	7.24
All		52	2.6-7.6	4.54	5.2-14.6	9.08

Transect location

View upstream from transect

View downstream from transect

Transect habitat near L bank

Habitat in mid channel

	
Silt-covered slope from mid-channel towards R bank	**Habitat near R bank margin**

Discussion of results

The overall mean loss of redox at 5cm depth for the entire transect was 33%. However, the loss in redox potential varied considerably going across the channel from Left to Right. From the Left bank to mid channel the loss was ~27.7%, but this increased to 34.3% and then to 43.4% near the Right bank. This reflects the more high energy scouring effect in the Left half and the more stable, silt depositing Right half of the channel. Redox measurements at 10cm depth could only be taken in the Right half of the channel and these shows very high losses of (mean) 55.4%.

Transect Sampling site 9: River Our 50 m above confluence with Kenzelbaach

Date:	20 September 2011
Surveyors:	Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	6	44.2979	6.112305 ^{o}E
Logitude	50	3	39.372	50.06094 ^{o}N

General description of Transect habitat

The transect lies across a wide section of the river with trees and tall herbs along the Left bank and a wider strip of herbs and young trees along the Right bank. The river at this point comprises a shallow run with a riffle a few metres downstream. The substrate in the first 3m from the Left bank comprised coarse cobble, but beyond 3m across the transect the substrate was relatively homogenous with a mix of both angular and lamellar cobble, and patches of coarse gravels. *Ranunculus* was patchily distributed, but much of the cobble had a coating of diatom growth and some filamentous algae.

Results

River Width at Transect [m]	23.3	**Water Depth [cm]**	Mean	22.1	**Water Flow [m/s]**	Mean	0.2
			Min	6		Min	0.0
			Max	32		Max	0.55

Conductivity [µS/cm] Centre channel	Water	181.8		**Temperature [˚C]**	12.9
	5 cm depth	185.6		**O2 [mg/l]**	10.95
	10 cm depth	183.3		**O2 [%]**	106.2
				pH	7.85
Conductivity [µS/cm]		181.6			

Redox Potential measurements				Value mV		% loss in redox potential	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
a	3m from R bank	5	9	259-321	289	28.7-42.4	35.8
		10	0	-	-	-	-
b	6m from R bank	5	10	269-342	307	24.0-40.2	31.8
		10	5	225-300	249	33.3-50.0	44.7
c	9m from R bank	5	9	268-339	308	24.7-40.4	31.6
		10	5	189-242	218	46.2-58.0	51.6
d	12m from R bank	5	9	269-348	308	22.7-40.2	31.6
		10	0	-	-	-	-
e	15m from R bank	5	10	264-333	304	26.0-41.3	32.4
		10	0	-	-	-	-
f	18m from R bank	5	6	249-301	279	33.1-44.7	38.0
		10	0	-	-	-	-
All	All sites combined	5	53	249-348	300	22.7-44.7	**33.3**
		10	10	189-300	233	33.3-58.0	**48.2**

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	Location	n	Range	Mean	Range	Mean
a	3m from R bank	10	3.3-4.9	4.13	6.6-9.8	8.26
b	6m from R bank	10	2.5-4.2	3.29	5.0-8.4	6.58
c	9m from R bank	10	2.7-5.2	3.41	5.4-10.4	6.82
d	12m from R bank	10	2.5-5.3	4.04	5.0-10.6	8.08
e	15m from R bank	10	2.9-5.2	4.06	5.8-10.4	8.12
f	18m from R bank	10	3.9-7.2	5.89	7.8-14.4	11.78
All		60	2.5-7.2	4.14	5.0-14.4	8.28

Transect location

View upstream from transect

View downstream from transect

View across transect from L to R bank

Substrate at 3m from L bank

	
Substrate at 9m from L bank	**Substrate at 15m from L bank**

Discussion of results

High losses in redox potential were recorded across the entire river channel at this location, the mean loss at 5cm depth at the 6 sample locations ranged from 31.6 to 38% (overall mean 33.3%). Readings from 10cm depth could only be obtained at 2 of the sample locations but high losses were recorded (overall mean 48.2%).

Transect Sampling site 10: River Our above confluence with Kenzelbaach / 30 m below sampling site 9

Date: 20 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	6	45.288	6.11258 °E
Logitude	50	3	38.79	50.06078 °N

General description of transect

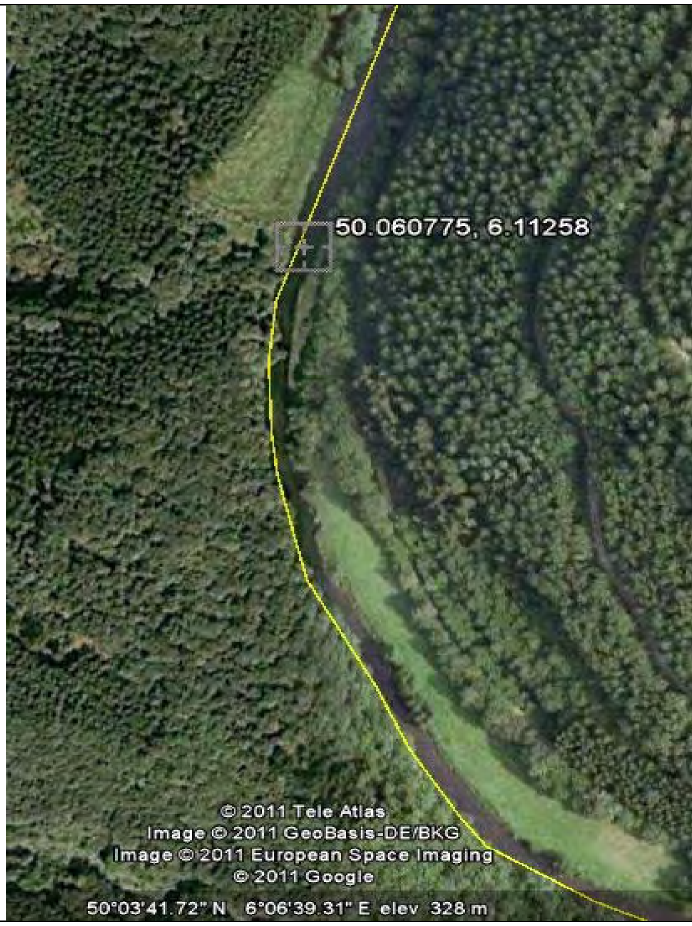
The transect lies in a relatively open section of the river with tall herbs and young trees along both banks. The transect lies c. 10 metres downstream of a riffle and in a moderately swift flow. It was generally very similar to Transect 9 but had more areas of *Ranunculus*. The substrate was coarser at the margins but had less of a coating of silt and detritus, and was noticeably cleaner in the centre part of the channel. A coating of filamentous algae was present on most of the cobble along both marginal ¼ channel widths.

River Width at Transect [m]	14.2	**Water Depth [cm]**	Mean	24	**Water Flow [m/s]**	Mean	0.3
			Min	5		Min	0.0
			Max	34		Max	0.65

Conductivity [µS/cm] Centre channel	Water	181.4		**Temperature [°C]**	13
	5 cm depth	182.7		**O2 [mg/l]**	10.06
	10 cm depth	182.3		**O2 [%]**	96.7
				pH	8.5
Conductivity [µS/cm]		181.6			

Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
a	3m from L bank	5	9	248-329	292	26.9-44.9	35.1
		10	0	-	-	-	-
b	6m from L bank	5	9	313-360	332	20.0-30.4	26.2
		10	0	-	-	-	-
c	9m from L bank	5	10	299-346	329	23.1-33.6	26.9
		10	0	-	-	-	-
d	12m from L bank.	5	10	259-342	301	24.0-42.4	33.1
		10	3	225-269	244	40.2-50.0	45.8
All	All sites combined	5	38	248-360	314	20.0-44.9	**30.2**
		10	3	225-269	244	40.2-50.0	**45.8**

Penetrometry Measurements			**Reading (cm)**		**Cone resistance (kg/cm^2)**	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	3m from L bank	10	2.7-5.9	4.53	5.4-11.8	9.06
b	6m from L bank	10	2.9-5.1	3.92	5.8-10.2	7.84
c	9m from L bank	10	2.4-4.2	3.41	4.8-8.4	6.82
d	12m from L bank	10	3.3-5.3	4.32	6.6-10.6	8.64
All		40	2.7-5.9	4.04	5.4-11.8	8.08



Transcect location

View upstream from transect

View downstream from transect

View from L bank to R bank

Clean (scoured) gravels amongst cobble c. 8m from L bank

Discussion of results

At this transect location there were relatively large differences between the losses in redox potential recorded in mid-channel (loss at 5cm depth 26.2-26.9%) compared to those from the margins (loss at 5cm depth 33.1-35.1%). Readings for a depth of 10cm could only be obtained for the sample site near the right bank where a mean loss of redox of 45.8% was recorded.

Transect Sampling site 11: River Our c. 50 m below confluence with Ruederbaach / River km 38

Date: 20 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	6	56.1539	6.115598 °E
Logitude	50	3	26.502	50.05736 °N

General description of Transect habitat

The transect lies approximately 20m upstream of weir in a section that is shaded by trees along both banks. The majority of the substrate in the river is ridged bedrock apart from a 3-5m wide strip along each bank. The substrate along the Left bank comprises rather clean (probably scoured) gravels and some cobble, whereas the substrate along the Right bank comprises angular and lamellar cobble covered with a thick veneer of muddy silt. There are also occasional boulders in the section with pockets of gravels on the downstream side.

Mussels formerly occurred along the Right bank in this section of river.

Results

River Width at Transect [m]	22.2	Water Depth [cm]	Mean	23.18	Water Flow [m/s]	Mean	0.3
			Min	11		Min	0.0
			Max	33		Max	0.6

Conductivity [µS/cm] Centre channel	Water	180.4		Temperature [°C]	13.3
	5 cm depth	182.4		O2 [mg/l]	10.82
	10 cm depth	181.3		O2 [%]	106.2
				pH	8.72
Conductivity [µS/cm]		180.8			

Redox Potential measurements				Value mV		% loss in redox potential	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
a	1m from L bank	5	11	308-366	336	18.7-31.6	25.3
		10	0	-	-	-	-
b	2m from L bank	5	11	301-375	339	16.7-33.1	24.7
		10	0	-	-	-	-
c	3m from L bank	5	12	287-361	328	27.1-36.2	27.1
		10	0	-	-	-	-
d	5m from L bank.	5	11	262-338	300	24.9-41.8	33.3
		10	0	-	-	-	-
e	20m from L bank	5	13	219-312	261	30.7-51.3	42.0
		10	0	-	-	-	-
All	All sites combined	5	58	219-375	311	16.7-51.3	**30.9**
		10	0	-	-	-	-

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	Location	n	Range	Mean	Range	Mean
a	1m from L bank	10	2.2-4.2	3.40	4.4-8.4	6.80
b	2m from L bank	10	2.9-4.1	3.43	5.8-8.2	6.86
c	3m from L bank	10	2.8-4.7	3.68	5.6-9.4	7.36
d	5m from L bank	10	2.8-5.3	3.78	5.6-10.6	7.56
e	20m from L bank	10	4.3-7.2	5.97	8.6-14.4	11.94
All		50	2.2-7.2	4.05	4.4-14.4	8.10

Transect location

View upstream from transect

View downstream from transect

Silt-covered bedrock ledges across most of channel

Clean (scoured) gravels amongst cobble along Left bank

Discussion of results

The relatively low loss in redox potential at 5cm depth (24.7-27.1%) along the Left part of the channel reflects the rather unstable scoured nature of the substrate such that it is not as highly infiltrated with silt as the Right part of the channel where the substrate is more stable, and the losses in redox are much higher (33.3-42%). The layer of gravel component was very thin throughout the transect and therefore it was not possible to obtain any redox measurements at a depth of 10cm.

Transect Sampling site 12: River Our 150 m below bridge in Dasburg

Date: 20 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude	6	6	56.1539	6.115598 °E
Logitude	50	3	26.502	50.05736 °N

General description of Transect habitat

The transect is located some 150m downstream of the bridge at Dasburg, in an open environment with grassland along both banks. At this point the river is wide and shallow with a slow flow. The substrate comprises mostly angular cobble with only very small pockets of gravels, all covered with a veneer of muddy silt. Sparse *Ranunculus* occurs throughout.

Results

River Width at Transect [m]	22.2	**Water Depth [cm]**	Mean	23.18	**Water Flow [m/s]**	Mean	0.3
			Min	11		Min	0.0
			Max	33		Max	0.6

Conductivity [µS/cm] Centre channel	Water	180.4		**Temperature [°C]**	13.3
	5 cm depth	182.4		**O2 [mg/l]**	10.82
	10 cm depth	181.3		**O2 [%]**	106.2
				pH	8.72
Conductivity [µS/cm]		180.8			

Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
a	2m from R bank	5	9	219-306	269	32.0-51.3	40.2
		10	0	-	-	-	-
b	5m from R bank	5	11	219-301	263	33.1-51.3	41.5
		10	0	-	-	-	-
c	10m from R bank	5	8	202-306	254	32.0-55.1	43.6
		10	0	-	-	-	-
d	13m from R bank.	5	11	211-300	257	33.3-53.1	42.9
		10	0	-	-	-	-
e	17m from R bank	5	13	212-311	262	30.9-52.9	41.8
		10	0	-	-	-	-
All	All sites combined	5	52	202-311	257	30.9-55.1	**42.9**
		10	0	-	-	-	**-**

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	2m from R bank	10	3.3-6.3	4.62	6.6-12.6	9.24
b	5m from R bank	10	3.7-7.1	5.62	7.4-14.2	11.24
c	10m from R bank	10	3.7-6.6	5.13	7.4-13.2	10.26
d	13m from R bank	10	3.9-6.5	5.57	7.8-13.0	11.14
e	17m from R bank	10	3.6-6.2	4.58	7.2-12.4	9.16
All		50	3.3-7.1	5.10	6.6-14.2	10.2

Transect location

View upstream from transect

View downstream from transect

View across transect towards Left bank

Silt covered cobble with sparse *Ranunculus*

Discussion of results

The slow flow in the section of river downstream of Dasburg Bridge has resulted in a very high level of siltation within the substrate as is clearly shown in the results of the redox measurements. There was very little variation across the channel with the mean loss in redox at each of the 5 sample locations ranging from 40.2 -43.6%. Due to the very coarse nature of the substrate and sparsity of gravels, it was not possible to obtain any readings at a depth of 10cm.

Transect Sampling site 13: River Our Hiour / Mussels

Date: 21 September 2011
Surveyors: Ian Killeen & Frankie Thielen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude				50.11134 °N
Logitude				06.13398 °E

This is a new location and was added to the 2011 monitoring as it was a site that still supported pearl mussels along the Left bank. It lies between Transect sites 2 and 3. Measurements of redox potential and penetrometry were focused in the habitat along the Left bank and not across the channel.

General description of Transect habitat

The section inhabited by the mussels comprises a riffle run with extensive bedrock, with a run of muddy cobble and some gravel patches along the Left bank, and more scoured gravels in parts of the centre channel and towards the Right bank. The Left bank was steep and tree-covered, whereas the Right bank was vegetated by tall herbs and small trees.

Results

River Width at Transect [m]	13.5	**Water Depth [cm]**	Mean	19	**Water Flow [m/s]**	Mean	0.3
			Min	6		Min	0.0
			Max	34		Max	0.7

Conductivity [µS/cm] Centre channel	Water			**Temperature [°C]**	12.8
	5 cm depth			**O2 [mg/l]**	10.1
	10 cm depth			**O2 [%]**	98.4
				pH	8.16
Conductivity [µS/cm]		162.6			

Redox Potential measurements				**Value mV**		**% loss in redox potential**	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**440**		
1	Penetrometry site a)	5	13	244-311	282	29.3-44.5	35.9
		10	0	-	-	-	-
2	Penetrometry site d)	5	12	224-300	261	31.8-49.1	40.7
		10	0	-	-	-	-
3	Penetrometry site h)	5	17	221-321	278	27.0-49.8	36.8
		10	0	-	-	-	-
4	Penetrometry site i)	5	13	249-321	289	27.0-43.4	34.3
		10	0	-	-	-	-
5	Mid channel riffle run with cobble and gravel	5	14	281-352	312	20.0-36.1	29.1
		10	0	-	-	-	-
6	Near R bank, very silted cobble and gravel	5	12	268-329	300	25.2-39.1	31.8
		10	0	-	-	-	-
All	All sites combined	5	81	221-352	287	20.0-49.8	**34.8**
		10	0	-	-	-	-

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	Location	n	Range	Mean	Range	Mean
a	1m from L bank and c.12m d/s of transect	10	4.4-6.2	5.43	8.8-12.4	10.86
b	10m downstream of a)	10	4.1-7.1	5.68	8.2-14.2	11.36
c	10m downstream of b)	10	4.4-7.0	5.55	8.8-14	11.1
d	By b) but 2.5m from L bank	10	2.9-5.3	4.52	5.8-10.6	9.04
e	5m u/s of a) and 2.5m from L bank	10	2.4-4.4	3.32	4.8-8.8	6.62
f	5m u/s of e)	10	2.9-4.6	3.67	5.8-9.2	7.34
g	Just u/s of transect	10	3.9-7.4	6.11	7.8-14.8	12.22
h	3m u/s of g) with 2 mussels	10	3.3-6.0	4.52	6.6-12	9.04
i	Close to h) but more gravels	10	2.9-5.2	4.05	5.8-10.4	8.10
All		90	2.4-7.1	4.76		9.52

Transect location

View upstream from transect

View downstream from transect

Habitat along Left bank

Mussel covered in silt

Discussion of results

In the sample locations along the Left bank (in the run where the mussels were living) the levels of siltation within the substrate were very high with losses in redox potential at 5m depth ranging from 34.3-40.7%. The losses in mid channel and towards the Right bank were lower (29.1 -31.8%) but still high showing the substrate to be infiltrated by silt. No measurements were taken at a depth of 10cm.

Sampling site 14: Channel at Kalborn Mill

Date: 21 September 2011
Surveyors: Ian Killeen

Location GPS:	Degrees	Minutes	Seconds	Decimal
Latitude				
Logitude				

General description of habitat

Measurements of redox potential and penetrometry were taken in the mill channel at Kalborn Mill to assess the suitability of the habitat as a receptor site for captive bred mussels. Gravels have been added to the channel.

Redox Potential measurements				Value mV		% loss in redox potential	
Site	**Location**	**Depth (cm)**	**n**	**Range**	**Mean**	**Range**	**Mean**
		Open water			**450**		
1	Penetrometry site b)	5	20	268-373	330	17.1-40.4	25.0
		10	17	264-328	299	27.1-41.3	33.6
2	Penetrometry site d)	5	24	268-368	324	18.2-39.1	28.0
		10	17	249-333	298	26.0-44.7	33.8
All	All sites combined	5	44	268-373	326	17.1-40.4	**27.6**
		10	34	249-333	298	26.0-44.7	**33.8**

Penetrometry Measurements			Reading (cm)		Cone resistance (kg/cm^2)	
Site	**Location**	**n**	**Range**	**Mean**	**Range**	**Mean**
a	Slightly on d/s side of upstream footbridge	18	2.3-5.3	3.77	4.6-10.6	7.54
b	3m d/s of bridge	21	2.2-4.8	3.15	4.4-9.6	6.30
c	5m u/s of downstream footbridge	21	2.8-4.7	3.50	5.6-9.4	7.0
d	3m u/s of bridge	23	3.6-7.1	5.20	7.2-14.2	10.4
All		83	2.2-7.1	3.90	4.4-14.2	7.80

Discussion of results

Whilst the loss in redox potential near the first mill bridge is relatively low (at both 5cm and 10cm depth) compared to most of the transects in the main River Our channel, the substrate is still infiltrated by silt as is seen in the photographs. The penetrometry readings show that the substrate near the first mill bridge is stable yet still relatively loose and uncompacted. However, the coarser substrate nearer the old bridge downstream is more compacted.

	
Habitat d/s of mill bridge	**Habitat d/s of mill bridge**
	
Silt plumes	**Habitat near old bridge downstream**