UCL ENVIRONMENTAL CHANGE RESEARCH CENTRE

Assessment of salmon spawning gravel in the River Frome, Gloucestershire

Report for the Environment Agency

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Report for The Environment Agency

ENSIS at the Environmental Change Research Centre, UCL

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Cover photo: Gravel habitat in the River Stiffkey © L. Mitchell

Summary

Three gravel freeze cores were extracted from each of three sites, identified as potentially suitable for salmon (*Salmo salar,* L.) spawning, on the River Frome. A quantitative assessment of the capacity of these gravel beds to support effective spawning was made based on the composition of the sampled substrata. Examined sediment size ranges included: optimum spawning gravel (16 > *D* > 64 mm), fine sediment (*D* <1 mm), coarse sand (2 mm > *D* ≥ 1 mm) and clay (*D* < 4 μm). A threshold limit of 14% of sediment *D* <1 mm was used. Results indicated that optimum spawning gravel occurred at all sites in varying amounts. The distribution of these, however, were within the smaller size range suitable for spawning. Moreover, significant deposits of sediment *D* <1 mm limit potential spawning quality at all sites. The overall composition of substrata at Button Mill offers the best potential spawning habitat of the identified sites.

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INTRODUCTION

Background

Gravel-bedded rivers are characterised by a surface layer of coarse sediment comprised of cobble (grain diameter *D* = 64-256 mm) and gravel (*D* = 2-64 mm)) above a mixed substrata (Kondolf, 2000). Sediment (*D* = 16-64 mm) within the gravel size range provide important spawning habitat for salmon (*Salmo salar*) populations (Louhi et al., 2008). Spawning substrata are characterised by both larger grained framework gravels, which provide support to the deposit, and finer grained matrix sediments that fill the interstices between framework gravels (Kondolf & Wolman, 1993; Milan et al., 2000). The relative contribution of matrix to framework sediments characterise the suitability of a spawning habitat. High quality spawning gravels are framework gravel supported by a low percentage of matrix sediment (Acornley & Sear, 1999; Kondolf, 2000; Milan et al., 2000).

During the redd cutting process, framework gravels should be easily moved by the female fish, the upper limits of which are dependent on fish length, water velocity and degree of gravel embededness (Crisp and Carling, 1989; Kondolf and Wolman, 1993). Stream velocity, turbulent mixing and sediment weight control the downstream sorting of the displaced substrata during redd construction (Greig et al., 2005a). The larger, heavier, substrata are not dislodged far relative to the finer material that is displaced further downstream. More than 40% of sediment *D* < 2 mm can be displaced during this process (Zimmermann and Lapointe, 2005). The grain size distribution of the tailspill therefore differs from the surrounding gravel environment. The absence of fine material creates greater interstitial water flow through the tailspill, delivering dissolved oxygen to incubating embryos and removing toxic metabolic waste products. Successful embryo incubation within the redd requires low concentrations of fine sediment.

Salmon populations of the British Isles have declined significantly over the past half century. One of the principal reasons is the reduced accessibility and/or the physical deterioration of spawning habitat. The latter has occurred through either complete habitat removal for flood management purposes, or the accumulation of fine grained sediments within spawning substrata. Fine sediment deposition is a natural process that is accelerated through anthropogenic activities such as diffuse run-off associated with arable land-use. Accumulation of excessive fine sediment has a detrimental effect on embryonic survival rates during incubation.

The size of deposited material has variable effects on redds and the incubating embryos. Accumulations of fine sediment (*D* < 1 mm) inhibits gravel permeability and consequently the delivery of oxygen-rich water to developing embryos. (Kondolf, 2000; Hartman & Hakala, 2006). A reduced interstitial flow is less able to remove toxic metabolic waste products associated with embryonic development. Clay particles (*D* < 4µm) block membrane micropore canals, significantly reducing the efficient exchange of oxygen across egg membranes (Greig et al., 2005b). Coarser sands (2 mm > *D* > 1.0 mm) tend to settle within surface substrata forming a physical barrier that can inhibit the passage of alevins during emergence (Crisp, 1993; Kondolf, 2000; Hartman & Hakala, 2006).

Quantification of the presence and abundance of fine sediment using a predetermined size threshold is consequently an indirect but cost effective, easily comparable and reliable method of assessing spawning gravel habitat quality.

Objective

This report provides a quantitative assessment of the suitability of preidentified gravel beds for salmon spawning at three sites on the Gloucestershire River Frome.

Sites

The River Frome, a tributary of the River Severn, drains a catchment area of approximately 220 km^2. It rises from several springs approximately 7 miles south east of Gloucester. The river flows in a southerly direction to the town of Sapperton at which point it turns west and flows through the towns of Stroud and Stonehouse on its way to Upper Framilode, where it discharges into the River Severn.

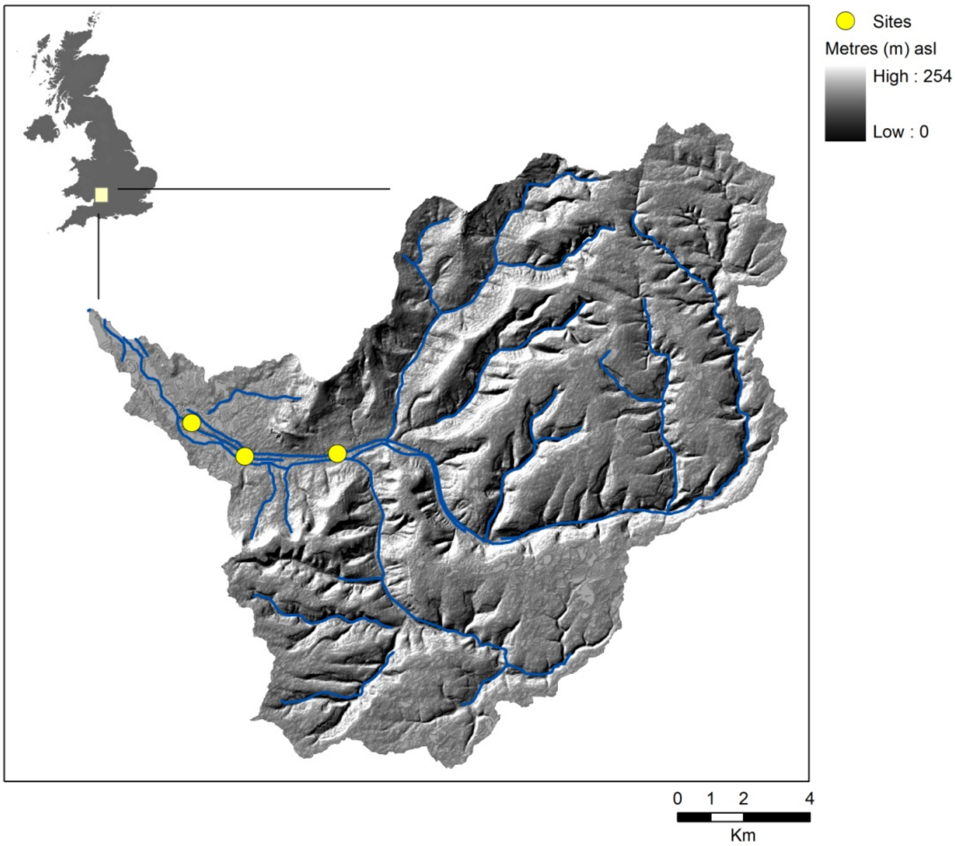
Three sites were identified as containing potential salmon spawning gravels within the lower reaches of the river between Eastington village and Stroud (Fig. 1).

The furthest upstream site (NGR: SO 828044), where the river course flows close to the historic Ebley Mill in which Stroud District Council are now housed, had well defined and vegetated banks. Good riparian shading and well developed undercut tree root structures provided potential fry rearing habitat. The identified gravel habitat measured approximately 100 m^2. A deep fish holding pool was situated immediately downstream of the sampled gravel habitat.

The Button Mill site (NGR: SO 799047), situated on arable land, lies on the south west fringe of the town of Stonehouse. A deep fish holding pool was situated immediately upstream of the gravel habitat. The banks were poorly vegetated although trees provided shading and root structure. The potential salmon spawning habitat measured approximately 112.5 m^2.

The gravel habitat as the river nears the village primary school in Eastington was the furthest downstream site (NGR: SO 783056). Gravels were within close proximity to the road bridge. The north bank an arable field. The gravel habitat measured approximately 140 m^2. Banks were well vegetated, provided potential fry refuge, and a small but deep fish holding pool was situated immediately downstream.

Water velocity at each site was within the range known to be suitable to permit successful spawning, 30-80 cm s^{-1}.



British Isles data from DIVA GIS (http://www.diva-gis.org/Data) (Hijmans et al. 2012)

Figure 1. River Frome catchment.

METHODS
Field sampling

Gravel freeze cores provided a vertical grain size distribution profile and substrate composition to a desired depth. Three cores were extracted from each of three sites determined to be fit for salmon spawning, on 12 and 13 March 2013. These were extracted from pseudorandom positions within each identified gravel habitat. For each core a pair of random measurement co-ordinates (width and length) were chosen between 1-20 metres and the core extracted at the intersection of these. Freeze cores were sampled in an upstream direction so that core 3 is the furthest downstream and core 1 the furthest upstream.

Freeze cores were extracted using the Centre for Environment, Freshwater and Aquaculture Science (Cefas) freeze core equipment. A 50 mm diameter and 1300 mm long stainless steel spiked-tube was driven 30 cm into the substrata. The core tube was closed and pointed at one end. An open-ended 50 cm^2 baffle was placed over the core tube and secured using two steel rods approximately 5-10 cm into the surface spawning sediments so that it lay diagonally across the river current. This prevented interstitial gravel flow within the top sediment layers and allowed even freezing of the substrate. Approximately 15-20 litres of liquid nitrogen were steadily introduced, freezing the associated sediments to the outside of the steel tube. The amount of liquid nitrogen required varied with substrate composition; less compaction required more liquid nitrogen in order to freeze larger volumes of water within the interstitial spaces. The core tube and attached sample were winched out from the river bed using an A-frame and chain block (Fig. 2). Substrata were defrosted over a unit stratified at 5 cm increments, thus enabling detailed analysis of the sample at this scale.

Figure 2. Fully assembled freeze core equipment.

Laboratory analysis

Each 5 cm gravel sample was dried at a temperature of 40°C and weighed. Samples were then wet sieved at D = 500 μm (0.5 mm) and the resultant fine sediment collected in solution to be analysed in a laser granulometer. The 500 μm fraction was removed in this manner to prevent sediment compaction that biased the sieving process. The resultant sample was dried and weighed again, then mechanically sieved for 10 minutes through sieves of 16 mm, 8 mm, 6.35 mm, 5.66 mm, 4.76 mm, 4 mm, 3.35 mm, 2.83 mm, 2.38 mm, 2 mm, 1.68 mm, 1.4 mm, 1.2 mm, 1 mm, 0.841 mm, 0. 71 mm, 0.6 mm, 0.5 mm aperture. The retained sediment fractions from each sieve were weighed. It was apparent that glass shards were present and therefore accounted for separately.

Supernatant water was removed from the 500 μm fraction and sediments were dried at 40°C and weighed. Samples was moistened and mixed sufficiently well enough to ensure a heterogeneous sample. A small quantity was analysed in a laser granulometer, a Malvern Hydro 2000 MU. The particle indicator was set for the measurement of silica, refractive index of 1.544, and the dispersant was water with a refractive index of 1.33. Five runs of each sample were taken and then averaged.

Data analysis

Examined sediment size ranges included: optimum spawning gravel (16 < D < 64 mm), fine sediment (D < 1 mm), coarse sand (2 mm > D ≥ 1 mm) and clay (D <4 µm). A threshold limit of 14% of sediment D <1 mm was used.

Stratigraphic plots of the freeze core samples and the grain size fractions of interest were drawn in the C2 data analysis software (Juggins, 2003).

Grain size statistics were derived from GRADISTAT version 4 (Blott, 2001) for the analysis of unconsolidated sediments. Geometric scaling was used within GRADISTAT to determine the median grain size, D_{50}, as well as the grain size at which 10% and 90% of the distribution lie below, D_{90} and D_{10}. These measurement parameters were based on methods used by Folk and Ward (1957). A physical textural description of each 5 cm core increment was determined based on sediment class (Folk, 1954).

In order to determine granulometric composition variance both within and between sites, analyses were performed using the Kruskal-Wallis test; a non-parametric equivalent of a one-way ANOVA. Post-hoc analysis was determined using pairwise Mann-Whitney U tests.

RESULTS

Grain size distribution varied greatly between the three sites ($P<0.001$). The distribution of each 5 cm increment of each core was polymodal and ranged from poorly sorted to very poorly sorted, generally with distance from surface substrata. Optimum grain sizes for salmon spawning were observed mostly in the lower fraction of the possible size range of 16-64 mm for all cores from all sites. Sediment D <1 mm frequently exceeded the 14% threshold of a healthy spawning habitat. All cores were extracted from water of known salmon spawning depth (Table 1).

Table 1. Water depth at positions where gravel freeze core were extracted.

Site	Core 1	Core 2	Core 3
Ebley Mill	45 cm	13 cm	14 cm
Button Mill	35 cm	20 cm	45 cm
Eastington School	55 cm	25 cm	30 cm

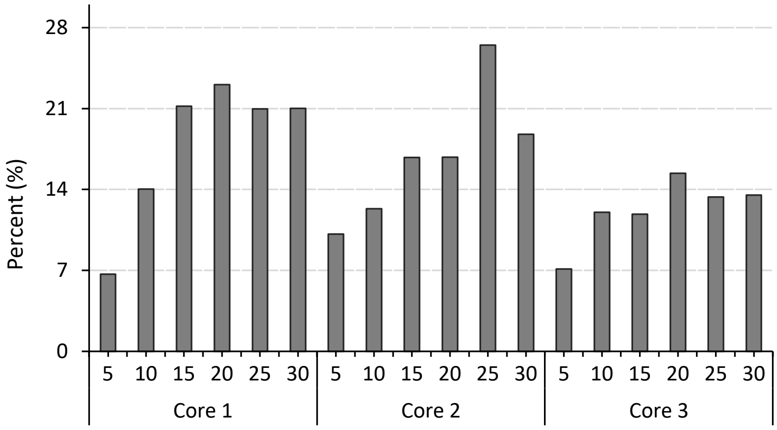
Ebley Mill

Cores extracted from the gravel habitat at the Ebley Mill site displayed the greatest grain size variation between cores of any site ($P<0.01$). Substrata had high levels of fine sediment D <1 mm (Fig. 3).

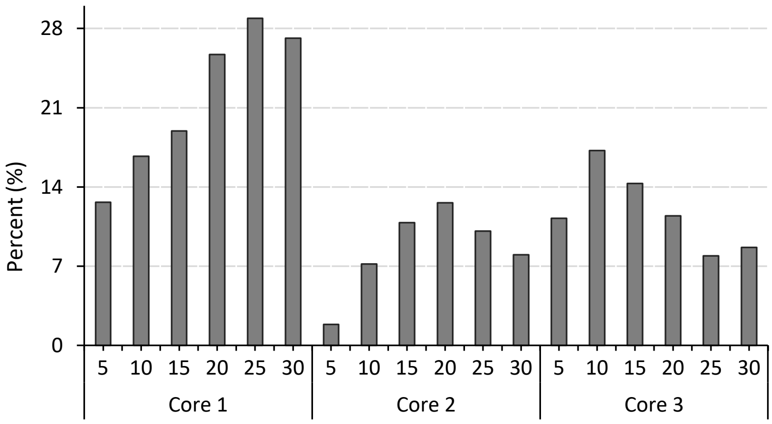
Core 1 had good spawning gravels on surface substrata, reducing with increased depth but never falling below 30% of the total substrata composition (Fig. 4, Table 2). A large amount of fine sediments were observed, with only surface substrata not exceeding 14% (Fig. 3). Clays (D<4µm) were present in the mid level sediment composition. Glass shards made a greater contribution from mid to lower core depths. Increased fines and reduction in spawning gravels were evident in the sudden drop in D_{10}, D_{50} and D_{90} values below the upper 5 cm substrata (Table 2). This was reflected in the textural classification as finer sediments became more prevalent.

The substrata in core 2 had a good composition of spawning gravels, decreasing to less than 30% only within lower core levels (Fig. 4, Table 2). Fine sediment remained high and increased with depth from surface substrata, whilst clays also contributed a greater proportion towards lower levels (Figs. 3 & 4). There was a general steady decline in D_{10}, D_{50} and D_{90} values from surface substrata (Table 2). Very little glass was observed (Fig.4)

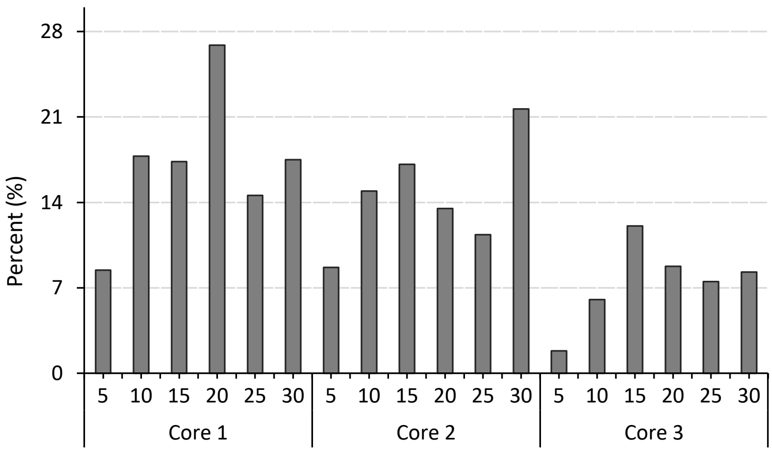
Fine sediment within core 3 remained predominantly below 14% while clay made up a slight proportion of this with increased depth (Figs. 3 & 4). This was reflected in the decreasing D_{10} value (Table 2). The contribution of spawning gravel of optimum sizes were low with a good abundance in surface and mid substrata levels only (Fig. 4). No glass was recovered from this core.



A) Ebley Mill



B) Button Mill



C) Eastington School

Figure 3. Comparison of fine sediment (*D* < 1 mm) of each 5 cm increment from each core extracted at each site. Note the frequency at which the 14% threshold is approached or exceeded.

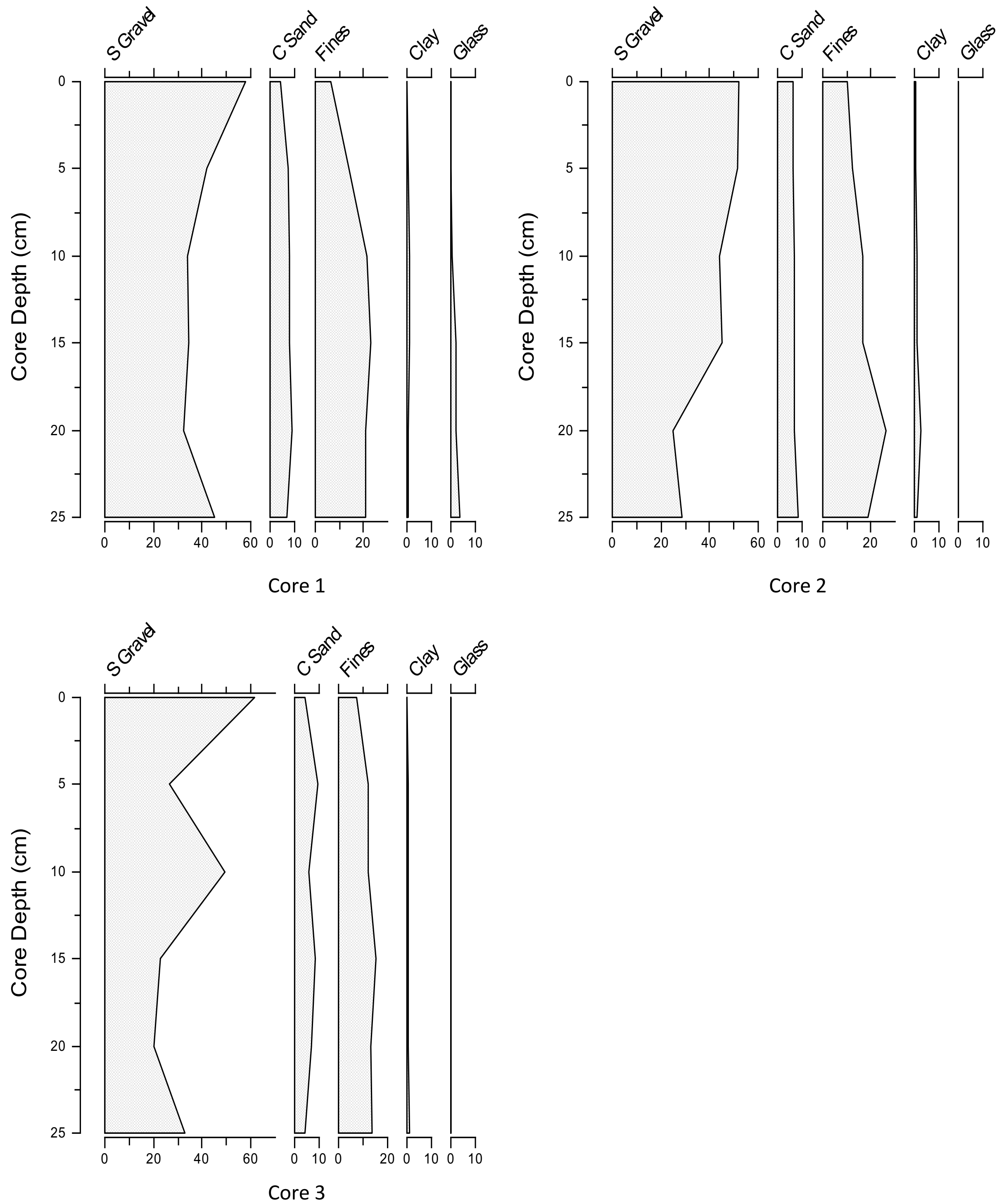


Figure 4. Stratigraphic plot of cores extracted from the gravel habitat at Ebley Mill, illustrating sediment size fractions of interest in percentage (%) contribution of the grain size distribution.

Table 2. Summary of sediment size fractions of interest from gravels at the Ebley Mill site. Grain size distribution statistics and textural classification are included.

Depth (cm)			S.Gravel	C.Sand	Fines	Clay	Glass	D_{10}	D_{50}	D_{90}	Textural Class
Core 1	0-5	%	57.76	4.23	6.67	0.24	0	1.74	18.19	42.23	Gravel
		g	438.44	32.11	50.66	1.78	0				
	5-10	%	41.70	7.41	14.04	0.47	0.15	0.69	11.11	29.08	Muddy Sandy Gravel
		g	256.64	45.60	86.43	2.90	0.91				
	10-15	%	33.88	8.10	21.21	0.87	0.51	0.37	7.80	43.31	Muddy Sandy Gravel
		g	271.29	64.83	169.83	6.95	4.11				
	15-20	%	34.41	7.90	23.08	1.08	1.98	0.26	8.25	31.62	Muddy Sandy Gravel
		g	253.65	58.26	170.12	7.95	14.63				
	20-25	%	32.60	8.92	20.96	0.58	2.08	0.54	8.15	24.74	Muddy Sandy Gravel
		g	108.54	29.69	69.78	1.92	6.92				
	25-30	%	45.06	7.10	21.01	0.54	3.74	0.53	12.84	44.13	Muddy Sandy Gravel
		g	283.12	44.59	132.00	3.38	23.51				
Core 2	0-5	%	52.02	6.48	10.13	0.35	0	0.98	16.66	42.65	Gravel
		g	740.27	92.22	144.15	4.97	0				
	5-10	%	51.56	6.11	12.33	0.60	0	0.76	16.51	42.39	Gravel
		g	801.11	94.92	191.50	9.39	0				
	10-15	%	44.03	7.00	16.78	0.89	0	0.50	11.87	47.17	Muddy Sandy Gravel
		g	567.45	90.24	216.28	11.45	0				
	15-20	%	45.03	6.73	16.79	0.87	0	0.50	12.63	38.88	Muddy Sandy Gravel
		g	543.09	81.12	202.50	10.46	0				
	20-25	%	24.73	6.72	26.50	2.39	0.01	0.03	6.49	26.99	Muddy Sandy Gravel
		g	233.03	63.32	249.72	22.51	0.05				
	25-30	%	28.51	8.24	18.78	1.26	0	0.41	7.56	24.06	Muddy Sandy Gravel
		g	144.16	41.67	94.96	6.37	0				
Core 3	0-5	%	61.75	4.42	7.12	0.26	0	1.60	20.59	48.47	Gravel
		g	595.05	42.61	68.64	2.46	0				
	5-10	%	26.58	9.28	12.02	0.40	0	0.84	6.94	23.68	Muddy Sandy Gravel
		g	216.50	75.57	97.91	3.29	0				
	10-15	%	49.35	5.81	11.85	0.43	0	0.78	15.45	45.81	Gravel
		g	534.89	62.99	128.47	4.61	0				
	15-20	%	23.04	8.56	15.39	0.60	0	0.59	6.59	22.84	Muddy Sandy Gravel
		g	197.62	73.48	132.05	5.15	0				
	20-25	%	20.26	6.71	13.35	0.64	0	0.66	7.64	22.00	Muddy Sandy Gravel
		g	201.95	66.92	133.11	6.37	0				
	25-30	%	32.73	4.36	13.51	0.86	0	0.56	8.95	29.21	Gravel
		g	370.52	49.40	152.96	9.70	0				

Button Mill

The grain size distribution of cores 2 and 3 extracted from the Button Mill gravels were not highly variable (P=0.625). Core 1 did, however, illustrate great distribution variability (P<0.001).

Substrata within mid levels of core 1 had a good proportion of spawning sized gravels, although very high levels of fines were observed throughout (Figs. 3 & 5). Clays were present mostly in the upper surface layers. Levels of fine material in the lower depths were the highest recorded, evident in the low D_{10} value of the surface sediments (Table 3). High D_{50} values and low D_{10} values within the mid core distribution indicate the presence of both smaller sized sediment fractions and larger spawning gravels. A relatively high proportion of glass shards were observed in mid level substrata (Fig. 5).

Core 2 comprised a very good proportion of optimum spawning sized gravel throughout the vertical profile (Fig. 5). Very low levels of coarse sand and fine material were observed. These observations were reflected in the relatively high D_{10}, D_{50} and D_{90} grain size distribution values throughout the vertical extent of the core (Table 3). The textural classification of the vertical extent of core 2 provides a good indication of the larger sediment sized distribution of each 5 cm increment (Table 3). A low proportion of glass was found.

There was a relatively low composition of spawning gravel throughout the vertical extent of the substrata of core 3 (Fig. 5). Fine sediment was more predominant in the upper-middle levels, of which clay comprised very little (Figs. 3 & 5). Coarse sand did not exceed 10%. Generally there was a high proportion of fines and coarse sand in mid core depths with more suitable spawning substrata above and below. Very little glass was observed.

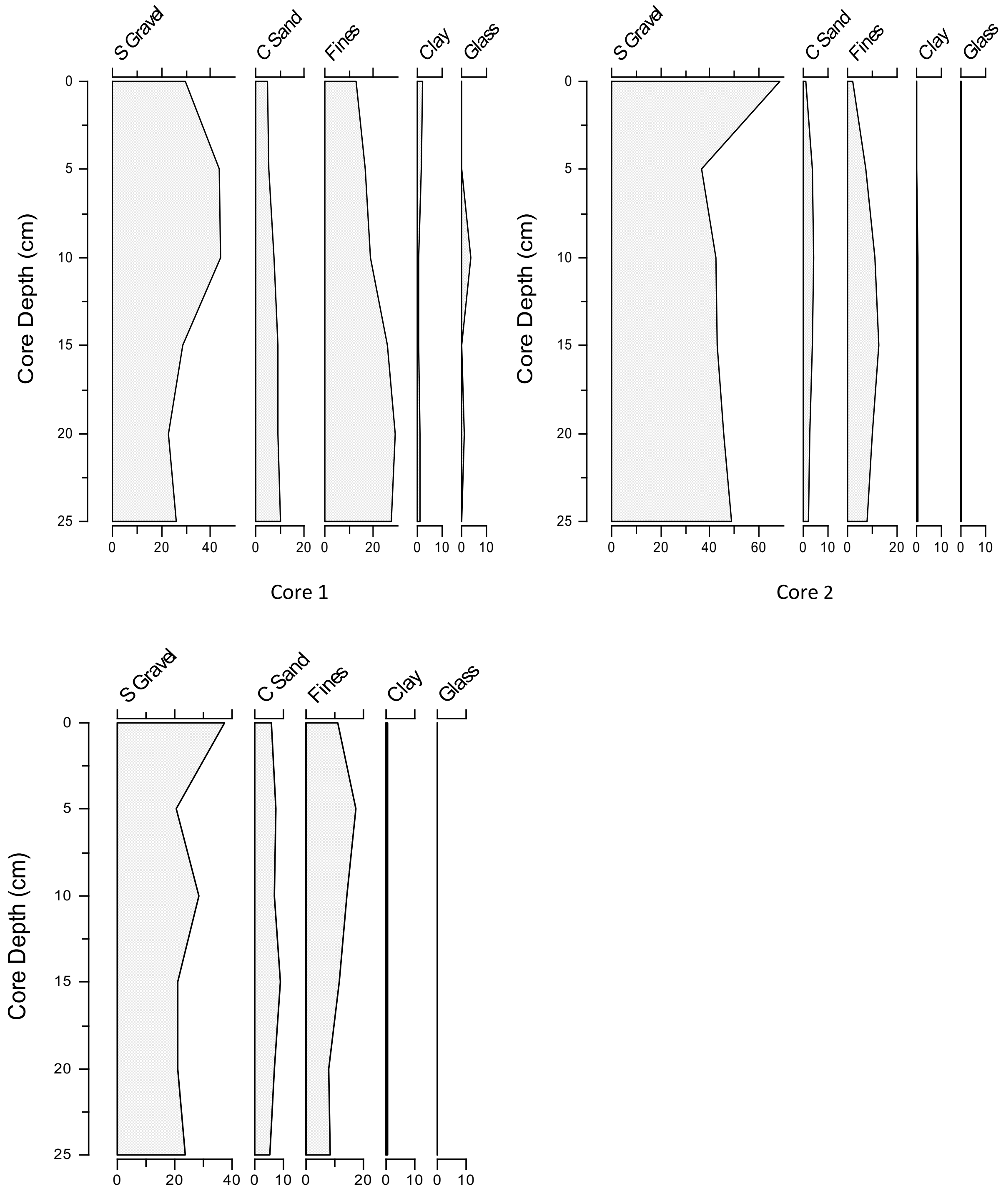


Figure 5. Stratigraphic plot of cores extracted from the gravel habitat at Button Mill, illustrating sediment size fractions of interest in percentage (%) contribution of the grain size distribution.

Table 3. Summary of sediment size fractions of interest from gravels at the Button Mill site. Grain size distribution statistics and textural classification are included.

	Depth (cm)		S.Gravel	C.Sand	Fines	Clay	Glass	D_{10}	D_{50}	D_{90}	Textural Class
Core 1	0-5	%	29.61	5.06	12.66	2.05	0	0.61	9.64	44.74	Gravel
		g	151.73	25.94	64.87	10.48	0				
	5-10	%	43.76	5.59	16.72	1.45	0	0.53	11.96	42.06	Muddy Sandy Gravel
		g	241.24	30.83	92.16	8.00	0				
	10-15	%	44.03	7.74	18.94	0.39	3.69	0.61	11.59	26.01	Sandy Gravel
		g	314.26	55.24	135.22	2.78	26.36				
	15-20	%	28.95	9.32	25.70	0.75	0.09	0.52	6.37	26.16	Muddy Sandy Gravel
		g	294.14	94.69	261.13	7.60	0.9				
	20-25	%	22.89	8.95	28.91	0.95	1.12	0.36	5.08	22.80	Muddy Sandy Gravel
		g	162.80	63.69	205.62	6.75	7.99				
	25-30	%	26.06	10.21	27.14	1.01	0.12	0.38	5.13	32.44	Muddy Sandy Gravel
		g	230.46	90.31	239.97	8.93	1.09				
Core 2	0-5	%	68.36	1.04	1.87	0.06	0	8.13	21.51	47.38	Gravel
		g	415.90	6.30	11.35	0.39	0				
	5-10	%	36.60	3.83	7.19	0.23	0.04	1.71	11.97	25.27	Gravel
		g	197.71	20.71	38.86	1.22	0.2				
	10-15	%	42.67	3.97	10.86	0.33	0	0.88	13.13	34.92	Gravel
		g	357.81	33.28	91.08	2.80	0				
	15-20	%	42.85	3.85	12.61	0.64	0.01	0.69	13.02	43.45	Gravel
		g	377.43	33.87	111.07	5.62	0.05				
	20-25	%	45.74	2.82	10.11	0.46	0	0.98	14.24	29.61	Gravel
		g	244.92	15.09	54.16	2.48	0				
	25-30	%	48.74	2.19	8.02	0.42	0.07	1.89	15.34	38.18	Gravel
		g	451.73	20.33	74.31	3.86	0.62				
Core 3	0-5	%	37.18	5.87	11.23	0.30	0	0.87	10.54	43.94	Gravel
		g	211.42	33.40	63.83	1.68	0				
	5-10	%	20.39	7.56	17.22	0.65	0.08	0.56	6.97	22.04	Muddy Sandy Gravel
		g	110.55	41.01	93.36	3.55	0.42				
	10-15	%	28.28	6.90	14.30	0.48	0	0.62	8.29	24.02	Muddy Sandy Gravel
		g	175.30	42.77	88.67	2.97	0				
	15-20	%	20.92	9.07	11.44	0.51	0	0.84	6.39	22.21	Muddy Sandy Gravel
		g	140.26	60.83	76.70	3.41	0				
	20-25	%	21.14	6.80	7.93	0.37	0	1.37	6.98	22.28	Gravel
		g	104.93	33.75	39.37	1.86	0				
	25-30	%	23.72	5.09	8.66	0.47	0.13	1.32	7.97	23.02	Gravel
		g	116.57	24.99	42.58	2.29	0.65				

Eastington School

The grain size distribution of cores 1 and 2 extracted from the gravels at the Eastington School site did not display high variation (P=0.071). Core 3, however, illustrated great distribution variability (P<0.001).

There was good availability of optimum spawning gravels throughout the vertical extent of core 1, although these diminished within the mid core depths (Fig. 6). Apart from surface substrata, the composition of fine sediment material throughout the core exceeded the 14% limit for a healthy spawning habitat (Figs. 3 & 6). Clay comprised a greater proportion of the fine sediment material with increased depth. Very little glass was observed in this core. The sudden drop in D_{10} and D_{50} values in the 15-20 cm increment range was due to the decreased spawning gravels and a simultaneous sharp increase in the fine sediments contribution (Table 4).

Gravels of a suitable size for spawning were present throughout the vertical extent of core 2, but these did not contribute as much to the overall grain size distribution as observed in core 1 (Fig. 6). Deposits of fine material were high in the sub-surface layers (Figs. 3 & 6). Clay proportions increased with depth. A high percentage of glass shards were recovered from these deeper levels. Coarse sands were proportionately relatively high in the mid core substrata.

Core 3 was characterised by a reduced proportion of spawning gravels (Fig 6). Spawning gravel was only present in high proportions in the surface substrate. However the textual classification and the relatively high D_{10}, D_{50} and D_{90} grain size distribution values indicate the occurrence of gravels slightly smaller than optimum (Table 4). Fine sediment was below 14% at all depths and clay sized material (D<4 μm) contributed very little to this size fraction (Figs.3 & 6).

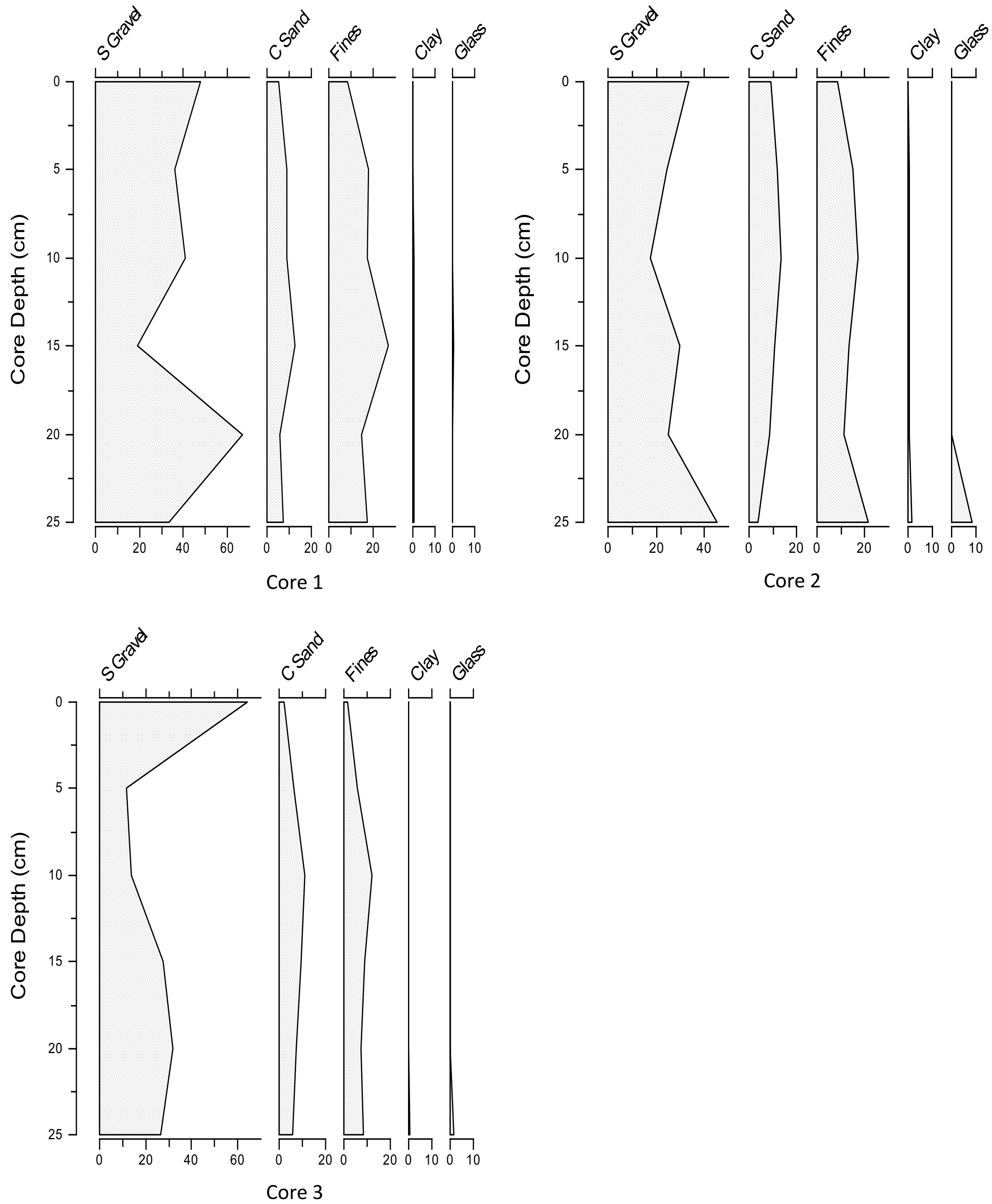


Figure 6. Stratigraphic plot of cores extracted from the gravel habitat at Eastington School, illustrating sediment size fractions of interest in percentage (%) contribution of the grain size distribution.

Table 4. Summary of sediment size fractions of interest from gravels at the Eastington School site. Grain size distribution statistics and textural classification are included.

	Depth (cm)		S.Gravel	C.Sand	Fines	Clay	Glass	D_{10}	D_{50}	D_{90}	Textural Class
Core 1	0-5	%	47.48	5.02	8.44	0.09	0	1.20	14.86	26.28	Gravel
		g	253.58	26.79	45.09	0.48	0				
	5-10	%	35.91	9.03	17.79	0.20	0	0.67	9.20	36.08	Sandy Gravel
		g	193.80	48.72	96.01	1.06	0				
	10-15	%	40.94	9.18	17.34	0.34	0	0.66	10.14	44.79	Sandy Gravel
		g	324.15	72.66	137.27	2.70	0				
	15-20	%	19.28	12.77	26.89	0.68	0.34	0.42	3.56	37.76	Muddy Sandy Gravel
		g	85.93	56.93	119.85	3.04	1.5				
	20-25	%	66.75	5.68	14.57	0.50	0	0.64	32.00	52.91	Muddy Sandy Gravel
		g	901.52	76.76	196.74	6.79	0				
	25-30	%	33.53	7.21	17.49	0.69	0	0.51	8.63	24.87	Muddy Sandy Gravel
		g	112.74	24.25	58.79	2.33	0				
Core 2	0-5	%	33.61	8.99	8.68	0.08	0	1.11	9.41	24.88	Gravel
		g	123.10	32.94	31.80	0.30	0				
	5-10	%	24.47	11.81	14.94	0.37	0	0.71	6.39	23.20	Sandy Gravel
		g	143.71	69.34	87.74	2.19	0				
	10-15	%	17.74	13.74	17.13	0.51	0	0.64	4.58	21.05	Sandy Gravel
		g	94.85	73.45	91.59	2.73	0				
	15-20	%	30.05	11.01	13.49	0.47	0.08	0.75	7.19	24.34	Muddy Sandy Gravel
		g	153.76	56.32	69.04	2.41	0.4				
	20-25	%	24.83	8.50	11.36	0.45	0.18	0.88	7.30	23.29	Gravel
		g	141.59	48.45	64.74	2.54	1.05				
	25-30	%	45.31	3.59	21.65	1.50	8.22	0.05	13.23	26.11	Muddy Sandy Gravel
		g	140.74	11.16	67.26	4.67	25.55				
Core 3	0-5	%	64.39	1.85	1.84	0.01	0	4.83	20.88	47.77	Gravel
		g	310.81	8.95	8.87	0.06	0				
	5-10	%	11.73	6.52	6.03	0.06	0	1.61	8.62	17.55	Gravel
		g	36.58	20.33	18.81	0.19	0				
	10-15	%	13.73	11.00	12.06	0.16	0	0.86	5.36	18.98	Sandy Gravel
		g	47.43	38.02	41.68	0.54	0				
	15-20	%	27.65	9.41	8.77	0.17	0	1.14	8.10	23.90	Gravel
		g	103.84	35.33	32.93	0.63	0				
	20-25	%	31.94	7.15	7.51	0.22	0	1.36	9.08	24.64	Gravel
		g	112.41	25.16	26.43	0.77	0				
	25-30	%	26.39	5.63	8.30	0.31	1.51	1.31	10.04	23.64	Gravel
		g	86.98	18.54	27.35	1.04	4.97				

OVERVIEW

The spawning potential is inconsistent both between and within each of the identified gravel habitat sites. Spawning gravels are present at each site, although these fall within the smaller diameters of gravels known to be of a suitable range to permit successful spawning. However, construction of redds on each site should be readily possible. Fine sediment is the greatest limiting factor to successful embryo incubation within all sites. Excessive fine sediment deposits within the framework spawning gravels increase the risk of high embryo mortality rates. Moreover, glass shards may be cause for concern as spawning fish could become seriously injured. Spawning potential is greatest within shallow depths on the Ebley Mill and Button Mill sites. The increase in fine material in lower substrata levels reduce the capacity of the gravel to support successful spawning.

The spawning habitat at Ebley Mill contains good proportions of the sediment size range required for salmon spawning and therefore has the potential for redd construction. These gravels contribute well to mostly upper substrata levels. Apart from core 3, fine sediment increases rapidly from the mid to lower depths placing developing embryos at risk of interstice blockage.

Moderate proportions of spawning sized gravel are present at the Button Mill site. These gravels are more prevalent in the upper half of sampled substrata. Very high levels of fine material observed in core 1 are indicative of high embryo mortality risk. However, reduced contributions of fine sediments, mostly below 14%, are observed in core 2 and 3, thus reducing this risk. The overall composition of substrata at Button Mill offers the best potential spawning habitat of the identified sites.

Spawning potential within river bed substrata at the Eastington School site is reduced by large fine sediment deposits observed in cores 1 and 2. Low proportions of spawning gravel in core 3 may limit redd construction on the downstream end of the riffle. This core is also characterised by a lower proportion of fine sediment deposits when compared with cores 1 and 2, and is indicative of the fickle nature of sediment distribution in spawning habitats.

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APPENDIX

Gravel freeze cores extracted from the Ebley Mill site

CORE 1

CORE 2

CORE 3

Gravel freeze cores extracted from the Button Mill site

CORE 1

CORE 2

CORE 3

Gravel freeze cores extracted from the Eastington School site

CORE 1

CORE 2

CORE 3