

EFFECTS OF A FLASH-FLOOD ON CHANNEL MORPHOLOGY AND SOME INSECTS OF A SMALL STONY STREAM IN THE PEAK DISTRICT, DERBYSHIRE

MIKE DOBSON, HELEN CARISS AND BLAIRE MURRAY

*(Dr M. Dobson, H. Cariss and B. Murray, Department of Environmental and
Geographical Sciences, Manchester Metropolitan University, Chester Street,
Manchester M1 5GD, England.)*

[Tel: 0161 2471587; Fax: 0161 2476318;

E-mail: m dobson @ [mmu.ac.uk](mailto:m.dobson@mmu.ac.uk).]

Introduction

An occupational hazard for those of us who carry out long-term studies in small streams is the possibility of occasional catastrophic floods which are characteristic of these systems. Anybody who carries out such work over a long period of time can expect to suffer such a setback, but the irregular and unpredictable nature of these flash-floods or spates means that they can occur at any time. The loss of a long-running experiment or an entire set of field equipment is, at the very least, a nuisance, and can be disheartening, but the opportunity to gather information about the effects of such spates should be seized because, despite their importance, they are very difficult to study directly.

Here we present some observations made following a flash-flood which occurred in Stake Clough, a small tributary of the River Goyt in the Peak District of Derbyshire, during the evening of 6 August 1996. Whereas previous studies on the effects of floods, such as those of Giller et al. (1991) and Hendricks et al. (1995), have generally examined long-term changes, through repeated sampling at relatively long intervals before and after the event, we were able to make observations and commence our studies within two days of its occurrence. The observations are not entirely rigorous, in that they lack controls, adequate replication, or a detailed investigation of all possible parameters. They are, however, precise rather than anecdotal and, if nothing else, they may give some ideas for fruitful areas of study to others who are unfortunate and lose everything in one stormy night.

The stream

Stake Clough (technically the name of the valley rather than the stream itself) lies about 4 km west of Buxton, in Derbyshire. It rises at an altitude of 500 m and flows for around 1 km across peat moorland before descending into a shallow wooded gorge ca. 500 m in length. At the base of this gorge, at an altitude of 250 m, it opens out into a tiny, cone-shaped floodplain, 150 m long

and 40 m wide at its base, before passing under a road and descending as a series of waterfalls to the River Goyt. The gorge is wooded with common oak *Quercus robur*, rowan *Sorbus aucuparia* and silver birch *Betula pendula*, but is surrounded by a plantation of European larch *Larix decidua*, Norway spruce *Picea abies* and Scots pine *Pinus sylvestris*: the floodplain (National Grid Reference SK Oil 736), the point at which all our observations were made, is shaded by oak, larch and pine, although few trees are rooted on the floodplain itself. The stream is consistently acid, spot measurements on various dates during 1993 to 1996 all being in the range pH 4 to 5.

The flood

During the evening of 6 August 1996 there was a severe but very localised storm in the region of the Goyt Valley. Local inhabitants tell us that a thunderstorm was followed by ca. two hours of very heavy rain. Precise rainfall readings are not available, but a rain gauge within 1 km of Stake Clough, emptied every three days, recorded 40 mm of rain for the period around this date. Such a large volume of rainfall is by no means exceptional for the Goyt Valley, but comparison with daily readings taken in Buxton suggests that 20 to 30 mm of rain may have fallen during this single storm. Furthermore, it followed a dry spell that had lasted for several months.

The flood scoured the bed of Stake Clough but, more significantly, caused it to change course along the middle part of the floodplain (Fig. 1). In the central portion of the floodplain reach, the flood deposited gravel into the original channel, leaving two pools and a new, poorly-defined channel spread across the adjacent land, breaking into a series of braids before rejoining the original channel (Figs 2-4). Unconsolidated gravel was spread widely across the floodplain, allowing subsurface flow into and out of the pools in the former channel. Within two weeks after the flood, most of the flow in the modified stretch had apparently gone underground, leaving a static marsh, but further rain over the weekend 24-26 August restored flow in the new channel.

Heavy rain towards the end of October scoured the original channel (now acting as an overflow channel), reducing the pools to around one-half of their original surface area and maybe one-quarter of their volume, but at the same time it consolidated the main flow in the new channel by cutting away much of the loose gravel. Further rain during November and December developed the new channel so that by the beginning of 1997 the braiding had been reduced and a single main channel was present (Fig. 1c).

Invertebrates in Stake Clough

After the flood, the benthos of the stream was dominated numerically by chironomids (not yet identified but believed to be mainly a single species) and leuctrid stoneflies (*Leuctra nigra*, *L. hippopus* and *L. inermis*). Other taxa

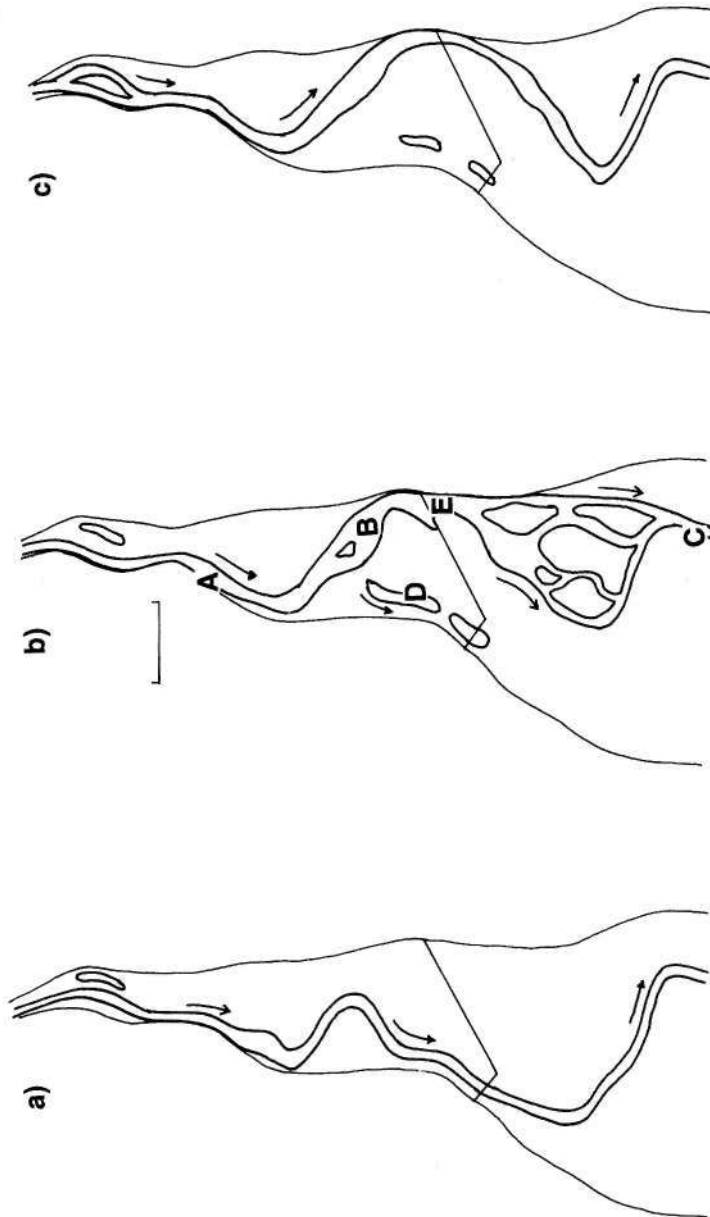


FIG. 1. Configuration of the channel of Stake Clough on its floodplain: (a) before the flood (July 1996); (b) six days after the flood (12 August 1996); (c) five months after the flood (January 1997). The lines on each side of the diagrams represent the edges of the floodplain; the straight lines crossing the floodplain show the location of a wire-mesh stock-fence; arrows show direction of water flow. The scale bar is 10 m long. Letters A-D represent sample points referred to in the text and in Figs 2-5.

present were naidid worms, nemourid stoneflies (*Nemoura cambrica*, *Nemurella pictetii*, *Protonemura meyeri*, *Amphinemura sulcicollis*), several caddis species (*Potamophylax cingulatus*, *Drusus annulatus*, *Rhyacophila dorsalis*, *Plectrocnemia conspersa*), alderfly (*Sialis fuliginosa*) and a variety of dipterans (*Dicranota* sp., Limoniinae, Tipulinae and *Simulium* sp.). Occasional dytiscid beetle larvae and two adults (*Agabus didymus*) were recorded and, during October, the stonefly *Capnia* sp. started to appear.

Patterns in distribution and abundance

We were able to visit the site eight times between 8 August and 30 October 1996, to take samples and make observations on the stream. Samples were taken from the streambed, using a Surber sampler (area covered 25 x 25 cm, mesh size 0.5 mm) at four points in the stream channel: the original channel upstream (point A in Fig. 1b), the braided new channel (point B), the original channel downstream (point C, first sampled on 12 August) and pools in the former channel (point D). Additionally, on 8 August, samples were taken from the vicinity of the wire stock-fence in the new channel (point E), but this site was abandoned because the old wire stock-fence was removed and replaced with a new one shortly after the flood. These samples form part of an ongoing monitoring programme, the results of which will be published in due course, but some preliminary observations are presented here.

The most striking observation was that numbers of insects in all stretches of the stream channel itself (upstream, braided and downstream) were initially very low, ranging between 100 to 200 per m², but then gradually rose to population densities approaching ten times this figure, whereas numbers in the pool were initially high (nearly 1000 per m²) and increased only by a small proportion. Results are, however, confounded by a gradual increase in numbers of very young larval stages, representing recruitment from eggs of the new summer cohort rather than redistribution of individuals within the original population, and by a chironomid cohort, possibly representing a fugitive species, whose numbers rose rapidly in every site for several weeks and then declined so that, by mid-October, they had almost disappeared. The results presented here, therefore, concentrate on larvae that would not have been affected by such demographic trends over such a short period of time. These are later instars (total body length 1.5 to 3 cm) of the four largest insects in the stream: *Sialis fuliginosa*, *Plectrocnemia conspersa*, *Rhyacophila dorsalis* and *Potamophylax cingulatus*. Immediately following the flood, there were very high numbers of these taxa in the pool, relative to sites within the stream channel, but this difference did not persist beyond the first few days as numbers in the pool declined (Fig. 5). In comparison, samples taken from adjacent to the stock-fence on 8 August caught a mean of 13 larvae per m², higher numbers than in the other stream stretches but appreciably lower than in the pool.



FIG. 2. Effects of the flood on Stake Clough (with dates on which the photographs were taken). *Above*: looking downstream from point A (Fig. 1b), before the flood (21 March 1995). *Below*: looking downstream from point A, after the flood (29 August 1996).



FIG. 3. Effects of the flood on Stake Clough (with dates on which the photographs were taken). *Above*: looking upstream from point A after the flood (8 August 1996); the stream channel has been displaced about 1 m to the left (as viewed in this photograph), removing a large chunk of the dry-stone wall which had stood there. The old channel is beneath the rubble in the centre of the photograph. *Below*: looking across the floodplain after the flood, showing point D (Fig. 1b; the former channel) in the foreground, and point B (the new channel) in the background (8 August 1996).



FIG. 4. Effects of the flood on Stake Clough (with dates on which the photographs were taken). *Above*: the former channel downstream of the fence, looking upstream (29 August 1996); the channel has been completely infilled with coarse gravel. *Below*: the new channel at point E (8 August 1996), showing aggregation of detritus on the fence.

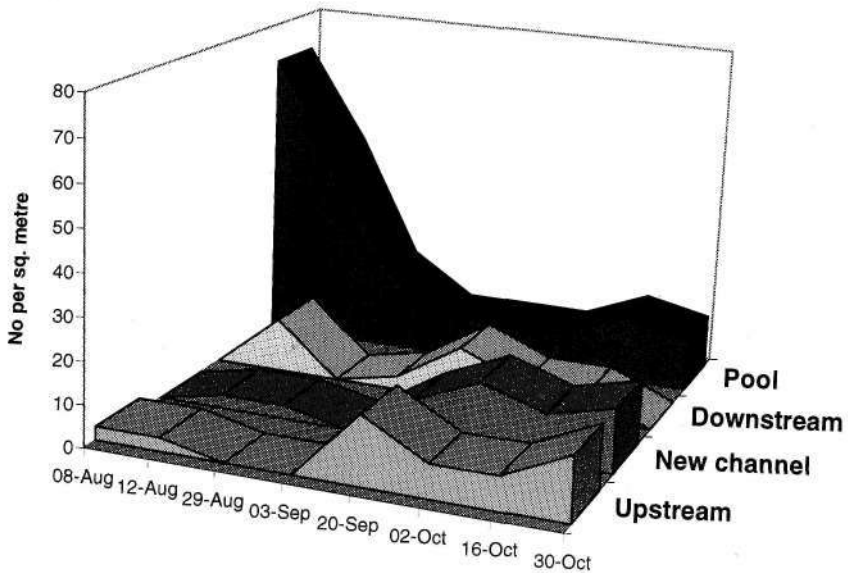


FIG. 5. Numbers (per m²) of the larger insect larvae (*Potamophylax cingulatus*, *Rhyacophila dorsalis*, *Plectrocnemia conspersa*, *Sialis fuliginosa*) at four sampling points (see Fig. 1b) on eight sampling dates from 8 August to 30 October 1996. Sampling points (see Fig. 1b) are: pool = point D; downstream = original channel downstream (point C); upstream = original channel upstream (point A); new channel = point B.

Colonisation of mesh bags

On 8 August 1996, 12 mesh bags, each containing 4 to 5 g (dry mass) of conditioned oak leaves, were placed into the stream, three each at points A, B, D and E. These were collected after 24 hours. Primarily they were being used to attract larvae of the caddis *Potamophylax cingulatus*, which were required for a laboratory feeding experiment, but all macroinvertebrates colonising the bags were counted.

Mesh bags were dominated by chironomids, but also contained relatively high numbers of *P. cingulatus* (Table 1). The 12 bags collected on 9 August contained a total of 24 large *P. cingulatus* larvae (14 in the pool), whereas 20 benthic samples taken on 8 August caught nine (8 in the pool) and on 12 August caught six (5 in the pool). Of the 12 bags, three placed adjacent to the fence did not attract any caddis larvae. Interestingly, mesh bags containing oak leaves had been placed into the stream on five separate occasions during the two months prior to the flood, but had not attracted a single cased caddis. Four mesh bags placed into the stream one week prior to the flood and left for three days had, between them, attracted one nemourid stonefly, one adult aquatic beetle (*Helobates* sp.) and a small number of chironomids.

Table 1. Mean numbers of aquatic insects (no. per 5 g detritus) collected in mesh bags (during 24 hours) and in detritus caught on a wire fence, based on samples taken on 9 August 1996. Asterisks indicate estimated numbers, rather than actual counts of individuals.

Taxon	Mesh bags:-				Fence:-	
	In pool (Point D)	Below fence (Point E)	New channel (Point B)	Original channel (Point A)	In new channel	In pool
Chironomidae	920*	400*	90*		220*	15
Nemouridae	4	4	3	1	1	—
<i>Potamophylax</i>	14	—	2	9	1	5
<i>Leuctra</i>	—	—	—	—	6	—
Others	3	2	—	—	2	1

Detritus on the stock-fence

The wire-mesh fence, in the vicinity of both the original and the new channel, was covered in detritus (Fig. 4). On 9 August, three large handfuls, each containing 4 to 9 g (dry mass) of leaf litter, were carefully removed from the base of each part of the fence, just below the waterline, and macroinvertebrates within them were counted.

The variety of species contained within these samples matched that caught in the mesh bags on the same day, but, although it is difficult to make direct comparisons, numbers of individuals per unit volume of detritus were generally lower and, in the case of chironomids, appreciably lower in detritus on the fence than numbers in the mesh bags (Table 1).

Effects on behaviour of *Potamophylax cingulatus* larvae

The new pools that appeared in the former channel were a particularly fruitful source of observations, as they were shallow and clear. On 8 August, several 4th- and 5th-instar larvae of the case-bearing caddis *Potamophylax cingulatus* could be seen clearly wandering around on the bed of the upper pool, whereas numerous examinations of the streambed prior to the flood had never revealed larvae of this species exposed to view. Rapid colonisation of the three mesh bags placed in the pool (site D, Fig. 1) suggests the possibility that they were actively seeking food or shelter. On 8 August a *P. cingulatus* larva was seen to enter a mesh bag containing oak leaves within an hour of its placement in the pool, and several other larvae, not previously visible, were apparently making their way towards it. On 12 August, we observed a larva eating the remains of a dead fly that was attached to a mesh bag.

One of the Surber samples taken in the pool on 8 August caught four large (5th-instar) *P. cingulatus* larvae without cases. All were very active and apparently uninjured; they were placed in a tank containing sand and gravel and, upon inspection 24 hours later, three of the larvae had constructed new cases. The fourth, although still alive, was in the process of being eaten by its colleagues and had lost half its abdomen. Four other *P. cingulatus* larvae caught in the pool on this occasion, at other sampling points, bore cases as normal. None of the caddis caught on this date were visible on the surface of the streambed prior to samples being taken.

Refugia

Potentially three types of refugia are available to benthic organisms in the event of a flood: subsurface sediments (the hyporheic zone), pools in the floodplain, and dead zones within the stream channel itself (Hildrew & Giller 1994). We were unable, in the time available immediately following the flood, to investigate subsurface sediments, though their uncompacted nature and clear evidence for subsurface flow may have provided suitable habitat for invertebrates, but we made some crude observations on the other two refugia.

The nature of the flood probably reduced dead zones to a minimum, as it picked up and redistributed the channel bed to a depth of up to 30 cm. One structure which survived, however, was the wire stock-fence, flattened in places but remaining upright where both the old and new channel passed beneath it. This caught a large volume of detritus and presumably, therefore, would have acted as an effective trap for invertebrates dislodged by the stormwater. If it did, however, trapped animals must have quickly dispersed after the water had receded, because numbers of invertebrates in and around the fence were no higher than those caught elsewhere.

Floodplain refugia are represented by the pools in the former channel, apparently bypassed by the main flow of water and therefore providing a zone into which drifting invertebrates could be deposited. Numbers of individuals were relatively high in the pool immediately after the flood, suggesting that it had, indeed, acted as a refugium or a point of aggregation. Unfortunately, without information on benthic densities immediately prior to the flood, we are unable to comment on whether these individuals simply persisted in these pools or were deposited there by floodwater. A potential problem with floodplain pools is that, although animals may be deposited within them during a flood event, once the flood waters recede they are isolated from the main stream and may, therefore, act as traps rather than refugia. In the case of Stake Clough, the pools studied were clearly still flowing, albeit slowly, due to extensive subsurface water movement through unconsolidated sediment along the course of the original channel. It would have been interesting to determine whether animals, too, were moving along this channel.

Leaf packs and larvae of *P. cingulatus*

The aggregative behaviour of the larvae of *P. cingulatus* in our oak leaf-packs (held in mesh bags), mentioned above, is worthy of note. Prior to the flood, this behaviour was hardly ever recorded. Such activity, involving the same species, was observed by the senior author in the Oreval, a small tributary of the River Tarn in south-western France, following a spate on 1 June 1991. At first, there was no evidence that any case-bearing caddis larvae had persisted in the stretch under study but, within a few days, larvae of *P. cingulatus* started to appear, wandering around openly on the riverbed, and it was not unusual to see them at densities of 100 or more per m² in the more sheltered parts of the river. This diurnal activity in a normally nocturnal species (Giller & Sangradub 1993) obviously made them vulnerable to predation and may have been a response to food shortage when their usual food items had been washed away. Food limitation occurs commonly in this species (Otto 1975) and in the related limnephilid *Chaetopteryx villosa* (Wagner 1990) towards the end of larval development, and would be exacerbated by removal of what little food remained. In the Oreval in June 1991, mesh bags containing alder leaves were rapidly colonised by detritivores (Dobson 1994), including large numbers of *P. cingulatus*; on one occasion a mesh-bag filled with 5 g of dried alder leaves, placed into the river on 24 June, contained 95 5th-instar *P. cingulatus* on the following day, and the leaves had been almost completely consumed. Less palatable beech leaves were not colonised to anything like the same extent, however, suggesting that requirement for shelter is not an explanation for this aggregative behaviour.

In Stake Clough, nothing so extreme as in the Oreval was observed, but the same pattern of behaviour by *P. cingulatus* was seen - no apparent interest in offered leaf packs before a flood, followed by clear interest afterwards. If *P. cingulatus* larvae are reacting to food shortage after floods, then the larvae must persist during spates better than their food source. It may be that, whereas the detritus upon which they habitually feed is floated away by floodwater, *P. cingulatus* larvae, weighed down by stone cases, act more like gravel and are deposited wherever gravel aggregates. Circumstantial evidence for this comes from the capture of uncased larvae in the pool, which had formed over a large aggregation of gravel that completely entombed the original channel and was devoid of any obvious detritus. Why these larvae should have abandoned their cases is unclear, although they were not visible in the clear, shallow water of the sample point before the sample was taken, so must have been buried in the gravel. Perhaps, if buried by a deposit of gravel, the caddis have great difficulty in moving through the substratum when confined within their bulky cases, so these are abandoned in order to return to the surface, where they build new cases. This possibility is currently under investigation.

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