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The effects of sand deposition upon the macro-invertebrate fauna of the River Camel, Cornwall

P. M. NUTTALL *Cornwall River Authority, Launceston, Cornwall*

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Summary

Erosion from a tributary of the River Camel deposited an estimated 10,000 m^3 of sand in the main river over a period of 2 years. The poor incidence of plants and macro-invertebrates from the river was associated with the unstable shifting nature of the sand deposits, rather than turbidity or abrasion caused by particles in suspension. Sand deposition accounted for the low diversity of invertebrate species below the tributary, and resulted in the elimination of several species which were frequent up-stream. *Baetis rhodani*, *Rhithrogena semicolorata*, and Tubificidae were abundant where sand deposition had occurred.

Introduction

Early in 1968 the Stannon tributary of the River Camel was diverted from its original channel as a result of china-clay pit operations. The new water course was cut through unstable and sandy ground which became rapidly eroded. Sand and gravel was carried into the main river from the tributary and by 1970 resulted in the silting of pools and riffles over a distance of 17 km.

The volume of sand deposited in the River Camel as the result of erosion from the tributary was estimated to be 10,000 m^3. The predominant particle size of dried samples of loose bed material, primarily quartz, taken from the river was in the size range 0·300–0·599 mm, described as medium to coarse sand. Sand deposition resulted in the in-filling of many major salmon pools and many small pools became obliterated by sand and over-topped with stones.

The River Camel flows west along the northern edge of Bodmin Moor and discharges into the Atlantic at Wadebridge on the north Cornish coast. It has a catchment area of 209 km^2 above Denby gauging station (NGR SX 017682), a mean summer (April–September) flow of 2·55 m^3/s, a mean winter flow of 8·32 m^3/s and an average daily flow (1964–71) of 5·46 m^3/s.

Table 1 summarizes the water quality over the period 1971 from data supplied by the Cornwall River Authority. Although the number of samples upon which the Table is based is small, the following generalizations can be made: (a) the water tends to be slightly alkaline, with a pH in the region of 7·2 throughout the catchment; (b) dissolved

Correspondence: Mr P. M. Nuttall, Cornwall River Authority, St Johns, Western Road, Launceston, Cornwall, England.

oxygen concentrations are generally high; (c) the permanganate value, biochemical oxygen demand, ammonia concentration and metal analyses indicate the absence of any organic or toxic pollution; (d) suspended solids tend to be low. Samples were taken during low flow conditions. However, during spate or flash-floods which frequently

Table 1. Water quality of the River Camel summarized for the period 1971

	Station								
	1	2	5	6	7	10	11	13	Date
Suspended solids	7	1	1	5	16	2	3	2	8 Feb. 1971
(mg/l)	3	5	7	1	2	1	1	—	4 Oct. 1971
B.O.D. (mg/l)	0·6	1·4	1·6	1·4	1·2	1·7	1·8	2·0	8 Feb. 1971
	1·1	0·8	0·6	0·6	1·4	0·8	0·5	—	4 Oct. 1971
Temperature (°C)	7·5	8·0	7·5	8·0	8·0	8·0	6·8	7·5	8 Feb. 1971
	13·7	14·6	14·2	14·9	15·7	15·2	15·0	—	4 Oct. 1971
Dissolved oxygen	96	100	99	101	101	102	103	102	8 Feb. 1971
(% sat.)	95	101	96	97	99	100	102	—	4 Oct. 1971
Calcium as Ca	9·0	7·5	17·5	6·5	4·8	4·0	5·5	7·5	8 Feb. 1971
(mg/l)	1·5	—	0·5	1·0	3·5	2·0	1·5	—	4 Oct. 1971
Magnesium as Mg	2·1	2·0	1·0	3·2	2·0	1·9	2·1	3·3	8 Feb. 1971
(mg/l)	1·9	—	0·7	1·7	3·4	2·3	1·6	—	4 Oct. 1971
Silica (mg/l)	3·3	4·9	5·5	7·0	5·7	5·8	5·8	6·8	8 Feb. 1971
	5·0	—	6·2	6·2	14·7	9·6	6·2	—	4 Oct. 1971

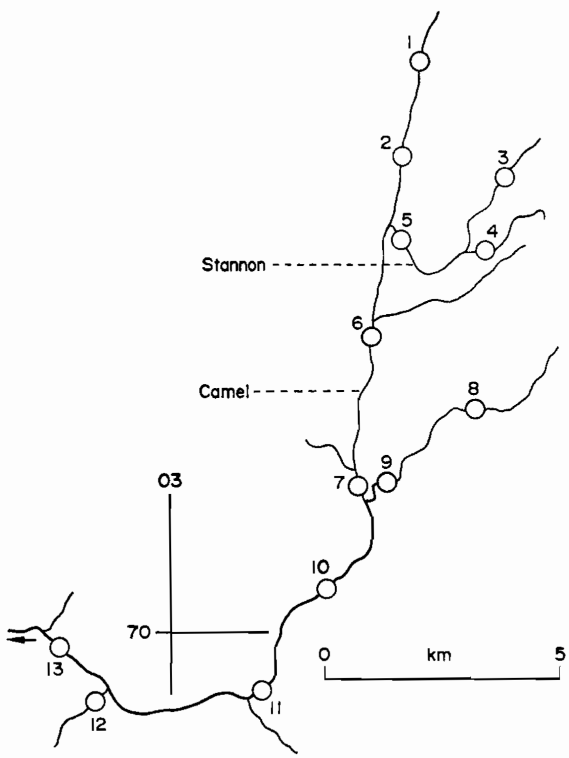

Fig. 1. Sampling points on the River Camel.

Table 2. Relative abundance of the more important invertebrate species for the period 1971(B) and 1972(A) expressed as a percentage of the total

	1		2		3		4		5		6		7		8		9			
Species	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	
Total Plecoptera	23·4	15·2	9·1	10·7	21·2	43·7	29·5	—	12·6	6·3	3·8	19·8	5·6	—	26·3	49·8	20·7	8·7	—	
Leuctra nigra	—	—	—	<35	—	5·3	—	—	—	—	—	—	—	—	—	—	—	—	—	
L. hippopus	3·0	5·1	2·3	4·3	<18	5·3	—	—	—	—	—	—	—	—	—	—	—	—	—	
Amphinemura sulcicollis	—	3·3	—	<35	—	6·4	—	—	—	—	—	—	—	—	—	—	—	—	—	
Protonemoura meyeri	8·8	—	2·3	—	9·6	24·0	23·5	—	8·3	6·3	3·8	—	—	—	26·3	28·3	20·7	8·7	—	
Total Ephemeroptera	35·2	52·5	29·4	69·7	26·4	18·7	70·5	50·0	58·1	71·9	45·1	36·0	22·2	18·1	41·9	7·3	10·8	30·8	—	
Baetis rhodani	3·0	13·5	9·1	36·2	14·6	16·0	70·5	50·0	41·5	59·4	9·4	13·9	8·3	4·5	41·9	7·3	5·4	29·5	—	
Caenis rivulorum	—	—	4·5	2·1	3·0	—	—	—	—	—	—	5·5	—	4·5	—	—	—	—	—	
Ecdyonurus dispar	3·0	—	4·5	2·1	3·0	—	—	—	—	3·1	—	—	<35	<18	—	—	—	—	—	<
Rhithrogena semicolorata	29·2	39·0	11·3	29·3	5·8	2·7	<9	—	16·6	9·4	35·7	16·6	13·9	9·1	<9	—	5·4	1·3	—	
Total Trichoptera	5·8	—	13·6	2·1	8·8	10·7	—	—	8·3	3·1	7·6	5·5	—	4·5	—	9·6	26·1	15·9	—	
Hydropsyche instabilis	5·8	<12	9·1	<35	—	5·3	<9	—	8·3	<7	3·8	—	<35	4·5	<9	7·3	15·3	10·5	—	<
Polycentropus kingi	—	—	4·5	—	3·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Total Diptera	11·7	13·5	4·5	10·7	—	2·7	—	—	4·3	9·4	3·8	—	—	—	—	—	5·4	3·5	—	
Simuliidae	11·7	10·2	<12	2·1	—	2·7	—	—	—	—	—	—	—	—	—	<18	5·4	—	—	
Chironomidae	—	—	4·5	4·3	—	—	—	—	—	6·3	1·9	—	—	—	—	—	—	3·5	—	
Total Oligochaeta	3·0	10·2	36·3	2·1	8·8	10·6	—	50·0	12·6	9·4	20·7	19·4	61·2	70·4	—	—	20·7	36·9	—	
Tubificidae	3·0	10·2	34·0	2·1	5·8	5·3	—	50·0	8·3	9·4	20·7	19·4	55·6	65·9	—	—	15·3	33·4	—	
Polycelis felina	—	1·7	—	2·1	—	2·7	—	—	—	—	—	—	—	—	—	—	<6	—	—	
Gammarus pulex	8·8	3·3	2·3	<35	1·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Total others	12·1	6·9	4·8	2·6	33·8	10·9	—	—	4·1	—	39·0	19·3	11·0	5·0	31·8	33·3	13·3	4·2	—	
No. of species	20	15	24	21	19	20	5	3	13	10	19	14	16	15	12	9	17	13	—	
No. of individuals	599	688	514	645	604	437	149	70	422	224	933	634	1260	771	167	247	111	665	—	14

1971(B) and 1972(A) expressed as a percentage of the total

Stations 4 A	4 B	5 A	5 B	6 A	6 B	7 A	7 B	8 A	8 B	9 A	9 B	10 A	10 B	11 A	11 B	12 A	12 B	13 A	13 B
29·5	—	12·6	6·3	3·8	19·8	5·6	—	26·3	49·8	20·7	8·7	—	2·4	3·6	1·9	—	6·3	—	2·8
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·9	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<9	—	—
23·5	—	8·3	6·3	3·8	—	—	—	26·3	28·3	20·7	8·7	—	2·4	<12	—	—	—	—	1·4
70·5	50·0	58·1	71·9	45·1	36·0	22·2	18·1	41·9	7·3	10·8	30·8	—	9·7	49·2	24·1	8·1	41·4	15·1	21·6
70·5	50·0	41·5	59·4	9·4	13·9	8·3	4·5	41·9	7·3	5·4	29·5	—	2·4	5·5	<12	5·4	29·0	3·8	6·9
—	—	—	—	—	5·5	—	4·5	—	—	—	—	—	—	—	—	—	—	—	1·4
—	—	—	3·1	—	—	<35	<18	—	—	—	—	—	<35	—	—	—	—	—	—
<9	—	16·6	9·4	35·7	16·6	13·9	9·1	<9	—	5·4	1·3	—	7·3	43·7	24·1	2·7	12·4	11·3	13·3
—	—	8·3	3·1	7·6	5·5	—	4·5	—	9·6	26·1	15·9	—	2·4	1·9	1·9	13·5	12·9	1·9	17·7
<9	—	8·3	<7	3·8	—	<35	4·5	<9	7·3	15·3	10·5	—	<35	1·9	<12	2·7	6·3	1·9	13·6
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	4·3	9·4	3·8	—	—	—	—	—	5·4	3·5	—	—	1·9	—	8·1	13·6	—	1·4
—	—	—	—	—	—	—	—	—	<18	5·4	—	—	—	—	—	5·4	—	—	—
—	—	—	6·3	1·9	—	—	—	—	—	—	3·5	—	—	1·9	—	—	13·6	—	1·4
—	50·0	12·6	9·4	20·7	19·4	61·2	70·4	—	—	20·7	36·9	—	78·0	36·3	66·5	59·5	9·6	34·0	42·3
—	50·0	8·3	9·4	20·7	19·4	55·6	65·9	—	—	15·3	33·4	—	78·0	36·3	59·1	59·5	3·3	22·6	35·5
—	—	—	—	—	—	—	—	—	—	<6	—	—	—	<12	—	—	—	1·9	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·9	—
—	—	4·1	—	39·0	19·3	11·0	5·0	31·8	33·3	13·3	4·2	—	7·5	7·1	5·6	10·8	16·2	45·2	14·2
5	3	13	10	19	14	16	15	12	9	17	13	—	15	16	18	14	16	23	22
149	70	422	224	933	634	1260	771	167	247	111	665	—	1435	641	631	259	272	931	1283

(*Facing p.* 183)

occur in the area, the water becomes highly turbid from a suspension of sand and clay particles.

Methods

A total of fifty-four samples were taken from thirteen stations on the River Camel (Fig. 1) during the summer (July–October) of 1970, and winter (February) of 1971 and 1972. Methods were not standardized until the winter collections, so that comparisons between summer and winter samples of numbers of animals cannot be made (Table 2).

Samples were taken with an F.B.A. net (64 meshes/cm) from the riffle section of the river. The bottom of the river was disturbed by kicking and allowing the current to carry the dislodged material into the net (Elliott, 1971). By slowly moving upstream for a fixed period of 2 min, this technique ensured collecting a representative quantity of material over a large area of bottom.

Samples thus obtained were washed from the net into a collecting tray, concentrated using part of the collecting net and put into a polythene container with 4% formalin as preservative.

In the laboratory, samples were individually washed with tap water in an Endecott sieve (140 meshes/cm) and then transferred to a large sorting tray (35 × 26 cm) marked out by grid lines into six equal divisions. Animals were picked out from one or one to six of the divisions, according to the amount of material present, and placed in a Petri dish for counting. Large animals and members of each species present were also removed and placed in a separate Petri dish for identification.

Results

Emergent and submergent vascular plants were not abundant throughout the catchment, and were absent from Stations 4–7 (Fig. 1). Starwort (*Callitriche* sp.) appeared to be the dominant flora, with moss (*Fontinalis* sp.) abundant at Stations 1–3 and 8–9. Filamentous algae were frequent at Stations 1–3, 8–9 and 13 but absent from other sampling points. The Stannon tributary of the River Camel does not support much plant life, even though a secondary tributary (Station 3) to it was rich in *Potamogeton* sp., *Ranunculus* sp. and *Fontinalis* sp.

Results from winter collections of macro-invertebrates are given in tabular form in Table 2. A total of sixty-five taxa were identified of which forty-two were at species level. One or more species of stonefly nymphs were found at all stations, and this would indicate the absence of any gross pollution by organic or toxic wastes (Hynes, 1960). However, there was a distinct reduction in species diversity at Station 4 on the Stannon tributary compared with upstream samples. Subsequent downstream samples indicated a recovery in the diversity of species relative to the distance from the tributary (Fig. 2).

Discussion

Plants

Jones (1943) has concluded that at least one of the reasons for the lack of plants in the River Rheidol in Cardiganshire is due to the shifting nature of the bed. This situation is comparable to the River Camel where the natural river substrate is covered with a constantly shifting layer of sand which must prevent the establishment of plants and algae. The turbidity of water carrying a heavy suspension must also prevent the establishment of plant growth by abrasion, and decrease photosynthesis by a reduction in the

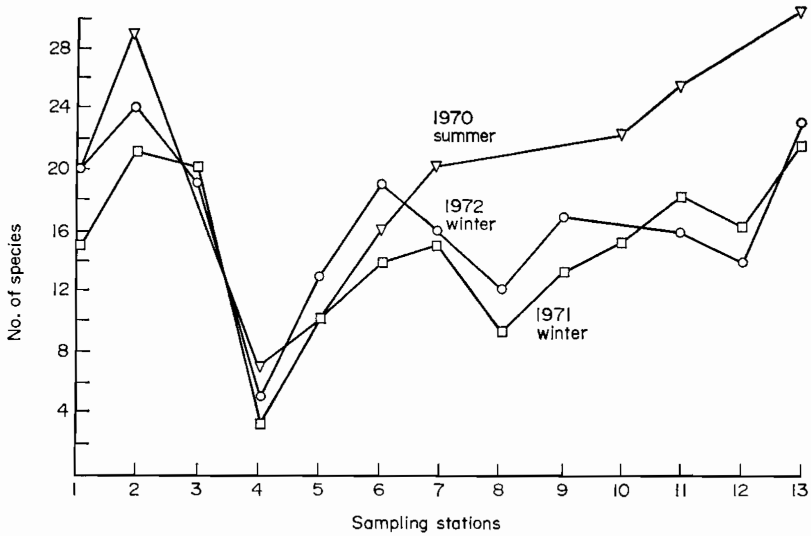

Fig. 2. Diversity of species at different sampling points on the River Camel.

penetration of light. However, the River Camel does not carry a high suspension except during times of heavy spate, and turbidity can be discounted as a major reason for the poor incidence of plants in the river.

Macro-invertebrates

Apart from Stations 2 and 12, which appear to be influenced by slight sewage enrichment, only stations downstream (6, 7, 11 and 13) from the eroded tributary had a high relative abundance of Tubificidae, *Baetis rhodani* and *Rhithrogena semicolorata.* This is associated with the silted habitat in which burrowing forms become dominant. The flattened Ecdyonurid *Rhithrogena* sp. is regarded as intolerant of even mild organic pollution (Hynes, 1960), and this would substantiate that the dominance of the Tubificidae was the result of sand deposition, rather than any incidence of organic

Table 3. The reaction of various species of invertebrates to sand deposition

1. Species immediately eliminated by sand deposition:	
Leuctra nigra	*Baetis pumilus*
L. hippopus	*Polycentropus kingi*
L. geniculata	*Gammarus pulex*
Amphinemura sulcicollis	*Polycelis felina*
Ephemera danica	*Sericostoma personatum*
2. Species showing an increase in numbers with sand deposition:	
Tubificidae	*Rhithrogena semicolorata*
Baetis rhodani	
3. Species not immediately affected by sand deposition:	
Leuctra fusca	*Gyrinus* sp.
Caenis rivulorum	Naididae
Protonemoura meyeri	*Ancylastrum fluviatile*
Hydropsyche instabilis	

pollution. *B. rhodani*, usually the most tolerant of the Baetidae to poor water quality (Langford & Bray, 1969), dominated the sparse fauna of the eroded tributary, but was reduced in relative abundance towards the lower reach of the river Camel. *B. pumilus*, which was found only in summer collections, was restricted to stations not affected by sand deposition.

Lists of animals associated with a silted habitat, such as *Ephemera* sp., *Caenis* sp. Oligochaeta and *Tanytarsus* sp. have been summarized by Hynes (1960). However, there is a clear departure from the situation which develops downstream from perhaps a sewage works with the deposition of fine-grain, organically rich mud to the situation in the River Camel with the deposition of inert, sand particles (Table 3). Chironomidae, *Limnaea pereger*, *Asellus* sp. and the leeches *Glossiphonia complanata* and *Erpobdella octoculata*, often occurring in high numbers in organically rich muds (Klein, 1962), were either absent from stations affected by sand deposition or occurred sporadically (Chironomidae) with a low relative abundance. *Ephemera danica* and *Amphinemura sulcicollis*, usually frequent in silt deposits (Hynes, 1970) were eliminated from the sections of the river affected by sand deposition. *Caenis rivulorum*, also known to tolerate silt (Hynes, 1960) appeared to be unaffected by sand deposition.

The early forms of *Leuctra* sp. were restricted to stations upstream of the sand deposits, but the summer form *L. fusca* was found to occur at all stations in the main river. *Leuctra geniculata*, however, which was restricted to summer collections, was not found downstream of the Stannon tributary.

The net-spinning caddis-fly larva *Hydropsyche instabilis* occurred in all collections from the main river, but was absent from the Stannon tributary, whereas *Polycentropus kingi* was eliminated from stations affected by sand deposition. This latter species constructs nets on the underside of stones (Hickin, 1967) and is clearly affected by sand deposition infilling the interstices between stones.

The *Simuliidae* were found to be either absent or reduced in abundance at stations below the Stannon tributary. These larvae attach themselves by means of a basal, adhesive pad to the upper surface of stones, and presumably are unable to establish themselves on unstable, shifting sand deposits. *Gammarus pulex* was also eliminated from stations affected by sand deposition and this is perhaps due to the infilling of the interstices between stones of the river bed.

Similar results have been obtained by other workers. Behning (1924) in his early study of the Volga found twenty to forty animals per square metre on sand, fifty to 100 on clay and up to 800 on muddy sand. Wu (1931) showed that the distribution of *Simulium* depended on the amount of silting permitted by the current. Ellis (1936) found that freshwater mussels thrived in special trays which prevented the accumulation of silt while those on the bottom died when the silt became ¼–1 in. thick. Grindley & Pentelow (1940, unpublished data) found that where the river bed was completely covered with sand the normal fauna was absent, but where the stones were partially free from the deposit, animals typical of the unaffected part of the river were present. The fact that rubble supports more animals than does sand is almost certainly correlated. with the amount of available living space and with the greater probability that organic matter will lodge among stones and provide food (Hynes, 1970).

Hamilton (1961) observed in a Scottish stream that small amounts of fine washings from quarried sand eliminated some mayflies and stoneflies, and encouraged Oligochaetes. He found that high turbidity produced by finely divided inorganic material did not, by itself, affect adversely the bottom fauna. However, the normal fauna was absent over a short stretch of river where the bed was covered with a heavy deposit of sand and mud.

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