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Hydrobiological Studies in the Catchment of Vaal Dam, South Africa Part 2. The Effects of Stream Contamination on the Fauna of Stones-in-current and Marginal Vegetation Biotopes

Contents

1. *Introduction*

The faunal zonation of the streams and rivers in the Vaal Dam catchment has been described in Part 1 (CHUTTER, 1970) from sampling points where there was no chemical or circumstantial evidence that contamination or pollution of the water was likely to be affecting the composition of the fauna. The sampling points whose fauna is described here were all in the Unstable Depositing Zone, and it is with natural communities of this zone that the communities described here will be compared.

As in Part 1 the year is divided into three seasons, the Winter, the Dry Early Summer and the Summer. The position of sampling points is shown in Fig. 1 of Part 1. Methods used in both the biological and chemical sampling and analysis are those described in that paper, while the term significance used with species or any other taxon retains its meaning defined in Part 1. As in Part 1 the Cladocera and Copepoda found in samples have not been described, but are to be considered in Part 3 (Chutter, 1971). A complete list of the taxa identified appears in the Appendix to Part 1.

2. *The sampling points*

a. Station 4 (Standerton)

Station 4 was situated just below where a milk processing factory effluent, said to be can washing water, was piped into the river. The effluent was warm, but being considerably diluted, had no detectable effect on the temperature of the river water. The only marked change that took place in the chemical quality of the water was a small increase in the oxygen absorbed in 4 hours from $KMnO_4$ (Table 1). A simultaneous 24 hour study of the dissolved oxygen in the water above and below the effluent was made at hourly intervals on one occasion. The effluent had no direct effect on the dissolved oxygen for at both points it rose to 110% saturation in the late afternoon and fell to 82% at dawn. There was often a wind-blown scum at the water's edge. In spite of this lack of chemical changes due to the effluent, there were particularly marked changes in the flora and fauna of the river.

Table 1. Water analyses for stations 4, 5 and 17 together with the range and mean values for unpolluted sampling points in the Unstable Depositing Zone of the Vaal River

Station number		4	5	17	Unstable Depositing Zone
pH (field measurements)	mean	7.8(7)	7.8(9)	8.2(5)	7.8(17)
	range	8.4—7.1	8.5—7.2	9.4—7.6	8.7—7.2
pH (laboratory measurements)	mean	7.9(7)	7.9(6)	8.2(8)	7.9(14)
	range	8.4—7.5	8.5—7.4	9.5—7.6	8.4—7.0
Free and saline Ammonia ppm N.	mean	0.21(9)	0.34(12)	0.28(10)	0.32(11)
	range	0.40—N. D.	2.0—N. D.	0.84—N. D.	0.80—N. D.
Nitrites ppm N.	mean	trace (13)	0.01(12)	0.07(13)	trace (15)
	range	trace-N. D.	0.03—N. D.	0.16—0.01	0.01—trace
Nitrates ppm. N.	mean	0.11(13)	0.42(12)	1.2(13)	0.16(15)
	range	0.50—N. D.	1.87—N. D.	4.0—0.2	0.70—N. D.
Kijeldahl nitrogen ppm. N.	mean	0.11(13)	2.5(8)	0.7(8)	0.8(9)
	range	0.5—N. D.	13.3—0.2	1.3—N. D.	1.1—0.5
Oxygen absorbed in 4 hours from $KMnO_4$, ppmO_2	mean	2.9(13)	3.1(11)	5.1(13)	0.22(15)
	range	5.6—1.0	6.0—1.1	16.8—1.6	4.0—1.2

N. D. means not detectable

The current speed in the stones-in-current biotope was similar to that recorded at other unpolluted sampling points in the Unstable Depositing Zone. Fringing vegetation was present only in the summer, for in other seasons the water level fell so that the vegetation was no longer at the water's edge.

b) Station 5 (Standerton)

At Station 5 treated sewage works effluent was irrigated on fields sloping down towards the river. No direct surface runoff into the river from these fields was ever seen, though there was probably underground seepage into the river bed. All forms of nitrogen and oxygen absorbed in 4 hours from $KMnO_4$ were slightly higher than they were in the Unstable Depositing Zone (Table 1).

Current speeds were not exceptional and the marginal vegetation was permanently in the water.

c) Station 17

During the time that the studies reported here were carried out a new gold mining area was being developed in the headwaters of the Waterval River on which Station 17 was located. Sewage works effluent, water pumped out of mines and drainage from mine slimes dams found their way into the river about 15 km above Station 17. MALAN (1960) showed that the maximum concentrations of sodium, chloride and sulphate ions were high in the Waterval River. The mineral quality of the water underwent further deterioration during the course of these studies and the trend continued in a further series of samples taken in 1961 (Table 2). The pH of the Waterval River was higher than in the Unstable. Depositing Zone of the Vaal River, as also were the nitrites, nitrates and oxygen absorbed in 4 hours from $KMnO_4$ (Table 1). Maximum values for nitrites and nitrates were recorded in the Dry Early Summer. Kjeldahl nitrogen was low, but this may be misleading a it was not analysed in the two samples which contained the highest concentrations of nitrates.

Table 2. Water analyses from station 17, for various periods between 1957 and 1961

	1957—1958 (MALAN 1960)			1959—1960			1960—1961
	maximum	mean	minimum	maximum	mean	minimum	maximum
Total dissolved solids ppm.	431	186	60	926	346(9)	122*	1200
Total alkalinity ppm $CaCO_3$	238	110	24	189	103(9)	14*	452
Total hardness ppm $CaCO_3$	188	93	29	129	94(9)	48*	200
Chlorides ppm Cl	102	25	8	477	113(9)	16*	507
Sulphates ppm SO_4	25	10.1	4.5	38	17(9)	N. D.*	170
Sodium ppm Na.	94	29	6	424	102(9)	4*	450

*) exceptionally low values recorded when the river was in heavy flood. The number of analyses for the 1959/60 analyses are shown in brackets after the mean. 1957—58 and 1960—61 data are based on analyses of daily water samples.

Current speeds in the stones-in-current biotope were high (105 cm/sec in the winter, 72 cm/sec in the dry early summer and 63 cm/sec in the summer).

d) Station 11a (Harrismith)

This sampling point was situated just downstream from some ponds on the river bank into which a milk processing factory effluent flowed. Drainage from these ponds into the river was subterranean. Water at this sampling point was analysed only once, in August 1961 when unusually high values for forms of nitrogen were recorded at both contaminated and uncontaminated sampling points (Table 3). Turbidity and oxygen absorbed in 4 hours from $KMnO_4$ were high at this station, but otherwise the water was apparently normal.

The river water was held back by a weir so that there was no stones-in-current biotope. The fringing vegetation was in still water in periods of low flow, but as the sampling point was near the upstream end of the dammed water the biotope was exposed to gentle currents in the summer.

Table 3. Water analyses from sampling points in the southern part of the Vaal Dam Catchment, based on snap samples collected in August 1961

	Contaminated sampling points				Uncontaminated sampling points		
Station number	11a	11b	11x	42	10	13	44
pH (field measurements)	6.8	7.1	7.4	7.8	8.4	8.6	8.4
pH (laboratory measurements)	7.6	7.6	8.2	8.3	7.9	8.7	8.6
Total dissolved solids at 105 °C ppm.	99	90	107	179	59	113	132
Total nitrogen ppm N. (A)	3.2	4.0	8.6	3.1	3.4	3.5	2.2
Kjeldahl nitrogen ppm N.(B)	1.2	3.4	6.9	2.7	1.7	1.7	1.6
Nitrates + Nitrites (A minus B) ppm N.	2.0	0.6	1.7	0.4	1.7	1.8	0.6
Total Hardness ppm $CaCO_3$	36	37	40	104	30	90	150
Chlorides ppm Cl	36	41	62	109	26	47	64
Sulphates ppm SO_4	13	8	10	26	13	5	15
Sodium ppm Na	12	13	19	30	10	22	32
Turbidity ppm SiO_2	64	62	58	50	33	20	43
Oxygen absorbed in 4 hours from $KMnO_4$, ppm O_2.	9.4	8.6	9.4	12.7	6.6	3.9	8.4

e) Station 11b (Harrismith)

Station 11b was about 1 km below Station 11a and was below the weir which held back the water at Station 11a. Here there were ponds in which the effluent from a textile factory was treated. Kjeldahl nitrogen and oxygen absorbed values were higher than usual (Table 3).

f) Station 11x (Harrismith)

This station was only about 200 m below Station 11b, but between the two stations there were more seepages of water from effluent ponds into the river. This seepage water obviously contained large amounts of chlorides, of nitrogenous compounds and of material contributing to the oxygen absorbed in 4 hours (Table 3).

g) Station 11c (Harrismith)

Station 11c was about 4 km below Station 11b. Water samples for chemical analysis were not collected from this sampling point.

h) Station 42 (Bethlehem)

Bethlehem straddles the river on which Station 42 was sited (Part 1, Fig. 1) and the entire drainage from the town is carried into a large shallow dam just above Station 42. The chloride, sulphate and sodium ion concentrations of the water were higher than usual and the oxygen absorbed in 4 hours was very high (Table 3). The amount of combined nitrogen in the water was, however, not unusual suggesting that there was probably nitrogen removal in the impounded water.

The current speed in the stones-in-current biotope was a little higher than was usually recorded in the Unstable Depositing Zone.

3. *The fauna*

a. Stones-in-current biotopes

Stations 4, 5 and 17 were all sampled regularly. At Station 4 there was an unusually obvious growth of blue-green algae on the stones. In the Dry Early Summer *Thiochaete chutteri* WELSH, which superficially resembles sewage fungus, uniformly blanketed the tops of the stones so that only their shape could be seen. In Winter the stones were covered by a dark slimy layer up to 1 cm thick, largely made up of *Phormidium* sp. Growths of these algae were very much reduced in the Summer. The diversity of the fauna at Station 4 was lower than at comparable sampling points (Table 4). The densities of the animals found there were also unusual (Table 5). The high densities of Nematoda, *Nais* spp., Chironomidae (mainly Orthocladiinae) and *Burnupia* sp. were associated with *T. chutteri* which could have been a source of food and would certainly provide shelter from the current. Numbers of Tubificidae and of *Chironomus* sp. appeared in the Dry Early Summer. In Summer the numbers of Tubificidae, *Nais* and *Burnupia* wera considerably reduced, those of Nematoda and the Chironomidae less so. The Ostracoda, Hydrachnellae, Baetidae, *Neurocaenis* sp., Hydropsychidae and Simuliidae were always poorly represent *erpes* or absent. There was no chemical evidence of severe oxygen depletion (see above, description of Station 4) and this is confirmed by the regular occurrence in fair numbers of two Ephemeroptera, a Caenid and *Chorot* (*Euthraulus*) sp. Both these animals probably live under stones rather than on top of them (CHUTTER, 1958). The immediate factor causing the changes in the fauna was therefore most probably the algal growths which smothered the habitats of some animals and provided food and shelter for others. The interesting point about Station 4 is that these very pronounced faunal changes were ultimately due to an effluent which caused very little chemical change in the river water. Some algae are known to assimilate organic nitrogen (FOGG 1953, SYRETT 1962) and it may be that traces of organic nitrogen from the effluent were the crucial factor stimulating the very large growths of *T. chutteri* and *Phormidium*. HYNES

Table 4. The numbers of significant taxa recorded from stones-in-current biotopes at the sampling points shown, season by season

Sampling Point	Winter	Dry Early Summer	Summer
Uncontaminated			
Station 3	32	24	16
Station 5a	27	24	14
Contaminated			
Station 4	24	16	9
Station 5	27	23	21
Station 17	28	23	15

Table 5. The mean seasonal density (numbers per 0.1 sq m) of the commoner stones-in-current animals in the Unstable Depositing Zone and at contaminated sampling points

Taxon	Season	Mean density in Unstable Dep. Zone	Station 4	Station 5	Station 17	Station 11b	Station 11c	Station 42
Tricladida	W*	15	43	50	75	0	—	230
	D	15	112	149	—	0	0	—
	S	4	0	68	82	0	0	—
Nematoda	W	22	370	87	40	12	—	759
	D	17	328	5	—	19	6	—
	S	0	100	36	1	1	1	—
Tubificidae	W	12	56	11	69	29	—	1
	D	22	220	22	—	62	4	—
	S	1	2	28	50	4	6	—
Nais sp.	W	11	6472	494	2336	775	—	246
	D	113	1441	290	—	1670	779	—
	S	2	2	1	288	65	1	—
Chaetogaster sp.	W	2	53	18	202	293	—	620
	D	1	0	0	—	1	0	—
	S	0	0	0	51	0	0	—
Ostracoda	W	14	1	1	72	0	—	69
	D	141	0	97	—	26	32	—
	S	1	0	3	1	0	—	—
Hydrachnellae	W	1	0	0	0	0	—	0
	D	1	0	1	—	0	1	—
	S	2	0	4	0	0	6	—
Baetidae	W	168	10	88	13	0	—	0
	D	175	26	67	—	0	42	—
	S	116	0	67	4	0	1	—
Choroterpes (*Euthraulus*) sp.	W	114	21	203	0	0	—	0
	D	113	55	371	—	0	0	—
	S	25	55	617	0	0	0	—
Neurocaenis sp.	W	4	1	3	0	0	—	0
	D	33	2	12	—	0	0	—
	S	299	0	18	6	0	1	—
Caenidae	W	1	12	14	1	8	—	2
	D	4	1	33	—	1	0	—
	S	2	15	14	1	0	1	—
Hydropsychidae	W	183	33	273	2795	1	—	60
	D	152	1	322	—	1	0	—
	S	160	18	1120	1147	0	0	—
Elmidae	W	15	56	56	433	0	—	0
	D	4	7	52	—	0	0	—
	S	3	0	15	132	0	0	—
Simuliidae	W	65	2	7	107	7	—	330
	D	13	0	16	—	2	28	—
	S	14	0	0	268	0	0	—

Table 5 continued

Taxon	Season	Mean density in Unstable Dep. Zone	Station 4	Station 5	Station 17	Station 11b	Station 11c	Station 42
Chironomus spp.	W	0	0	0	0	1	—	0
	D	0	13	0	—	2	0	—
	S	0	0	0	0	3	0	—
Other Chironomidae	W	190	1098	477	2728	263	—	423
	D	70	649	108	—	30	42	—
	S	3	77	90	277	7	2	—
Burnupia spp.	W	1	103	19	6	6	—	14
	D	1	610	255	—	0	0	—
	S	2	15	3	10	0	0	—
Total Numbers	W	862	8479	1988	9164	1407	—	2751
	D	998	4631	2133	—	1827	937	—
	S	666	297	2175	2523	76	21	—

* W — Winter, D — Dry early summer, S — Summer
— no sample collected

(1960, p. 92) records that in the Bristol Avon in England milk wastes resulted in the growth of large amounts of sewage fungus with little deoxygenation of the water.

The fauna recovered rapidly below Station 4, and 3 km away at Station 5 the variety of animals recorded (Table 4) was comparable with that recorded in the Unstable Depositing Zone. Blue-green algae were no longer apparent at Station 5, but they were to some extent replaced by diatoms, growths of which were very obvious in the Winter and Dry Early Summer. Densities of Baetidae, *Neurocaenis* and Simuliidae were low, but in most other taxa there was a distinct increase in density (Table 5). This was most obvious in Tricladida, *Choroterpes* (*Euthraulus*) sp., the Hydropsychidae and *Burnupia* spp. The large numbers of Hydropsychidae, which were mainly *Cheumatopsyche thomasseti* and *Amphipsyche scottae*, may have been associated with the large numbers of Cladocera and Copepoda found at this station (Part 3). The Cladocera and Copepoda were indicative of an increase in the amount of particulate organic matter in the river. There was no corresponding increase in the Simuliidae which also feed on particulate organic matter. This might be associated with the large numbers of Hydropsychidae, which it has been suggested, are successful predators of and competitors with the Simuliidae (Chutter, 1968).

At Station 17 the Waterval River was dammed by a dolerite sill above which there was a very long quiet reach of the river. The sampled biotope was below the sill. There were profuse growths of filamentous algae among the stones in the Dry Early Summer. The diversity of the fauna was normal (Table 4). In other respects it was highly unusual. Large numbers of Cladocera and Copepoda were carried over the sill, and, as happened at Station 5, there were very large increases in the density of *Cheumatopsyche thomasseti* and *Amphipsyche scottae* (Table 5, Hydropsychidae). There was also some increase in the density of the

Simuliidae. This is unusual where there are very large numbers of Hydropsychidae (Chutter 1968) and it may be that the Simuliidae were favoured by the high current speed (see description of Station 17 above). Unusually large numbers of *Nais*, Elmidae (*Stenelmis thusa*) and Orthoclad Chironomids were also recorded. These animals were associated with the filamentous algae. Ephemeroptera were scarce, possibly because they were crowded out by the Hydropsychidae whose cases were so dense that they would have blocked access to the underside of most stones. This is the day-time habitat of *Choroterpes* (*Euthraulus*) sp., *Neurocaenis* sp. and the Caenidae.

Table 6. The numbers of taxa found in the stones-in-current biotopes at Stations 11 b, 11 c and 42 and for comparison the numbers found at Stations 3 and 5 a during the months Stations 11 b, 11 c and 42 were sampled. (Note — Table 4 shows "significant" taxa, this Table shows all taxa, because Stations 11 b, 11 c and 42 were not sampled sufficiently frequently to identify "significant" taxa).

Sampling Point	Winter	Dry Early Summer	Summer
uncontaminated			
Station 3	47	43	37
Station 5 a	34	38	27
contaminated			
Station 11 b	16	23	10
Station 11 c	—	24	12
Station 42	27	—	—

— no sample collected

The variety of animals at Station 11 b was limited (Table 6). The only groups found in large numbers were *Nais*, *Chaetogaster*, Tubificidae and Chironomidae, of which *Chironomus* sp. larvae were always present in small numbers (Table 5). No Triclads, Hydrachnellae, Baetidae, *Choroterpes* (*Euthraulus*) sp., *Neurocaenis* or Elmidae were recorded and there were only scattered individuals of Caenidae, Hydropsychidae and Simuliidae. This peculiar community may have been due to unidentified toxic substances in the textile mill effluent. If oxygen depletion due to excessive organic matter had been responsible for the disappearance of many groups, then large populations of tolerant animals such as Tubificidae and *Chironomus* sp. should have been found. The fauna had recovered slightly at Station 11 c where some Baetids occurred (Tables, 5, 6).

The stones sampled at Station 42 were in the overflow of the dam (see above). There was a lot of *Phormidium*-like blue-green algae and also of green algae growing on the stones. The number of animal taxa recorded was rather low (Table 6). The fauna was very largely made up of Triclads, Nematoda, *Nais* sp., *Chaetogaster* sp., Simuliidae and Orthoclad Chironomidae (Table 5). The Ephemeroptera and Trichoptera were very poorly represented and no Tubificidae, Hydrachnellae or Elmidae were found. Large numbers of Cladocera and Copepoda were collected and the low numbers of Hydropsychidae are surprising in these circumstances. As the water was cascading in places between the spillway and the sampled stones it is unlikely that severe oxygen depletion was an important factor limiting the numbers of Hydropsychidae. Quite probably the habitat of these animals and also of the Baetidae was considerably reduced by the encrusting slimy blue-green alga.

b. Marginal vegetation biotopes

The fauna of this biotope is considerably influenced by water currents (Part 1) so that the presence or absence of these must be taken into account in assessing the changes in the fauna in relation to effluent discharges. At Station 4 the vegetation was sparse, and, due to fluctuations in the river level, was not permanently in the water. The fauna was also sparse and consisted mainly of *Centroptilum excisum*, *Micronecta* spp. and *Nychia marshalli* (Table 7). At Station 5 there were increases in the density of most taxa (Table 7). *Baetis bellus* was not as abundant in the Summer as it was in the Unstable Depositing Zone, but this was due to the current through the vegetation which resulted in the replacement of *B. bellus* by *B. gaucus*, a current-loving species not shown in Table 7. The fringe of vegetation at Station 17 was sheltered from the current, and the fauna had the characteristic features of a sheltered vegetation biotope — Baetidae dominated by *Cloeon* spp., a high density of *Micronecta* spp, and many *Nais* sp., Ostracoda and Chironomidae found in the Summer. The fauna is compared with that of the Stable Depositing Zone, in which the marginal vegetation was sheltered in Winter and the Dry Early Summer in Table 7. The large numbers of Caenidae in the Stable Depositing Zone were a characteristic of that zone and were not found in the Unstable Depositing Zone, to which Station 17 belongs. The small number of Caenidae at Station 17 was therefore not unusual, but *Chaetogaster* sp., *Cloeon africanum*, *Pseudagrion* spp. and Chironomidae were found in comparatively large numbers. Taking the density of the fauna as a whole (Table 7) it was no higher at Station 17 than it was in the Stable Depositing Zone. At Station 11a conditions were sheltered in the Winter and the Dry Early Summer, but in the Summer the vegetation was exposed to gentle currents. Here the fauna was peculiar. Baetidae were very rare, *Caridina nilotica* was not recorded and in the Dry Early Summer the density of *Nais* sp., *Chaetogaster* sp. and Chironomidae was high (Table 7). At Station 11b very few animals were found and most of them were *Chaetogaster* sp. The biotope was the type in which large numbers of *B. bellus* would have been expected in a natural river. Yet another type of community was found at Station 42, where the fauna was particularly dense, due to unusually large numbers of Triclads, Nematoda, *Nais* sp., Ostracods and Caenidae. As at Station 11a very few Baetidae were recorded and *Caridina nilotica* was absent.

The diversity of the fauna recorded at three uncontaminated sampling points (Part 1) is shown with the diversity of the fauna at stations which have been described here in Tables 8 and 9. In biotopes which were sheltered from the current the diversity was usually reduced where there was contamination. This was due mainly to the absence of many species belonging to the Baetid Ephemeroptera, the Trichoptera and the Elmid, Hydraenid and Hydrophilid

Table 7. The mean seasonal density (numbers per 0.3 m) of the commoner marginal vegetation animals at contaminated and uncontaminated sampling points

Taxon		Biotopes sheltered from the current				Biotopes exposed to the current			
		uncontaminated	contaminated			uncontaminated	contaminated		
		Stable Depositing Zone	Station 17	Station 11a	Station 42	Unstable Depositing Zone	Station 4	Station 5	Station 11b
Tricladida	W*	1	1	1	133	2	—	1	—
	D	1	1	2	—	1	0	1	—
	S	1	1	1	—	1	0	1	1
Nematoda	W	61	1	4	451	3	—	12	—
	D	4	4	19	—	4	0	0	—
	S	7	3	4	—	1	1	1	1
Nais sp.	W	3	31	4	128	17	—	82	—
	D	48	54	263	—	1	0	65	—
	S	1	18	1	—	1	1	1	3
Chaetogaster sp.	W	5	64	44	96	8	—	1	—
	D	1	175	280	—	1	0	12	—
	S	1	2	0	—	0	1	1	21
Ostracoda	W	19	5	9	404	26	—	93	—
	D	123	50	74	—	26	2	96	—
	S	20	58	0	—	1	2	7	0
Caridina nilotica	W	2	4	0	0	1	—	1	—
	D	4	3	0	—	1	1	1	—
	S	6	4	0	—	1	1	5	0
Baetis bellus	W	1	1	0	0	3	—	7	—
	D	3	0	0	—	5	0	1	—
	S	58	0	1	—	28	2	11	1
Centroptilum excisum	W	1	3	0	0	29	—	57	—
	D	8	1	0	—	181	16	23	—
	S	1	1	0	—	3	10	8	1
Cloeon africanum	W	1	15	0	0	1	—	1	—
	D	1	15	0	—	0	2	0	—
	S	1	3	0	—	1	1	0	0
Cloeon spp.	W	2	8	1	1	1	—	1	—
	D	1	3	2	—	1	0	1	—
	S	1	2	2	—	0	1	0	0
Baetid juveniles	W	1	12	0	0	15	—	8	—
	D	12	1	1	—	16	0	3	—
	S	15	1	0	—	9	2	7	0
Caenidae	W	21	1	2	104	4	—	12	—
	D	69	1	5	—	3	0	1	—
	S	13	1	1	—	2	1	8	1
Pseudagrion spp.	W	2	6	2	2	1	—	2	—
	D	1	2	1	—	1	1	1	—
	S	2	8	7	—	1	1	4	1

Table 7 continued

Taxon		Biotopes sheltered from the current				Biotopes exposed to the current			
		uncontaminated	contaminated			uncontaminated	contaminated		
		Stable Depositing Zone	Station 17	Station 11a	Station 42	Unstable Depositing Zone	Station 4	Station 5	Station 11b
Nychia marshalli	W	0	0	0	0	0	—	0	—
	D	1	0	0	—	1	32	0	—
	S	1	2	1	—	1	2	1	1
Micronecta spp.	W	4	2	1	1	1	—	1	—
	D	6	25	17	—	2	14	1	—
	S	13	10	5	—	1	1	1	1
Chironomidae	W	60	112	26	40	85	—	15	—
	D	76	172	176	—	11	2	55	—
	S	10	42	3	—	6	7	6	3
Whole fauna	W	609	308	108	1460	258	—	368	—
	D	820	568	871	—	275	81	231	—
	S	152	186	30	—	53	37	85	36

* W — Winter, D — Dry Early, Summer S — Summer
. — no sample collected

Coleoptera. However, in Summer the diversity at Station 17 was greater than at Station 21 (Table 8) because the biotope at Station 21 was not as sheltered in the Summer as it was in other seasons. In biotopes exposed to the current the diversity of the fauna was lower than it was in sheltered biotopes and there was no evidence of a reduction in diversity where there was contamination.

The most striking change in the marginal vegetation fauna of these sampling points where there were effluents was an increase in the Cladocera and Copepoda which is described elsewhere (Part 3). Otherwise there were not the very large increases in density that were frequently found in the stones-in-current biotope.

Table 8. The numbers of significant taxa recorded from marginal vegetation biotopes at the sampling points shown, season by season

Sampling Point	Winter	Dry Early Summer	Summer
Sheltered from current:			
Station 21 (uncontaminated)	41	32	26
Station 17 (contaminated)	23	25	34
Exposed to current:			
Station 3 (uncontaminated)	21	25	17
Station 5a (uncontaminated)	18	16	—
Station 4 (contaminated)	—	—	18
Station 5 (contaminated)	24	18	14

Table 9. The numbers of taxa found in marginal vegetation biotopes at Stations 11a, 11b and 42 and for comparison the numbers found at Stations 21, 3 and 5a during the months Stations 11a, 11b and 42 were sampled. (Note — this table differs from Table 8 in the same way and for the same reason that Table 6 differed from Table 4)

Sampling Point	Winter	Dry Early Summer	Summer
Sheltered from current:			
Station 21 (uncontaminated)	56	85	72
Station 11a (contaminated)	32	64	33
Station 42 (contaminated)	40	—	—
Exposed to current:			
Station 3 (uncontaminated)	34	61	28
Station 5a (uncontaminated)	29	34	—
Station 11b (contaminated)	—	—	34

4. *Discussion*

Most of the changes in the fauna described here have their parallels in some other South African river. Thus the increase in the Simuliidae and Hydropsychid Trichoptera found at Station 17 was in some ways similar to that found by OLIFF (1963) in parts of the Buffalo River system. Increases in the density of *Nais*, Chironomidae and *Burnupia*, such as were found in the stones-in-current at Stations 4 and 5, were similar to the changes taking place in the same biotope of the Great Berg River in the Paarl and Wellington section (HARRISON 1958), though in the Great Berg River the Ancylid snail was *Ferrissia* and not *Burnupia*. On the other hand at no sampling points in the Vaal Dam catchment did the addition of effluents result in the large numbers of *Baetis harrisoni* (Ephemeroptera) found in the polluted Jukskei River by ALLANSON (1961).

Changes in the marginal vegetation fauna associated with effluents were slighter than were changes in the stones-in-current fauna. This has previously been reported (HARRISON, 1958), while comparisons of the marginal vegetation fauna from several rivers (CHUTTER 1963) or from different zones in the same river (OLIFF 1960) have shown that it varies less from river to river or from zone to zone than does the stones-in-current fauna. This all suggests that the marginal vegetation fauna is more tolerant of a wide range of ecological conditions than is the stones-in-current fauna: some possible reasons for this have previously been discussed (CHUTTER 1963).

The role of biotic interrelations in the faunal changes associated with effluents is gradually becoming clearer. In the stones-in-current biotope it has been suggested above that the presence of large numbers of Hydropsychid Trichoptera was associated with the presence of large numbers of Cladocera and Copepoda. The Hydropsychid species concerned were *Amphipsyche scottae*, *Cheumatopsyche thomasseti* and *Macronema capense* (Appendix, Part 1). An earlier study (CHUTTER 1968) showed that large larvae of *M. capense* were probably carnivorous, of *A. scottae* were omnivorous and of *C. thomasseti* were also probably omnivorous but ingested more plant than animal material. Thus it seems that there are possibly two major food chains involved in the increase of the Hydropsychidae. Firstly allochthonous organic material in the form of microorganisms and other small food particles are taken up by Cladocera and Copepoda which fall prey, in the stones-in-current, to species such as *M. capense* and *A. scottae.* Secondly nutrient salts lead to increases in algae which, as they become detached and drift with the current, are fed upon directly by species such as *C. thomasseti.* This seems to be confirmed by results from the Umzinyatshana River in Natal (OLIFF 1963) where pollution with nutrient salts (and other mineral salts) led to an increase in algae and *Cheumatopsyche* species. There was no increase in Cladocera and Copeoda and *M. capense* and *A. scottae* were not recorded.

The Hydropsychidae themselves undoubtedly have a considerable effect on the stones-in-current community. When really abundant their sand grain refuges alter the biotope by blocking crevices and limiting access to the underside of stones. Ephemeroptera using these microhabitats (*Afronurus, Neurocaenis,* Caenidae, *Choroterpes* (*Euthraulus*)) are adversely affected. Secondly the Hydropsychidae, just as they feed on drifting Cladocera and Copepoda, will feed on any stones-in-current animals which stray into their nets. The Simuliidae seem to be particularly susceptible to this, except in biotopes where the current speed is very high. The low numbers of Baetid mayflies recorded where Hydropsychidae were abundant indicate that they too may be preyed upon. (One hesitates to suggest that a species such as *Baetis harrisoni* is crowded out of its microhabitat, as it spends at least the day-light hours on top of stones). Other members of the community such as *Nais*, the Orthoclad Chironomids and *Burnupia* are not adversely affected by the Hydropsychidae. Being algal feeders they increase in numbers.

However, stones-in-current communities dominated by *Nais*, *Baetis harrisoni* and less frequently by Chironomidae were often found in the Jukskei River (ALLANSON 1961). None were dominated by the Hydropsychidae. Cladocera and Copepoda were plentiful. The Jukskei River is fast flowing. Its headwater is within an urban area so that run-off after rainfall is considerable and rapid. The results is that the physical environment in the Jukskei is highly unstable and this may be one of the reasons why the Hydropsychidae have not become established.

In the marginal vegetation the role of biotic relationships is less apparent than in the stones-in-current. The only animals appearing in large numbers in the marginal vegetation at Station 4 were *Centroptilum excisum*, a Baetid mayfly and therefore presumably not very tolerant of a lowering of the dissolved oxygen, and two air-breathing Hemiptera. These animals are not restricted to the marginal vegetation and were often present in the open water benthic fauna. They obviously occupied the temporarily aquatic fringing vegetation when opportunity arose. At Stations 5, 11 a and 17 the main increases were in feeders on algae and detritus (*Nais*, *Chaetogaster* and Chironomidae) and to a lesser extent in *Pseudagrion* (Zygoptera), a predator which eats these animals and also Cladocera and Copepoda (CHUTTER 1961).

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6. Summary

The animals found in stones-in-current and marginal vegetation biotopes in streams and rivers in the Vaal Dam catchment affected by effluents are compared with the animals found in the same biotopes in natural streams and rivers in the same area. An attempt is made to explain some of the observed changes in terms of the biotic interrelationships of some of the animals, the role of the Hydropsychidae in the stones-in-current biotope receiving particular attention.

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