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Hydrobiological Studies in the Catchment of Vaal Dam, South Africa. Part 1. River Zonation and the Benthic Fauna

Contents

1. Introduction

Vaal Dam (27°6′ E, 26°53′ S) is situated on the elevated plateau which forms the interior of South Africa and is a little less than 1500 m above sea level. The sources of most of the streams and rivers flowing into the dam are about 2000 m above sea level, though some of them flow more than 300 km before reaching the impoundment. The physical geography of the Vaal Dam catchment therefore stands in marked contrast to that of other South African catchments in which extensive surveys of the riverine benthic fauna have been made (Harrison 1964, Oliff 1960). Indeed the author is not aware of a study of a similar river system on a high-lying interior plateau anywhere.

From the Great Berg River study HARRISON & ELSWORTH (1958) concluded that the upper river fauna was limited to this part of the river by high summer temperatures, by increasing silt loads during floods and also by the deposition of silt after floods in the lower zones. Species found in the lower river could tolerate summer temperatures and silting. Some of them were limited to the lower regions by their food requirements. From his study of the Tugela River, OLIFF (1960) concluded that it was mainly temperature which was responsible for the faunal zonation, though in his study of the Mooi River (OLIFF & KING 1964) he placed greater emphasis on the importance of other factors, among which he included silt, current speed and changes in the nature of the substratum.

In the Vaal Dam catchment temperature changes along the course of rivers were not large, but there was considerable variation in the silting of the river beds. As the catchment lies in an area with a clear-cut rainy season and as there is considerable soil erosion in places, there is a seasonal variation in the accrual of sedimentary material to water courses and also in its transport. This paper is a contribution to our understanding of the variation of the fauna of three biotopes, stones-in-current, stony backwaters and marginal vegetation, in relation to silting.

2. *Methods and apparatus*

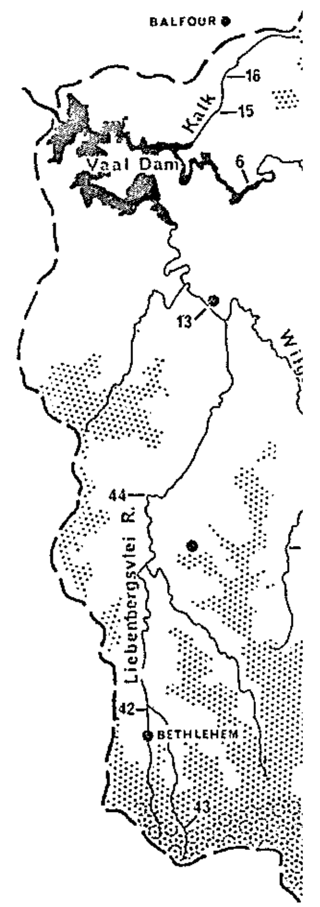
a) Field

Sampling points were established on the streams and rivers of the area (Fig. 1). During a preliminary study all sampling points were visited and the fauna of the stones-in-current, marginal vegetation and sediment biotopes was collected. This preliminary study lasted from September 1958 to February 1959 and during this period monthly samples were collected from Stations 1 to 14, the remaining sampling points being visited as opportunity arose. It was then decided that detailed studies should be made in the Vaal, Klein Vaal and Waterval Rivers and the Kafferspruit, and from July 1959 to October 1960 sampling of these streams was carried out at more or less monthly intervals. Finally in August 1961 samples were collected from most of the other sampling points in the catchment, so that sampling points were visited at least once in the summer and once in the winter. Sampling points are shown in Figure 1. Their precise position is given elsewhere (CHUTTER 1967, Table 11).

A one square foot Surber sampler (SURBER 1936) was used to collect the stones-in-current fauna, but where the water was deep enough to cover the upright frame of the Surber sampler, a hand net of 25 cm (10 ins) diameter was used. Stony backwater and marginal vegetation biotopes were sampled with the hand net. In the marginal vegetation the hand net was swept vigorously back and forth so that each area of vegetation sampled was covered twice, once in each direction. Estimates of the length of the fringe of vegetation sampled were made. The netting used for biological field sampling was bolting silk with 23 meshes/cm and an average distance between threads of 0.29 mm.

Water samples for chemical analysis were collected in dark screw cap glass bottles following standard procedure and stored in an insulated ice box until arrival at the laboratory where they were immediately placed in a cold room.

Temperatures were measured in the field with a mercury thermometer in flowing water where possible, but at sampling points where there was no perceptible flow the bulb of the thermometer was held about 5 cm below the water surface. Current speeds were measured only in the stones-in-current and an Ott Laboratory Minor propellor driven meter was used. pH was measured in the field initially with a portable glass electrode meter. This proved to be unreliable and was subsequently replaced with a Lovibond comparator used with chlorophenol red, bromo-thymol blue, phenol red and thymol blue indicators covering the pH range of 4.8 to 9.6.



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Kjeldahl nitrogen was determined by the methods given in „Standard methods for the examination of water, sewage & industrial wastes", American Public Health Association, New York. 10th edition 1955.

Methods used for analysis of biological samples were based on a subsampling technique described by Allanson and Kerrich (1961) and were the same as those used in an earlier study (Chutter, 1963).

3. *The environment*

a) General description of the catchment of Vaal Dam

The catchment of Vaal Dam covers about 38,000 sq km of the southern Transvaal and north-eastern Orange Free State. The greater part of the area is gently-rolling country lying between 1,450 m (4,750 feet) and 1,753 m (5,750 feet) above sea level (Fig. 1). The high lying ground of the catchment is in the south-east and south, where a tributary of the Wilge River rises on the northern slopes of Mont-aux-Sources, whose eastern slopes carry the headwater streams of the Tugela River studied by Oliff (1960). The western, northern and north-eastern boundaries of the catchment are not mountainous, so that the rivers which rise in these parts do not fall steeply from their sources (Fig. 2, Vaal, Kafferspruit

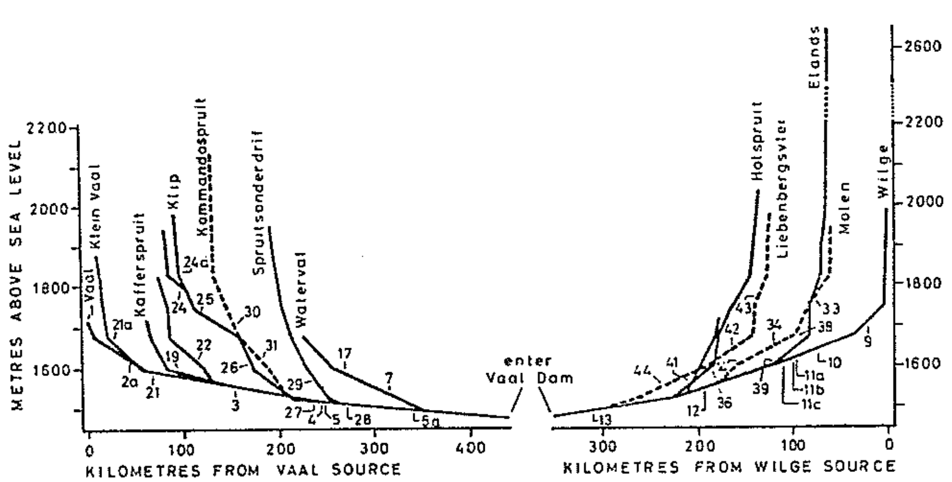

Fig. 2. Profiles of Vaal Dam catchment streams and rivers, showing the position of sampling points. Broken lines have been used where one river might be confused with another.

and Waterval Rivers). The two main water courses in the catchment are the Wilge River, which rises in the south and flows northwards, and the Vaal River which rises in the east and flows westwards (Fig. 1). Their important tributaries are named in Figure 1.

Geological formations of the Karroo System, namely the Ecca, Beaufort and Stormberg Series, underlie nearly the whole of the catchment (Du Toit, 1954). The distribution of these series is closely related to the topography of the area, the highest lying ground belonging to the Stormberg Series. A characteristic feature of the Karroo System is the occurrence of numerous intrusive dykes

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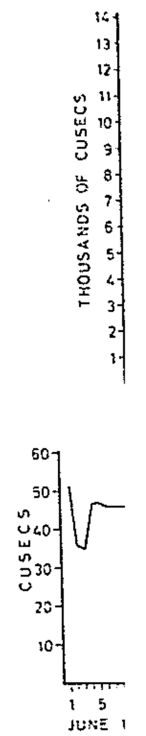

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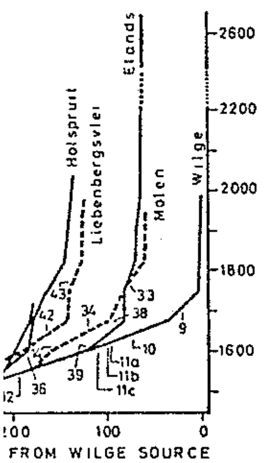

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and sills of igneous rock known as Karroo Dolerite. This dolerite is less easily eroded than the sedimentary rocks of the Karroo System with the result that nearly all the runs, stickles and cascades (Allen 1951) in the streams and rivers of the Vaal Dam Catchment are found where the water courses cut through dolerite dykes or where sills are exposed in their beds.

On the foothills of the mountains along the south-eastern border of the Vaal Dam Catchment the soils are more sandy and the horizons thicker than in the northern part of the area (van der Merwe, 1941). These differences in soil characteristics have an important bearing on the type of sediments found in water courses.

The catchment lies in a summer rainfall area and 80 to 85 per cent of the annual precipitation occurs between October and March (Weather Bureau 1954). In the south and east of the catchment there are limited areas where the annual rainfall is up to 1500 mm (60 ins), but over most of the catchment it ranges between 600 and 800 mm. The reliability of the rainfall is high by South African standards, the annual rainfall varying from 60 per cent to about 160 per cent of the normal rainfall. Over 90 per cent of the summer rain falls from thunderstorms which often yield heavy downpours of short duration. In most winters there are falls of snow on the mountains to the south and south-east of the catchment.

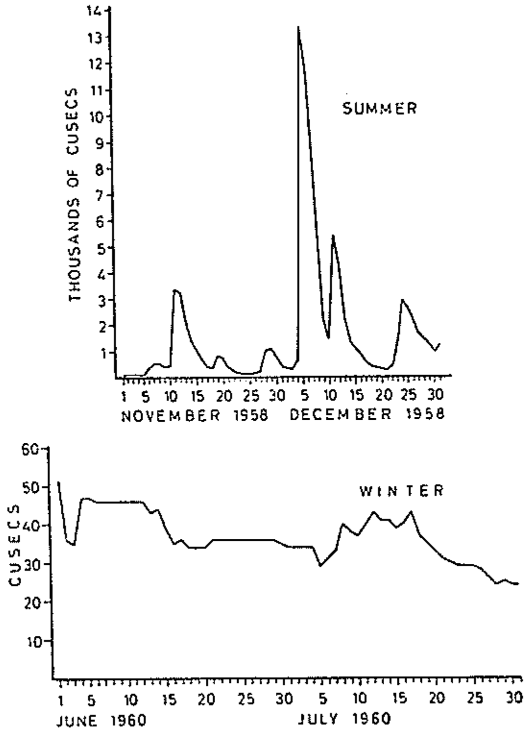


Fig. 3. Daily variation in the flow of the Vaal River at Standerton in the Summer (wet season) and in the Winter (dry season). (1 cusec equals 28.32 litres per second).

During the summer, flows of the streams and rivers fluctuate widely and rapidly due to the thunderstorm origin of the rain (Fig. 3). After the summer, flows are far less variable and show a gradual decrease from the end of the rainy season through the dry winter until the rains commence again.

Over the greater part of the Vaal Dam catchment human activities are mainly directly concerned with, or dependent on, agriculture. Extensive areas in the Vaal and lower Wilge valleys are cultivated. In the more hilly country there is mainly stock farming. The larger towns in the area, Bethlehem, Harrismith, Ermelo and Standerton, have all attracted secondary industries, such as milk processing and textile manufacturing. There are gold mines in the area between Leslie and Kinross and coal mines in the Ermelo district and near Balfour.

b) A zonation of the streams and rivers

MOON (1939) suggested that rivers could be divided into three major regions on the basis of the amount of silt deposited in their beds. The upper reaches of a river, where the profile is steep, forms the erosion zone. Here the stream bed is stony and deposition of silt and sand is at a minimum. This is followed by an intermediate zone in which the profile is less steep and areas of erosion and deposition alternate. Finally there is the deposition zone where the profile of the river is nearly flat and where silt is deposited. The zonation of the streams and rivers in the catchment of Vaal Dam has been based on MOON's description of rivers. The zones recognised were the Source Zone, the Eroding Zone, the Stable Depositing Zone, the Unstable Depositing Zone and two special cases, the Muddy and the Sandy High-lying Unstable Depositing Zones. Conditions in each of these zones are described below, the descriptions being based largely on the Vaal and the Klein Vaal Rivers.

The Source Zone.

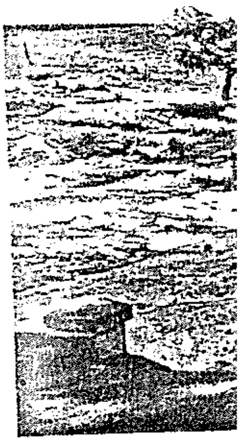
In the whole study area the sources of only two rivers, the Vaal and the Klein Vaal, were visited. The sources of both rivers are sponges from which water drains into muddy bottomed pools. In the summer the pool at the head of the Vaal was succeeded by a grassy furrow through which the water flowed into another pool, and so on until the stream was out of sight. In the winter, the dry season, these pools of water persisted but were no longer connected by a surface flow of water. Sponges were probably the usual sources of streams and rivers in the Vaal Dam catchment. The sponge and pools at the headwaters of streams have been called the Source Zone. Station 1, on the Vaal River, was the only sampling point in this zone.

The Eroding Zone.

Eroding Zone conditions were found in the Klein Vaal River at Station 21a (Fig. 4). There were no semi-aquatic or fully aquatic macrophytes because the stream bed was stony, and there were no banks of silt or sand on which such vegetation might take root. Pools were deep and the stream bed was filled by the winter (dry season) flow. In addition to Station 21a, Stations 22, 24a, 24, 25, 26, 33, 9 and 43 were also on streams in their Eroding Zones.

The Stable Depositing Zone.

At Station 21 on the Klein Vaal River, the first sampling point downstream from Station 21a (Fig. 1), deposition had started to take place. Where mud or gravel occurred in the stream bed there was *Potamogeton thunbergii* CHAM. & SCHLECHNDL. in the flowing water, and *Nitella* sp., *Crassula natans* THUNB. and *Lagarosiphon* sp. in the quieter parts. A moss,



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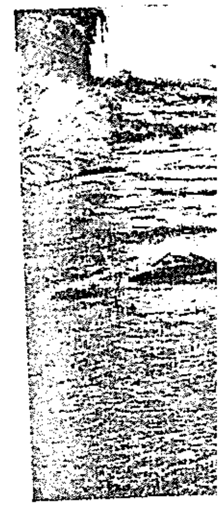

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Fig. 4. The Klein Vaal River at Station 21a. Eroding Zone. The stream bed is stony and there is no aquatic vegetation.

Fissedens capensis (C.M.) BROTH.. grew on many of the stones in the current. There were semiaquatic plants, predominantly *Cyperus fastigiatus* ROTTB. on the banks of the stream (Fig. 5). Pools were again stony bottomed, but the stones on the bottom of the pools were covered by a thin layer of fine silt. The dry season flow was sufficient to fill the stream bed. Stable Depositing Zones with plant growths as profuse and varied as those at Station 21 were found nowhere else in the streams and rivers of the study area. However, Station 2a (on the Vaal River) and Station 10 (on the Wilge River) can be considered as belonging to this zone. At both these points there was rather more deposition than at Station 21, but there was fringing semi-aquatic vegetation and some fully aquatic plants.

Fig. 5. The Klein Vaal River at Station 21. Stable Depositing Zone. There is a well-defined growth of fringing emergent vegetation and also a lot of fully aquatic vegetation, some of it trailing in the stream in the centre foreground.

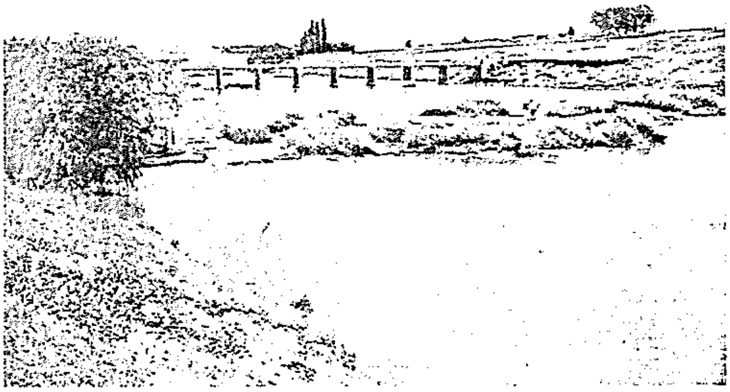

Fig. 6. The Vaal River at Station 5a. Unstable Depositing Zone. The only aquatic or semi-aquatic vegetation is the *Scirpus* growing on the small islands.

The Unstable Depositing Zone.

This zone was the lowermost in the catchment of Vaal Dam. It was characterised by extensive sand and mud banks devoid of higher plants, in the river beds. Marginal aquatic plants were scarce and limited mainly to *Scirpus* sp., a tough plant which was most often found growing on stony islands (Fig. 6). The dry season flow was not sufficient to fill the river beds and sand and mud banks were exposed, while there was usually a fringe of mud at the water's edge (Fig. 7). The Vaal River downstream from between Stations 2a and 3

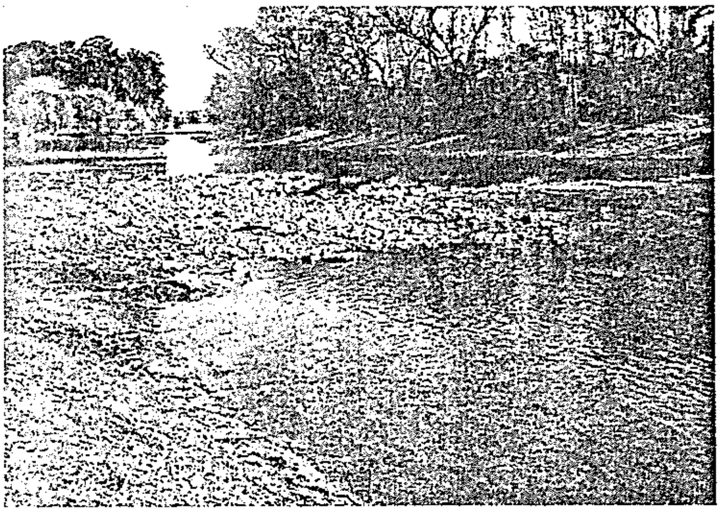

Fig. 7. The Wilge River at Station 13. Unstable Depositing Zone, showing the lack of fringing vegetation.

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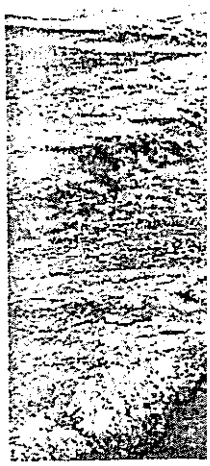

Fig. 8. The Kommandospruit
The only stones visible in the

the Klip River downstream from between Stations 26 and 27 and the Wilge River downstream from between Stations 10 and 11a were all Unstable Depositing Zone rivers.

The High-lying Unstable Depositing Zones.

These zones occurred in parts of rivers where stream profiles and the general topography of the surrounding countryside suggested that Eroding or Stable Depositing Zones should have been found. There were two types recognised, Muddy and Sandy.

The Muddy High-lying Unstable Depositing Zone.

At Station 19, the profile of the Kafferspruit falls gently (Fig. 2), and there was an unusually large deposition of very fine silt. The tops of stones out of the current were covered by a layer of silt up to a centimetre thick and a hand operated Ekman grab would sink into the muddy bottom until it disappeared. There was very little sand in the river bed. There were no fully submerged aquatic plants, such as *Potamogeton* sp. and *Lagarosiphon* sp., but there was a more or less continuous fringe of semi-aquatic plants on the banks of the stream. There was no other sampling point where conditions were similar to those found at Station 19.

The Sandy High-lying Unstable Depositing Zone.

In the southern part of the study area there was a number of streams of comparatively steep profile with beds typical of the Unstable Depositing Zone. These were the Kommandospruit at Stations 30 (Fig. 8) and 31, the Molen River at Stations 34 and 14 (Fig. 9), the Klerkspruit at Station 40 and the Elands River at Station 39 (Fig. 10). Figure 10 clearly shows the particularly severe silting of the Elands River, whose bed had reached a stage where pools were completely obliterated. Further upstream at Station 38 the bed of the river consisted of small round pebbles between which there was sand and silt. Pools were gradually being filled with these pebbles and there was marked bank erosion.

The key factors governing the zonation of rivers following Moon are the profile of the river and the resultant speed with which the water flows. Where the river falls slowly current speeds are low and suspended material is deposited,

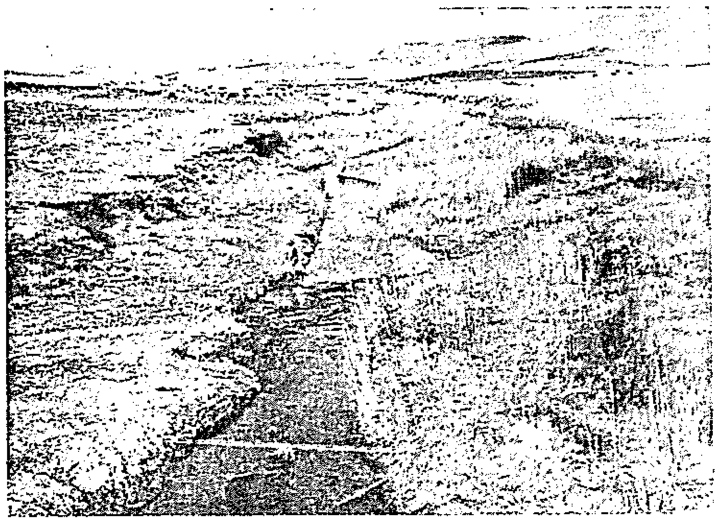

Fig. 8. The Kommandospruit at Station 30. Sandy High-lying Unstable Depositing Zone. The only stones visible in the stream bed were those near the man, and they had been put there to make a drift.

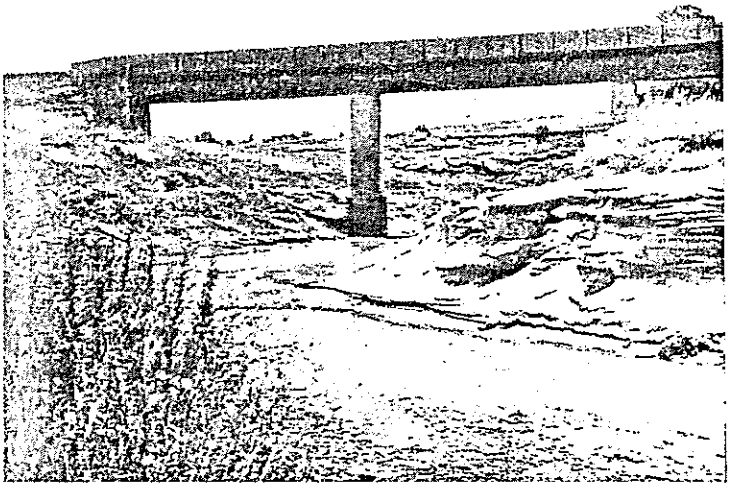

Fig. 9. The Molen River at Station 14. Sandy High-lying Unstable Depositing Zone. The sand bank to the right of the photograph appeared between December 1958 and February 1959.

Fig. 10. The Elands River at Station 39. Sandy High-lying Unstable Depositing Zone. The entire river bed is sand and there is no vegetation in it.

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but it would appear that the amounts of suspended material were not as great in the rivers cited by MOON as they are in the catchment of Vaal Dam. Soil erosion, in addition to profile and current speed, is obviously another key factor in the Vaal Dam catchment. In the Unstable Depositing Zones soil has been carried into the watercourses faster than it can be transported downstream, but this has not led to conditions comparable to MOON's deposition zones, which should really be compared with the Stable Depositing Zone. The paucity of macrophytic vegetation in the Unstable Depositing Zones is due to the severity of floods, the associated high turbidity of the water and the movement of the sediments which occur during floods. Where dams, weirs and sometimes dolerite sills resulted in some stability in the river beds in the Unstable Depositing Zones, fringing semiaquatic plants appeared on the river banks. As might be expected, the type of sediment found in the stream beds was related to the distribution of soil types in the study area. The Muddy High-lying Unstable Depositing Zone was found in a stream where the soils are less sandy and the Sandy High-lying Unstable Depositing Zone occurred where the soils were more sandy.

c) Seasons of biological importance

Inspection of the biological data revealed that the greatest changes in the composition of the fauna occurred with the first summer spates in the streams and rivers. Spring and autumn pass very quickly in the Vaal Dam catchment. For purposes of describing seasonal changes in the fauna, the year has therefore been divided into the following three seasons:
1. Winter — from late April to August. This is a period during which spates very seldom occur and flows gradually decline from their summer peaks. The water becomes clear and growths of diatoms and other algae appear.
2. Dry Early Summer — from September until widespread and heavy summer rains. In 1958 and 1960 the summer rains came after the October field trip, but in 1959 they were later, coming after the November field trip. Water temperatures rise during this period, the water is clear to slightly cloudy, flows are low and steady and growths of algae are greatest.
3. Summer — from the first summer rains to early April. Flows fluctuate widely and rapidly, the water does not lose its turbidity in the lower reaches of the rivers, and algae are virtually absent.

d) Water temperature

Nowhere in the Vaal Dam catchment were water temperatures under continuous observation, and readings made on field trips are the only data available. Since these were not made simultaneously they can only be used to show the broader trends of temperature change in the streams and rivers of the area. It should, however, be borne in mind that far more visits were made to sampling points on the Vaal River and its north bank tributaries and to the Klein Vaal River than to other parts of the catchment, so that mean temperatures (Table 1) are weighted in favour of conditions in these parts. Mean temperatures were always lowest in the Source Zone (Table 1). In the Eroding Zone they were usually as high as they were in the Unstable Depositing Zone, but the water was cooler in the Stable Depositing Zone, which lies between the Eroding and Un-

Table 1. A summary of water temperatures in degrees Centigrade, recorded in streams and rivers in the Vaal Dam Catchment, season by season. The number of measurements on which the mean is based is shown in brackets after the mean.

		Source Zone	Eroding Zone	Stable Depositing Zone	Unstable Depositing Zone	High-lying Unstable Depositing Zones
Mean temperature	W*	9.4(5)	10.0(8)	10.0(10)	11.4(33)	9.6(8)
	D	16.7(3)	17.9(4)	16.8(7)	17.4(27)	16.5(9)
	S	20.5(7)	22.4(7)	20.8(9)	22.5(41)	22.2(8)
Maximum temperature	W	20.5	14.5	16.0	17.7	13.5
	D	22.2	25.0	22.5	24.0	20.8
	S	27.0	28.8	24.4	28.2	30.5
Minimum temperature	W	5.9	7.0	4.2	4.5	4.4
	D	14.0	12.0	10.0	10.5	8.0
	S	17.2	18.2	17.0	18.2 7.5**	17.5

* W — Winter, D — Dry Early Summer, S — Summer.
** After a hailstorm.

stable Depositing Zones, than in either of these two zones. This apparent temperature anomaly was not due to the sequence in which the sampling points were visited or to the time of day when temperatures were measured. The Stable Depositing Zone was a zone where pools tended to be rather deep and there was some shading of the rivers by trees at Stations 21 and 10, two of the three sampling points in this zone. There was little difference between the mean temperatures recorded from the Eroding and the High-lying Unstable Depositing Zones. Seasonal temperature changes were obvious and the Dry Early Summer was a warm season.

Some of the temperature extremes are worthy of comment. The highest Winter temperature was recorded from the Source Zone when the flow had ceased. The highest Summer temperature was recorded from a stream in the Sandy High-lying Unstable Depositing Zone, where the water was shallow and meandering over a sandy bed. Winter minimum temperatures were nearly as low in the Unstable Depositing Zone as they were anywhere else in the study area. The low temperature after a hailstorm shows the large temperature fluctuations to which the fauna may be exposed. Such changes may take place very quickly.

On two occasions water temperatures were measured at hourly intervals for twenty-four hours, and these records indicate the daily range of temperature variation under normal weather conditions. At Station 4 in mid April the temperature ranged from 15.0 °C to 21.6 °C and at Station 17 in early September it ranged from 13.5 °C to 18.2 °C.

In conclusion the variation in mean temperatures from zone to zone was small, though individual temperature readings varied considerably. Mean temperatures in the Eroding zone and in all types of Unstable Depositing Zones were so uniform that temperature may be discounted as a factor likely to influence faunal differences between these zones.

c) Water chemistry

MALAN's (1960) work on the chemistry of the surface waters of the Vaal Dam catchment showed that they were well-buffered and alkaline with a large part of the dissolved solids made up of the bicarbonates of calcium and magnesium. Sodium, chloride and sulphate ions usually occurred in small concentrations. MALAN's data are summarised in Table 2 which shows the range of analysis

Table 2. A summary of MALAN's (1960) analyses of water at some sampling points. All results are in parts per million and are based on daily water samples.

River	Station		Total Dissolved Solids	Total Alkalinity (as $CaCO_3$)	Total Hardness (as $CaCO_3$)	Chlorides (as Cl)	Sulphates (as SO_4)	Sodium (as Na)
Vaal	2	mean	67	31	27	11	5	9
		range	53–99	19–52	15–48	6–16	1–13	5–14
Vaal	6	mean	133	93	86	9	6	15
		range	78–185	40–152	44–140	4–18	3–10	8–19
Wilge	11a	mean	57	27	23	7	4	7
		range	27–81	14–42	13–36	3–12	1–7	3–11
Wilge	13	mean	124	86	75	9	14	5
		range	65–212	35–170	35–150	4–15	8–20	2–13
Kaffer-spruit	19	mean	230	185	167	15	9	22
		range	175–292	124–255	112–228	8–20	6–14	14–28
Klip	27	mean	135	92	80	10	6	16
		range	65–285	25–220	30–170	5–24	2–24	4–48
Cornelius	35	mean	128	88	76	9	5	15
		range	65–219	25–182	30–157	3–23	3–12	6–27
Lieben-bergsvlei	42	mean	167	124	103	10	8	20
		range	75–289	34–250	29–212	6–20	4–13	9–34

figures usually encountered and also how the concentrations of ions increased down the course of the Vaal and Wilge Rivers. MALAN was unable to show that there were differences in the nature of the water due to the geological formations over which it had flowed. During the zoological studies MALAN's work was extended over a greater area and also by the determination of pH, ammonia, nitrites, nitrates, Kjeldahl nitrogen and oxygen absorbed in 4 hours from $KMnO_4$. Analysis results have been recorded in detail in CHUTTER (1967). Important findings were that the pH of the Source Zone water (Station 1) was slightly acid, ranging from 5.8 to 6.8, and contrasted with other zones where the pH of the water was usually about 7.8. Oxygen absorbed and Kjeldahl nitrogen values were higher at Station 1 than elsewhere, most probably because it was used as a stock-watering point during the dry season. Other than these peculiarities at Station 1 there was no evidence of any chemical abnormalities likely to affect the fauna at the sampling points whose fauna is described here.

f) Current speed in the stones-in-current

Current speeds over the stones-in-current biotopes varied both from sampling point to sampling point and also from season to season (Table 3). They were not closely related to the zones of the rivers. The relationship between the stones-in-current fauna and current speed has been examined elsewhere (CHUTTER, 1969a). It was found that the density of some animals followed current speed at single sampling points but that when data from several sampling points were compared the relationship between these same species and current speed no longer held. It was concluded that only in exceptional circumstances would it be possible to ascribe faunal changes to current speed in the stones-in-current biotope.

Table 3. Current speeds in cm/sec recorded in stones in current biotopes in the catchment of Vaal Dam zone by zone and by season. The number of occasions on which current speeds were measured are shown in brackets after the means.

Zone	Station number	Mean			Maximum			Minimum		
		W*	D	S	W	D	S	W	D	S
Eroding	21a	44(2)	50(2)	68(1)	74	54	84	24	41	41
	24a	21(1)	—	—	23	—	—	20	—	—
	24	24(1)	—	—	39	—	—	20	—	—
	25	49(1)	—	—	67	—	—	26	—	—
	26	76(1)	—	—	100	—	—	51	—	—
	9	—	71(1)	52(2)	—	87	84	—	49	19
	43	29(1)	—	50(1)	36	—	74	21	—	31
Stable	21	35(3)	51(2)	50(4)	62	69	90	16	29	37
Depositing	2a	36(3)	40(3)	30(3)	62	62	39	18	12	24
	10	64(1)	—	79(1)	79	—	102	44	—	59
Unstable	3	32(2)	37(3)	52(3)	62	47	64	20	20	21
Depositing	5a	51(3)	51(2)	63(3)	77	72	87	19	29	39
	12	12(1)	—	—	18	—	—	10	—	—
	13	57(1)	—	32(2)	82	—	52	39	—	16
	41	33(1)	—	—	36	—	—	31	—	—
	44	57(1)	—	59(1)	79	—	64	36	—	57
high-lying	19	21(2)	40(2)	44(1)	28	54	44	18	29	43
Unstable	30	45(1)	—	—	62	—	—	31	—	—
Depositing	38	81(1)	—	—	100	—	—	64	—	—

* W — Winter, D — Dry early summer, S — Summer

4. *The fauna*

a) General remarks

A considerable problem in the presentation of the biological data arising out of series of faunal samples taken at monthly intervals is to decide which data have biological meaning in terms of the aims and objectives of the study and which data may be ignored. HARRISON and ELSWORTH (1958, p. 170) laid down criteria for the selection of species, the aim of which was "to select species from the biotopes which really belonged there and to eliminate casual migrants from the discussion". On the other hand ALLANSON (1961) considered species which were likely to be collected in a repetition of the sampling to be important and his basis for selecting species was therefore aimed at discarding species unlikely to be collected in repeated sampling.

The Vaal Dam Catchment has been studied to increase our knowledge of the factors governing the major faunal changes taking place along the course of the rivers, and also through the seasons of the year, in the commonest biotopes. It is desirable therefore to take as many taxa into account as possible, but at the same time it is not desirable to base interpretations on data which include species so rare that there is not a high probability of encountering them again. The author's reasons for selecting taxa are therefore the same as ALLANSON's. However the basis on which ALLANSON recognised such taxa included an assumption of the way in which the proportion of a single species would vary in a set of replicate samples. In the paragraphs which follow the criteria used by HARRISON and ELSWORTH and by ALLANSON to recognise the taxa they selected are re-examined.

HARRISON and ELSWORTH called their selected species "significant". Their significant species were those animals which

1. constituted more than 5 per cent of the total fauna in one or more samples in a season, or,
2. occurred in lower percentages in two or more of the samples in a season (there were three samples per season).

Criteria very similar to these are arrived at here to recognise the taxa likely to be collected in a repetition of sampling.

ALLANSON called the species he selected 'common'. Basing his analysis on an assumed binomial distribution of the proportion, p, that a species would constitute of the fauna collected in a single sample in a set of replicate samples, he showed that as the size of samples increases the confidence limits of estimates of p become narrower. In samples containing more than 578 individuals, species constituting 1 per cent or more of the fauna could reasonably be expected to be found 19 times out of 20 in replicate sampling. Since his samples were always larger than this he defined common species as those species whose percentage in individual samples was 1 or >1 for at least three consecutive months in a season. The stipulation of at least three consecutive months was made especially to omit those species "which bloom rapidly and die down equally rapidly". Since HARRISON and ELSWORTH used a net of wider mesh than ALLANSON, their samples usually contained less than 578 individuals. For these smaller samples ALLANSON was able to suggest that animals constituting 5 or more per cent of the fauna were those likely, in 19 cases out of 20, to be collected in replicate sampling. This then apparently added a further meaning to HARRISON and ELSWORTH's choice of 5 per cent in their definition of significant animals.

CHUTTER and NOBLE (1966) took ten separate square foot samples on one day from a stony run in the Vaal River at Standerton. Since the sampling method and apparatus was the same as that used by ALLANSON in this type of biotope and since the numbers of animals in the individual samples varied between 778 and 2831 (mean 1633), then following ALLANSON's criteria for the recognition of "common" taxa it should be expected that:

1. Taxa absent from some samples should very rearly exceed 1 per cent of the numbers of individuals in separate samples.

2. Taxa present in all ten samples should exceed 1 per cent of the animals in each separate sample always or very nearly always (in 19 samples out of 20).

The analysis of CHUTTER and NOBLE's data in Table 4 has been made to show how these expectations fit the results of replicate sampling. Only 3 of the 43 taxa absent from some samples exceeded 1 per cent of the fauna of individual samples. Owing to the fact that one of these 3 taxa exceeded 1 per cent twice there were four occasions on which percentages of taxa absent from some samples exceeded

Table 4. An analysis of CHUTTER & NOBLE's (1966) data from a series of 10 replicate samples to show the relationship between the number of samples in which taxa were found and the number of times the separate taxa exceeded 1 per cent of the total numbers of animals in the samples in which they were found.

	Number of taxa which exceeded 1 per cent of the fauna in individual samples: – 10 times	9×	8×	7×	6×	5×	4×	3×	2×	1×	never	Total numbers of taxa
Taxa found in each of the 10 samples	6	4	3	2	1	1	1	2	3	2	1	26
Taxa found in only 9 of the 10 samples		—	—	—	—	—	—	—	—	—	1	1
Taxa found in only 8 of the 10 samples			—	—	—	—	—	—	1	1	2	4
*Taxa found in only 6 of the 10 samples					—	—	—	—	—	—	1	1
Taxa found in only 5 of the 10 samples						—	—	—	—	1	1	2
Taxa found in only 4 of the 10 samples							—	—	—	—	7	7
Taxa found in only 3 of the 10 samples								—	—	—	3	3
Taxa found in only 2 of the 10 samples									—	—	10	10
Taxa found in only 1 of the 10 samples										—	15	15

* No taxa were found in only 7 of the 10 samples

1. The actual percentages were 3.2, 2.5, 1.6 and 1.2. Thus the first of the two expectations based on ALLANSON's criteria is borne out by the replicate sampling. Approaching the problem solely from the point of view of the first expectation it would therefore be reasonable to assume that taxa not found in all of a series of replicate samples would never exceed a percentage somewhat above 3.2, say 5 per cent, of the fauna of any single sample.

As there were 10 and not 20 replicate samples in CHUTTER and NOBLE's data, taxa found in all 10 samples should exceed 1 per cent of the fauna of individual samples 10, 9 or perhaps 8 times in order to confirm the second expectation arising out of ALLANSON's findings. However, only 13 of the 26 taxa found in all of CHUTTER and NOBLE's samples exceeded 1 per cent 8 or more times (Table 4). In 8 taxa 1 per cent was exceeded 3 or less times and one taxon never exceeded 1 per cent. These data therefore show that the second expectation arising from ALLANSON's criteria is not correct, because there were too many instances of taxa found in all the replicate samples not exceeding 1 per cent of the animals in individual samples.

It was concluded earlier that taxa making up more than 5 per cent of the fauna in an individual sample were almost certain to be present in a replicate sample. The problem of recognising the many taxa which make up a very low percentage of the fauna in single samples, but which at the same time are likely to be found in replicate samples, remains to be considered. The only way in which data, based on single samples drawn at monthly intervals, may be used to reveal these taxa is to take account of the number of samples in which they were found. In this study the following criteria have therefore been used to recognise taxa likely to be found in a repetition of sampling:

1. Taxa found in more than half the samples collected in a season, irrespective of their percentage in individual samples.
2. Taxa making up more than 5 per cent of the fauna in single samples, irrespective of the number of samples in which they are found.

These criteria differ from HARRISON and ELSWORTH's only in that taxa present in more than half the samples in a season are included, the year being divided into three seasons of unequal duration, whereas HARRISON and ELSWORTH's year was divided into four equal seasons and they included taxa found in two of the three samples in a season. The author intends to follow HARRISON and ELSWORTH in naming his selected taxa "significant".

Many of the sampling points in the present study were visited only once or twice in a season. In these cases taxa have been considered significant if they:

1. constituted more than 5 per cent of the fauna in a sample, or,
2. occurred in both samples where two samples were collected, or,
3. occurred in only one sample but were significant at another comparable sampling point where there was more intensive sampling.

b) Presentation of results

During the course of this study many faunal samples were collected from areas of unknown dimensions. In order to compare data from such 'non-quantitative' samples, the numbers of individuals of each taxon found in a sample have been expressed as a percentage of the total number of all taxa found in the sample. This percentage transformation has been used by earlier workers (HARRISON & ELSWORTH 1958, ALLANSON 1961, OLIFF 1960) but it does have the disadvantage that the percentage of an animal, being an expression of its abundance relative to the numbers of the other animals, is not necessarily a good guide to the absolute abundance of that animal. The Cladocera and Copepoda which were found in very large numbers in the Dry Early Summer season had a particularly marked disruptive effect on the percentages of the other animals. It has therefore been found most convenient to ignore the Cladocera and Copepoda in calculating percentages. They are to be described elsewhere (CHUTTER in press).

In the sections which follow the fauna is treated biotope by tiotope. For each biotope the changes in the diversity of the fauna are first described. This is followed in the sections on the stones-in-current and marginal vegetation fauna by a description of the changes in the density of the fauna in relation to river zonation and in relation to the three seasons recognised. Here only 'quantitative' data (that is data from samples of known dimensions) are used. Finally both 'quantitative' and 'non-quantitative' data in the form of mean seasonal precentages are used to summarise the changes taking place in the dominant animals from the various zones. In the stones-in-current, taxa whose mean seasonal percentage were greater than 5 are regarded as dominant, but in the marginal vegetation 10 per cent or more is the criterion of dominance. There are therefore several differences between the dominant taxa and the significant taxa. The dominant taxa are recognised from mean seasonal percentages, whereas the significant taxa are recognised in part from percentages in individual samples and in part from their frequency of occurrence from month to month. In effect all dominant taxa are also significant, but not all significant taxa are dominant. The percentage data take in results from many more samples than do the 'quantitative' data. The mean seasonal percentage of a taxon is arrived at from the percentages calculated for each sample and not from pooled seasonal data. The sampling method used in the stony backwaters was never 'quantitative', so here the description of the changes in the fauna is based entirely on mean seasonal percentages and the dominants are not considered separately.

The Klein Vaal and Vaal Rivers embrace all the recognised zones except the Muddy and Sandy High-lying Unstable Depositing Zones. As these rivers were studied in most detail (see above) most emphasis has been placed on results from them. Station 19, which represents the Muddy High-lying Unstable Depositing Zone, was also sampled monthly, but the sampling points in the Sandy High-lying Unstable Depositing Zone were only occasionally visited. It has in places been found convenient to treat samples from this zone as though they had all been collected from a single sampling point and for this zone the mean seasonal percentages are therefore means of the data from a number of sampling points.

Tables of the fauna have been abbreviated by combining the data for species belonging to single groups. For instance in Table 5 data for *Baetis glaucus*, *B. harrisoni*, *Centroptilum excisum*, *C. sudafricanum* and several other Baetid Ephemeroptera have been combined and presented under the heading Baetidae. Important changes within such groups have been mentioned in the text. Further details may be found in the Appendix, while a very detailed account of the fauna is given in CHUTTER (1967).

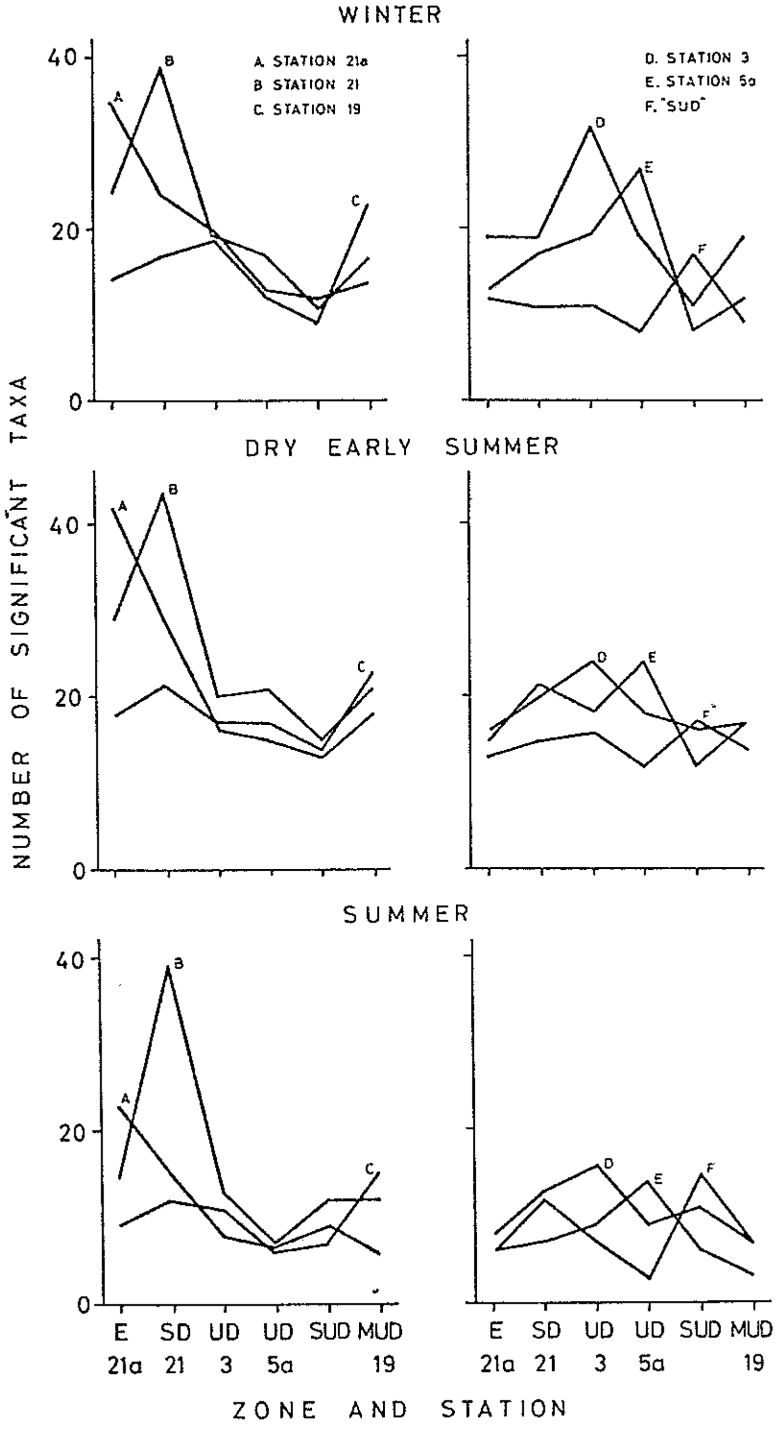
c) The fauna of stones-in-current biotopes

Diversity (Fig. 11). This section is based on results from the Klein Vaal and Vaal Rivers and from the High-lying Unstable Depositing Zones. The diversity of the fauna was clearly greatest in the Eroding and Stable Depositing Zones in all seasons. To a large extent this was due to the Baetidae, Hydroptilidae, Elmidae and Hydraenidae which were represented by many species in these zones. In Summer many Oligochaeta, Ostracoda, Elmidae, Hydraenidae, Simuliidae and Chironomidae disappeared from the fauna of all zones except the Stable Depositing Zone leading to a sharp reduction in the diversity of the fauna. This is an important observation for it shows that the summer disappearance of these groups from the other zones was not due to an intrinsic factor such as life-cycle, but must have been due to unfavourable environmental conditions. The most likely environmental changes with which the disappearance of these groups may be associated were the disappearance of algae, the greater instability of the river bed due to floods and, in the Unstable Depositing Zones, the adverse effects of the transport and deposition of silt and sand.

The diversity of the Unstable Depositing Zone fauna (Fig. 11 Stations 3 and 5a) was clearly greatest in the Winter, but unlike the diversity changes described in the previous paragraph, this was not due to major changes in the diversity of any particular taxa such as the Baetidae, Elmidae or Hydraenidae. Indeed most of the taxa which were significant only in the Unstable Depositing Zone in the Winter were significant in other zones in other seasons. There was no clearly apparent reason for their presence in the Unstable Depositing Zone only in the Winter.

The High-lying Unstable Depositing Zones were in parts of streams and rivers where, on the basis of their profile and altitude, communities similar to those of the Eroding Zone or of the Stable Depositing Zone might have been expected. However, it is clear from Figure 11 that the variety of the fauna in these zones was not nearly as great as in the Eroding and Stable Depositing Zones, and also that there were clear differences between the Sandy and Muddy High-lying Unstable Depositing Zones. The poorly represented groups in the Sandy High-lying Unstable Depositing Zone were the Ostracoda (none of which were significant), the Trichoptera, the Elmidae and the Hydraenidae, but in the Muddy High-lying Unstable Depositing Zone the poorly represented groups were the Ephemeroptera, the Hydroptilidae, the Elmidae and the Hydraenidae.

Density changes (Table 5). In the Eroding Zone the number of individuals belonging to the various taxa was rather variable. This was a zone in which the densities of the Baetidae and Simuliidae were high, while fewer Hydropsychidae and *Burnupia* were found than in the Stable Depositing and Unstable Depositing Zones. In the Stable Depositing Zone the density of Triclads, Hydrachnellae, Caenids, Elmids, Chironomids and *Burnupia* was high by comparison with other zones and the density of Baetids and *Neurocaenis* was rather low. Station 10 has been included in the Stable Depositing Zone, though in several respects the fauna found there resembled that of the Unstable Depositing Zone. The low density of Triclads and Caenidae and the lack of Ostracoda in the Summer at this station were all Unstable Depositing Zone features, but on the other hand Station 10 was similar to Stations 21 and 2a in respect of the Hydrachnellae, Baetidae and Hydropsychidae. Large numbers of Baetids,


WINTER
A. STATION 21a
B. STATION 21
C. STATION 19
D. STATION 3
E. STATION 5a
F. "SUD"
DRY EARLY SUMMER
SUMMER
NUMBER OF SIGNIFICANT TAXA
0
20
40
E SD UD UD SUD MUD
21a 21 3 5a 19
ZONE AND STATION

Choroterpes, *Neurocaenis* and Hydropsychidae were recorded in the Unstable Depositing Zone. In this zone there were few Hydrachnellae, Caenids, Elmids, Simuliidae and *Burnupia* and, in the Summer, very few Chironomids.

At the species level the most important changes in the fauna associated with the Eroding, Stable Depositing and Unstable Depositing Zones were as follows. The most abundant Eroding Zone Baetidae were *Baetis harrisoni* and *Centroptilum sudafricanum*, but these two species were replaced in the Unstable Depositing Zone by *B. glaucus* and *C. excisum*. The Stable Depositing Zone was a transition zone in respect of the Baetidae for low numbers of all these four species were recorded there. *Cheumatopsyche afra* was clearly the dominant Hydropsychid in the Eroding Zone, but it was replaced by *C. thomasseti* in the Unstable Depositing Zone. In this zone *Aethaloptera maxima*, *Amphipsyche scottae* and *Macronema capense* were also found in large numbers. As may be seen from the Appendix and from Table 5 there were striking changes in the species and abundance of the Elmidae and Simuliidae from zone to zone. In the Chironomidae both the Chironomini and the Tanytarsini were significant in all zones, but the Tanytarsini were most abundant in the Eroding Zone and became scarcer downstream to the Unstable Depositing Zone. The opposite held for the Chironomini, but large numbers of larvae of a third Chironomid group, the Orthocladiinae, were not associated with any particular zone. There were probably two species of the mayfly *Neurocaenis*, but they could not be separated in the larval stage. The first species occurred in large numbers in the Unstable Depositing Zone in the Summer. It was not recorded in July, August or September and was therefore similar to the species found in the lower Vaal River (Chutter, 1968). The second species was found throughout the year in the Eroding Zone. Unfortunately it was not possible to confirm that more than one species was involved by rearing nymphs to adults and *Neurocaenis* has consequently been treated as one species.

More samples than are shown in Table 5 were collected from the Sandy Highlying Unstable Depositing Zone but as they were not quantitative they contribute only to the data given when the dominants are considered. In this zone the Winter Baetidae were *B. harrisoni* and *C. sudafricanum*, but in the Summer these were replaced by the typical Unstable Depositing Zone species, *B. glaucus* and *C. excisum*. Other groups in which Summer densities in the two zones were similar were *Neurocaenis*, Hydrachnellae, Caenidae, Elmidae and Chironomidae (Table 5). The great similarity between the Summer faunas of these two zones was due to the similarity in physical conditions, particularly the presence of large amounts of moving silt and sand, in both zones in the rainy season. However, in the Winter flows were low, there was little movement of sediments

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Fig. 11. Stones-in-current fauna. The numbers of significant taxa found at sampling points in the Klein Vaal and Vaal Rivers and in the two High-lying Unstable Depositing zones, plotted with the numbers of the same taxa significant at the other sampling points, season by season. For instance, in the Winter 35 taxa were significant at Station 21a and of these 35 taxa, 24 were significant at Station 21, 19 at Station 3, 13 at Station 5a and so forth. Abbreviations: *E* Eroding; *SD* Stable Depositing; *UD* Unstable Depositing; *SUD* Sandy High-lying Unstable Depositing; *MUD* Muddy High-lying Unstable Depositing.

Table 5. Quantitative data from stones-in-current biotopes. The numbers of individuals per 0.1 sq m of the important taxa, season by season.

Zone		Eroding							Stable Depositing			Unstable Depositing					Muddy High-lying Unstable Depositing	Sandy High-lying Unstable Depositing			
Station		21a	22	24a	24	25	26	9	21	2a	10	3	5a	13	36	44	19	31	34	14	38
Tricladida	*W	37	—	2	15	14	1	—	48	5	8	10	21	14	—	17	2	—	—	—	0
	D	54	53	—	—	—	—	—	34	32	—	5	24	—	—	—	—	—	—	—	0
	S	72	—	—	12	23	—	1	58	12	6	2	2	3	11	—	3	11	0	2	—
Nais spp.	W	20	—	0	6	4	0	—	60	160	17	10	1	6	—	27	42	—	—	—	0
	D	80	35	—	—	—	—	—	335	8	—	38	188	—	—	—	—	—	—	—	58
	S	0	—	—	0	0	—	4	50	3	0	0	0	9	0	—	18	1	0	0	—
Ostracoda	W	1	—	0	0	0	0	—	9	4	0	52	5	0	—	0	100	—	—	—	0
	D	229	8	—	—	—	—	—	156	27	—	15	267	—	—	—	—	—	—	—	1
	S	13	—	—	0	0	—	1	42	28	0	0	0	0	2	—	42	0	0	1	—
Hydrachnellae	W	17	—	5	9	13	0	—	34	94	13	4	1	0	—	0	21	—	—	—	9
	D	75	6	—	—	—	—	—	32	27	—	1	0	—	—	—	—	—	—	—	3
	S	5	—	—	36	6	—	35	35	41	14	1	1	2	4	—	5	23	2	2	—
Baetidae	W	501	—	788	187	310	401	—	25	43	25	178	208	195	—	93	32	—	—	—	209
	D	217	71	—	—	—	—	—	9	24	—	220	131	—	—	—	—	—	—	—	260
	S	138	—	—	140	25	—	47	171	69	47	47	236	3	180	—	22	66	54	72	—
Choroterpes (*Euthraulus*) sp.	W	107	—	13	15	25	5	—	6	268	37	173	192	86	—	7	76	—	—	—	0
	D	172	242	—	—	—	—	—	11	310	—	223	144	—	—	—	—	—	—	—	0
	S	126	—	—	47	36	—	1	6	83	55	19	19	17	47	—	9	25	8	13	—
Neurocaenis spp.	W	44	—	5	14	9	1	—	1	1	4	16	2	0	—	0	0	—	—	—	1
	D	47	0	—	—	—	—	—	4	0	—	19	48	—	—	—	—	—	—	—	0
	S	27	—	—	142	15	—	2	12	5	70	384	307	55	449	—	0	209	116	467	—

Neurocaenis spp.	D	47	0	—	—	—	—	—	4	0	—	19	48	—	—	—	—	—	—	—	0
	S	27	—	—	142	15	—	2	12	5	70	384	307	55	449	—	0	209	116	467	—

Station		21a	22	24a	24	25	26	9	21	2a	10	3	5a	13	36	44	19	31	34	14	38
Caenidae	W	83	—	5	4	1	11	—	52	151	1	3	1	0	—	1	276	—	—	—	1
	D	157	2	—	—	—	—	—	26	471	—	1	7	—	—	—	—	—	—	—	1
	S	18	—	—	30	23	—	0	211	65	5	5	0	0	5	—	5	12	3	15	—
Hydropsychidae	W	11	—	16	31	33	7	—	44	106	25	94	108	258	—	272	92	—	—	—	4
	D	9	78	—	—	—	—	—	19	7	—	38	266	—	—	—	—	—	—	—	3
	S	23	—	—	191	53	—	14	112	175	75	32	221	243	146	—	8	98	21	18	—
Elmidae	W	29	—	40	1	3	1	—	107	79	9	6	14	8	—	32	12	—	—	—	0
	D	110	11	—	—	—	—	—	227	47	—	2	6	—	—	—	—	—	—	—	0
	S	73	—	—	11	1	—	2	236	38	28	0	1	10	0	—	1	4	1	1	—
Simuliidae	W	127	—	61	20	549	320	—	108	39	206	21	21	82	—	138	18	—	—	—	165
	D	73	139	—	—	—	—	—	281	8	—	4	23	—	—	—	—	—	—	—	31
	S	93	—	—	116	5	—	22	19	2	7	34	36	1	5	—	0	55	0	2	—
Chironomidae	W	30	—	110	299	72	121	—	153	1099	407	109	85	227	—	340	735	—	—	—	48
	D	40	74	—	—	—	—	—	298	81	—	44	96	—	—	—	—	—	—	—	85
	S	50	—	—	67	28	—	58	294	74	18	6	0	1	6	—	67	4	14	5	—
Burnupia spp.	W	0	—	0	0	1	1	—	18	1	2	0	2	2	—	0	0	—	—	—	0
	D	1	0	—	—	—	—	—	19	1	—	0	1	—	—	—	—	—	—	—	0
	S	0	—	—	1	0	—	0	19	0	0	0	1	7	0	—	8	0	0	0	—

* W — Winter, D — Dry Early Summer, S — Summer
— No quantitative samples

and the physical environment in the Sandy High-lying Unstable Depositing Zone was more similar to that in the Eroding Zone than it was in the Summer.

The fact that large amounts of very fine sediment settled in the Kaffersprruit at Station 19, representing the Muddy High-lying Unstable Depositing Zone, evidences not only the amount of fine material washed into the river but also a lack of scouring. This lack of scour is reflected in the fauna, in which *Nais* and the Ostracoda were found in comparatively large numbers in the Summer. In all other zones, except the Stable Depositing, these two groups tended to disappear in this season. On the other hand all the other taxa shown in Table 5 except the Chironomidae were recorded in only small numbers at Station 19 in the Summer, suggesting that very silty conditions do not suit them. Changes in the stones-in-current fauna where conditions were very silty were therefore very different to changes where there were large amounts of sand as well as of silt (Table 5).

Among the groups of animals shown in Table 5 there were many instances of seasonal changes of abundance. *Nais* spp. and Ostracoda were commonest in the Dry Early Summer. In the Eroding Zone and the Unstable Depositing Zone these animals nearly disappeared in the Summer but during the Winter their numbers gradually increased. They did not disappear in the Summer from the Stable Depositing Zone, as has been described above. Several other taxa such as *Choroterpes* (*Euthraulus*) sp., Simuliidae and Chironomidae were least abundant in the Summer, but in these taxa Winter densities were not obviously lower than Dry Early Summer densities. In Summer the Unstable Depositing and Sandy High-lying Unstable Depositing Zones were particularly unfavourable for the Chironomidae. The Unstable Depositing Zone *Neurocaenis* was mainly a Summer animal. There were no major taxa (Table 7) in which the highest densities were recorded in Winter and indeed very few species were significant only in this season (Appendix).

The dominants (Fig. 12). The percentages of the dominants from the Klein Vaal and Vaal Rivers and from the two High-lying Unstable Depositing Zones are shown in Figure 12. An example of the type of data used is given in the following table, which shows the contribution the dominant animals at Station 21a made to the fauna of other stations in the Winter:

Station	21a %	21 %	3 %	5a %	SUD* %	MUD* %
B. harrisoni	31.3	1.6	0.5	P	31.9	0.5
C. sudafricanum	8.6	0.2	—	—	3.4	—
Choroterpes (*Euthraulus*) sp.	10.5	0.8	23.3	21.0	0.6	3.5
Caenidae	8.2	8.7	0.7	P	8.6	13.1
Simuliidae	12.7	11.2	1.5	3.6	14.2	0.8
Total percentage	71.3	22.5	26.0	24.6	58.7	17.9

* see caption of Figure 11

In the construction of Figure 12 (and also of Fig. 15 for the marginal vegetation) taxa were identified as far as is shown in the Appendix, except in the Elmidae and Simuliidae, which, because of large numbers of unidentifiable juvenile stages, were treated as families.

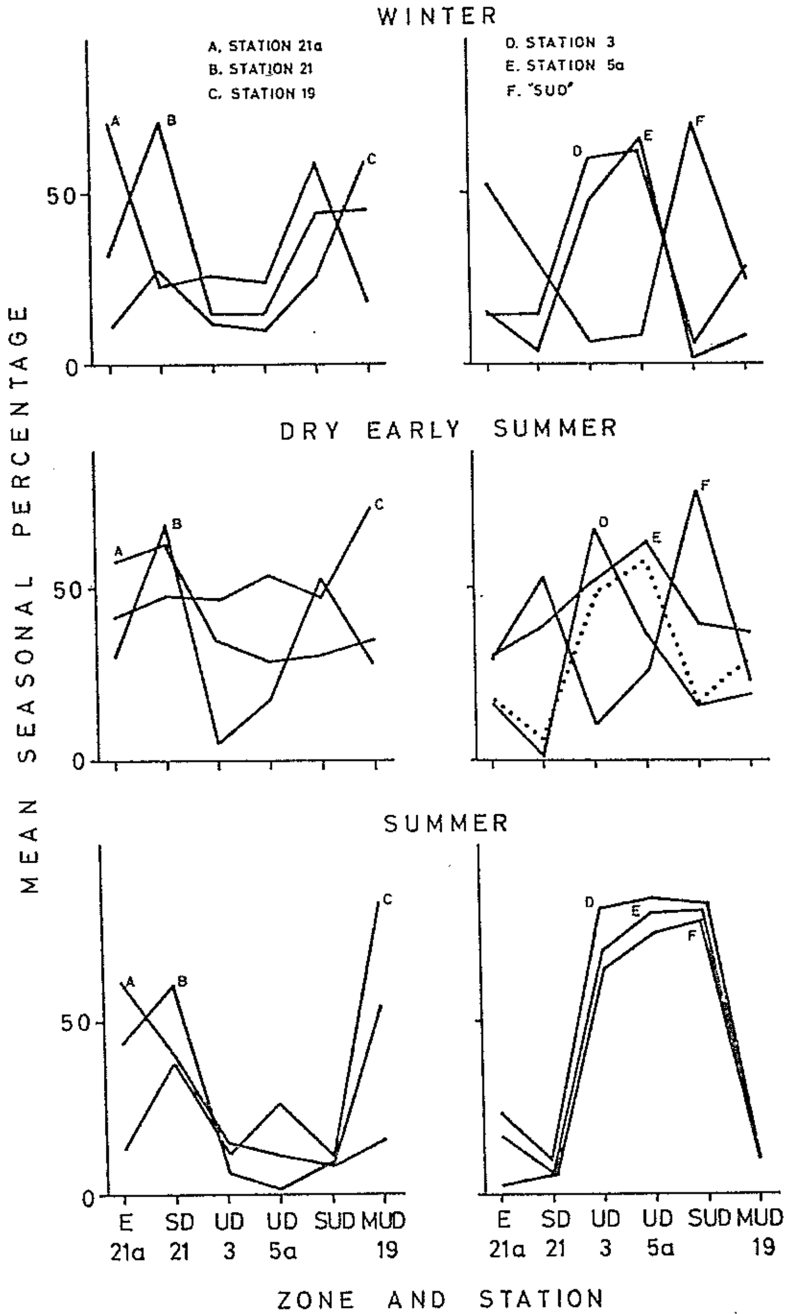

Fig. 12. Stones-in-current fauna. The percentages of dominant taxa at each sampling point plotted with the percentages of the same taxa at the other sampling points, as explained in the text. Abbreviations as in Fig. 11. ...... Station 5a omitting *Nais*. spp.

Several aspects of the zonation of the stones-in-current fauna are strikingly apparent from Figure 12. In the Winter the dominants of the Eroding, Stable Depositing and normal Unstable Depositing Zones were distinctly different from one another. The two normal Unstable Depositing Zone stations (3 and 5a) had very similar dominants. The dominant animals in the Sandy Highlying Unstable Depositing Zone were closest to those of the Eroding Zone, while those in Muddy High-lying Unstable Depositing Zone were closest to the Stable Depositing Zone. The only change in this pattern of similarities and dissimilarities between sampling points from Winter to Summer was an important and striking one; in Summer the fauna of the Sandy High-lying Unstable Depositing Zone was no longer similar to the Eroding Zone fauna but was very close to the normal Unstable Depositing Zone fauna. In the Dry Early Summer differences between the fauna found in the various zones were complicated by two factors. Firstly, large numbers of *Nais* were found at all the sampling points shown except Station 3. However, in respect of dominants other than *Nais* the Station 5a fauna was very similar to the Station 3 fauna, as is shown by the curve for Station 5a data omitting *Nais*. Secondly, the Dry Early Summer was a season in which taxa whose taxonomy was comparatively poorly known (*Nais*, the Chironomidae) made up a large part of the fauna nearly everywhere. This resulted in differences between the communities of the various zones being less obvious than they were in other seasons.

The changes in the percentages of the dominants clearly show how the stones-in-current fauna was closely associated with the zonation of the rivers, and therefore with the factors from which the zonation was recognised. The most important of these were of course the amount of silt and sand in the river beds and the seasonal nature of the rainfall.

d) The fauna of stony backwater biotopes

Stony backwaters were not found at all sampling points, and even where they did occur they were variable. Thus at Station 21a the biotope was made up of stones lying on top of a sheet of dolerite forming the bottom of a pool while at Station 5a the biotope was exposed to a gentle current. Stony backwaters were not found in the Sandy High-lying Unstable Depositing Zone because, being in parts of the river bed where sedimentation may easily take place, they were smothered by sand. Sampling of this biotope was started some months after sampling of the other biotopes and consequently there was only one month when samples were collected in the Dry Early Summer season.

Diversity (Fig. 13). The diversity of the stony backwater fauna responded to changes in the silting of the rivers in several ways. Diversity was greatest in the less silty zones (the Eroding and Stable Depositing) and least in the most silty (the Unstable Depositing and the Muddy High-lying Unstable Depositing). In Summer, when the environment was most unstable due to floods and sediment transport, diversity declined in the Muddy High-lying Unstable Depositing and Unstable Depositing Zones. It did not decline in this season in the Eroding and Stable Depositing Zones where there was little silt. There were, however, large differences between the taxa found in the Eroding Zone where silt was negligable and the taxa found in the Stable Depositing Zone where there was a little silt. The significant taxa of the stony backwaters at Stations 3 and 5a in the Unstable Depositing Zone differed. This was due to the gentle current at Station 5a.

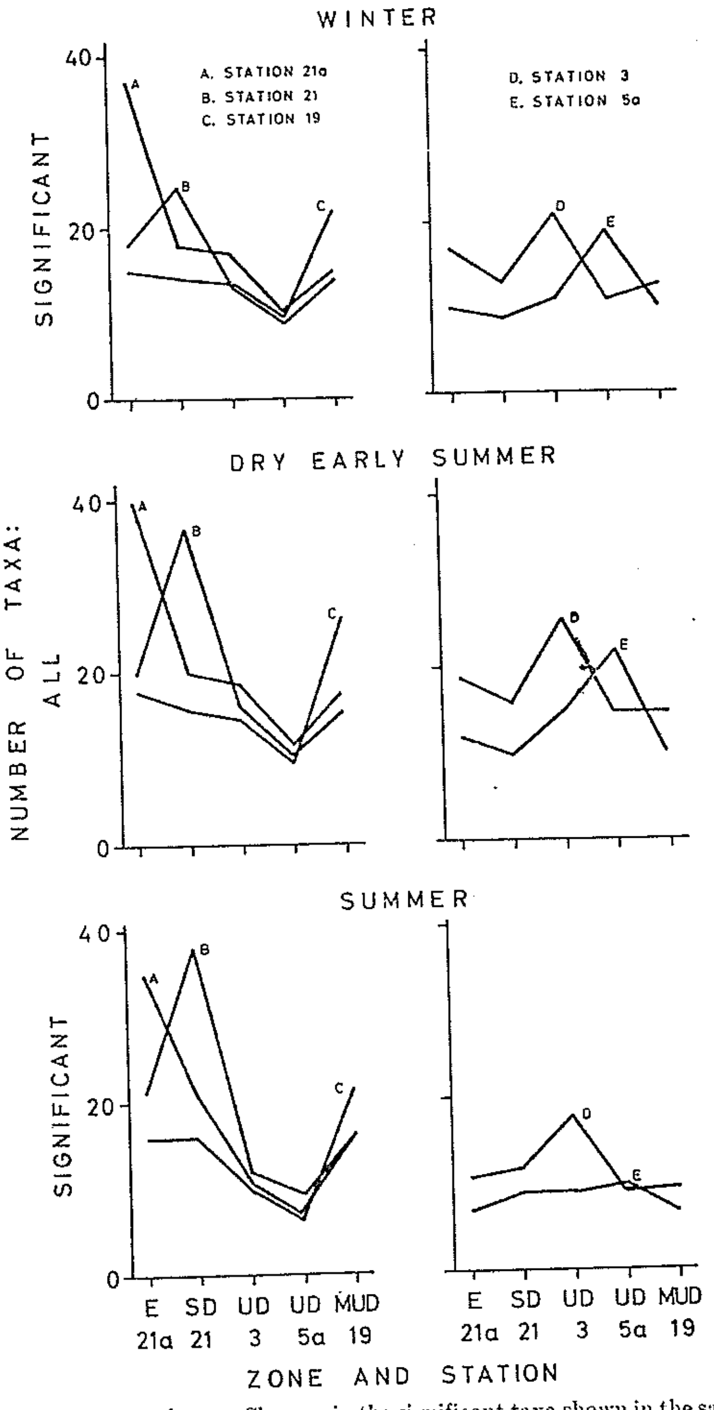

Fig. 13. Stony backwater fauna. Changes in the significant taxa shown in the same manner as they were shown in Fig. 11 for the stones-in-current fauna, except that as there was only one sample from each station in the Dry Early Summer all taxa and not significant taxa are shown in that season. Abbreviations as in Fig. 11.

Table 6. The mean seasonal percentages of widely distributed and important stony backwater taxa

Zone		Eroding					Stable Depositing			Unstable Depositing				Muddy High-lying Unstable Depositing
Station		21a	24a	24	25	26	21	2a	10	3	5a	12	13	19
Tricladida	*W	1	0	0	1	2	5	0	0	1	2	4	2	P
	D	3	—	—	—	—	3	P	—	P	1	—	—	0
	S	2	—	—	—	—	3	1	—	P	P	—	—	0
Nematoda	W	P**	0	1	0	1	1	0	12	1	1	0	0	1
	D	0	—	—	—	—	P	1	—	0	P	—	—	0
	S	0	—	—	—	—	3	6	—	2	P	—	—	0
Nais spp.	W	3	0	0	P	8	0	0	3	P	0	P	0	1
	D	P	—	—	—	—	4	P	—	0	0	—	—	1
	S	0	—	—	—	—	10	0	—	0	0	—	—	0
Ostracoda	W	6	0	0	0	0	3	3	16	3	P	0	0	23
	D	17	—	—	—	—	17	6	—	17	14	—	—	19
	S	P	—	—	—	—	3	16	—	3	1	—	—	8
Hydrachnellae	W	5	13	15	1	3	5	1	1	1	0	1	0	2
	D	2	—	—	—	—	3	P	—	1	0	—	—	4
	S	3	—	—	—	—	4	2	—	2	2	—	—	2
Centroptilum excisum	W	7	2	28	8	25	3	11	P	13	14	12	8	6
	D	8	—	—	—	—	16	6	—	9	46	—	—	44
	S	11	—	—	—	—	4	14	—	15	15	—	—	20
Centroptilum medium	W	0	P	0	0	0	1	0	0	1	1	0	0	P
	D	0	—	—	—	—	0	0	—	0	0	—	—	0
	S	26	—	—	—	—	3	8	—	10	9	—	—	5
Baetid juveniles	W	3	6	5	0	1	1	2	4	2	3	0	3	1
	D	6	—	—	—	—	23	P	—	2	5	—	—	0
	S	9	—	—	—	—	2	2	—	2	3	—	—	6

Choroterpes (Euthraulus) sp.	W	4	2	4	5	10	1	1	1	40	45	40	68	19
	D	8	—	—	—	—	P	0	—	46	21	—	—	11
	S	7	—	—	—	—	P	4	—	25	14	—	—	23
Afronurus sp.	W	2	8	7	4	18	P	0	7	P	1	P	2	0
	D	2					0	0		P	P	—	—	0
	S	4	—	—	—	—	P	P	—	P	0	—	—	0
Caenidae	W	29	1	2	4	2	44	31	8	7	1	1	0	4
	D	21	—	—	—	—	12	56	—	4	1	—	—	1
	S	13	—	—	—	—	30	14	—	10	5	—	—	3
Tanytarsini	W	3	3	3	19	2	2	5	1	1	P	P	0	10
	D	1	—	—	—	—	1	3	—	0	0	—	—	1
	S	2	—	—	—	—	7	5	—	0	P	—	—	3
Pentaneura spp.	W	1	1	2	3	2	7	4	10	4	2	6	3	1
	D	2	—	—	—	—	5	2	—	4	4	—	—	3
	S	1	—	—	—	—	1	3	—	3	1	—	—	6
Orthocladiinae	W	4	26	26	32	8	7	11	16	3	3	11	3	17
	D	2	—	—	—	—	3	2	—	0	0	—	—	5
	S	1	—	—	—	—	3	6	—	P	P	—	—	3

* W — Winter, D — Dry Early Summer, S — Summer
** P — present percentage less than 1
— no sample

At the species level there were many more Baetidae and Elmidae in the Eroding and Stable Depositing Zones than in the other zones (Appendix). Many Ostracod and Chironomid genera disappeared from the Unstable Depositing Zone stony backwaters in Summer. There was no corresponding decline in the variety of these animals in other zones, where the stony backwaters were more sheltered than in the Unstable Depositing Zone.

The relative abundance (percentage) of taxa from zone to zone (Tables 6 and 7). In parts of rivers where there are large amounts of silt and sand the permanent existence of stony backwaters depends on the periodic scouring out of sediments which accumulate in them. Consequently the really abundant taxa of stony backwaters in the Unstable Depositing Zone (*Centroptilum excisum*, *Choroterpes* (*Euthraulus*) sp.) were also inhabitants of the stones-in-current biotope. Where the biotope was more permanently bathed by gentle currents (Station 5a) *Baetis glaucus*, another stones-in-current animal was also abundant. In the Dry Early Summer, when more detritus and algal food was present than at other times and floods did not occur, Ostracoda were also abundant, but they were scarce in Summer. Only one species, *Cloeon* sp. nov. (Table 7) was found in fair numbers only in stony backwaters in the Unstable Depositing Zone. In the Stable Depositing Zone where there was less silt and sand and more detritus than in the Unstable Depositing Zone, Ostracoda and *C. excisum* were again abundant. *Choroterpes* (*Euthraulus*) sp. was rare and the most abundant taxon was Caenidae. In the Stable Depositing Zone Ostracoda were found in large numbers in the Summer and this was related to the comparatively sheltered conditions there. Other taxa which were commoner in the Stable Depositing Zone than in the Unstable Depositing Zone were *Centroptilum pulchrum*, *Micronecta* spp., Elmidae (Table 7). Tanytarsini and Orthocladiinae (Table 6). Detritus and sediments were least in the Eroding Zone, where the fauna was distinguished by the presence in large numbers of *Centroptilum sudafricanum*, *Centroptilum* sp. nov. II and *Afronurus*. These taxa probably require a very clean biotope. *Baetis harrisoni*, a stones-in-current species, appeared where there were currents (Table 7). Hydrachnellae, Caenidae, Tanytarsini and Orthocladiinae, in which percentages were similar in the Eroding and Stable Depositing Zones, did not appear to be affected by the presence of small amounts of silt in the Stable Depositing Zone, though they were not able to thrive in the far more silty Unstable Depositing Zone conditions. On the other hand *C. excisum* was found in large numbers in all three zones and was not affected by changes in the amount of detritus, silt or sand, or by gentle currents. Similarly Ostracoda were widespread in the Dry Early Summer, but they tended to disappear in the Summer in the Eroding and Unstable Depositing Zones, where there were currents through the biotopes.

The Muddy High-lying Unstable Depositing Zone fauna was intermediate between the Stable and Unstable Depositing Zone faunas. It was similar to the Unstable Depositing Zone fauna in that *C. excisum* and *Choroterpes* (*Euthraulus*) sp. were very abundant and Caenidae were few. It was similar to the Stable Depositing Zone in that fair numbers of Ostracoda and Orthocladiinae were recorded, even in the Summer, and in that Tanytarsini were common. The limiting factor in this zone was that there were large amounts of silt which made the biotope unsuitable for some taxa. However scouring floods bearing a lot of

Table 7. The mean seasonal percentages of stony backwater taxa which made up a large part of the fauna at only a few sampling points.

Taxon	Station	W**	D	S
Limnodrilus spp.	21a	1	P*	4
	3	1	3	4
Chaetogaster spp.	19	3	0	0
Baetis glaucus	5a	16	P	39
	12	8	—	—
Baetis harrisoni	21a	P	4	1
	24a	8	—	—
	26	11	—	—
Centroptilum pulchrum	2a	13	12	2
	19	P	0	3
Centroptilum sudafricanum	21a	11	19	6
	24a	5	—	—
Centroptilum sp. nov. II	21a	11	0	0
Cloeon sp. nov.	3	P	0	5
	5a	P	0	3
Cloeon africanum	2a	2	0	P
	3	6	4	1
	19	P	2	3
Adenophlebia sp.	21a	1	0	4
	24a	2	—	—
	24	4	—	—
	21	2	P	P
Micronecta spp.	21	P	5	2
	2a	4	5	2
	10	12	—	—
	3	4	5	2
	19	P	5	3
Elmidae	21	3	2	6
Eubrianax sp.	24a	7	—	—
Chironomini	21	P	0	2
	2a	2	1	6
	5a	2	P	P
	19	1	0	1
Burnupia spp.	5a	3	5	0
	12	3	—	—
Pisidium spp.	2a	0	P	4
	19	1	1	5

** W — Winter, D — Dry Early Summer, S — Summer.
* P is present, percentage less than 1.

sand did not occur and taxa which were rare in the Unstable Depositing Zone because of such floods were able to become established.

c) The fauna of marginal vegetation biotopes

A note on the sampling method used

As has already been described in the section on sampling methods the hand net was swept backwards and forwards through the vegetation in sampling.

This sampling method differed from that used by Oliff (1960) who made single sustained unidirectional sweeps through the vegetation. A simple investigation of the effect of sweeping the net twice through the vegetation in opposite directions was made during the course of the work on the Klein Vaal/Vaal River. Two individuals, each with a hand net, stood side by side in the river facing the vegetation to be sampled. The first worker swept his net through the vegetation for about two feet, lifted it out of the water, and the second worker immediately swept his net in the opposite direction through the same vegetation. The process was repeated until 8 or 10 feet had been sampled. Analysis of the samples collected in this way showed that the second sweep tended to collect more animals than the first (Table 8).

The proportion of the catch from both sweeps, yielded by the first sweep, for the most important taxa varied greatly (Table 9, range). However, on average (Table 9) the first sweep usually collected fewer individuals than the second, though for the Chironomidae there was little difference between the numbers caught by the two sweeps. It could be that the current set up by the first sweep carries animals into the area it has sampled and that, as the second sweep travels against this current, more water passes through the net on the second sweep than on the first sweep. Also, attached animals might be dislodged by the disturbance caused by the first sweep and collected by the second sweep. The most important point about the second sweep is, however, that it does collect large numbers of animals. The numbers of individuals per 0.3 m of the vegetation sampled in both directions which are presented in the following sections are comparable only with data collected using a hand net of the same opening, fitted with the same type of bolting silk and used in the same way as was done in this study. Moreover the length of vegetation sampled was estimated and not measured accurately (see above, field methods).

Table 8. The numbers of animals collected in two sweeps through the same marginal vegetation, the second sweep covering the area already sampled by the first sweep.

Station	Month and Year	Number of animals in: 1st sweep	2nd sweep	both sweeps together (Total catch)	Proportion of total catch yielded by first sweep
2a	6.60	1936	2146	4082	.47
2a	7.60	2631	2227	4858	.54
5	6.60	2010	1250	3260	.62
5	7.60	1719	2748	4467	.38
17	6.60	1329	2380	3709	.36
17	7.60	4787	10221	15008	.31
17	12.60	2167	4688	6855	.32
19	6.60	1483	3834	5317	.28
21a	6.60	500	770	1270	.39
21	6.60	265	472	737	.36
21	7.60	1002	1644	2646	.38
21	10.60	12649	13408	26057	.49
				Mean	.41

Table 9. The effect of sweeping the sampling net in two directions through the marginal vegetation. The proportion of the catch from both sweeps yielded by the first sweep, for the most important taxa. The sampling points and dates of sampling are shown in Table 8.

Taxon	Proportion of catch from both sweeps yielded by first sweep	
	Mean	Range
Nematoda	.31	0.00–0.71
Nais spp.	.44	0.00–0.80
Cladocera	.21	0.00–0.61
Copepoda	.44	0.27–0.75
Ostracoda	.20	0.00–0.62
Baetidae	.38	0.10–0.66
Caenidae	.25	0.00–0.59
Chironomidae	.47	0.21–0.71

The fauna

There were no stones-in-current or stony-backwater biotopes in the Source Zone and that zone is consequently brought into consideration for the first time here. There was no current through the biotope at Station 1, which consisted of the leaves of bank grasses trailing in the water. At Stations 19 and 21 the vegetation was mainly *Cyperus* spp. and it was to some extent sheltered from the current. There were currents through the vegetation at Stations 21a and 5a and at the sampling points in the Sandy High-lying Unstable Depositing Zone, while that at Station 3 was rather exposed and there were usually obvious gentle currents through it in the Summer. Owing to increases in water level it was not possible to collect samples from the vegetation at Station 5a in the Summer.

Diversity (Fig. 14). In the Source Zone there was practically no variation in the numbers of significant taxa from season to season. This zone was therefora in marked contrast to the other zones where there were fewer significant taxa in the Summer than in other seasons. This was because the Source Zone was the only Zone not exposed to summer floods. The importance of seasonal changes in the flow pattern of the rivers and also of water currents through the marginal vegetation biotope, as factors bearing upon the diversity of the fauna, is evident from the numbers of taxa significant at Station 1 which were found in other zones. In the Summer the numbers of Station 1 taxa at other sampling points was lowest, following the greater contrast in this season between physical conditions in the Source and the remaining zones. In the Winter the sampling points whose fauna was most similar to Station 1 were Stations 21 and 19 and this was due to the comparatively sheltered conditions at these two stations. In the Dry Early Summer, when conditions were most stable throughout the river system, the Source Zone shared more significant taxa with other sampling points, except Station 5a and the Sandy High-lying Unstable Depositing Zone where there were always rather marked currents through the sampled biotopes. Yet another way in which the numbers of kinds of significant taxa were related to the physical environment was apparent in the Summer when the numbers of significant taxa was clearly greatest at Stations 1, 21 and 19, the three places where there were not scouring floods.

On account of the large numbers of significant taxa which were not significant elsewhere, the Eroding (Station 21a) and Stable Depositing Zone (Station 21) each had a distinctive community. Far fewer significant taxa were recorded in the Unstable Depositing Zone than in these zones. Differences in the significant taxa at Stations 3 and 5a were due to the current at Station 5a. There was no evidence that the silty conditions at Station 19 in the Muddy High-lying Unstable Depositing Zone adversely affected the diversity of the marginal vegetation fauna. Not only was the diversity considerable, but also the community shared many more significant taxa with the Eroding and Stable Depositing Zones, where there was little silt, than it did with the Unstable Depositing Zone where there was much silt. The least diverse community was in the Sandy High-lying Unstable Depositing Zone. This zone had more significant taxa in common with the Eroding and Stable Depositing Zones in the Winter and Dry Early Summer when conditions were stable than in the Summer when conditions were unstable.

Density changes (Tables 10 & 11). Conditions at two sampling points require comment before the fauna is described. At Station 8 the Sandspruit was dammed up and this resulted in artificially stable conditions in which there were luxuriant growths of fringing macrophytes and also some fully aquatic plants. Station 41 was on a small tributary of the middle reaches of the Wilge River. The stream was flowing moderately when sampled in the Winter. When it was visited in the Summer there had been little rain in its catchment, and consequently it was made up of a series of pond-like pools connected by a trickle of water.

Taking all animals together (Table 10, whole fauna) the density of the fauna was clearly affected by the fluctuations in flow and water level which occurred in the Summer. Only in the Source Zone where there were no floods was the density of the fauna as great in the Summer as in the other seasons. Moreover at the truly riverine sampling points Summer densities were high only where there was shelter from the current (the Stable Depositing Zone and Station 41).

The Source Zone fauna reflected the pond-like conditions at Station 1. The most important Baetidae were the still water species, *Cloeon crassi* and *Cloeon virgiliae*, and typically riverine species such as *Baetis bellus* and *Centroptilum excisum* were rarely found. There were few Caenidae but Nematoda, *Nais*, Ostracoda and Chironomidae were recorded in fairly large numbers throughout the year. In other zones whenever the fringing vegetation was sheltered from the current and pond-like conditions prevailed the fauna had some similarity to that of the Source Zone. Sampling points in this category included all those in the Stable Depositing Zone, Station 8, Station 19 in the Muddy High-lying Unstable Depositing Zone and the Summer fauna at Station 41 in the Unstable Depositing Zone. At these sampling points *Cloeon* spp. were found in some numbers, Summer densities of Ostracoda and Chironomidae and less frequently of *Nais* were higher than usual and Nematoda were often common. Furthermore at Stations 41 (in the Summer only) and 8, the most sheltered of these stations, the typically riverine mayflies *Baetis bellus* and *Centroptilum excisum* were as rare as they were in the Source Zone. Thus the occurrence of what might be termed the pond element of the marginal vegetation fauna was not related to the river zonation except insofar as the Stable Depositing Zone was a zone in which the vegetation was sheltered. However large numbers of *Micronecta*

Table 10. Quantitative data from marginal vegetation biotopes. The numbers
(See also

Zone		Source	Eroding							Stable Depositing		
Station		1	21a	24a	24	26	9	33	43	21	2a	10
Nais spp.	W*	40	2	0	4	1	57	—	22	5	5	0
	D	35	2	—	—	—	81	—	—	87	10	—
	S	17	10	—	0	0	12	2	—	2	1	1
Ostracoda	W	26	7	1	1	1	0	—	0	18	6	32
	D	63	87	—	—	—	0	—	—	60	187	—
	S	11	12	—	1	2	0	1	—	27	33	2
Baetis bellus	W	0	0	0	0	1	0	—	0	2	1	0
	D	0	3	—	—	—	0	—	—	6	1	—
	S	0	14	—	5	9	52	11	—	23	23	129
Centroptilum excisum	W	0	5	0	16	4	1	—	11	1	1	1
	D	0	4	—	—	—	2	—	—	17	0	—
	S	1	1	—	2	0	0	1	—	1	1	1
Cloeon spp.	W	21	1	0	0	0	1	—	0	1	6	1
	D	1	1	—	—	—	0	—	—	1	1	—
	S	13	1	—	0	0	0	0	—	1	1	0
Baetid juveniles	W	2	2	18	13	1	8	—	8	2	2	0
	D	0	46	—	—	—	1	—	—	9	16	—
	S	2	0	—	4	7	6	5	—	10	22	13
Caenidae	W	1	49	3	5	3	84	—	62	20	19	23
	D	1	70	—	—	—	2	—	—	87	52	—
	S	1	18	—	7	1	2	5	—	18	19	3
Chironomidae	W	17	19	88	170	3	568	—	205	19	62	98
	D	30	9	—	—	—	42	—	—	71	82	—
	S	23	1	—	6	6	56	19	—	14	11	4
Whole fauna	W	142	203	472	250	48	776	—	397	110	142	357
	D	163	413	—	—	—	141	—	—	422	398	—
	S	173	83	—	30	28	143	52	—	151	143	161

* W – Winter; D – Dry Early Summer; S – Summer.
— no quantitative samples.

spp. (Corixidae) were found in sheltered riverine biotopes (Table 11) but not in the Source Zone. This may have been related to the unusual chemical nature of the Source Zone water (see above, Water Chemistry).

There were changes in the riverine marginal vegetation animals from zone to zone. These were most clearly apparent in the Ephemeroptera. In the Eroding Zone *Baetis harrisoni*, *Centroptilum sudafricanum* and *Pseudocloeon vinosum* were found where the current was strongest. *Baetis bellus* was most of individuals per 0.3 m vegetation of the important taxa, season by season. Table 11).

Unstable Depositing								Unusually Stable	Muddy High-lying Unstable Depositing	Sandy High-lying Unstable Depositing						
3	5a	27	29	12	36	41	44	8	19	30	31	34	14	38	39	40
6	1	3	—	—	—	526	59	—	2	1237	—	—	—	19	4	15
2	1	—	—	—	—	—	—	—	33	—	—	—	64	—	14	—
1	—	0	0	0	0	54	3	4	1	1	0	0	0	—	—	—
76	44	0	—	—	—	11	0	—	11	1	—	—	—	0	0	0
20	32	—	—	—	—	—	—	—	47	—	—	—	1	—	0	—
1	—	0	0	0	1	70	0	12	5	0	0	0	0	—	—	—
7	1	5	—	—	—	0	0	—	1	0	—	—	—	0	0	1
7	3	—	—	—	—	—	—	—	1	—	—	—	0	—	8	—
66	—	20	34	37	11	0	1	1	10	12	13	43	53	—	—	—
13	21	35	—	—	—	58	48	—	1	41	—	—	—	1	4	5
191	172	—	—	—	—	—	—	—	2	—	—	—	1	—	26	—
18	—	0	1	0	0	0	1	1	1	37	0	0	16	—	—	—
1	0	0	—	—	—	1	0	—	6	0	—	—	—	0	0	0
1	0	—	—	—	—	—	—	—	4	—	—	—	0	—	0	—
1	—	0	0	0	0	88	0	2	1	0	0	0	0	—	—	—
4	15	5	—	—	—	0	37	—	1	13	—	—	—	1	7	3
19	14	—	—	—	—	—	—	—	7	—	—	—	1	—	0	—
16	—	22	13	0	3	0	2	0	2	29	0	10	8	—	—	—
4	3	1	—	—	—	1	10	—	14	24	—	—	—	10	38	11
2	4	—	—	—	—	—	—	—	13	—	—	—	2	—	1	—
4	—	1	1	1	2	5	5	1	4	0	1	7	2	—	—	—
22	9	27	—	—	—	168	284	—	96	301	—	—	—	26	58	63
19	3	—	—	—	—	—	—	—	68	—	—	—	10	—	10	—
5	—	3	1	23	3	16	2	5	11	1	6	6	6	—	—	—
156	160	99	—	—	—	769	617	—	253	2272	—	—	—	107	172	189
258	292	—	—	—	—	—	—	—	239	—	—	—	87	—	84	—
106	—	48	55	63	21	336	27	80	79	84	22	102	113	—	—	—

abundant in the Summer which was the case in other zones. At some stations the density of the Caenidae was high. This group was also abundant in the Stable Depositing Zone but far fewer individuals were found in the Unstable Depositing Zone. *Centroptilum excisum* was most abundant in the Winter and Dry Early Summer in the Unstable Depositing Zone. In the Summer *B. bellus* was the only abundant animal in unsheltered biotopes in this zone. Where the current was strongest *B. glaucus* appeared, replacing *B. harrisoni*, *C. sudafricanum* and *P. vinosum* of similar biotopes in the Eroding Zone.

Table 11. Quantitative data from marginal vegetation biotopes. The numbers of individuals per 0.3 m vegetation of taxa which were abundant at only certain sampling points (see also Table 10).

Taxon	Station	Individuals per 0.3 m in W*	D	S
	1	13	13	38
Nematoda	21	9	2	16
	10	171	—	2
	8	—	—	6
	27	20	—	0
Chaetogaster spp.	30	538	—	0
	19	31	11	1
Caridina nilotica	2a	6	9	19
	5a	11	0	—
Baetis glaucus	44	33	—	0
	39	0	5	—
	24a	113	—	—
	26	14	—	0
Baetis harrisoni	38	9	—	—
	40	27	—	—
Centroptilum sudafricanum	24a	90	—	.
	21a	78	39	1
Pseudocloeon vinosum	39	22	—	—
	40	26	—	—
Pseudagrion spp. very	41	2	—	25
juvenile	34	—	—	32
Nychia marshalli	8	—	—	8
	21	3	11	35
Micronecta spp.	8	—	—	8
	19	4	7	12
	43	26	—	—
Hydraenidae	5a	20	3	—
	19	66	14	1
	39	20	—	0
	24a	163	—	—
	26	8	—	1
Simuliidae	5a	22	35	—
	44	105	—	8
	38	6	—	—
Burnupia spp.	24	2	—	4

* W — Winter; D — Dry Early Summer; S — Summer
— no quantitative sample.

Large numbers of *Chaetogaster* and of Hydraenidae were found in the Muddy High-lying Unstable Depositing Zone, but otherwise the densities of taxa in this zone were similar to densities in the Stable Depositing Zone. The lack of shelter in the marginal vegetation biotopes of the Sandy High-lying Unstable Depositing Zone is shown by the fact that there were no *Cloeon* spp. and that no Ostracoda were collected. In Winter there were many Caenidae, *B. harrisoni* and *P. vinosum* and the fauna was like that of the Eroding Zone. *B. bellus* and *C. excisum* were the only abundant species in the Summer, when the fauna was more like that of the Unstable Depositing Zone.

The dominants (Fig. 15). In the marginal vegetation the distribution of the dominants was sometimes not closely related to the river zonation. Thus a very large part of the Winter and Dry Early Summer fauna in the Sandy High-lying Unstable Depositing Zone was *Nais*. Since *Nais* was also a dominant in these seasons in the Source Zone, this resulted in a similarity between the two zones which was almost entirely dependant on this single, widely distributed animal. The same type of difficulty was encountered in the Winter Stable Depositing Zone fauna where Caenidae was the only dominant taxon. Current speed through the vegetation at Station 5a was greater in the Winter than in the Dry Early Summer so that the dominants differed from those at Station 3 in the Winter but not in the Dry Early Summer.

However the comparison of dominants from zone to zone in Fig. 15 does show that the Source Zone community was different from that of other zones in Winter. Omitting *Nais* it was slightly more similar to the Stable Depositing Zone community than to those of other zones on account of shelter from the current in the Stable Depositing Zone. The Eroding Zone dominants were always distinctive. In the Dry Early Summer the Stable Depositing Zone dominants were very different from those of the Unstable Depositing Zone, but in the Summer, when *B. bellus* was a dominant there was less difference between the two zones. The Sandy High-lying Unstable Depositing Zone and the Unstable Depositing Zone dominants differed most in the Winter, but were identical in the Summer when the environment in the two zones was most similar. In neither the Winter nor the Summer were the Muddy High-lying Unstable Depositing Zone dominants similar to those of other zones. *Centroptilum excisum* was the only dominant in the Dry Early Summer in the Unstable Depositing Zone (Stations 3 and 5a). It was also a dominant in the Sandy High-lying Unstable Depositing Zone, but was rather rare in other zones in this season.

5. *Discussion*

a) Factors which contribute to the zonation of the fauna

Water temperatures differed little from zone to zone in the Vaal Dam catchment. In fact the Eroding Zone was followed downstream by a zone in which mean temperatures were lower in two of the three seasons. Set against this temperature background it is obvious that the decline in the importance of Eroding Zone animals from Station 21a to Station 21 cannot be ascribed to rising temperatures, and must have been due to other factors, of which the most likely were changes in the nature of the river bed and an increase in the siltiness of the environment. The High-lying Unstable Depositing Zone fauna is important in this respect as it shows that many of the Eroding Zone animals

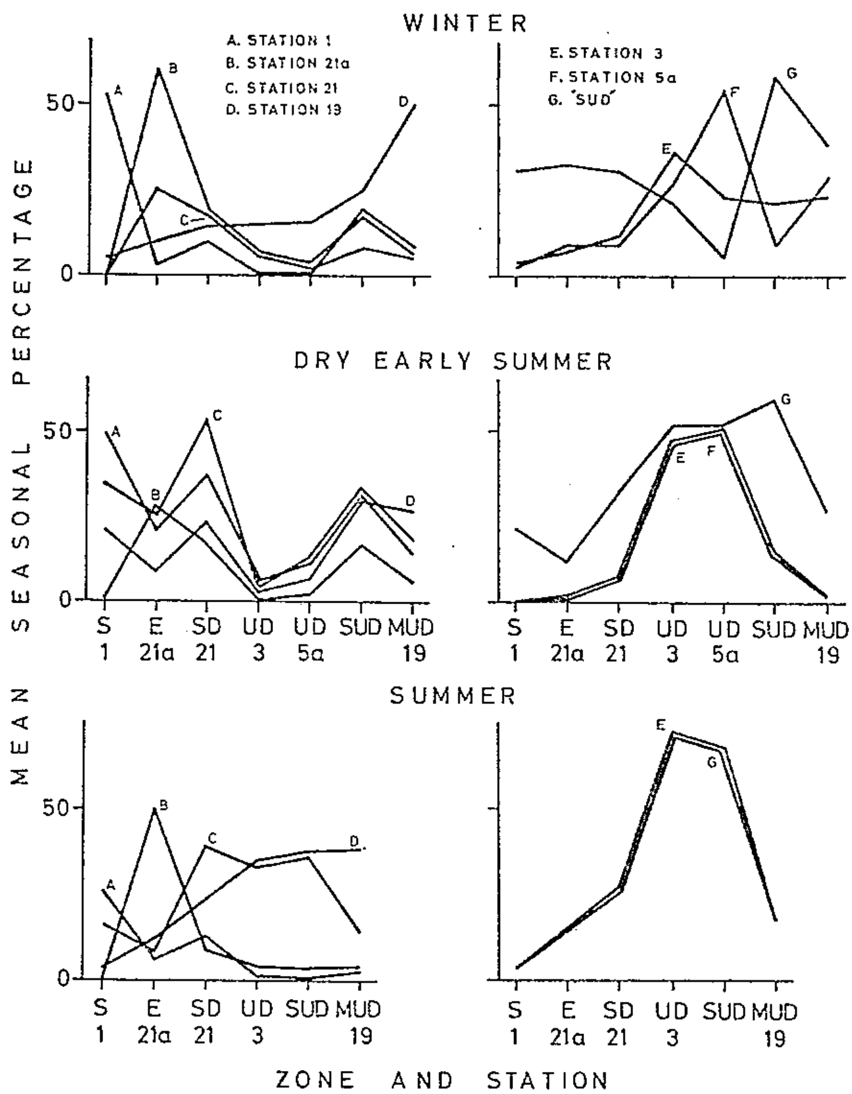

Fig. 15. Marginal vegetation fauna. Changes in the dominant taxa shown in the same manner as they were shown in Fig. 12 for the stones-in-current fauna. Abbreviations as in Fig. 14.

disappear where large amounts of silt and sand find their way into the streams. The precise way in which the silt and sand affect the fauna is not clear though it is reasonable to assume that some animals will be affected directly by an interference with respiration or by abrasion, but in others, and probably the majority, the effect will be more indirect through the smothering of micro-habitats and the alteration of the food resources of the environment, through the generally higher turbidities and instability of the river bottom affecting the growth of epiphytic algae.

However there remains the question of why the Stable and Unstable Depositing Zone animals do not invade the Eroding Zone. This would seem to be largely a question of the food available in the various zones, and is shown clearly by the animals from stones in the current. The distinctive feature of the Stable Depositing Zone fauna was the increase in the numbers and variety of animals such as the Elmidae, *Argyractis periopis* and the Chironomidae which would be likely to feed on the abundant aquatic vegetation, either directly, or as it decayed or on its Aufwuchs. This supply of food would be scarce in the Eroding Zone and also in the Unstable Depositing Zone. It does, however, seem likely that some of the characteristic lower river animals, in this case the Unstable Depositing Zone animals, are also restricted to the lower zones by their food requirements, as HARRISON and ELSWORTH (1958) suggested. The lower river species of *Neurocaenis* was found in large numbers only where there were large amounts of silt, that is in the normal and Sandy High-lying Unstable Depositing Zones. It was not found in the Muddy High-lying Unstable Depositing Zone, possibly because conditions were too silty even for it. Be that as it may, data on *Neurocaenis* from further down the Vaal River lend support to the idea that the lower river species requires large amounts of silt (CHUTTER 1969 b). The other major taxon which increased in the Unstable Depositing Zone was the Hydropsychidae (Trichoptera). These are filter feeders, but the presence of large amounts of filterable food may in their case be less closely related to lower zones than it was in *Neurocaenis*. There are indications, such as the moderately large numbers of these animals in the Eroding Zone of the Klip River that their numbers are related to the size of the river and the distance it has flowed from its source.

HYNES (1963) suggested that a most important source of food for animals found in the upper reaches of rivers is the organic material washed into the river bed. The animals whose distribution has been described here tend to show that the importance of allochthonous organic matter increases down the course of the river. However HYNES was evidently mainly discussing the fauna of streams situated in close proximity to large deciduous forests, for an important source of the food material he described was the autumn leaf fall. The high interior plateau of South Africa, in which the catchment of Vaal Dam lies, consists of grass lands. There are no riverine forests and practically the only trees found along the river banks are exotics, of which the weeping willow, *Salix babylonica*, is the most important. HYNES (1961) showed that the animal productivity of the Afon Hirnant is far greater in the winter, when it is based almost entirely on allochthonous material, than it is in the summer, which was the only season when algal growth could have played a significant role. It appears that the situation is very different in the Vaal Dam catchment. In this summer rainfall area the only period when allochthonous material would naturally reach the river in large quantities would be the summer, when it would be washed in by the rains. When willow trees were introduced this may have changed somewhat, but the question then arises as to whether any of the Vaal River fauna has adapted itself to exploit the leaf fall as a source of food material. To judge by the quantitative data on the fauna of stones-in-current and marginal vegetation biotopes at Stations 21 an 3 (Tables 5, 10, 11), the stations regularly sampled where willow trees were plentiful, it seems that if there was a faunal response to leaf fall, it was not detectable by the admittedly not very refined methods used in this study. On the other hand the Dry Early Summer was the period when autochthonous production of organic matter in the streams reached a peak and algae were most plentiful. The Dry Early Summer is the period when the water is low, clear and warming up after the cold winter temperatures. The interesting point about this is that the density of nearly all the groups of animals recognised in all the biotopes studied was highest in the Dry Early Summer. This suggests that the fauna as a whole may depend more on autochthonous organic matter as a food resource than does the fauna of streams in parts of the world where the rainfall is more evenly spread through the year and where there is an abundant leaf fall. The only animals whose numbers seemed to respond to the increase in the amount of allochthonous material were the lower river type of *Neurocaenis* and only at some sampling points, the Hydropsychidae, described by HYNES as 'indiscriminate eaters of anything they catch'. *Beatis bellus* was also a Summer animal, but it is difficult to visualise this animal living mainly on allochthonous material, for it is not a filter feeder and lives in vegetation exposed to the current, which in the Vaal Dam Catchment usually consists of *Scirpus* in which detritus does not easily become entangled. An observation made at Station 20, whose fauna has not been described here, has a bearing on the importance of autochthonous organic matter on stream productivity in the Vaal Dam Catchment. At this station (near Station 21a, Fig. 1) the entire fauna was poisoned (probably by water from a cattle dipping tank) just before a sampling visit and dead fish and crabs were lying on the margin of the stream. Up to this time there had been no obvious algal growths on the stones. The subsequent recolonisation was followed up and the observation made that a month after the poisoning there was very little fauna, but the stones were covered by a mat of Aufwuchs. This gradually decreased in amount as the fauna returned, suggesting that the grazing rate and the algal growth rate are normally high in the stones-in-current in the Vaal Dam catchment, as there was no evidence that the algal growth was due to a chemical change in the water.

b) River zonation

HARRISON (1965) suggested that the streams and rivers of South Africa, including the Vaal, could be fitted into ILLIES' (1961) classification of flowing waters. Insofar as the Vaal River is concerned HARRISON suggested that what has been described here as the Eroding Zone corresponding to ILLIES' Rhithron and the Stable Depositing and normal Unstable Depositing Zones corresponded to the Potamon. However the importance of silt and sand in the zonation of Vaal Dam Catchment streams and rivers had not at that time been appreciated, and so HARRISON made no provision for the Stable Depositing and the High-lying Unstable Depositing Zones. In fact HARRISON stated that it would be difficult usefully to divide the epipotamon. Nevertheless the division of the epipotamon or Depositing Zone into Stable and Unstable parts has aided considerably in understanding the relationship between the fauna and the environment in the catchment of Vaal Dam. It is not at all unlikely that in most rivers the epipotamon is either Stable or Unstable and, as indeed was the case in the Vaal Dam Catchment, few rivers have both types of conditions. In the Tugela system, the Mooi (OLIFF and KING 1964) was the only river which included a zone (above the village of Mooi River) in which conditions approached those of the Stable Depositing Zone.

It is clear that neither HARRISON nor ILLIES had experience of river systems in which silt and sand were such important environmental factors as they are in the Vaal Dam Catchment, and for this reason they both pinpoint temperature as the main factor limiting the downstream distribution of the typical mountain fauna. The Vaal Dam Catchment studies have shown that the downstream distribution of these animals was apparently limited by silt and sand. This was particularly clear in the Sandy High-lying Unstable Depositing Zone and in the Klein Vaal River. The downstream distribution of the mountain fauna in the catchment of Vaal Dam may also have originally been limited by rising temperatures. In this case what would appear to have happened is that siltation due to soil erosion has become limiting further upstream than temperature.

The Stable Depositing Zone, or a zone similar to it, has not been recognised in any of the other South African rivers so far studied. It seems, however, that it may be similar to the upper Potamon of streams and rivers in parts of the world in which there are not the strongly seasonal rainfall, scouring floods and heavy soil erosion that are so often found in South Africa. Here it would seem that the extent of soil erosion and the violence of floods are more important factors than the seasonal rainfall. Certainly some of the large rivers towards central Africa, such as the Okavango, show a seasonal variation in flow but their depositing zone is stable and full of aquatic plants (personal observation).

The author agrees with HARRISON and ILLIES that the sharpest change in the fauna of a normal river such as the Great Berg occurs between the Rhithron and the Potamon. Where the river changes from Rhithron to Potamon, the fauna of comparable biotopes such as stony runs or fringing vegetation in current changes. Where, however, the recognition of zones within the Rhithron is concerned, it seems that these have frequently been recognised rather by the general appearance of the river and the presence of certain types of biotopes (cascades, waterfalls, stony backwaters, soft bottoms, sandy bottoms) than by sharp changes in the composition of the fauna of single comparable biotopes, such as stony runs. This was the case in the Great Berg River where HARRISON and ELSWORTH recognised rhithron zones between which faunal differences were small and represented trends along the course of the whole rhithron. OLIFF (1960) also found that the greatest discontinuity in the distribution of the Tugela River fauna occurred where the river changes from his Foothill Torrent Zone to his Foothill Sand Bed Zone, that is where it changes from Rhithron to Potamon. However OLIFF presented his data in such a way that it is difficult to follow the faunal changes along the river, particularly insofar as gradual decreases or increases in the abundance of species are concerned. As far as one can see from the data presented by OLIFF, his Rejuvenated River Zone (in the Potamon), while it was clearly distinguishable from the river profile, did not have a distinctive fauna of its own. Some 600 km below Vaal Dam at Warrenton, the Vaal River also has what OLIFF would have called a Rejuvenation Zone. Most of the stones-in-current animals found at Warrenton (CHUTTER, 1969 b) were also found above Vaal Dam in the Unstable Depositing Zone. What appears to happen in these rejuvenated areas is that the stones-in-current biotopes lie closer together than in other zones. Although the rejuvenation area is a clear physical zone it is not a clear faunal zone because the majority of important species found in it are not restricted to it alone.

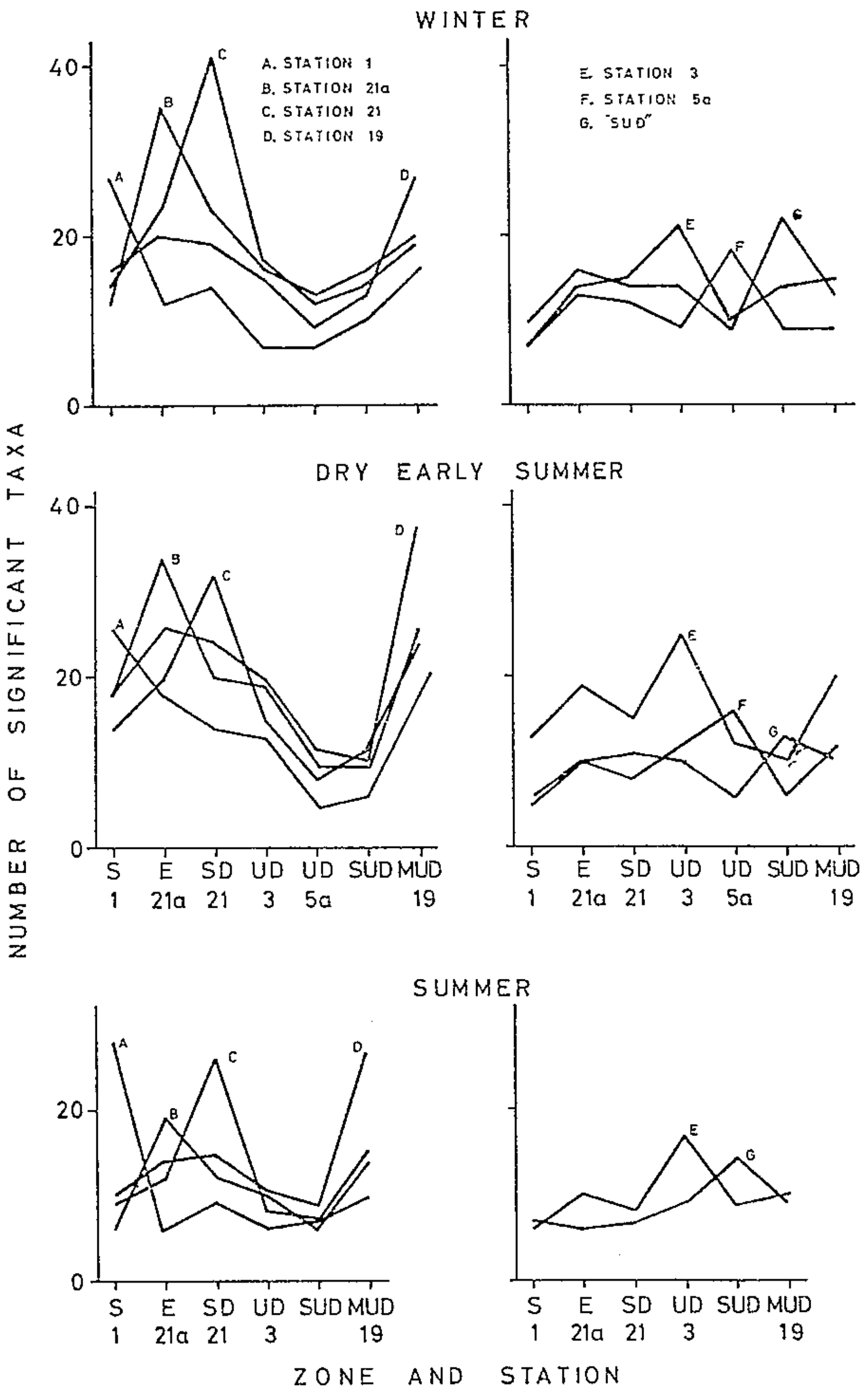

Fig. 14. Marginal vegetation fauna. Changes in the significant taxa shown in the same manner as they were shown in Fig. 11. for the stones-in-current fauna. Abbreviations: *S* Source; others as in Fig. 11.

6. *Summary*

The invertebrate fauna of three biotopes in the streams and rivers making up the catchment of Vaal Dam is described in relation to changes in the physical environment. Three major biological seasons are recognised; the rainy summer season when flows are greatest, floods occur and there may be considerable movement of silt and sand in the river beds; the winter when flows are low, the water clear and cold; the dry early summer when conditions are similar to the winter, except that the water is warmer. The fauna was found to vary with these seasons.

The major factor with which the distribution of the fauna was correlated was the amount of silt and sand present in the river beds. It could not be shown, as has been suggested from studies of other rivers, that the distribution of the fauna was regulated by temperature differences. It appeared that upper river species were limited to the upper river by their inability to live in silty or sandy rivers, while some lower river species may be limited to the lower river by their feeding requirements.

7. *Acknowledgments*

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9. *Appendix*

A complete list of all the significant taxa (except the Cladocera and Copepoda) recorded during the study and, in code form, of the biotopes, zones and seasons in which they were significant is given below. Data from sampling points in polluted parts of the rivers are included. Conditions at these stations (4, 5, 17, 11a, 11b, 11c and 42) are being described in a paper in preparation. The code to the biotopes, zones and seasons is as follows: —

Biotopes	Zones
1. all biotopes	1. all zones
2. stones in current	2. Source
3. stones out of current	3. Eroding
4. marginal vegetation in current	4. Stable Depositing
5. marginal vegetation out of current	5. Unstable Depositing
	6. Muddy High-lying Unstable Depositing

Seasons	Zones
1. all seasons	7. Sandy High-lying Unstable Depositing
2. winter	8. Stations where effluents entered rivers
3. dry early summer	
4. summer	

The literature used to identify the animals listed may be found in appendices an taxonomy in CHUTTER 1963 and 1967.

Animal	Biotope	Zone	Season
Coelenterata			
Hydra sp.	5	2.4.8	1
Turbellaria			
Tricladida	2.3	3,4.5.8	1
	4.5	5.8	1
Rhabdocoelida	5	2.4.8	1
Nemertea			
? *Prostoma* sp.	2,5	4.8	1
Nematoda			
Nematoda	1	2.3.4.5.6.8	1
Oligochaeta			
Limnodrilus spp.	1	8	1
Tubifex sp.	2,3	3,4.5.6.8	2
Nais spp.	1	1	1
Pristina sp.	1	8	1
Dero (*Aulophorus*) sp.	2	8	4
Dero (*Dero*) sp.	4.5	8	1
Chaetogaster sp.	4.5	2.4,5,6.7,8	2.3
	2,3	8	2
Hirudinea			
Salifa perspicax BLANCHARD	2,3	8	1
Batracobdella nilotica (JOHANSSON)	5	8	1
Batracobdella tricarinata (BLANCHARD)	3	8	1
Helobdella conifera (MOORE)	5	4	4
Ostracoda			
Cypridopsis sp.	2.3.4	4,5.6.8	3
	5	2.4.5.6.8	1
Ilyocypris sp.	2	3.4,5,6,8	3
	3,4,5	3.4,5,6,8	1
Isocypris sp.	4,5	2,3.4,5.6,8	2,3
Pionocypris sp.	5	8	3,4
Stenocypris sp.	5	1	1
Gomphocythere sp.	3,5	4,5,6.8	2,3
Cyprilla sp.	3	4	2,3
	5	3,4.5.6,8	1

Animal	Biotope	Zone	Season
Decapoda			
Caridina nilotica (P. Roux)	5	4,5,6,8	1
Hydracarina			
Hydrachnellae	1	2,3,4,5,6	1
	4,5	8	3,4
Plecoptera			
Neoperla spio (Newman)	2	3,4,5	1
Ephemeroptera			
Ephoron sp.	2	4	1
Baetis (*Acentrella*) sp.	2	3	4
Baetis bellus Barnard	4,5	3,4,5,6,7,8	1
Baetis glaucus Agnew	2	5,8	1
	2,4	7	4
Baetis harrisoni Barnard	2,4	3,4,7	1
	3	3	1
Baetis latus Agnew	5	5	1
Centroptilum excisum Barnard	2,3,4	3,4,5,6,7,8	1
Centroptilum flavum Crass	3	4	4
Centroptilum medium Crass	3	3,4,5	4
Centroptilum parvum Crass	2	4	4
Centroptilum pulchrum Crass	3,5	4,6	1
Centroptilum sudafricanum Lestage	2,3,4	3	1
Centroptilum species I	2,3	3,7	1
Centroptilum species II	3	3	2
Pseudocloeon maculosum Crass	2	3,4	2,3
Pseudocloeon vinosum Barnard	4	3	1
	4	4,7	2
Cloeon sp. nov.	3	5	4
Cloeon africanum E.-P.	3,5	4,5,6	1
Cloeon spp.*	5	2,4,6,8	1
Afronurus sp.	2,3	3,4,5	1
Choroterpes (*Euthraulus*) sp.	2,3	3,4,5,6,7	1
Adenophlebia sp.	2,3	3,4	2,4
Neurocaenis spp.	2	3	1
	2	4,5,7,8	3,4
Caenidae	2,3,4	3,4,5,6,7,8	1
Prosopistoma sp.	2,3	4,5	1
Odonata			
Chlorolestes sp.	5	3,7	4
Lestes sp.	5	4	2
Pseudagrion citricola Barnard	5	4,5,6,8	1
Pseudagrion natalense Ris	4,5	3	1
Pseudagrion salisburyense Ris	5	4,5,6,8	1
Pseudagrion vaalense Chutter	4,5	5,8	1
Pseudagrion spp.	4,5	3,4,5,6,7,8	1
Enallagma spp.	5	2,5,8	1
Anax sp.	5	4	2,4
Aeshna rileyi Calvert	2	3,4	1
Aeshna minuscula McLachlan	5	3,4	1

Animal	Biotope	Zone	Season
Hemiptera			
Anisops spp.	5	3,4,5,6,8	4
Nychia marshalli (SCOTT)	5	3,4,5,6,8	4
Sphaerodema capensis (MAYR)	5	2,4,5,8	4
Laccocoris limigenus (STÅL)	5	3,4	2,4
Ranatra parvipes SIGNORET	5	5	1
Plea picannina HUTCHINSON	5	2,3,4,5,8	3
Plea pullula STÅL	5	2,5,6,8	1
Micronecta citharistia HUTCHINSON	3,5	2,4,5,6,8	1
Micronecta dimidiata POISSON	3,5	2,3,4,6,7,8	1
Micronecta scutellaris (STÅL)	3,5	2,3,4,5,6,8	1
Micronecta spp.	3,5	1	1
Trichoptera			
Aethaloptera maxima ULMER	2	4,5	4
Amphipsyche scottae KIMMINS	2	4,5,8	1
Cheumatopsyche afra (MOSELY)	2	3,4	1
Cheumatopsyche thomasseti (ULMER)	2	3,4,5,6,7,8	1
Cheumatopsyche ? sp. nov.	2	3	1
Hydropsyche sp.	2	3	1
Macronema capense (WALKER)	2	4,5,8	1
Ecnomus spp.	2,3	3,4,5,6,8	1
	5	8	3,4
Athripsodes harrisoni BARNARD	5	3	2
Athripsodes sp.	3	3	2,3
Parasetodes sp.	5	4	4
?*Nyctiophylax* sp.	5	4	2,3
Hydroptila cruciata (ULMER)	2,3	3,4	1
Orthotrichia spp.	2,3	3,4,5,6,8	1
	4,5	3,4,5,6,7,8	2
Oxyethira sp.	2,4,5	2,3,4	1
Hydroptilid — sand case	2,3	3,4	1
Lepidoptera			
Argyractis periopis HAMPSON	2	4	2,4
Nymphula sp.	5	4	1
Dytiscidae (Col.)			
Laccophilus pellucidus SHARP	5	4,5,6,8	1
Laccophilus cyclopis SHARP	5	6	1
Potamonectes vagrans OMER-COOPER	5	3	4
Uvarus peringueyi (RÉG.)	5	3	2
Dytiscid larvae	5	2,3,4,5,8	3,4
Elmidae (Col.)			
Microdinodes transvaalicus GROUVELLE	2	4	2,3
Microdinodes pilistriatus DELÈVE	2	4	2,3
Pachyelmis convexa GROUVELLE	2	3,4	1
Pachyelmis rufomarginata DELÈVE	2	4	1
Lobelmis harrisoni DELÈVE	2	3,4	1
Helminthopsis bifida DELÈVE	2,3,4,5	3,4,6	1
Helminthopsis ciliata DELÈVE	2	4	2

Animal	Biotope	Zone	Season
Helminthocharis cristula Delève	2.3	3,4	1
Stenelmis gades Hinton	2.3	5	2
Stenelmis thusa Hinton	2	4,5,8	1
Leptelmis fragilis Delève	2,5	3,4	2
Elmid larva type 1	2	3,4	1
Elmid larva type 2	2,3	3,4	1
Elmid larva type 3	3	3,4	2.3
Elmid larva type 4	5	4	3
Elmid larva type 6	2,3	3,4	1
Elmid larva type 7	2	3,4,5,6,8	1
Elmid larva type 8	2	3,4	1
Gyrinidae (Col.)			
Aulonogyrus spp. larvae	2,4	3,4,5,7	1
Orectogyrus spp. larvae	1	3,4	2,4
Haliplidae (Col.)			
Haliplidae	5	2,4	1
Hydraenidae (Col.)			
Hydraenid type A	4,5	2,3,4,5,6,7	1
Hydraenid type B	2,4,5	3,4,5,6	2.3
Hydraenid type C	2,4,5	3,5,6,7	1
Hydraenid type D	5	4	3
Hydraenid type E	5	2,3	1
Hydraenid type G	5	2	2
Hydraenid type H	5	5	2
Hydraenid larvae	4,5	3,4,5,6,7	2
Hydrophilidae (Col.)			
Hydrophilid type A	5	3	3
Hydrophilid type G	5	2,5	1
Hydrophilid larvae	5	2,4,5,8	4
Psephenidae (Col.)			
Eubrianax sp.	2,3	3	2,4
Diptera			
Tipulidae	2,3	3,4	2.3
Anopheles sp.	5	3,4.5	1
Culex sp.	5	2,3,4.5,6	3,4
Simulium adersi Pomeroy	2,4	4,5,8	1
Simulium alcocki occidentale Freeman & De Meillon	2,4	3	1
Simulium bequaerti Gibbins	2	3	2
Simulium ?bovis de Meillon	2,4	3	2
Simulium chutteri Lewis	2,4	5,8	1
Simulium damnosum Theobald	2,4	4,5,8	1
Simulium dentulosum Roubaud	2	3	2
Simulium griseicolle Becker	2,4	5	4
Simulium impukane de Meillon	2.4	3,4	2.3
Simulium mcmahoni de Meillon	2,4	3,4,5.8	1
Simulium medusaeforme Pomeroy	2,4	3,4,7.8	1
Simulium nigritarsis Coquillet	2,4	3,4,5.6,7.8	1

Animal	Biotope	Zone	Season
Simulium ruficorne MACQUART	4	2	4
Simulium unicornutum f. *rotundum* GIBBINS	2,4	3.4	2,3
Simulium vorax touffeum GIBBINS	2	7	2
Simulium wellmanni ROUBAUD	2,4	3,7	2,3
Simulium spp. larvae	2,4	1	1
Chironomini	4,5	1	1
	2,3	4,8	1
	2,3	3,5,6,7	2,3
Chironomus sp.	2,5	8	1
Tanytarsini	1	2,3,4,5,6,7	1
Procladius sp.	5	2,4,6,8	2,3
Tanypus sp.	3	4,5	1
Pentaneura spp.	1	1	1
Corynoneura spp.	4,5	3,4,5,6,7,8	2,3
Orthocladiinae	1	1	1
Bezzia-type larvae	1	1	1
Rhagionid- ?*Atherix* sp.	2,3	4	1
Muscid- ?*Limnophora*	2	4,5,8	2,3
Empididae	2	5	3
Gastropoda			
Gyraulus lamyi (GERMAIN)	4,5	3,4,5,6,8	1
Bulinus sp.	5	4,8	3,4
Burnupia spp.	1	3,4,5,6,8	1
Pelecypoda			
Pisidium spp.	1	2,3,4,5,6,8	1
Corbicula africana (KRAUSS)	2	4,6	2
Anura			
Anuran tadpoles	5	2,3,4,8	3

* *Cloeon crassi* AGNEW and *Cloeon virgiliae* (BARNARD)

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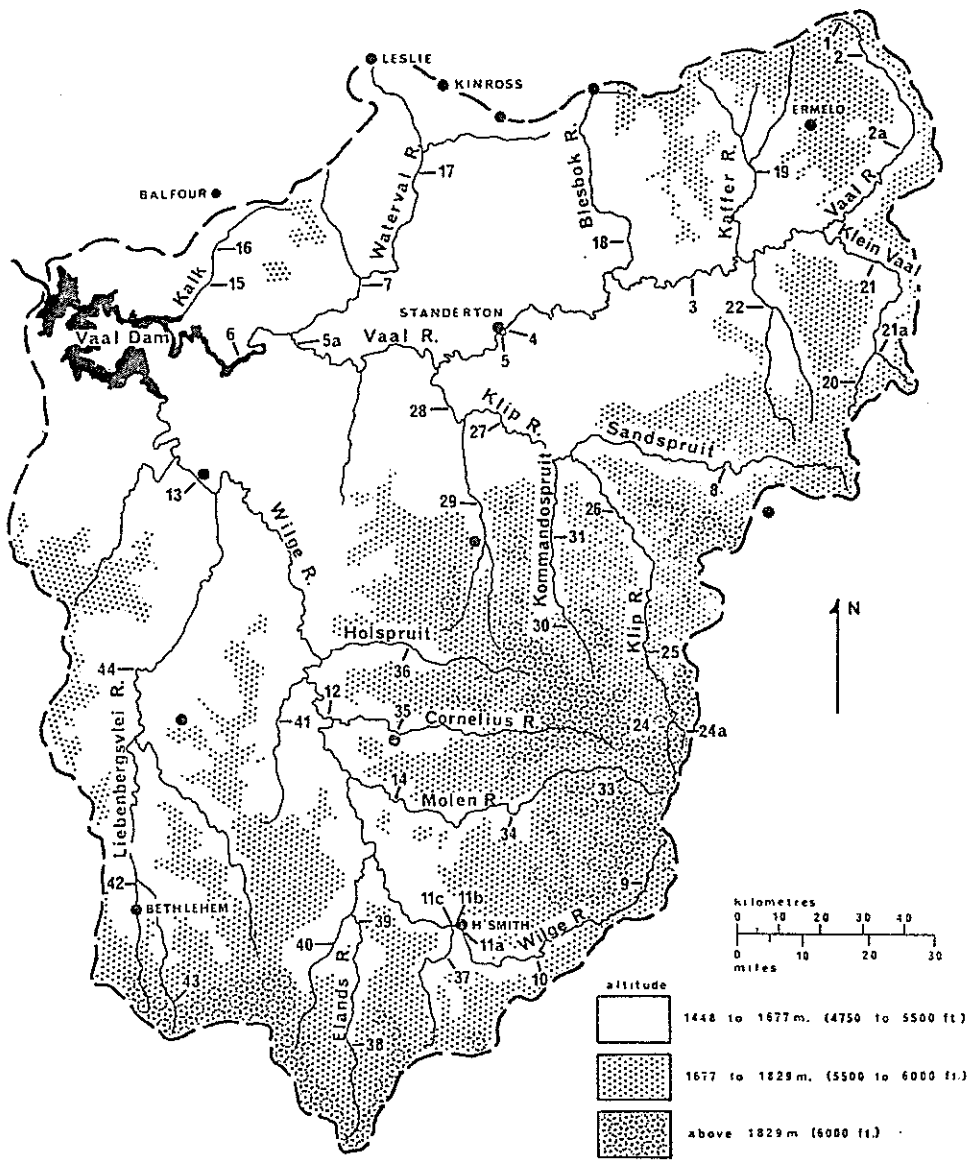

Fig. 1. Water courses, topography, sampling points (numbered) and towns in the catchment of Vaal Dam. Only towns mentioned in the text are named.

b) Laboratory

Methods used in the analysis of water samples were the same as those used by ALLANSON (1961) with the following additions and exceptions:
Nitrate nitrogen was determined by the method of MÜLLER and WIDEMANN (1955);
Sulphates were determined by the method of VOSLOO & SAMPSON (1958);