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Benthic invertebrate communities and the biological assessment of the water quality of the Breede River during 1975 and 1976

A.H. Coetzer 1986

The part of the Breede River included in this study can be divided into three sections based on stream-flow regime. Application of the Bray-Curtis Index of Similarity to the results of invertebrates collected qualitatively in 1975 and 1976 revealed that each river section supported its own unique invertebrate community. These communities changed from 1975 to 1976, with the lowermost section of the river showing the least change. A functional feeding group analysis of the invertebrates and a biological index for the assessment of water quality supported the results of the Bray-Curtis Index and confirmed the existence of the three river sections. The biological index also showed that the middle section of the river, in which flow was augmented by water releases from Brandvlei Dam, had the best water quality.
Bontebok 5:42-51 (1986)

Die gedeelte van die Breërivier wat bestudeer is kan op grond van stroomvloei in drie afdelings onderverdeel word. Toepassing van die Bray-Curtis Indeks van Ooreenstemming op resultate verkry uit kwalitatiewe invertebraat-versamelings gedurende 1975 en 1976, het getoon dat elk van hierdie afdelings van die rivier 'n eie unieke invertebraat-gemeenskap onderhou het. Hierdie gemeenskappe het vanaf 1975 tot 1976 verander, met die minste verandering in die laagliggendste afdeling van die rivier. 'n Funksionele voedinggroep-ontleding van die invertebrate en die toepassing van 'n biologiese indeks vir die bepaling van waterkwaliteit, het die resultate van die Bray-Curtis Indeks ondersteun en die bestaan van die drie rivier-afdelings bevestig. Die biologiese indeks het ook aangetoon dat die beste waterkwaliteit in die middelste afdeling van die rivier voorkom waar stroomvloei deur vrylatings uit die Brandvleidam aangevul word.
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Author's address:
Jonkershoek Nature Conservation Station
Private Bag 5014, Stellenbosch
7600 South Africa

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Introduction

The Breede River is a partially regulated river system in which man's activities have probably resulted in disturbances of the benthic invertebrate communities. The establishment of benthic invertebrate communities is dependent on complex biotic and abiotic interactions, effectively a cause-and-effect relationship for which there is no simple explanation. In ecological classifications ordination techniques can be applied to quantitative data of biotic communities (*e.g.* benthic invertebrates) to demonstrate the degree of relationship which exists amongst different biotic communities. These relationships are expressed by the construction of compositional gradients from a direct comparison of quantitative data of the biotic communities without considering other variables such as environmental factors. Such an ecological classification may provide an indication of the interaction between biotic and abiotic phenomena (Bray & Curtis 1957).

Biological methods for the assessment of water quality have received a great deal of attention during the past few decades (cf. Allanson 1961; Schmitz 1970; Chutter 1972; Hilsenhoff 1977, 1982). These methods include studies of community diversity using mathematical expressions and studies of indicator organisms, but for both methods the calculated estimate is difficult to interpret (Chutter 1975).

Chutter (1972) developed a biological method to assess the water quality of South African rivers. The method is based on the structure of the invertebrate community of the stones-in-current biotope. Each taxon of specific, generic or higher taxonomic level is assigned a quality value (cf. Chutter 1972), the final estimate (*i.e.* the biological index value) lying between '0' (clean unpolluted water) and '10' (polluted water with higher values of chemical parameters associated with organic pollution). This method is based on three hypotheses, namely that the fauna of clean water is definable, that it changes in a predictable way with the addition of organic matter, and that the greater the amount of oxidizable organic matter added the greater the faunal change. The biological index value (BIV) therefore summarizes the difference between an expected natural invertebrate community and the observed invertebrate community in a stream (Chutter 1972).

Merritt and Cummins (1978) classified aquatic insects of North America into functional feeding

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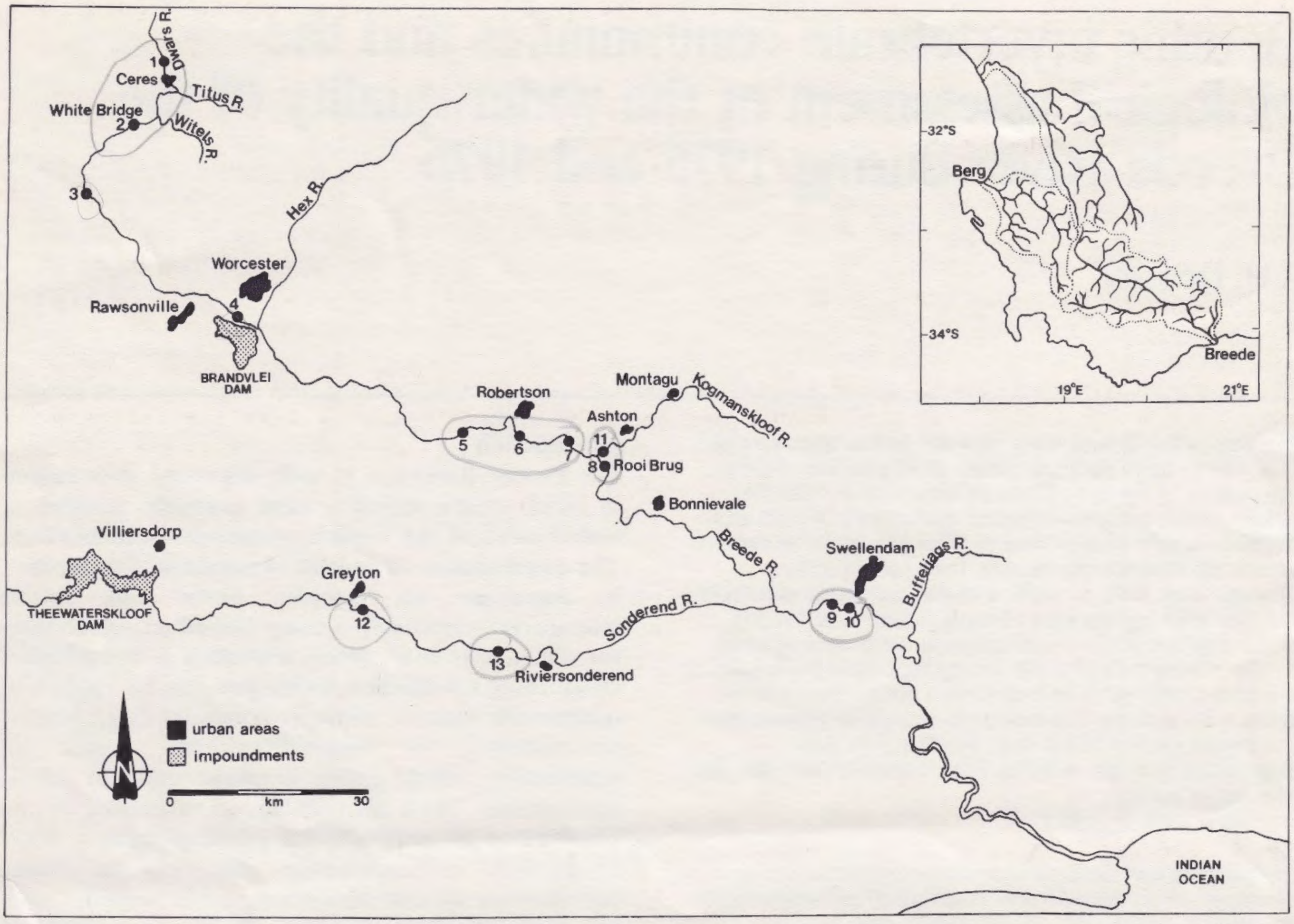

Fig. 1 The Breede River system showing the sampling localities, urban areas and major impoundments.

groups (FFGs) which they related to habitat types. The FFG classification is based on the feeding mechanisms of insects without considering a particular mode of feeding. The compositon of the diet of many aquatic species, however, is dependent on the site, habitat and size of a specific organism (Hawkins 1985) and the FFG classification is therefore based on generalizations. In an attempt to clarify the phenomenon of natural change of aquatic insects along a river course, Vannote, Minshall, Cummins, Sedell and Cushing (1980) made use of the FFG classification to formulate their River Continuum Concept. This was taken further by Ward and Stanford (1983) in their formulation of the Serial Discontinuity Concept. In essence they state that biotic communities adjust to spatial resource gradients caused by downstream environmental change, and that the effect of stream perturbations (discontinuities) can be quantified in terms of 'reset distances'.

The aim of this paper is to describe the aquatic communities present during 1975 and 1976 in a part of the Breede River which was divided into three sections based on stream-flow regime, and document the invertebrate fauna for future use. The Bray-Curtis Index of Similarity was applied in identifying various invertebrate communities which were then compared with those communities identified using FFG analyses. Such a functional analysis, which is based on information for North American insects (Merritt & Cummins 1978), is probably not strictly applicable to the South African situation, and it was therefore not intended to clarify FFG distribution along the Breede River. Based on the assumption that the BIV-method of Chutter (1972) gives a fair assessment of water quality in general, the method was applied to assess the water quality of the Breede River.

Study area

The Breede River system falls within the winter rainfall region of the Cape Province. Streams draining the eastern slopes of the Skurwe Mountains give rise to the Dwars River which becomes the Breede River below Ceres (Fig. 1). It flows southwards for a short distance, turning west and eventually south-east before reaching the Indian Ocean. Streams from the eastern slopes of the Franschhoek Mountains form the Sonderend River which is the main tributary of the Breede River. Water from the upper catchment of the Breede River is diverted to augment the water supply to Voëlvlei Dam situated in the Berg River drainage region. The Theewaterskloof Dam in the upper Sonderend River is interlinked by a network of channels with the Berg River. This study, however, was undertaken before completion of the

Theewaterskloof Dam.

High mountain peaks (1000 to 2000 m a.s.l.) are found in the upper catchment of the Breede River. From here the river descends rapidly to an altitude of 290 m at White Bridge downstream of Ceres, from where the altitudinal fall is more gradual. Mountains of the upper catchment are largely composed of Table Mountain Sandstone containing little soluble salt. Below Wolseley the main river has cut through Table Mountain Sandstone formations, and below Robertson it flows largely over Bokkeveld Shales (cf. Cole 1961; Du Toit 1966). These main geological formations are also found along the course of the Sonderend River.

Larger towns along the Breede River are centres of light industry. Agricultural activities in the upper catchment centre on orchards and vineyards, while further downstream vineyards are replaced by wheatlands. The Brandvlei Dam at Worcester is situated in a natural basin adjacent to the main stream. It receives its water from tributaries draining the eastern slopes of the Du Toit's Mountains. Water released from the dam into the main stream supplies irrigation water to the Robertson area and several weirs across the river divert this water into concrete canals for distribution. The result of these water releases is that the river has become a perennial canal during the dry summer months (Fourie 1976).

Methods

Sampling localities were chosen above and below the main urban centres along the Breede River (Fig. 1; Table 1). The part of the main stream included in this study can be divided into three sections based on stream-flow regime; firstly Localities 1-4 downstream as far as Brandvlei Dam where limited amounts of water are abstracted by riparian farmers for agricultural use although cessation of stream flow may occur upstream of Locality 4 during the dry summer months, secondly Localities 5-7 from Brandvlei Dam as far downstream as Locality 8 (Rooi Brug) where large amounts of water are abstracted for irrigation by means of weirs constructed across the river, and finally Locality 8 (Rooi Brug) downstream to Locality 10 at Swellendam where river flow is mainly a result of return-flow of irrigation water during the dry summer months (Fourie 1976).

Water from the Kogmanskloof River which enters the main stream some distance upstream of Locality 8,

Table 1 Sampling localities along the Breede River system during 1975 and 1976. Loc. = Locality, Alt. = Altitude in m.

Loc.	Grid reference	Alt.	Habitat
1	33° 20′36″S; 19° 17′52″E	450	About 3 km north of Ceres. Stony bottom in stickle.
2	33° 25′15″S; 19° 15′57″E	290	Main-road bridge over Breede River near the farm White Bridge on the Ceres-Wellington road. Stony bottom in a wide slow-flowing stream.
3	33° 32′33″S; 19° 12′31″E	230	Low-level bridge *en route* to Slanghoek. Stones in shallow slow-flowing stretch.
4	33° 41′05″S; 19° 25′19″E	195	Main road bridge over Breede River between Worcester-Villiersdorp. Stones in water with little flow at time of sampling.
5	33° 49′51″S; 19° 47′17″E	160	Weir in rivier on the farm Goree. Stones below weir simulating cascade conditions.
6	33° 50′13″S; 19° 52′25″E	140	About 1,5 km upstream from the farm Silver Oaks which is about 4 km south of Robertson. Stones in stickle.
7	33° 50′44″S; 19° 57′17″E	135	Low-level bridge on the farm Goedemoed about 9 km downstream from Locality 6. Stones in stickle.
8	33° 53′24″S; 20° 00′50″E	125	Road-bridge (Rooi Brug) across Breede River on the Stormsvlei turn-off between Robertson and Bonnievale. Stones in run.
9	34° 04′12″S; 20° 23′27″E	45	Bridge across main river on the farm Ou Pont, about 3,5 km upstream from Locality 10. Stones in run bordering on stickle-cascade conditions.
10	34° 04′02″S; 20° 24′52″E	45	National Road-bridge across Breede River at Swellendam. Stones in shallow slow-flowing river stretch.
11	33° 52′18″S; 20° 00′08″E	135	Road-bridge across Kogmanskloof River between Robertson-Bonnievale. Stones in run or flat, slow-flowing at time of sampling.
12	34° 04′13″S; 19° 36′46″E	185	Road-bridge across Sonderend River in the Greyton Allotment Area, about 2 km due south of Greyton. Stones in flat.
13	34° 07′39″S; 19° 50′23″E	150	Road-bridge across Sonderend River between Riviersonderend and Greyton. Stones in flat.

is highly mineralized (Fourie 1976). This river flows past Montagu and areas of intensive irrigation before its confluence with the main stream. An additional sampling locality (11) was therefore situated in the Kogmanskloof River to check the "biological water quality" of the water entering the main stream. The Sonderend River was sampled only at two localities (12 and 13) because at the time of sampling it was dry for most of its length, except for some marshy areas along its course. Invertebrates collected from these three localities are included in Table 2 as additional information without further discussion.

Table 2 The percentage composition by taxa of benthic invertebrates collected from the Breede River in 1975 and 1976. For each taxon: Top line = 1975 results, italics = 1976 results. Cf = collector-filterer, Cg = collector-gatherer, Pr = predator/piercer, Sc = scraper, Sh = shredder, — = no sample, * = unidentified juveniles, p = present (<0,05%).

FAUNAL IDENTITIES AND FUNCTIONAL FEEDING GROUPS	SAMPLING LOCALITIES 1	2	3	4	5	6	7	8	9	10	11	12	13
COELENTERATA (Pr)													
Hydra sp.	0,0	0,0	1,8	0,0	0,0	1,4	0,0	1,2	0,0	0,0	0,0	0,1	0,0
	—	*0,0*	*2,7*	—	*0,0*	*0,0*	*0,0*	*p*	*0,0*	*0,1*	—	—	—
TURBELLARIA (Pr)	1,4	0,0	0,3	0,0	1,5	0,0	0,0	0,2	0,0	0,0	0,1	0,0	0,0
	—	*0,0*	*0,0*	—	*0,0*	*0,0*	*0,0*	*0,2*	*1,0*	*1,9*	—	—	—
NEMATODA (Cg, Sh, Pr)	0,8	0,0	0,0	0,0	0,0	1,4	0,1	0,2	0,0	0,0	0,3	0,0	0,0
	—	*4,4*	*0,0*	—	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	—	—	—
ANNELIDA (Cg)	33,1	0,0	1,2	0,0	0,0	1,4	0,5	0,0	0,0	0,0	37,3	0,3	0,6
	—	*13,3*	*12,2*	—	*1,9*	*0,1*	*0,0*	*0,5*	*0,0*	*0,5*	—	—	—
OSTRACODA (Cf)													
Cypridopsis sp.	1,3	0,0	0,0	0,0	0,0	0,0	0,0	4,3	0,0	0,0	0,0	0,0	0,0
	—	*0,0*	*12,2*	—	*0,0*	*0,1*	*5,1*	*1,4*	*0,1*	*1,1*	—	—	—
Other spp.	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HYDRACARINA (Pr)	0,1	0,0	0,9	55,0	0,0	11,1	4,0	0,2	0,0	0,0	0,0	0,0	1,8
	—	*0,0*	*0,0*	—	*0,4*	*0,4*	*0,8*	*0,1*	*0,0*	*0,0*	—	—	—
PLECOPTERA (Sh, Sc)	0,0	0,0	1,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	—	*11,1*	*0,0*	—	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,2*	—	—	—
EPHEMEROPTERA													
Baetidae (Cg, Sc)													
Baetis (Acentrella) sp./*Centroptilum varium*	0,0	0,0	0,9	0,0	0,0	2,8	8,1	0,0	0,0	0,0	0,7	0,0	0,6
Baetis bellus	0,0	0,0	0,0	2,5	0,0	6,1	1,1	0,0	0,0	0,6	0,7	0,0	0,0
Baetis harrisoni	1,9	0,0	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	—	*0,0*	*0,0*	—	*10,1*	*0,4*	*10,3*	*6,7*	*5,4*	*13,2*	—	—	—
Baetis latus	0,0	0,0	0,3	0,0	0,0	1,2	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	—	*0,0*	*0,0*	—	*0,8*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	—	—	—
Centroptilum excisum	1,3*	4,6	0,6	0,0	8,9	18,5	5,9	0,8	0,0	0,0	2,1	0,0	22,2
	—	*0,0*	*0,0*	—	*1,1*	*0,1*	*0,1*	*3,5*	*0,0*	*0,0*	—	—	—
Centroptilum medium	1,3*	0,0	0,0	0,0	0,0	4,7	6,4	1,1	0,5	0,4	0,0	0,0	0,0
	—	*0,0*	*1,4*	—	*0,0*	*0,0*	*0,0*	*3,9*	*0,0*	*0,2*	—	—	—
Centroptilum crassi	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,6
Cloeon africanum	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cloeon virgiliae	—	*0,0*	*2,7*	—	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	—	—	—
Pseudocloeon maculosum	0,0	0,0	2,1	0,0	2,2	0,5	6,4	0,0	1,6	1,3	0,0	0,5	0,0
	—	*0,0*	*0,0*	—	*0,0*	*7,1*	*6,5*	*0,4*	*0,0*	*1,1*	—	—	—
Caenidae (Cg)	0,9	0,0	3,8	2,5	6,7	4,0	12,5	0,2	0,0	0,2	0,0	0,1	11,7
	—	*0,0*	*1,4*	—	*7,8*	*1,4*	*1,0*	*0,2*	*0,1*	*1,2*	—	—	—
Heptageniidae (Cf)													
Afronurus sp.	0,0	0,0	0,0	0,0	0,0	1,6	1,5	0,0	0,0	0,0	0,0	0,0	11,1
	—	*0,0*	*0,0*	—	*0,8*	*0,1*	*3,9*	*0,0*	*0,0*	*0,0*	—	—	—
Tricorythidae (Cf)													
Neurocaenis discolor	0,0	0,0	0,6	0,0	2,6	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0
	—	*0,0*	*0,0*	—	*0,0*	*11,8*	*0,0*	*0,1*	*0,0*	*0,3*	—	—	—
Leptophlebiidae (Cf)													
Adenophlebia sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,8
ODONATA (Pr)													
Helothemis/Trithemis sp.	0,0	0,0	0,9*	15,0*	0,0	0,0	0,0	0,0	0,0	0,0	0,1*	0,0	0,0
	—	*0,0*	*0,0*	—	*0,0*	*0,4*	*0,3*	*0,0*	*0,0*	*0,0*	—	—	—
Aeschna/Sympetrum sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0
	—	*0,0*	*2,7**	—	*0,0*	*0,0*	*0,0*	*0,1*	*0,1*	*0,1*	—	—	—
HEMIPTERA (Pr)	1,5	40,9	0,3	0,0	1,1	0,2	0,0	0,2	0,0	0,0	0,1	0,0	5,3
	—	*8,9*	*1,4*	—	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,1*	—	—	—

Table 2 continued

FAUNAL IDENTITIES AND FUNCTIONAL FEEDING GROUPS	SAMPLING LOCALITIES 1	2	3	4	5	6	7	8	9	10	11	12	13
TRICHOPTERA													
Eruciform larvae	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,8
Cheumatopsyche afra (Cf)	8,1	0,0	5,6	0,0	5,6	0,0	2,0	0,9	1,2	0,8	0,4	0,1	0,0
	—	*0,0*	*0,0*	—	*8,2*	*2,8*	*1,0*	*0,4*	*0,9*	*2,0*	—	—	—
Cheumatopsyche thomasseti (Cf)	0,0	0,0	6,8	0,0	3,4	2,1	2,5	7,9	3,9	28,9	0,0	0,4	0,0
	—	*2,2*	*0,0*	—	*3,4*	*3,2*	*4,4*	*0,7*	*4,6*	*10,5*	—	—	—
Macronema capense (Cf)	0,0	0,0	0,0	0,0	1,5	1,4	0,8	0,2	0,0	1,9	0,0	0,0	0,6
	—	*0,0*	*0,0*	—	*2,6*	*0,2*	*0,1*	*0,1*	*0,7*	*2,6*	—	—	—
Hydroptila sp. (Sc, Pr)	0,0	0,0	0,0	0,0	1,5	0,9	2,5	0,0	0,0	1,1	0,8	0,0	8,8
	—	*0,0*	*0,0*	—	*3,4*	*0,8*	*0,9*	*0,2*	*0,8*	*2,6*	—	—	—
Orthotrichia sp. (Cg, Pr)	0,0	0,0	0,0	0,0	0,0	0,0	2,4	1,6	0,0	0,0	0,0	0,0	0,0
	—	*0,0*	*0,0*	—	*0,0*	*1,1*	*0,5*	*0,2*	*0,8*	*0,1*	—	—	—
Oxyethira sp. (Cg, Pr)	0,0	0,0	0,0	7,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ecnomus sp. (Cg)	0,0	0,0	0,0	0,0	2,6	4,7	2,3	4,0	0,3	2,3	0,0	0,0	0,0
	—	*0,0*	*0,0*	—	*4,1*	*7,9*	*4,0*	*3,1*	*0,0*	*5,8*	—	—	—
COLEOPTERA													
Hydraenidae/Hydrophilidae (Pr,Cg,Sc)	0,2	0,0	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,1	0,0
Dryopidae (Sh, Sc)	0,0	0,0	0,9	10,0	0,7	1,6	3,0	1,7	0,0	3,2	0,0	0,0	1,2
	—	*0,0*	*0,0*	—	*0,0*	*0,0*	*0,2*	*0,2*	*0,6*	*1,7*	—	—	—
Gyrinidae (Pr)													
Aulonogyrus sp.	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Orectogyrus sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0
	—	*0,0*	*0,0*	—	*0,0*	*0,1*	*0,2*	*0,0*	*0,0*	*0,0*	—	—	—
DIPTERA													
Chironomini (Cg)	0,6	13,6	0,3	0,0	1,5	0,4	3,2	0,5	0,0	0,6	0,2	0,0	0,0
	—	*0,0*	*1,4*	—	*0,0*	*57,4*	*45,9*	*0,2*	*0,6*	*1,2*	—	—	—
Tanytarsini (Cf, Cg)	0,5	27,3	2,7	0,0	1,9	15,9	12,5	0,7	0,0	6,1	1,2	0,1	5,9
	—	*0,0*	*16,2*	—	*0,0*	*0,0*	*1,6*	*0,5*	*7,8*	*6,6*	—	—	—
Orthocladiinae (Cg, Sc)	9,1	0,0	36,6	2,5	11,9	6,2	5,8	13,6	1,9	40,5	24,9	0,4	8,8
	—	*60,0*	*31,1*	—	*40,3*	*1,4*	*6,3*	*3,3*	*6,3*	*4,7*	—	—	—
Tanypodinae (Pr)	1,9	0,0	1,2	5,0	0,7	0,7	1,5	0,5	0,0	0,0	0,4	0,3	2,3
	—	*0,0*	*1,4*	—	*0,0*	*0,0*	*0,1*	*1,2*	*0,1*	*1,0*	—	—	—
Ceratopogonidae (Cg)	0,2	0,0	0,3	0,0	21,9	2,8	0,0	0,0	0,0	0,0	0,1	0,0	0,0
	—	*0,0*	*0,0*	—	*4,9*	*0,1*	*0,0*	*p*	*0,0*	*0,0*	—	—	—
Simuliidae (Cf)	27,4	0,0	0,9	0,0	3,0	0,0	9,3	59,5	90,3	7,2	22,0	97,7	4,7
	—	*0,0*	*0,0*	—	*10,1*	*1,0*	*1,2*	*70,8*	*68,9*	*7,7*	—	—	—
Other spp.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0
	—	*0,0*	*0,0*	—	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,2*	—	—	—
PELECYPODA (Cg)	0,0	0,0	0,0	0,0	8,2	3,6	1,8	0,5	0,0	2,3	0,0	0,0	0,0
	—	*0,0*	*0,0*	—	*0,0*	*0,5*	*2,7*	*0,3*	*0,1*	*32,3*	—	—	—
GASTROPODA													
Ancylidae (Sh)	7,4	13,6	24,8	0,0	11,5	4,3	2,4	0,3	0,0	1,7	5,8	0,0	10,5
	—	*0,0*	*2,7*	—	*0,0*	*1,8*	*2,7*	*1,6*	*1,0*	*0,8*	—	—	—
Other spp. (Sh)	0,1	0,0	4,7	0,0	0,0	0,9	0,0	0,0	0,0	1,1	2,4	0,0	0,0
	—	*0,0*	*10,8*	—	*0,4*	*0,0*	*0,0*	*0,0*	*0,1*	*0,0*	—	—	—
Total	1291	22	339	40	269	578	794	4656	2968	529	1129	811	171
	—	*45*	*74*	—	*268*	*1675*	*973*	*4161*	*1446*	*1231*	—	—	—

Stream order as defined by Strahler (1954, 1957) was determined from the 1: 50 000 topographical map series with only streams indicated by solid lines being considered. All sampling localities in the main stream were in a third order stream, except Locality 1 where the stream was of the second order.

Qualitative macro-invertebrate sampling was carried out during the first week of March in 1975 and 1976. Certain sampling localities, however, could not be resampled in 1976 because the river was dry. This time of sampling was chosen because it falls within a period of steady stream-flow before the onset of the winter rainfall season.

At each sampling locality invertebrates were collected from the stones-in-current biotope with a hand net or Surber sampler equipped with 290 μm mesh bolting cloth (cf. Chutter 1972). After collection the invertebrates were preserved in formalin for laboratory analysis.

The laboratory method described in Chutter (1963) was used for sorting and counting of invertebrates, except that macro and micro-samples were separated with a 595 μm mesh sieve instead of the 1 mm sieve used by Chutter. Copepods and cladocerans were not included in the counts (cf. Chutter 1972). The biological index value was calculated as:

$$BIV = \frac{(a \times b)}{\text{Sum of all invertebrates per sample}}$$

where a = number of individuals per taxon, and b = quality value (cf. Chutter 1972).

Not all the invertebrates collected were identified to specific level, but at least the level of identification required for calculating the BIV. For example, Chutter (1972) allocated a quality value of '0' to many taxa, and because a quality of '0' does not influence the numerator, further identification became unnecessary.

The BIV in effect measures the departure from a river's ability to support a natural invertebrate community, thus the BIV can be equated with a measure of 'biological water quality'. In the text 'biological water quality' therefore refers to the ability of river-water to support a natural invertebrate community as opposed to 'physical and/or chemical water quality'.

The invertebrate communities of the main stream were determined by the Bray-Curtis Index of Similarity and calculated as:

$$BCI = \frac{2w}{u + v}$$

where u = the sum of all taxa present in sample A
v = the sum of all taxa present in sample B
w = the sum of the lesser values of the taxa common to both samples A and B (Bray & Curtis 1957).

Since invertebrate sampling was of a qualitative nature, the results were reduced to uniformity and expressed as percentages to facilitate comparisons. Because the results were reduced to uniformity, the BCI equalled $\frac{2w.}{200}$

The UPGMA-method (cf. Sneath & Sokal 1973) was applied to the triangular matrices obtained, and the information presented as dendrograms. In calculating the BCI for the main stream only those localities sampled in both years were taken into account, which excluded Localities 1 and 4.

The insect fauna was assigned to five functional feeding groups (collector gatherers, collector filterers, scrapers, shredders, predators/piercers) based on Pennak (1953) and Merritt and Cummins (1978). FFG classification for North American insects was used because it is based on feeding mechanisms, and because such a classification is not available for South African insects. Where a taxon could be assigned to more than one FFG, it was proportionately divided between the groups.

Physical and chemical parameters were not considered in this study because Fourie (1976) investigated some of the mineralization aspects in the Breede River during 1969/70. Because mineralization problems are still a primary concern in the Breede River (Anon. 1986, Chapman 1986), the trend in TDS values revealed by Fourie's study is probably still applicable; *i.e.* low TDS values immediately below Brandvlei Dam, progressively increasing further downstream. The BIV results were therefore compared with the trend in TDS of 1969/70 (cf. Fourie 1976).

Results

Total stream flow for the months that preceded invertebrate sampling was relatively low and fairly constant at White Bridge (Locality 2) in 1975 and at Rooi Brug (Locality 8) for both years (Fig. 2).

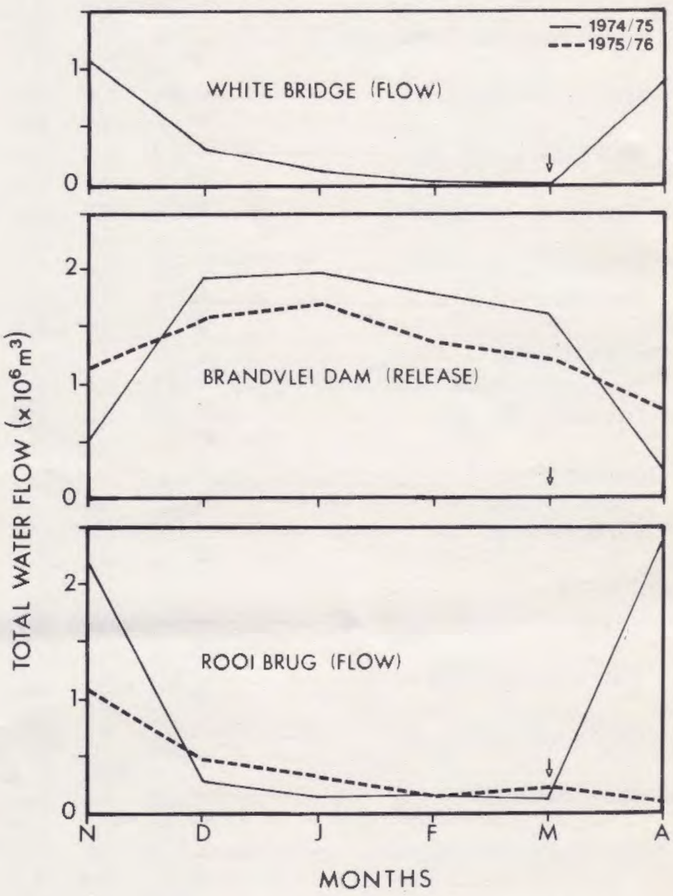

Fig. 2 Total monthly flow volumes for 1974/75 at White Bridge and for 1974/75 and 1975/76 at Rooi Brug, as well as the total monthly irrigation water releases from Brandvlei Dam during the same periods. Month of sampling indicated by arrow. (Hydrological information supplied by the Department of Water Affairs.)

Although flow data are not available for 1976 at White Bridge, it can be assumed that river flow was reduced because there was no water at localities 1 and 4 during the sampling of 1976. At Rooi Brug the monthly flow volume for March 1975 and 1976 differed only slightly. A fairly constant release of irrigation water took place at Brandvlei Dam in 1974/75 and 1975/76, except that the quantities of water released in 1975/76 were generally lower, despite large volumes of water released in November 1975.

The 1975 and 1976 results of the invertebrates were compared (Table 2) and it was found that the proportions of certain taxa changed. For example, at Localities 2 and 3 in the section above Brandvlei Dam, the annelids, plecopterans and orthocladiids increased as a proportion of the total fauna during 1976, while turbellarians, water mites, trichopterans (*i.e. Cheumatopsyche afra, C. thomasseti*), hydraenids, dryopids, simuliids and ancylids decreased. Most taxa that either disappeared, or whose occurrence became reduced upstream of Brandvlei Dam, increased downstream of it in 1976. The exceptions are water mites, hemipterans, dryopids and ceratopogonids, all of which also decreased in the downstream section.

In 1976 the invertebrate groups did not increase uniformly throughout the sections below Brandvlei Dam. For example, *Cheumatopsyche thomasseti* increased as a proportion of the total fauna at Localities 6, 7 and 9, whereas *C. afra* decreased at these localities. In 1976 the proportion of Caenidae increased at Localities 5, 9 and 10 but decreased at Localities 6, 7 and 8. Increases in the proportions of the baetids, tanypodids and ancylids were limited to Localities 8, 9 and 10.

Certain taxa such as *Afronurus* sp., *Macronema capense, Hydroptila* sp., *Orthotrichia* sp., *Ecnomus* sp. and pelecypods were only recorded from below Brandvlei Dam during both years.

Upstream or downstream shifts in the invertebrate taxa were largely at the generic or specific level, and less so at higher taxonomic levels. For example, ostracods occurred at Localities 1 and 8 in 1975, but increased in 1976 in the lower sections of the river because of an increase in *Cypridopsis* sp. The increase in baetid proportions of the total fauna in 1976 was largely due to *Baetis harrisoni, Centroptilum excisum, C. medium* and *Pseudocloeon maculosum*. Most other baetids declined in terms of their proportion of the total fauna. Upstream and downstream shifts in heptageniids and tricorythids were also at specific level.

In both years young unidentifiable anisopterans were present in the section above Brandvlei Dam, but in 1976 *Helothemis/Trithemis* spp. occurred in the middle section and *Aeschna* and *Sympetrum* spp. in the lower section of the river.

The separable invertebrate communities of the main stream during 1975 and 1976 are shown by dendrograms constructed from the Bray-Curtis Index of Similarity values (Fig. 3). The results obtained in 1975 grouped Localities 5, 6 and 7 (Cluster X) of the middle section of the river mainly as a result of the large proportions of baetids and tanytarsines shared by these localities. Localities 8 and 9 in the lower section of the river were clustered together in 1975 (Cluster Z) because of the high faunal proportions of simuliids they shared. Localities 3 and 10 (Cluster Y) shared high hydropsychid and orthocladiid faunal proportions in 1975. Locality 2 had little in common with other sampling localities in 1975 and stood alone (Cluster W).

In 1976 Localities 8 and 9 again formed a cluster (Z) because of the high faunal proportions of simuliids. Locality 10 linked up with this cluster because it shared a large faunal proportion of baetids with Locality 8. Localities 6 and 7 again formed a cluster (X) in 1976 because they shared a large faunal proportion of chironomines. However, Locality 5 did not change in the same way as Localities 6 and 7 and separated off to form a cluster (W) with Localities 2 and 3, all of which had orthocladiid faunal proportions greater than 10%.

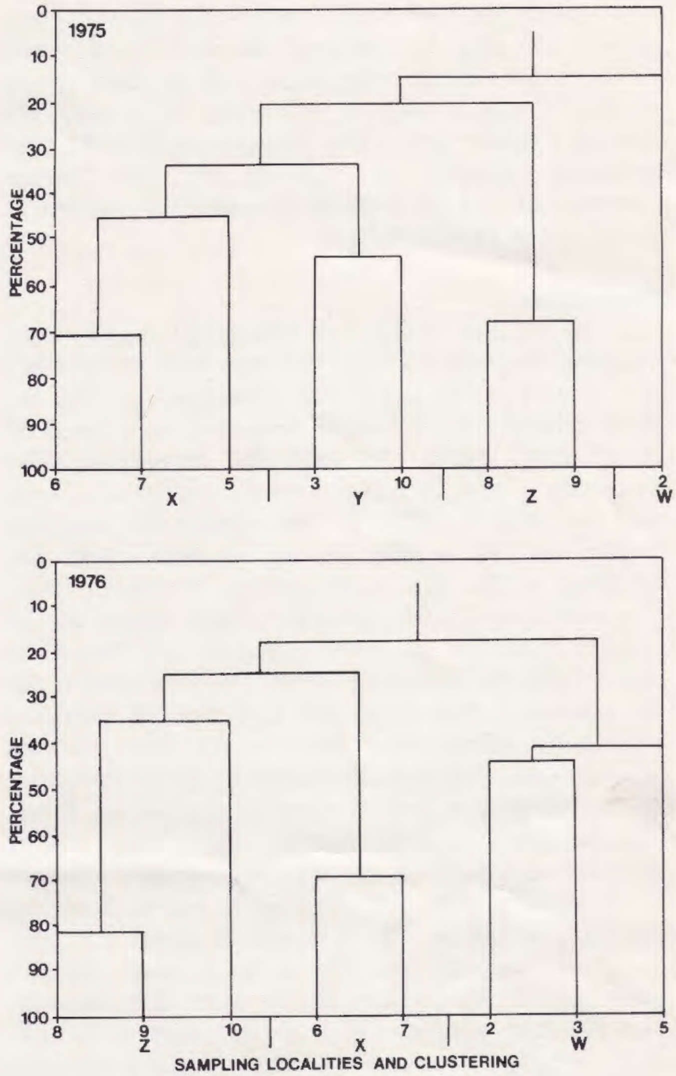

Fig. 3 The percentage of similarity amongst the different sampling localities that were sampled during both 1975 and 1976 as determined by the Bray-Curtis Index of Similarity.

FFG analysis of the three river sections showed that in 1976 the proportions of collector gatherers increased along the whole stretch of the main river studied compared with 1975 (Fig. 4). Scrapers increased in the section above Brandvlei Dam, but decreased in the sections below the dam. Predators/piercers decreased in the upper sections in 1976 but increased below Rooi Brug while the proportion of collector filterers decreased above Brandvlei Dam and remained more or less constant in the sections below the dam. In 1976 the proportions of shredders decreased in all three river sections.

Biological index values started high in the upper river section, decreased towards the middle and increased again further downstream in 1975 (Fig. 5). In 1976 a similar BIV-pattern was found, except that the BIVs in the upper and middle sections where higher than in 1975, and lower in the lower section of the river.

Fourie found that in 1969/70 TDS increased slowly from Locality 4 downstream as far as Locality 7, but with a sharp increase in TDS at Locality 8 and further downstream (Fig. 5). Although the BIVs of 1975 and 1976 are not directly comparable with the TDS values of 1969/70 due to the time difference, BIVs and TDS showed a similar trend. For example, in 1975 the BIV increased sharply at Locality 8 and further downstream, but the increase at Locality 8 was not as prominent in 1976 as in 1975.

Discussion

The Bray-Curtis Index of Similarity grouped the sampling localities for both 1975 and 1976 into clusters which, with certain exceptions, corresponded with the three divisions of the Breede River that were based on stream-flow regime. In 1975 the exceptions were Localities 3 and 10 which formed a separate cluster and in 1976 Locality 5, the uppermost sampling locality of the middle section, clustered with the localities of the river section above Brandvlei Dam. The clustering of 1976 could have been caused by the smaller quantities of water released from Brandvlei Dam. From the clustering pattern for both years it can be concluded that Localities 3, 5 and 10 exhibited transitional characteristics between the three different river sections. Although the Similarity Index confirmed the stream-flow regime divisions of the Breede River, the predominant taxa of the upper and middle sections, as well as the monthly flow volumes, changed from 1975 to 1976. At Localities 8 and 9, however, simuliids remained the predominant group for both years of sampling and the monthly flow volumes showed little change from 1975 to 1976. It is therefore possible that environmental factors, such as stream-flow, largely influenced the invertebrate community composition in the different river sections.

Stream-flow characteristics structure habitat types along a river course and stream-flow also effects erosion and deposit-zones, oxygen saturation levels and temperature (Hynes 1963). Various authors (cf. Hawkins & Sedell 1981; Canton & Chadwick 1983; MacFarlane 1983) have also recognized that the abundance of certain invertebrate FFGs correspond with stream characteristics.

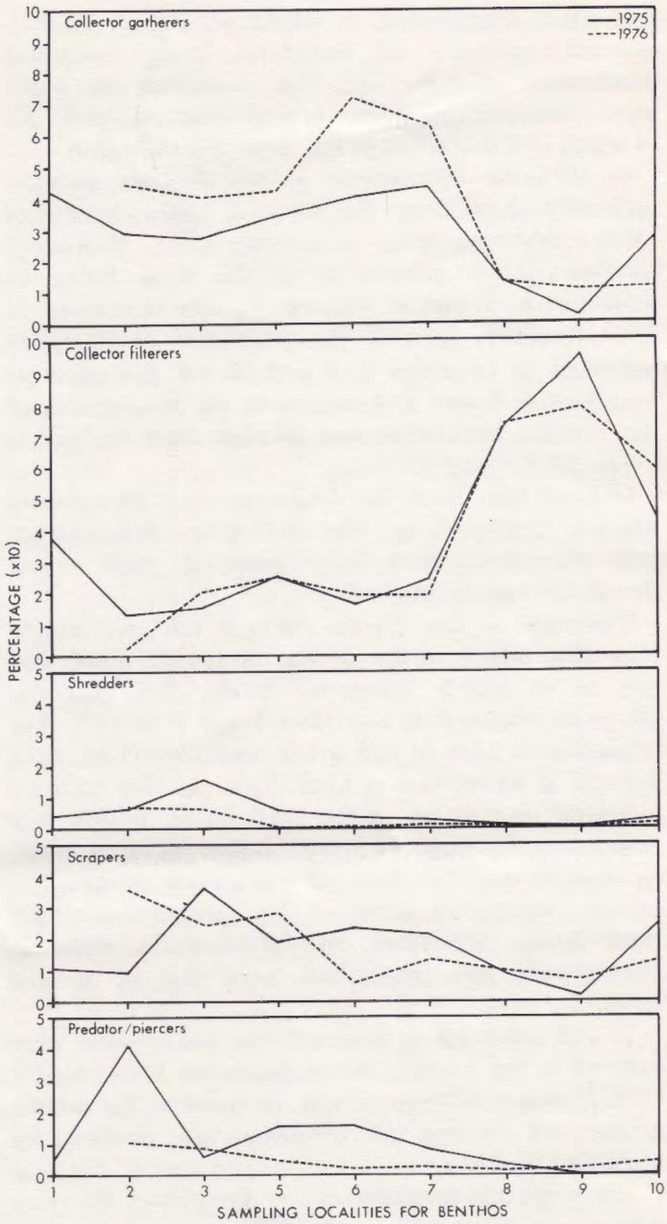

Fig. 4 Distribution of invertebrate functional feeding groups along the part of the Breede River studied in 1975 and 1976, with the exclusion of Locality 4 which was sampled only in 1975.

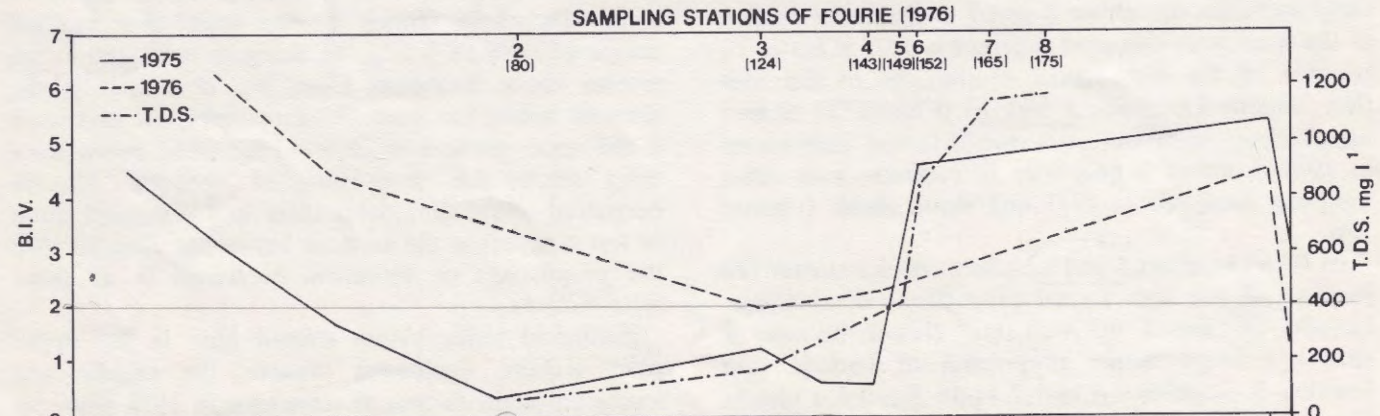

Fig. 5 Biological index values (BIVs) at different sampling localities along the part of the Breede River studied in 1975 and 1976 in relation to total dissolved solid (TDS) concentrations measured in 1969/70. (TDS values taken from Fourie 1976.)

In the United States it was found that collectors increased in importance in downstream sections of rivers (Hawkins & Sedell 1981) and that collector gatherers were more important in deposit-zones (MacFarlane 1983). The fact that the proportions of collector gatherers increased in all three sections of the Breede River in 1976 could probably be attributed to the reduced river flow of that year which resulted in an increase of deposit-zone features throughout the river section studied. This was also corroborated by the fact that the proportion of scrapers was found to have increased in the section above Brandvlei Dam whereas the proportions of collector filterers, shredders and predators/piercers had decreased. This is supported by Hawkins and Sedell (1981) who found that in Oregon streams scrapers were more important in intermediate river sections, and by MacFarlane (1983) who found collector filterers to be more typical of erosion-zones.

The large proportion of collector gatherers in the middle section of the river in 1975 and 1976 could be one of the results of the large amounts of water abstracted for irrigation use, which in turn would have caused an increase in deposit-zone features in this section of the river. Similarly the high proportion of collector filterers in the lower river section could probably be attributed to large amounts of return-flow of irrigation water because erosion-zone features occurred at sampling localities in this section. FFG distribution along the three river sections generally confirmed the results obtained by the Bray-Curtis Index of Similarity which also corresponded with river stream-flow regime.

The BIVs for 1975 categorized Localities 1, 2 and 3 as 'enriched', 'slightly enriched' and 'clean water' respectively (cf. Chutter 1972 for definition of terms). Silt and organic matter observed between the stones at Locality 1 were probably the cause of the high BIV measured in 1975. Locality 2 receives water that has flowed through the town of Ceres. The total number of invertebrates collected at this locality was less than 50 individuals per 0,1 m for both years. In 1976 the biological water quality in terms of the BIV deteriorated to that of 'enriched' water at Localities 2 and 3. The lower BIVs at Locality 3 in both years compared with Localities 1 and 2, were probably a result of clean water that reached the main stream from tributaries draining undeveloped mountainous areas.

Releases of good quality water from Brandvlei Dam were reflected by the low TDS measurements of Fourie (1976). TDS concentrations, however, increased downstream as a result of return-flow of irrigation water (Fourie 1976). For example, Fourie measured TDS as high as 1644 mg l^{-1} in the Kogmanskloof River which joins the Breede River just upstream of Locality 8. BIVs obtained at Localities 5, 6 and 7 in 1975 indicated that the river water was of good biological quality. At Locality 8 the BIV increased sharply in 1975, but less sharply in 1976. In 1976 the Kogmanskloof River was dry and the lower BIV at Locality 8 and further downstream was probably a result of the influence of high TDS loads from the Kogmanskloof River on the biota of the main stream.

BIVs generally confirmed the visual impressions of the water quality, although contradicting values were obtained from Localities 9 and 10. The impression at Locality 9 was that of better biological water quality than Locality 10, but this was disproved by the BIV results. To obtain a higher level of BIV-resolution it would be necessary to study specific faunal and environmental elements, which is not always practical.

Conclusions

In biological terms as well as stream-flow regime, the part of the Breede River studied can be divided into three distinct river sections. These are the section upstream of Brandvlei Dam, the section from the dam as far downstream as Rooi Brug, and the section downstream of Rooi Brug. Conservation monitoring of the biological water quality of the river could therefore be limited to three of the sampling localities used in this study. The results suggest that Locality 2 downstream of Ceres is suitable to monitor conditions in the upper catchment, Locality 5 at the first water abstraction weir situated downstream of Brandvlei Dam to monitor the effect of water releases, and Locality 8 where the influence of both water abstraction and return-flow could be monitored.

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