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Western Cape System Analysis

Berg River Invertebrate Study

November 1992 (Final)

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WESTERN CAPE SYSTEM ANALYSIS

32. BERG RIVER INVERTEBRATE SURVEY

EXECUTIVE SUMMARY

INTRODUCTION

The Berg River in the south-western Cape rises in the Franschhoek and Drakenstein Mountains and flows northwards past the towns of Paarl and Wellington and the village of Hermon, before arcing westwards past Gouda, Piketberg and Hopefield. It reaches the Atlantic Ocean at Velddrif (ca 130km north of Cape Town) in St Helena Bay, and has a total length of about 300km. There are nine major and seven minor tributaries on the Berg River (Figure 32.1.1).

It was the first river in South Africa on which a detailed limnological and chemical study was conducted (Harrison & Elsworth 1958, Harrison 1958a, 1958b, Scott 1958). Follow-up studies in the 1970s (Fourie & Steer 1971, Fourie & Görgens 1977, Coetzer 1978), assessed the Berg River in terms of water quality, mineralisation, and the invertebrate fauna respectively. This extensive historical database for a river system is unusual in South Africa and warrants detailed analyses.

Increased agricultural and industrial development in the Berg River catchment area and the increasing demand for water has focused the attention of "users" on this river system. Concern over the current state of the Berg River has prompted recent studies, including one on water quality undertaken by the Hydrological Research Institute, in conjunction with the Water Quality Management Unit of the Department of Water Affairs and Forestry.

The present study was designed to assess the current status of the invertebrate fauna along the Berg River, and to enable comparisons to be made with an earlier study by Harrison & Elsworth (1958). The current faunal status is assessed in light of water quality and flow records, and tentative conclusions have been drawn with regard to flow requirements for the macroinvertebrates.

METHODS

Invertebrate faunal communities were sampled at ten major (nine on the Berg River and one on the Wemmers Tributary) and four minor stations (all on the Berg River, Figures 32.1.1 and 32.2.1, Table 32.2.1), using benthic samplers to collect animals living in the stones-in-current habitat, and sweep-nets to collect animals associated with marginal vegetation.

Physical and chemical variables were measured, including temperature, conductivity, pH, dissolved oxygen saturation and water clarity.

SUMMARY OF RESULTS

From this survey of the Berg River, it is clear that changes, as assessed by comparing the communities of aquatic invertebrates, have occurred since the Harrison & Elsworth (1958) study.

The Upper Berg Station (Zone II) in the Franschhoek Forest Reserve is the least changed and its faunal community is still similar to that found in 1951.

The most obvious changes have occurred in zone IIIA, especially at the Jim Fouché Bridge station (JFB) where the complete dominance of the faunal community by chironomids is apparent. From this it is clear that pollution, mostly organic, which was previously absent above Paarl (Harrison & Elsworth 1958; Fourie & Steer 1971), is now prevalent. Potential sources of this organic pollution include the trout farm at Dew Dale, transfer of Theewaterskloof Dam water and increased agricultural activities in the Franschhoek Valley.

The middle reaches of the river, which have had a high organic loading since the 1950s, have not changed very much, except for a general increase in organic pollution and silt loading, as indicated by increases in the proportional occurrence of chironomids and oligochaetes.

Changes in the faunal communities of the lower reaches, notably the rarity of certain mayfly species (e.g. *Tricorythus discolor, Baetis bellus*) and the presence of previously less common ones (*Baetis latus*), together with the presence of the estuarine amphipod *Afrochiltonia capensis* at the lowest station, Kersefontein, supports the water quality data in demonstrating increasing salinisation of the lower reaches.

With respect to flow and water quality, it seems probable that changes in the faunal communities of the upper reaches are related both to an increase in discharge from the Theewaterskloof Tunnel, and reduced water quality (e.g. increased agriculture, Theewaterskloof water quality, Dew Dale trout farm). In the lower reaches changes in flow are negligible, and thus the faunal changes noted in this survey presumably reflect changes in water quality over the past 40 years. Since water quantity has either increased or remained the same, one cannot predict the effects of low flow from the data collected.

WESTERN CAPE SYSTEM ANALYSIS

32. BERG RIVER INVERTEBRATE STUDY

CONTENTS **Page No.**

32.1	**INTRODUCTION**		1
	32.1.1	Physical Geography	1
	32.1.2	Geology	3
	32.1.3	Historical Records	3
	32.1.4	Current Status and Industrial Geography	4
32.2	**METHODS**		6
	32.2.1	Study Sites	6
		Mountain Torrent Zone (Zone II)	10
		Upper Foot-hill, Stony Run Zone (Zone IIIA)	10
		Lower Foot-hill, Stony Run Zone (Zone IIIB)	11
		Foot-hill, Soft Bottom Zone (Zone IV)	11
		Flood Plain Zone (Zone V)	12
	32.2.2	Faunal Sampling	12
	32.2.3	Analysis of Data	13
	32.2.4	Physical and Chemical Variables	13
32.3	**RESULTS**		14
	32.3.1	Invertebrate Communities	14
		Faunal communities of the stones-in-current habitat	14
		a) Oligochaeta	16
		b) Plecoptera	16
		c) Ephemeroptera	16
		d) Trichoptera	18
		e) Coleoptera	18
		f) Diptera	18

32.3.1 (Continued)		Page No.
	Fauna associated with the marginal vegetation	19
	a) Mollusca	19
	b) Oligochaeta	19
	c) Plecoptera	19
	d) Ephemeroptera	19
	e) Odonata	21
	f) Trichoptera	21
	g) Hemiptera	22
	h) Coleoptera	22
	i) Diptera	22
	j) Crustacea	23
32.3.2	Physical and Chemical Characteristics	23
32.4 DISCUSSION		25
32.4.1	Description of Changes within Each Zone	25
	Mountain Torrent Zone (Zone II)	25
	Upper Foot-hill, Stony Run Zone (Zone IIIA)	25
	Lower Foot-hill, Stony Run Zone (Zone IIIB)	26
	Foot-hill, Soft Bottom Zone (Zone IV)	26
	Flood Plain Zone (Zone V)	26
32.4.2	Analyses of Communities	27
	Stones-in-current	27
	Marginal vegetation	28
32.4.3	Flow	33
32.4.4	Water Quality	34
32.5 CONCLUSIONS		36

TABLES

32.2.1	Description of sampling stations (number and name), locality and types of samples taken. The zones and station numbers used by Harrison & Elsworth (1958) are included.	7
32.3.1	Physical and chemical variables measured at sampling stations along the course of the Berg River. Minimum (min) and maximum (max) values for Spring 1951 (from Harrison et al 1958) and one-off values taken during the November 1991 survey. (-) indicates no values published.	24

TABLES (Continued)

		Page No.
32.4.1	Average monthly flow values ($m^3 \times 10^6$ $month^{-1}$) for four stations along the Berg River. Simulated flow data for 1950 and patched observed flow data for 1980s. Spring values include the months of September, October and November; and summer values include the months of January, February and March.	34
32.4.2	Values for selected water quality analyses for Spring 1951 within each zone (from Harrison & Elsworth, 1958). (-) = no values given. TDS = total dissolved solids.	35
32.4.3	Values for selected water quality analyses for October 1989 at DWAF gauging stations in the respective zones. (-) = no values given. TDS = total dissolved solids.	35

FIGURES

32.1.1	Map of the Berg River showing the zones, tributaries, towns and relevant landmarks.	2
32.2.1	Map of the Berg River catchment area showing sampling station numbers and names.	8
32.2.2	Schematic diagram of the Berg River showing the tributaries and types of flow.	9
32.3.1	Percentage composition of the major groups of invertebrates in the stones-in-current habitat in 1951 and 1991.	15
32.3.2	Percentage composition of Ephemeropteran (mayfly) families in the stones-in-current habitat in 1951 and 1991.	16
32.3.3	Percentage composition of common baetid species in the stones-in-current habitat in 1951 and 1991.	17
32.3.4	Percentage composition of major invertebrate groups associated with marginal vegetation in 1951 and 1991.	20
32.3.5	Percentage composition of common baetid species associated with marginal vegetation in 1951 and 1991.	22
32.4.1	Dendrogram showing classification of stones-in-current faunal samples collected at seven stations along the Berg River in 1951 (modified from Harrison & Elsworth, 1958).	27
32.4.2	Dendrogram showing classification of stones-in-current faunal samples collected at six stations along the Berg River and one station on the Wemmers Tributary in 1991.	28

FIGURES (Continued) Page No.

		Page No.
32.4.3	Dendrogram showing classification of marginal vegetation faunal samples collected at 12 stations along the Berg River in 1951 (modified from Harrison & Elsworth, 1958).	29
32.4.4	Dendrogram showing classification of marginal vegetation faunal samples collected at 13 stations along the Berg River and one station on the Wemmers Tributary in 1991.	30
32.4.5	Dendrogram showing classification of stones-in-current faunal samples collected in 1951: ○ and 1991: □, and marginal vegetation faunal samples collected in 1951: ◇ and 1991:	31
32.4.6	MDS ordination of stones-in-current faunal samples collected in 1951: ○ and 1991: □ and marginal vegetation faunal samples collected in 1951: ◇, 1991: .	32

APPENDICES

Appendix A : Percentage composition of invertebrate fauna sampled in the stones-in-current and marginal vegetation habitats in "spring" 1951 and November 1991.

Appendix B : Average monthly rainfall (mm) from 1972 to 1989 at two stations in close proximity to the Wemmers River (CCWR), and average monthly inflow and spillage ($m^3 \times 10^6$) to and from Wemmershoek Dam for the years 1972 to 1989. The values above the months of July, August, September and October are spillage values for 1991, immediately prior to this study.

REFERENCES

ACKNOWLEDGEMENTS

TERMS OF REFERENCE

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WESTERN CAPE SYSTEM ANALYSIS

32. BERG RIVER INVERTEBRATE SURVEY

Dallas 1992

32.1 INTRODUCTION

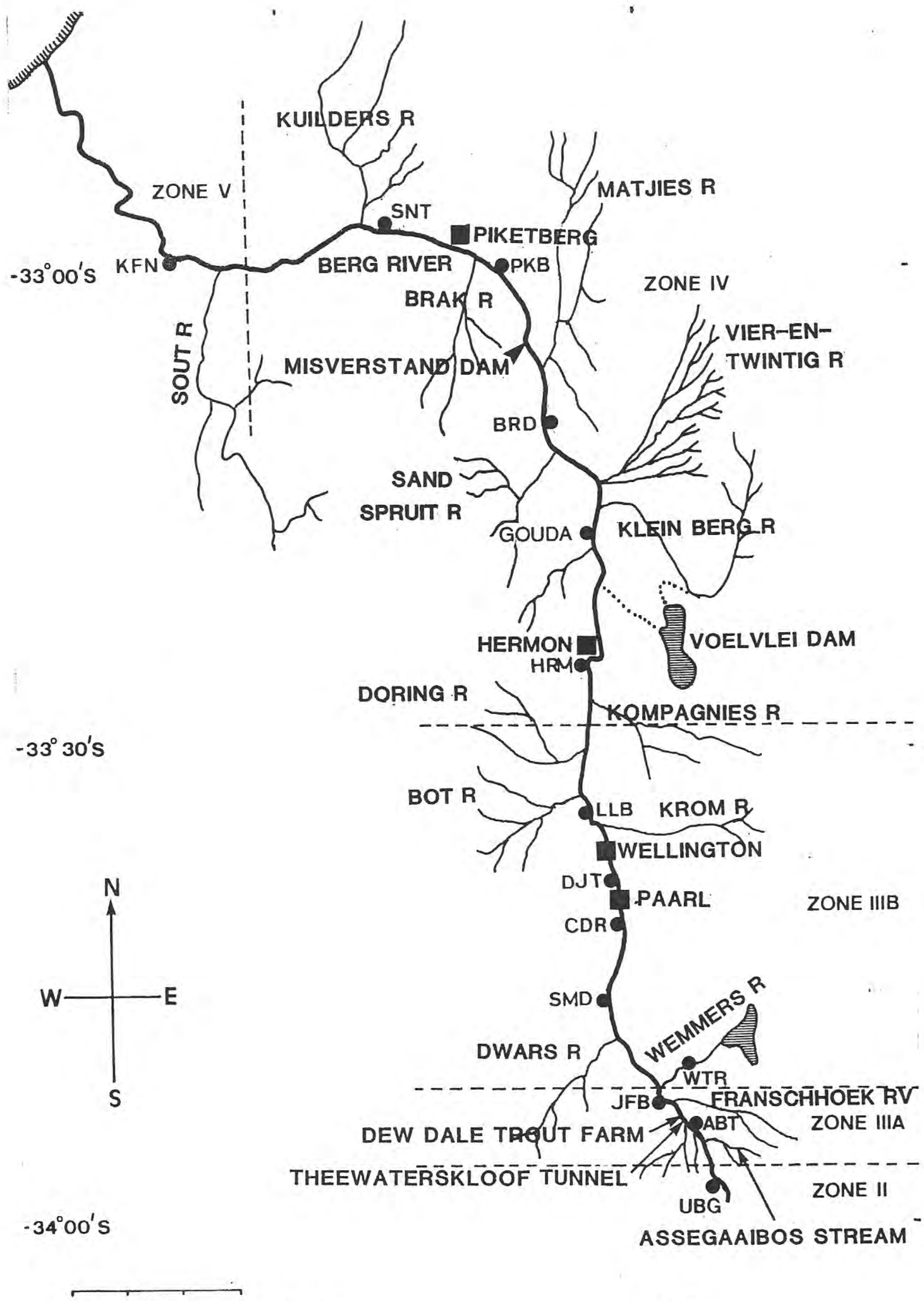
Description of the Berg River

The Berg River was the first river in South Africa on which a detailed limnological and chemical study was conducted (Harrison & Elsworth 1958, Harrison 1958a, 1958b, Scott 1958).

32.1.1 Physical Geography

The Berg River rises in the Franschhoek and Drakenstein Mountains (1220 to 1800m above sea level) approximately 60km east of Cape Town, and flows northwards past the towns of Paarl and Wellington and the village of Hermon, before arcing westwards past Gouda, Piketberg and Hopefield. It reaches the Atlantic Ocean at Velddrif (ca 130km north of Cape Town) in St Helena Bay, and has a total length of about 300km. There are nine major and seven minor tributaries (Figure 32.1.1).

The Berg River Basin lies within the winter rainfall region, although this rainfall is not evenly distributed during the season, and 80% falls as short winter downpours. Rainfall is high - up to 5000 mm y^{-1} in the mountains, but drops to 400-500 mm y^{-1} in the middle and lower reaches. Historically, six of these tributaries are perennial (Franschhoek, Wemmers, Dwars, Klein Berg, Twenty-Four and Kuils Rivers), although flow is often considerably reduced in summer in all but the Wemmers River, which has an upstream catchment area of 125 km^2. A dam completed in 1957 regulated the water flow along this tributary and inflow into the Berg River. The other tributaries are ephemeral and normally dry up in summer. Voëlvlei Dam, constructed prior to 1951 by enlarging a natural lake and later supplementing the inflow with two canals tapping the Klein Berg, Twenty Four and Leeu River tributaries, maintains a minimum flow in the lower river during the dry season. Releases from Voëlvlei enter the Berg River between Hermon and Gouda. Misverstand Weir/Dam is situated between Bridgetown (BRD) and Piketberg (PKB), immediately before the Maatjies Tributary enters the Berg River.



WESTERN CAPE SYSTEM ANALYSIS	Map of the Berg River showing the zones, tributaries, towns and relevant landmarks	32.1.1

32.1.2 Geology

Geologically the Berg is an old river, and the vertical drop from the mountain source to Paarl (12% of its length) is 900 m. The peaks and most of the mountain catchment are composed of quartzitic Table Mountain Sandstone (TMS). Water running off from these formations is generally very low in mineral content, and is acidic and poorly buffered. In the Paarl Region a few small tributaries arise in granite hills and flow through clayey soils consisting of weathered granite material. Near Piketberg the erodable Malmesbury Shales become the dominant underlying rock formation. Associated with these rock formations are large amounts of salts which leach into the water as it flows over them, resulting in a high mineral content in the lower reaches of the Berg River. Tributaries with a particularly high salt content include the Sout, Brak and Matjies Rivers. Another characteristic of the lower reach is the meandering nature of the river, a feature which is directly linked to the erodable nature of the Malmesbury Shales.

32.1.3 Historical Records

The Berg River survey of Harrison & Elsworth (1958) began in May 1950 and continued over a period of three years (hereafter referred to as data of 1951). It included both qualitative and quantitative faunal studies and water quality determinations. Fifteen sampling stations were selected along the course of the river, the first in the pristine upper reach within the Franschhoek Forest Reserve. The lowest station was at Kersefontein (ca 30km from the river mouth) where the upper tidal effect occurs. Sampling was also carried out on certain tributaries, namely the Assegaaibos stream (in the Franschhoek Forest Reserve) and Franschhoek, Wemmers, Dwars, Klein Berg, Matjies and Sout Rivers. This study provides a firm basis of the historical faunal communities and zonation patterns occurring along the river course. Potential sources of pollution included wineries, food-canning and processing, and textile factories located at Paarl and Wellington. Sewage works were associated with the towns. The only factory above Paarl was a fruit-canning factory at Groot Drakenstein. Deciduous fruit and vine cultivations were prevalent in the Franschhoek and Tulbagh Valleys, and grain farming common below Wellington. Mild organic pollution was present below Paarl and Wellington, but the effects of this organic pollution had disappeared approximately 20 km below Wellington.

In the 1970s, two studies, one on water quality from 1963 to 1970 (Fourie & Steer 1971) and one on mineralisation from 1974 to 1976 (Fourie & Görgens 1977) were conducted on the Berg River. They included detailed physical and chemical analyses, bacteriological and epidemiological studies. Above Paarl the river was unpolluted with respect to the physical and chemical conditions/variables. In the Paarl-Wellington area, organic loading was high. In this area stormwater run-off comes from agricultural and urban sources, and industrial activites included wine and spirit production, food processing and canning, wool washing, textile milling, and cigarette and tobacco manufacturing. Water-borne sewage was treated before being discharged into the river. Apart from this semi-urban pollution, most pollution was associated with agricultural activity along the banks, including re-entry of seepage water from irrigation, run-off from ploughed fields and livestock wastes. Increased conductivity in the lower reaches of the Berg River indicate mineralisation and sea-water contamination has been recorded in the last 80km.

In 1972, Coetzer (1978) qualitatively sampled the invertebrate fauna during the months of March, June and September at seven localities, some of which corresponded to the original stations of Harrison. Coetzer used Chutter's Biotic Index to evaluate water quality and to make comparisons with Harrison & Elsworth's (1958) results. Conclusions were that the river had become more polluted organically since the 1951 study, as indicated by an increase in the percentages of chironomids (mainly Orthocladiinae - usually associated with mild organic pollution) and in oligochaetes (associated with more severe pollution). Coetzer also noted vegetation-dwelling ephemeropterans living in the stones-in-current habitat which suggested an increase in silt load and deposition of debris among the rocks. He also concluded that Chutter's Biotic Index gave a satisfactory indication of the pollution status of the river.

32.1.4 Current Status and Industrial Geography

Increased agricultural and industrial development in the Berg River catchment area and the increasing need for water has focused the attention of "users" on this river system. Concern over the current state of the Berg River has led to an investigation by the Hydrological Research Institute, in conjunction with the Water Quality Management Unit of the Department of Water Affairs and Forestry, which is investigating water quality along the course of the Berg River with particular reference to point and non-point sources of pollution.

The upper reaches have been altered since Harrison & Elsworth's (1958), Fourie & Steer's (1971), Fourie & Görgens (1977) and Coetzer's (1978) studies. Two major changes in the Berg River above Paarl include the presence of a trout farm, Dew Dale (begun in 1985), and an interbasin transfer connection which transfers water from Theewaterskloof Dam (Riviersonderend Catchment) to the Upper Berg in summer, and transfers surplus flow from the Banhoek and Wolwekloof tributaries in the opposite direction during winter. The trout farm is situated immediately below the Franschhoek Forest Reserve in the La Motte State Forest [between sampling stations 2 (ABT) and 3 (JFB)]. A detailed study on the effects of trout farms on riverine ecosystems is currently being conducted by members of the Freshwater Research Unit at the University of Cape Town. The effect of transferring water from one catchment area to another has not been ascertained. Both changes may have a significant effect on the water quality and ecology of the reaches below.

The extensive historical database for this river system is unusual in South Africa and warrants detailed analyses. The present survey was designed to enable comparisons to be made with Harrison & Elsworth's (1958) study, so that the current status of the invertebrate fauna could be assessed. The faunal status is also related to water quality and flow records, and tentative conclusions have been drawn with regard to flow requirements for the macroinvertebrates.

32.2 METHODS

The following section outlines the methodology and describes the different zones, sampling stations (Figure 32.2.1) and sites (both on the macro- and micro-scale). Table 32.2.1 summarises this information and relates it to Harrison et al's (1958) study sites. The zonation patterns used are as described by Harrison & Elsworth (1958).

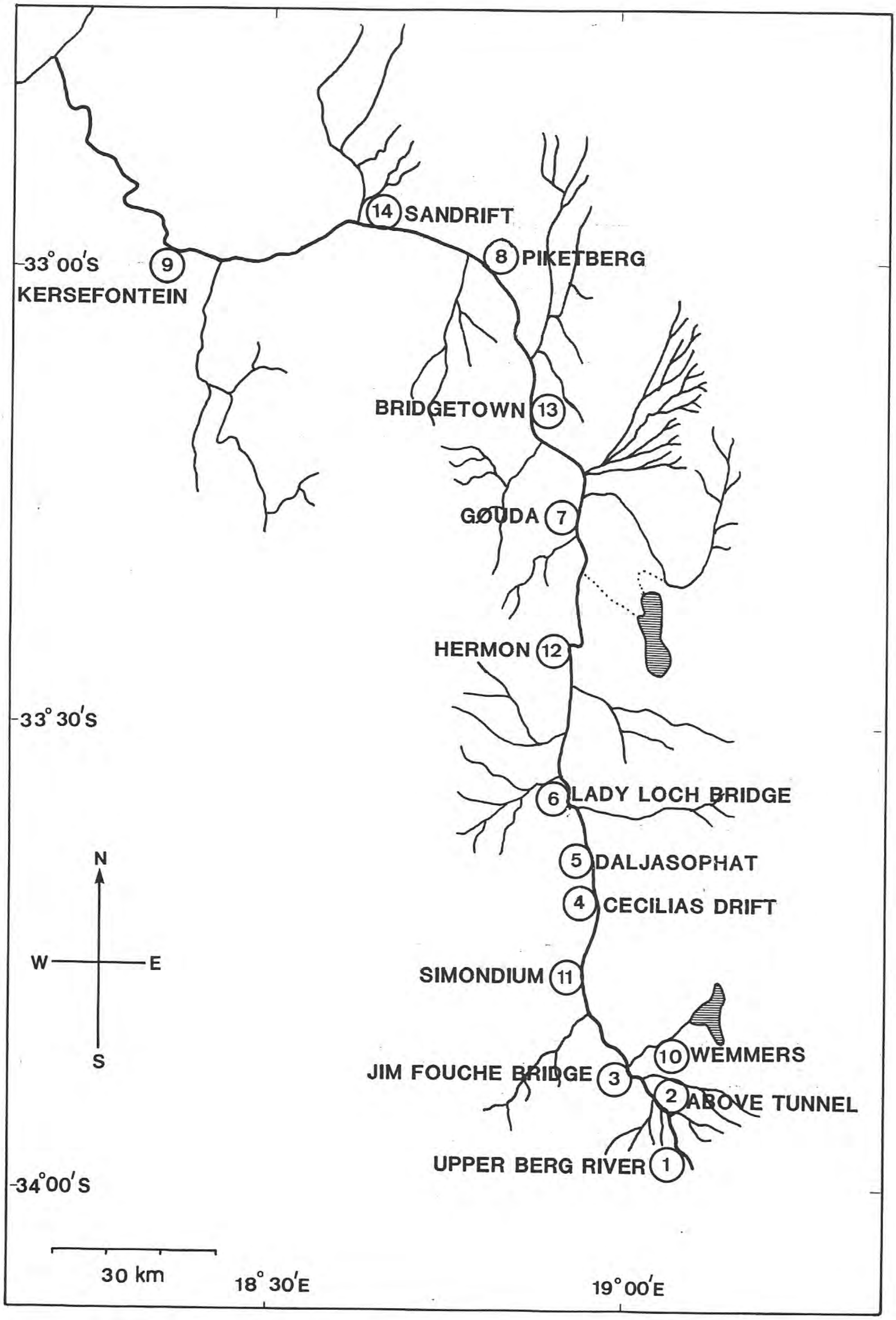
A preliminary reconaissance was undertaken with Professor Harrison to establish first-hand the localities of the original stations used in the 1951 study. Samples were taken as near to the original stations as possible, excepting where developmental changes, e.g. bridge construction, necessitated sampling at an adjacent locality. The survey was conducted in November 1991 over a three day period. Nine major stations were selected on the Berg River and one on the Wemmers Tributary, the latter specifically to check the effect that the construction and regulated flow of the Wemmershoek Dam (built in 1957) has on the aquatic fauna. Four minor stations supplemented the major stations.

32.2.1 Study Sites

The sampling stations are described in the order that they occur down the river. The Wemmers Tributary was described by Harrison & Elsworth (1958) as being very similar to the upper reaches (Station UBG) of the Berg River, and thus it is discussed in the same section as this upper station. A schematic diagram of the Berg River and its main tributaries and inflow pipes from source to sea is presented in Figure 32.2.2.

Table 32.2.1 : Description of the sampling stations (number and name), locality and types of samples taken. The zones and station numbers used by Harrison & Elsworth (1958) are included.

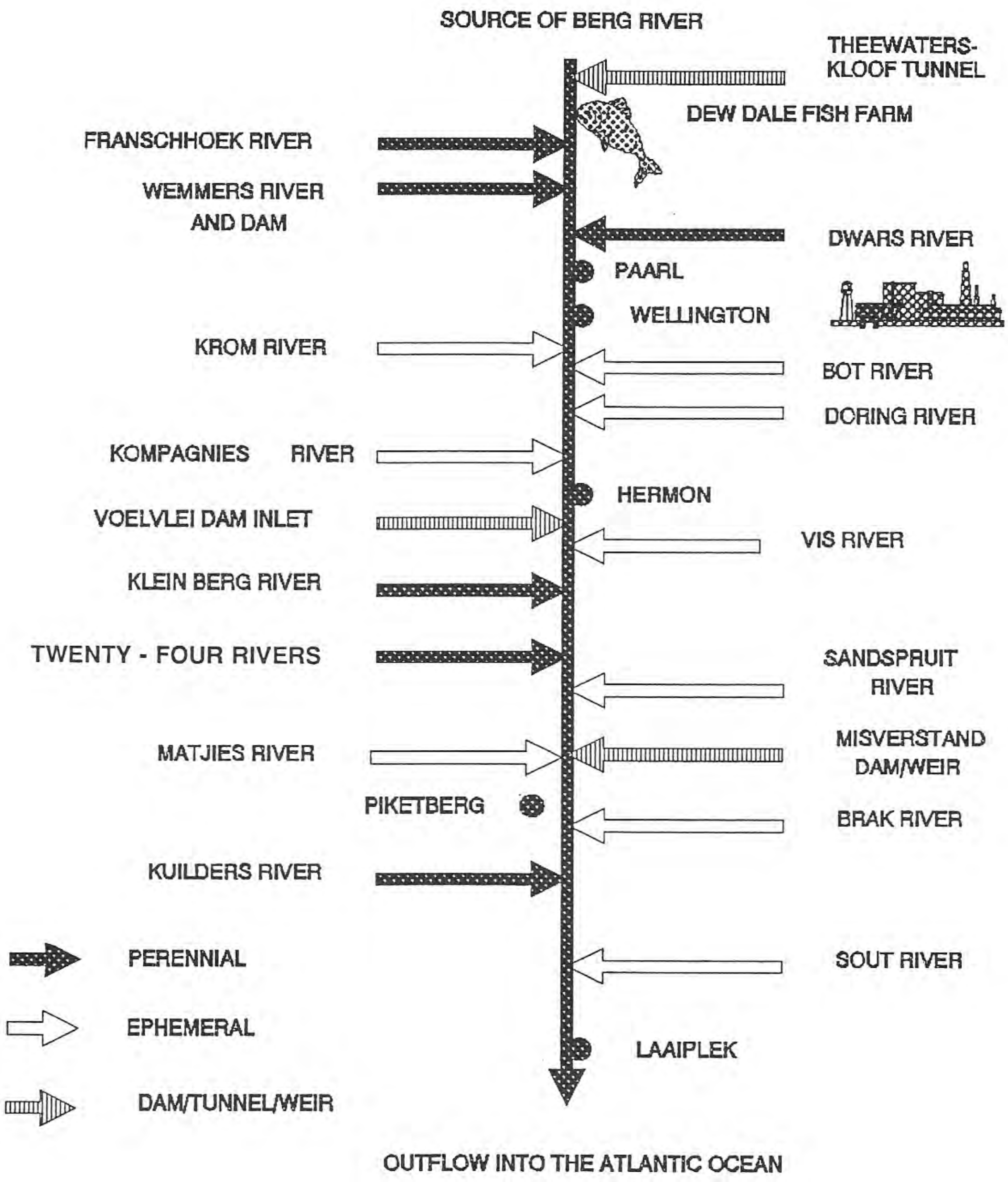
STATION			LOCALITY	TYPES OF SUBSTRATUM SAMPLED FOR FAUNA	NO. OF SAMPLES	HARRISONS STATIONS	
NO.	NAME	TYPE				ZONE	NO.
1	UBG	Major	Pristine stream, Franschhoek Forest Reserve (FFR)	Stones-in-current Marginal vegetation	2 1	II	1
2	ABT	Major	Above Theewaterskloof tunnel, FFR	Stones-in-current Marginal vegetation	2 1	IIIA	3
3	JFB	Major	Road bridge at Jim Fouché picnic area	Stones-in-current Marginal vegetation	2 1	IIIA	5
11	SMD	Minor	Farm Keunenberg, 100m downstream of Simondium	Marginal vegetation	1	IIIB	9
4	CDR	Major	Cecilia's Drift, national road bridge above Paarl	Stones-in-current Marginal vegetation	2 1	IIIB	10
5	DJT	Major	Farm Firgrove, opposite Daljasophat	Sandy bottom Marginal vegetation	2 1	IIIB	11
6	LLB	Major	Lady Loch Bridge, Wellington	Stones-in-current Marginal vegetation	2 1	IIIB	12
12	HRM	Minor	Hermon road bridge	Marginal vegetation	1	IV	13
7	GOU	Major	Goedverwag farm bridge, Gouda	Mixed mud and sand Marginal vegetation	2 1	IV	14
13	BRD	Minor	Farm De Pont, opposite Bridegtown	Marginal vegetation	1	IV	16
8	PKB	Major	Piketberg, national road bridge	Stones-in-current Marginal vegetation	2 1	IV	18
14	SNT	Minor	Farm Sandrift	Marginal vegetation	1	IV	19
9	KFN	Major	Farm Kersefontein	Mud bottom Marginal vegetation	2 1	V	21
10	WTR	Major trib.	Wemmers tributary, road bridge	Stones-in-current Marginal vegetation	2 1		6



WESTERN CAPE SYSTEM ANALYSIS

Map of the Berg River
Showing sampling station numbers and names

32.2.1



Schematic diagram of the Berg River showing the tributaries and types of flow

32.2.2

Mountain Torrent Zone (Zone II)

Station 1 (Upper Berg River, UBG): This station represents the pristine stream in the mountains of the Franschhoek Forest Reserve. The river (ca 3m wide) consisted of runs (water of moderate to rapid flow), riffles (rapid flow with protruding rocks breaking the surface water), cascades (rapid flow over a steep gradient which produces white water) and pools (low and smooth flow over deeper reaches) [classification of habitat sites modified from Allen (1951) in Harrison & Elsworth (1958)]. The unstable substratum consisted of large and small, round and sub-angular rocks and boulders. The water was clear and light brown. Patches of aquatic moss and *Scirpus digitatus* occurred on the more stable surfaces. Marginal vegetation (submerged plants and foliage present at the river's edge) was sparse although small clumps of *Prionium serratum* (Palmiet) were present. Riparian vegetation consisted of pine trees (*Pinus radiatus*) and various fynbos species. Sample 1 was taken in a riffle area above a cascade and sample 2 in a run.

Station 10 (Wemmers Tributary, WTR) : Samples were taken in a riffle area above the road bridge on the Wemmershoek road. The bed is unstable and the substratum consists of large and small, round and sub-angular rocks and boulders, often covered with a silty deposit. Epiphytic algae and slime were present on the rocks. The water was light brown and clear. Marginal vegetation was sparse, with the odd branch of foliage dragging in the water.

Upper Foot-hill, Stony Run Zone (Zone IIIA)

Station 2 (Above Theewaterskloof Tunnel, ABT) : The river (ca 6m wide) was sampled above the inflow pipe from the Theewaterskloof tunnel, above the small causeway in the Franschhoek Forest Reserve. There were slimy and silty deposits over both the large and small, round and sub-angular rocks. The water was light brown and clear. Marginal vegetation consisted of a few *Prionium serratum* individuals, but most of what was sampled was dead branches, plant roots and debris. Riparian vegetation included pine trees and *Acacia* spp. Sample 1 was taken in a run and sample 2 in a riffle.

Station 3 (Jim Fouché Bridge, JFB) : Samples were taken from the river (ca 4m wide stream in a 10m wide bed) above the road bridge at the Jim Fouché picnic area. Large amounts of silt and slime were deposited over the large and small, round and sub-angular rocks. The water was light brown and clear. The marginal vegetation sampled included some *Prionium serratum*, but again it was mostly dead branches, plant roots and debris. Riparian vegetation included pine trees and *Acacia* spp. Samples 1 and 2 were both taken in a riffle.

Lower Foot-hill, Stony Run Zone (Zone IIIB)

Station 11 (Simondium, SMD) : This was a minor station where only marginal vegetation was sampled. The river appeared to have been physically disturbed by mechanical grading and the natural physical flow patterns appeared to be altered. There were small amounts of slime on the round, sub-angular rocks and the water was light brown and clear.

Station 4 (Cecilia's Drift, CDR) : The area sampled was approximately 200m above Harrison's equivalent sampling area and consisted of fast flowing riffles and runs. Slime covered some of the large and small, round and sub-angular rocks. The water was light brown and clear. The marginal vegetation was sparse and consisted mainly of grasses. The banks were mostly rocky. Samples 1 and 2 were both taken in a riffle.

Station 5 (Daljasophat, DJT) : This was the area between Paarl and Wellington. The substratum was sandy and the river shallow (ca 0,5m). Numerous tracks of dragonfly larvae were present on the sand and there were large amounts of sewage fungus (black and orange) growing in the river. The sand samples were taken with a corer (approximate volume 1750ml). The water was light brown and clear.

Station 6 (Lady Loch Bridge, LLB) : Samples were taken in a run (width ca 10m) above the Lady Loch Bridge below Wellington. The substratum was flat rock mixed with loose shale and sand. "Bottle-brush" plants lined the bank and were very dense in patches. The riparian vegetation included *Acacia* spp., *Eucalyptus* spp. and a vineyard lined one bank. The water was brown and turbid.

Foot-hill, Soft Bottom Zone (Zone IV)

Station 12 (Hermon, HRM) : Marginal vegetation was sampled above the small weir situated immediately underneath the road bridge. The water was very silty and turbid. First signs of canalisation were present and the river-bed was mostly sandy with the exception of one bank section that consisted of large black, jagged pieces of rock.

Station 7 (Gouda, GOU) : Three mud cores were taken on the steeply sloping bank of the canalised river (width ca 15m) at the road bridge at Goedverwag. Part of the river bank was trampled as a result of livestock using the area for drinking. The marginal vegetation consisted of a few grasses and reeds along the bank and the water was turbid.

Station 13 (Bridgetown, BRD) : The marginal vegetation sampled was mostly grasses and reed beds. The river here is still canalised, wide (approximately 50m wide) and deep, with steeply sloping banks, turbid waters and slow flow.

Station 8 (Piketberg, PKB) : Samples were taken on a rocky bed formed by jagged pieces of slate mixed with smaller chips, quartzitic pebbles and sand, downstream of the old national road bridge (river approximately 8m wide). The river water was turbid and the banks were sandy with clumps of reeds and grasses that were sampled for marginal vegetation fauna. All benthic samples were taken in a fast flowing run.

Station 14 (Sandrift, SNT) : A marginal vegetation sample was taken from the grassy verges and overhanging branches. The river is approximately 20m wide, with steep, sandy banks; and turbid, silty water.

Flood Plain Zone (Zone V)

Station 9 (Kersefontein, KFN) : Cores of mixed mud and sand were taken on a gently sloping bank amongst reeds, *Phragmites communis* and *Cyperus textilis,* which form dense patches along the banks. Most of the canal-like river had very steep banks.

32.2.2 Faunal Sampling

Where possible faunal samples were taken in the stones-in-current (rocky substratum) habitat as this generally has a more abundant fauna than sandy areas. Where no rocky substratum was present, samples were taken in sandy or muddy areas. Two quantitative benthic faunal samples were taken at each major station. Qualitative samples of marginal vegetation fauna were taken at all major and minor stations.

Stony-bed animals were sampled using a square-framed benthic sampler (mesh size 250 µm) that sampled 0,1 m^2 of the river-bed, and which was secured flush to the river-bed, and animals inside were collected and immediately placed in 5% formalin. Animals from soft substrata were sampled by taking cores from the substratum. Animals were separated from the sand and mud by flotation and sieving (250 µm mesh). Fauna on marginal vegetation was sampled by sweeping a hand-net through submerged vegetation 10 times and collecting the animals in a 250 µm mesh sieve. In the laboratory all marginal vegetation samples were sorted through a 950 µm mesh sieve, and in instances where the resultant sample was particularly large, sub-samples were taken. Animals were, where possible, identified to a taxonomic level comparable to that of Harrison & Elsworth (1958).

32.2.3 Analysis of Data

Data were analysed numerically (percentage composition) to detect changes in faunal community composition along the river (separately for 1951 and 1991 and for each habitat, namely stones-in-current and marginal vegetation). The relationship between station and years, according to their faunal community structure, was investigated using the classification procedures compiled by M.R. Carr (Plymouth Marine Laboratory, United Kingdom) using the Bray-Curtis index of similarity. Results of the classification were summarised by group average sorting and depicted in dendrogram plots. Similarity between sampling stations and years was reflected on a two-dimensional axis using the multi-dimensional scaling (MDS) ordination technique.

32.2.4 Physical and Chemical Variables

Measurements were made of temperature, pH (Crison pH meter Portable 506), conductivity (Crison CDTM-523 conductivity meter), dissolved oxygen (YSI Model-57 oxygen meter) and turbidity (secchi disc, 200mm) at all major and minor stations.

32.3 RESULTS

32.3.1 Invertebrate Communities

This section briefly describes the distribution of common faunal groups. Changes noted between 1951 and 1991 study are outlined. In each case, percentage composition values are for percentage abundance within whole samples. Percentage composition values for 1951 are those published as the "spring" data (including September, October and November) of Harrison & Elsworth (1958).

Faunal communities of the stones-in-current habitat

The percentage composition of the major invertebrate faunal groups collected from the stones-in-current habitat in 1951 and 1991 are represented in Figure 32.3.1.

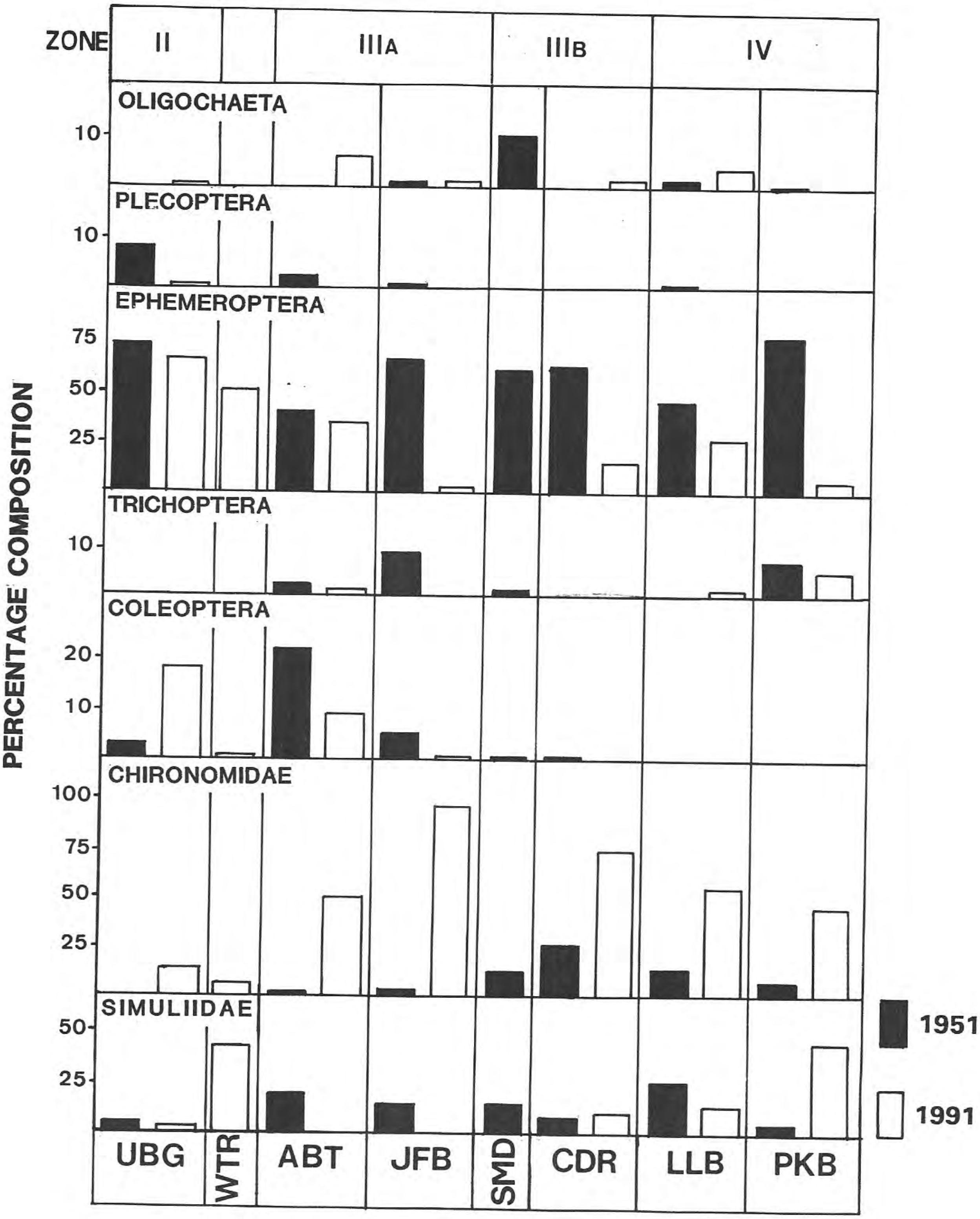


Figure 32.3.1 : Percentage composition of the major groups of invertebrates in the stones-in-current habitat in 1951 and 1991

(a) *Oligochaeta* : In 1951 oligochaetes were uncommon in this habitat except at SMD where *Nais* sp. formed 10% of the faunal composition. In 1991 abundances increased and oligochaetes became more widespread. Notable increases to 5,8% and 3,8% composition were evident at ABT and LLB respectively (this includes *Nais* sp. and *Pristina* sp.).

(b) *Plecoptera (stoneflies)* : Nymphs within the family Notonemouridae (most probably one or more species of the genus *Aphanicerca*) were most common at UBG (8,1%) and ABT (2,4%) in 1951, but were almost completely absent from the stones-in-current habitat in 1991.

(c) *Ephemeroptera (mayflies)* : There was an overall decrease in the percentage of ephemeropterans from 1951 to 1991 (Figure 32.3.2).

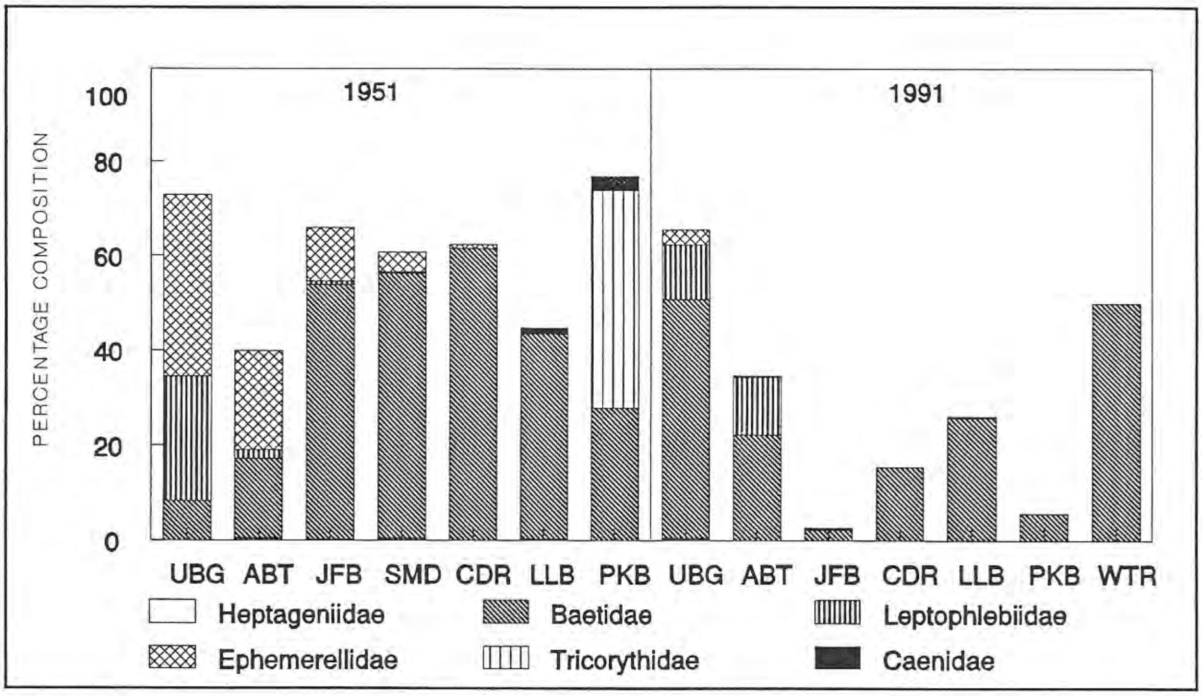


Figure 32.3.2 : **Percentage composition of Ephemeropteran (mayfly) families in the stones-in-current habitat in 1951 and 1991**

(1) *Heptageniidae* : *Afronurus harrisoni* occurred in relatively low numbers in both 1951 and 1991 and was restricted to the upper stations.

(2) *Baetidae* : This was the most common family of mayflies during both study periods (Figure 32.3.3). *Baetis harrisoni* represented the greatest percentage in both years, although in 1951 *B.capensis* formed a significant percentage of the fauna at UBG (4,8%), *B.glaucus* contributed 24% at PKB, while *Pseudocloeon vinosum* was common at CDR and LLB. Harrison et al (1958) suggested that this might be the result of increased vegetable detritus caught up between the stones, since *P.vinosusm* is commonly associated with vegetation. In 1991 *B.harrisoni* was the only baetid consistently found along the river course. *B.harrisoni* was more abundant at UBG and ABT in 1991 than in 1951, and less abundant at JFB, CDR and LLB in 1991 than in 1951.

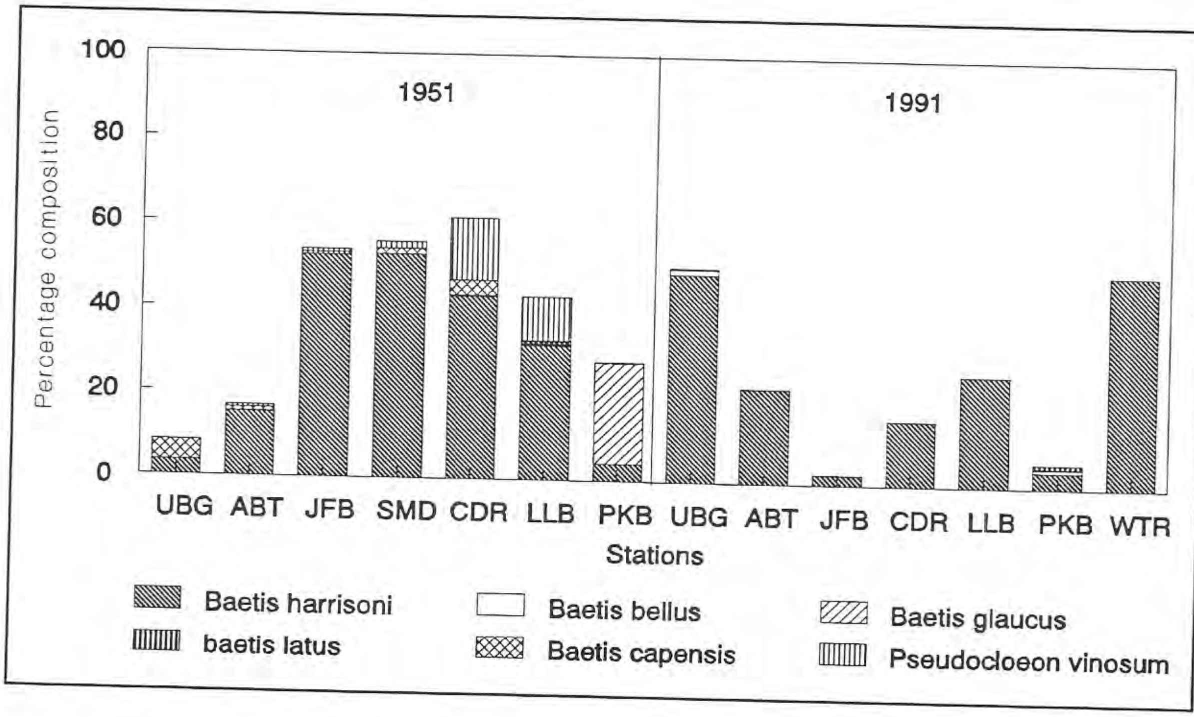


Figure 32.3.3 : Percentage composition of common baetid species in the stones-in-current habitat in 1951 and 1991

(3) *Leptophlebiidae* : This family, mostly represented by the species *Aprionyx peterseni* (8,4%) and *Castanophlebia calida* (17,8%), was numerically important at UBG in 1951. In 1991, *A.peterseni* made up 3,5% at UBG and 12% at ABT, while *C.calida* was common at UBG (8,2%).

(4) *Ephemerellidae* : *Lithogloea harrisoni* constituted 6,6% at ABT and 9,2% at JFB, whilst *Lestagella penicillata* was very abundant at UBG (38,1%) and at ABT (14%) in 1951. Both species were rare in 1991, with *L.penicillata* only making up 2,7% at UBG.

(5) *Tricorythidae* : *Tricorythus discolor* dominated at PKB in 1951 (45,8%) but was rare (2 individuals) at PKB in 1991.

(6) *Caenidae* : *Austracaenis* sp. was important at PKB but was absent in the stones-in-current in 1991.

(d) *Trichoptera* : Fairly high incidence at ABT (2,4%), JFB (8,4%) and PKB (one species *Cheumatopsyche zuluensis,* 6,8%) in 1951. They were much less common in 1991, and formed 4,7% of the faunal composition at PKB.

(e) *Coleoptera* : Helodid larvae were rare in 1951, but fairly common at UBG (11,2%) and ABT (6,3%) in 1991. The elmids, *Elpidelmis capensis* and *Peloriolus granulosus* (both adults and larvae), were abundant at ABT (17,6%, 4,0% respectively), and present at UBG (0,4%, 2,2%) and JFB (2,8%, 2,2%) in 1951. 1991 pecentage composition values were lower, with peak composition occurring at UBG (1,8%, 4,9%), and decreasing immediately at ABT (0,8%, 1,9%). Other coleopteran larvae and adults constituted <0,1%.

(f) *Diptera* : Three families were commonly found in 1951 and two in 1991.

(1) Blephariceridae : *Elporia* sp. had the highest incidence at UBG, but were not found in the 1991 study.

(2) Chironomidae : Percentage composition was greatest at CDR (25,6%) and LLB (12,6%) in 1951. They were significantly more abundant in 1991, and were most common at JFB (95%), then CDR (72,8%), LLB (54,3%), ABT (48,6%), PKB (44,6%) and least abundant at UBG (13,3%). The differences in the mesh size of the collecting sampler between 1951 (approximately 950 μm) and 1991 (250 μm) partly explains this increase in chironomids. Percentage composition at UBG only increased by 12,7% however, and so the increases must be due, at least partly, to other influences.

(3) Simuliidae : They were most abundant at LLB (25,5%), ABT (19,3%) and JFB (14,1%), and < 8% at the other stations. Percentage composition decreased at all stations, with the exception of CDR and PKB (44,8%). In the Wemmers Tributary (WTR), which was reported by Harrison et al (1958) to have a faunal composition very similar to the upper Berg River (UBG), simuliids formed 43,1%.

(4) A few other dipteran species constituted < 0,1%.

In 1991 small numbers of planarians and *Hydra* sp. were noted at LLB but were absent in the spring of 1951. Large numbers of planktonic crustaceans were present at Piketberg (>5000 m^{-2}) and were noted in smaller numbers at most stations along the river. Watermites (Hydracarina) were also present at most stations.

Fauna associated with the marginal vegetation

The percentage compositions of the major invertebrate faunal groups associated with marginal vegetation in 1951 and 1991 are represented in figure 32.3.4.

(a) **Mollusca** : *Lymnaea columella*, which occurred in HRM (2,4%) and GOU (3,6%) in 1951, was not found during the 1991 study. This is an introduced North American species. *Ferrissia* sp. constituted 15,5% at GOU, 2,3% at LLB, 1,6% at PKB and 1,8% at KFN in 1951, and 2,8% at GOU and 3% at KFN in 1991.

(b) **Oligochaeta** : *Nais* sp. formed 5,1% at LLB, while *Stylaria fossularis* was characteristic of SDT and KFN (3,1%) in 1951. *Nais* sp. formed 4,4% at JFB, *Pristina* sp. and *Slavina appendiculata* formed 9% at DJT and 6,4% at LLB.

(c) **Plecoptera** : Notonemouridae formed 11,9% at UBG, but was absent at all the lower stations in 1951, and present at 0,5% at UBG in 1991.

(d) **Ephemeroptera** : The most significant mayflies on marginal vegetation were the baetids (Figure 32.3.5).

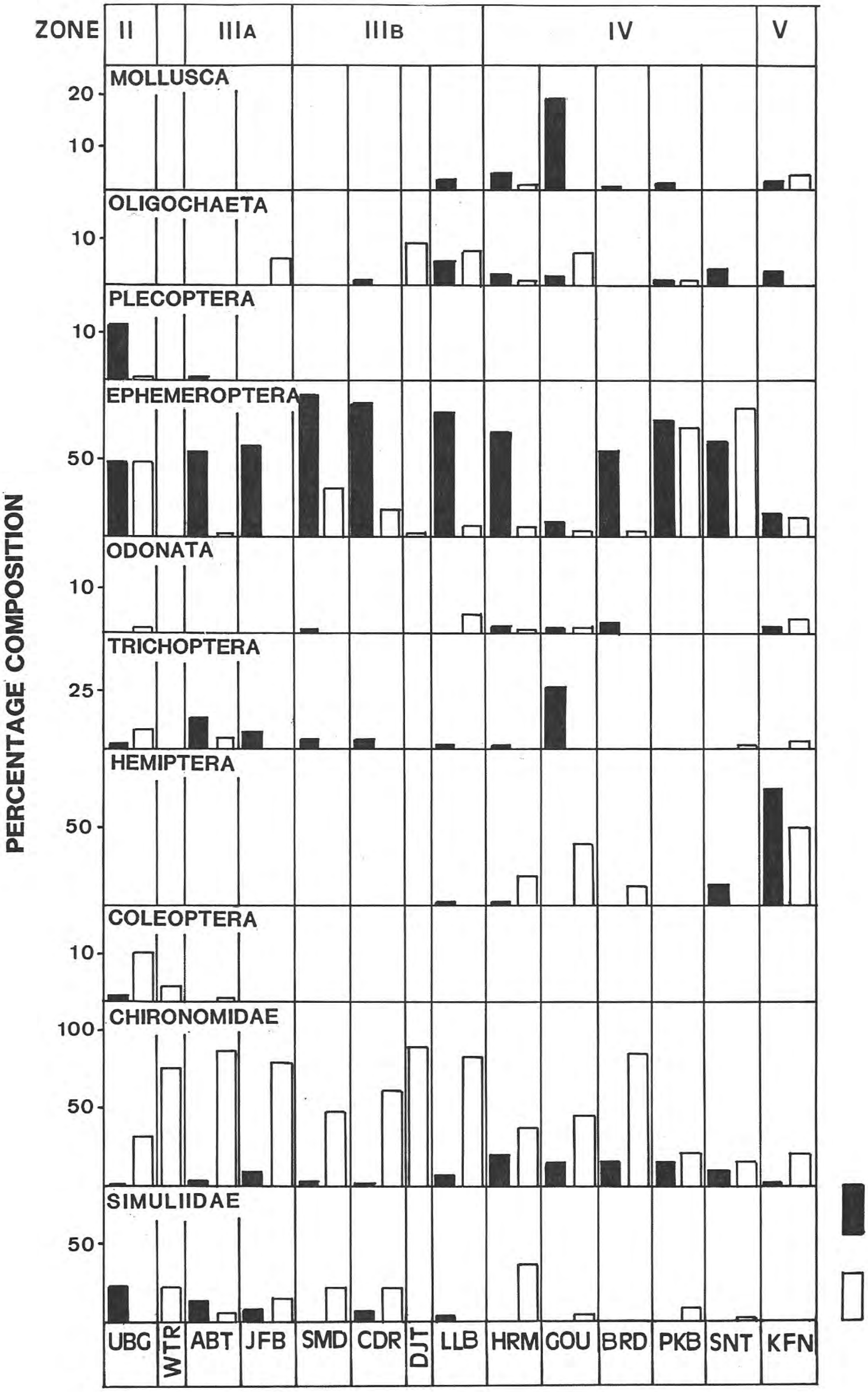


Figure 32.3.4 : Percentage composition of major invertebrate groups associated with marginal vegetation in 1951 and 1991

(1) On average *B.harrisoni* formed ≃ 1% of the species in 1951, and ≃ 5% in 1991. This increase was particularly obvious at SMD (29,9%) and CDR (15,0%). This species is normally associated with stones-in-current, although if flow or disturbance increases it becomes more widely distributed, especially in fast flowing currents near marginal vegetation.

(2) *B.bellus,* a true vegetation dweller, formed a significant percentage of the fauna from LLB (28,8%), HRM (62,9%) to KFN (7,1%) in 1951. However this species had all but disappeared in 1991, and was only of relative importance at HRM (3,7%).

(3) *B.latus* was never numerous in 1951, with the highest percentage at PKB (10%). In 1991 it dominated the marginal vegetation fauna at PKB (68,2%), SNT (80,8%) and KFN (12,1%).

(4) *P.vinosum,* another typical vegetation dweller, was numerous at all stations, peaking at CDR (84,3%) in 1951. In 1991, it formed a significant percentage at UBG (43,7%) only.

(5) *Centroptilum* spp., this includes *C.sudafricanum, C.excisum,* and *Centroptilum* sp.A, although only the latter was found in significant numbers. It was common at the upper stations: UBG (6,7%) to SMD (3,5%) in 1951. These species were only found at UBG in 1991 (total % = 4,1).

(e) ***Odonata*** : Nymphs of *Pseudagrion* sp. (Zygoptera) were relatively common all along the river in both 1951 and 1991. Anisopteran nymphs formed 1,3% of the fauna at LLB in 1991.

(f) ***Trichoptera*** : Individuals of this group occurred all along the river in 1951, highest at GOU (25,8%) and JFB (7,2%). They were mostly Leptoceridae. They were less common in 1991 : 2,9% at UBG, 4,6% at ABT. *Barbarochthon brunneum* (Sericostomatidae) was present at UBG (2,2%) and common at ABT (12,5%) in 1951, but only found at UBG (4,8%) in 1991.

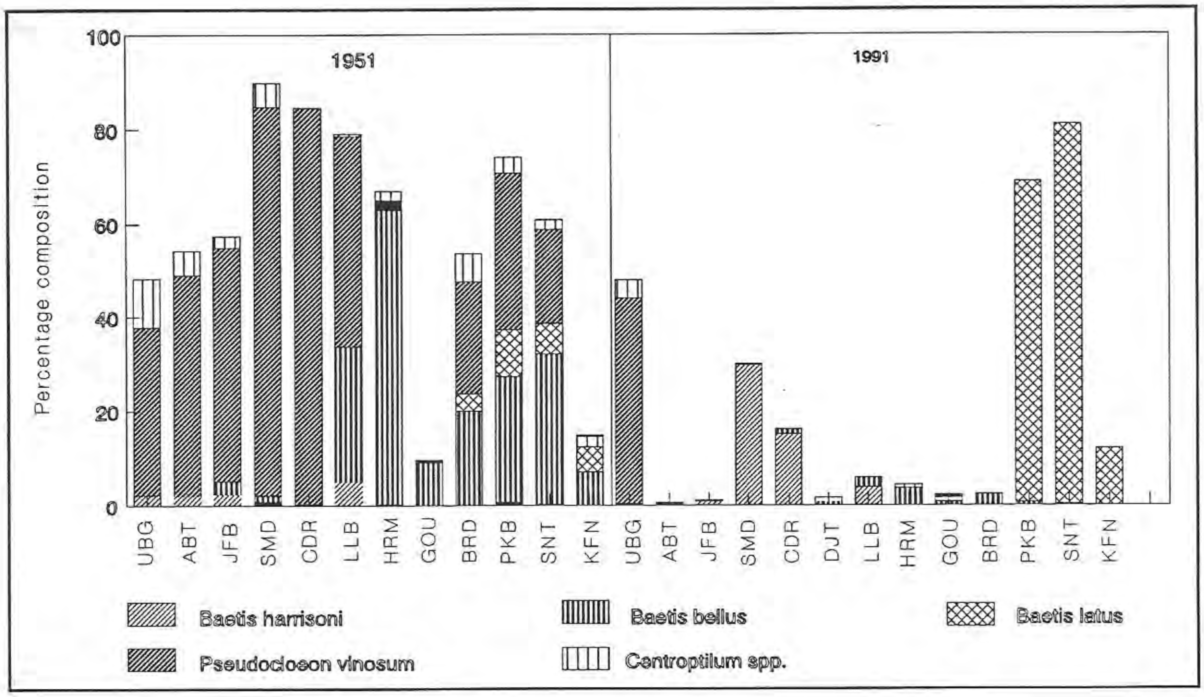


Figure 32.3.5 : **Percentage composition of common baetid species associated with marginal vegetation in 1951 and 1991**

(g) ***Hemiptera*** : Most abundant at the lower stations (KFN 64%) in 1951, but formed greater percentages higher up the river at HRM (17,4%), GOU (31%), BDT (12,2%) and KFN (48,5%) in 1991. Most of these were the corixid, Micronecta diminiata.

(h) ***Coleoptera*** : Very low percentage in 1951, and in 1991 only significant at UBG (10%).

(i) ***Diptera*** :

(1) Chironomidae : Highest incidence at HRM (20,4%) in 1951. In 1991 percentage composition > 70% at ABT, JFB, DJT, LLB and WTR. UBG increased from 0,6% in 1951 to 31,5% in 1991. The effect of mesh size on chironomid numbers should be considered as with the stones-in-current habitat.

(2) Simuliidae : Highest at UBG (22,6%) then ABT (12,9%), decreasing downriver in 1951. Significantly less at UBG (1,1%) in 1991, and greater percentage at HRM (36,2%), and >21,5% at SMD, CDR and WTR.

(j) ***Crustacea*** : Although not examined in detail in the 1991 study, other than the recording and estimating abundance of planktonic organisms, the amphipod *Afrochiltonia capensis* formed 9,1% of the faunal composition at KFN.

A few other organisms are worth mentioning: the Nemertine, *Prostoma* sp. formed 20,6% at GOU in 1951, but had decreased to 1,9% in 1991. *Hydra* sp. formed 3,6% at GOU in 1951, but was absent in 1991.

32.3.2 Physical and Chemical Characteristics

For stations where minimum and maximum 1951 and 1991 temperatures are available, only UBG temperature was higher in 1991 (Table 32.3.1). 1991 pH values were within the minimum/maximum 1951 ranges, with the exception of UBG, ABT, SMD and GOU, all of which had pH values lower than the minima in 1951. Conductivity increased at a number of stations, although the most dramatic increase was at KFN (1951 maximum of 390, 1991 value of 1174 $\mu S\ cm^{-1}$). The dissolved oxygen was always >70% saturation in 1951, but was $\leq$70% saturation at DJT, GOU, BRD and KFN in 1991.

Table 32.3.1 : Physical and chemical variables measured at sampling stations along the course of the Berg River. Minimum (min) and maximum (max) values for Spring 1951 (from Harrison et al, 1958) and one-off values taken during the November 1991 survey. (-) indicates no values published.

Station		Temperature (°C)			pH			Conductivity (μScm^{-1})			Dissolved Oxygen			Secchi disc
No.	Name	1951		1991	1951		1991	1951		1991	1951		1991	1991
		min	max		min	max		min	max		min	max		
1	UBG	10,0	15,0	18,0	4,3	5,9	3,5	8	22	37	100	100	100	1000
10	WTR	-	-	18,5	-	-	4,5	-	-	57	-	-	85	1000
2	ABT	10,0	20,5	17,5	4,7	6,4	4,4	10	19	33	89	100	98	1000
3	JFB	-	-	18,5	5,2	6,8	5,6	16	32	61	82	100	98	1000
11	SMD	-	-	20,5	5,9	7,0	5,5	19	35	76	80	100	100	1000
4	CDR	-	-	18,2	6,0	7,3	6,7	23	78	92	89	100	100	1000
5	DJT	-	-	18,8	6,2	7,1	6,6	30	130	119	82	100	79	1000
6	LLB	12,0	25,0	18,5	6,2	7,1	6,8	32	225	212	0	99	91	800
12	HRM	-	-	18,0	6,6	7,1	6,6	36	160	236	83	99	80	700
7	GOU	-	-	20,0	6,6	7,9	6,3	42	280	151	81	99	74	350
13	BRD	15,0	23,0	22,0	6,4	7,8	6,6	30	295	208	83	98	74	700
8	PKB	-	-	20,5	6,4	8,2	7,0	30	721	531	85	100	84	525
14	SNT	-	-	20,0	6,4	8,2	6,8	35	370	507	81	100	80	450
9	KFN	9,0	23,0	22,0	6,4	7,5	7,0	42	390	1174	71	96	66	225

32.4 DISCUSSION

Description of changes within each zone

Mountain Torrent Zone (Zone II)

This zone (Upper Berg River, UBG) has changed little in the 40 years since Harrison's study. All the species and groups noted in the stones-in-current and marginal vegetation habitats in 1951 were present in 1991, although in some cases, e.g. plecopterans, simuliids and certain ephemeropterans (*Lestagella pennicillata, Castanophlebia calida, Centroptilum* sp.A), percentage composition was lower. The aim of sampling this upper station was for it to act as a "temporal" control, against which changes at the lower stations could be assessed. As already mentioned, the differences in mesh size between the two study periods may contribute partly to the increased incidence of chironomids. Given that the data for 1951 were taken from samples collected over three months (September, October and November) and grouped together as spring, it might also be expected that the richness of this "three-month" sample would be greater than the faunal richness of samples collected over the single survey in November 1991. Such a faunal community at this station is however, still highly varied and rich.

Upper Foot-hill, Stony Run Zone (Zone IIIA)

Initially it was intended to have one station below the Theewaterskloof tunnel so that its effect could be assessed, but earlier examination, in October 1991, by the Freshwater Research Unit showed that few organisms lived immediately below the tunnel outlet. Thus the area above the tunnel was sampled, namely the station ABT. The second station in this zone is below the Dew Dale Trout Farm (not present in 1951) and the inflow of the Franschhoek Tributary. Harrison & Elsworth (1958) remarked that the fauna of this zone was the most varied of the whole river. The faunal variety is still high at ABT, although certain groups, namely chironomids and oligochaetes, are more common now than in 1951, while others (plecopterans, simuliids and the mayfly *Pseudocloeon vinosum)* are less common. These changes are probably the result of a noticeable increase in silt deposits and reduction in marginal vegetation (e.g. palmiet) which was common in 1951. The lower station (JFB) has changed dramatically and has a faunal community dominated by chironomids (95% of the stones-in-current faunal numbers), with oligochaetes and simuliids comprising the remainder. Such a faunal community is indicative of organic and nutrient enrichment. This enrichment may come from the following sources: the Franschhoek Tributary, which is naturally more mineralised (it has its source in the French Hoek Bed formations), and receives run-off and pollution from the town of Franschhoek and neighbouring farms (increased agriculture) and/or from the Dew Dale Trout Farm. Input of water of a different quality from Theewaterskloof may also contribute.

Lower Foot-hill, Stony Run Zone (Zone IIIB)

Harrison et al (1958) noted that all faunal groups decreased in this zone, especially those species typical of the upper reaches of the river, namely Notonemouridae, Leptophlebiidae, Ephemerellidae, Heptageniidae, most Trichoptera, and all Elmidae, while the appearance of Lymnaeidae was important. In 1991 chironomids and the mayfly *Baetis harrisoni* were the most common components of all stations in this zone, with simuliids contributing fairly significantly at SMD and CDR, and oligochaetes at DJT and LLB. The complete absence of *P.vinosum* may again be linked to the increase in silt that accumulates on the trailing vegetation, which is the preferred habitat of this mayfly.

Foot-hill, Soft Bottom Zone (Zone IV)

Certain groups appear for the first time, namely corixids, (mostly *Micronecta diminiata*), and lymnaeid molluscs. Chironomids contributed significantly at all stations, whilst simuliids were common at HRM and PKB only. In 1951 *Baetis bellus* was the most common mayfly at most lower stations, although in 1991 *Baetis latus* was most abundant at PKB and SNT. The intrusion of the Malmesbury Shales into the river-bed at PKB provides a stones-in-current habitat that is longitudinally separated from the previous such habitat at LLB. It seems to rejuvenate the river and different mayfly species, such as *Baetis glaucus* and *Tricorythus discolor,* were commonly found in 1951, although rare in 1991. Changes in mayfly species composition may relate to the increased mineralisation of the lower sections of the Berg River as has been reported by various studies (e.g. Fourie & Steer, 1971). This could be tested by determining the relative salinity tolerances of the two baetid species. The Nemertine, *Prostoma* sp. was only found at GOU in 1991.

Flood Plain Zone (Zone V)

This zone was poor in variety and often in number of invertebrates. Corixids, chironomids, nymphs of the mayfly *Baetis latus,* the lymnaeid mollusc *Ferrissia* sp. and the amphipod *Afrochiltonia capensis,* characterise this zone, the latter showing an increase in percentage composition relative to 1951. Again this could be related to increases in salinity. Oligochaetes were very common (especially *Nais* sp. and small lumbricids) in the core samples. The latter are normally associated with the roots of the marginal vegetation, from among which the cores were taken.

32.4.2 Analyses of Communities

Separate analyses were done for the faunal samples of 1951 and 1991.

Stones-in-current 1951 (Figure 32.4.1): Piketberg (PKB), with its Malmesbury Shale intrusions and tropical faunal influence (Harrison, pers comm.), was the first station to split off in the dendrogram. The Upper Berg Station (UBG) was 20% and ABT 40% similar to the other stations which formed a group (JFB, SMD, CDR, LLB).

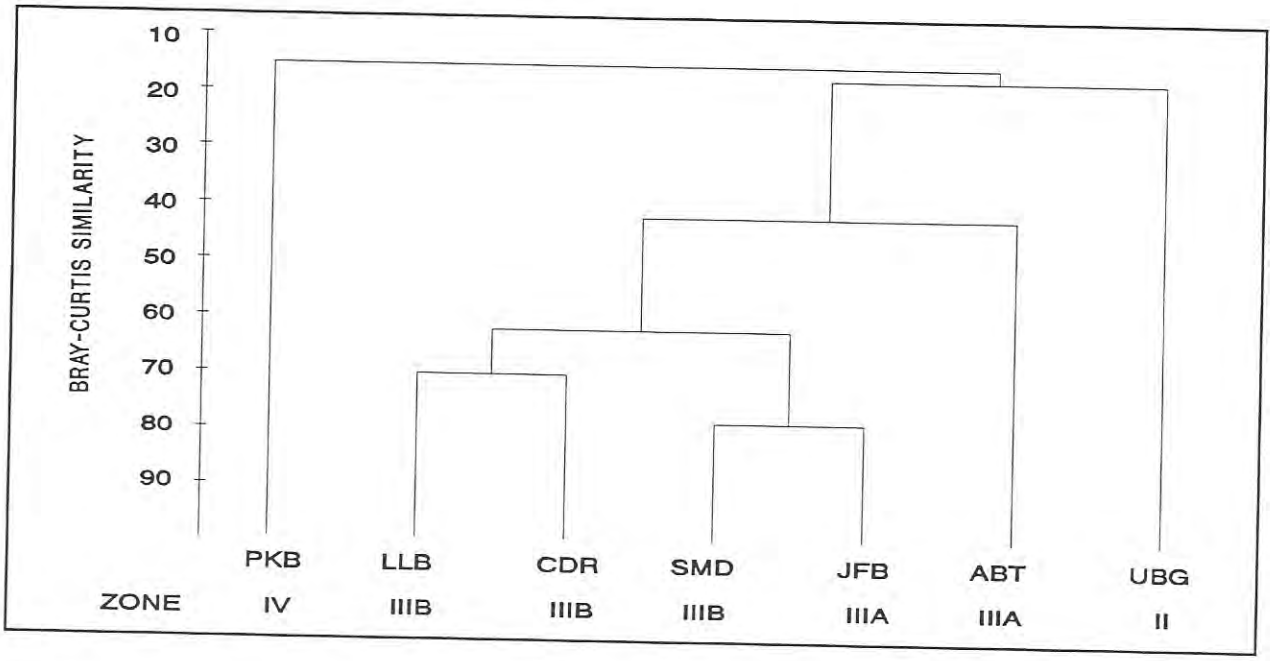


Figure 32.4.1 : **Dendrogram showing classification of stones-in-current faunal samples collected at seven stations along the Berg River in 1951 (modified from Harrison & Elsworth, 1958)**

Stones-in-current 1991 (Figure 32.4.2): Piketberg (PKB) only split off at the 60% level, indicating that the fauna at this station was no longer distinct. The UBG was grouped with the Wemmers Tributary (WTR), but was distinct (30% level) from the other stations. This suggests that little change has occurred in the Upper Berg River or in the Wemmers Tributary even though a dam was constructed on the latter in the late 1950s. It should however be noted that the sampling was conducted immediately after the rainfall season and when spillage from the dam was occurring (see Appendix B). The impact of the dam during this period can be expected to be at its lowest, and to realistically assess this impact further samples should be taken immediately after the dry season, i.e. January, February and March, when rainfall is low (< 20 mm month^{-1}) and spillage zero (Appendix B).

Separate analyses were done for the faunal samples of 1951 and 1991.

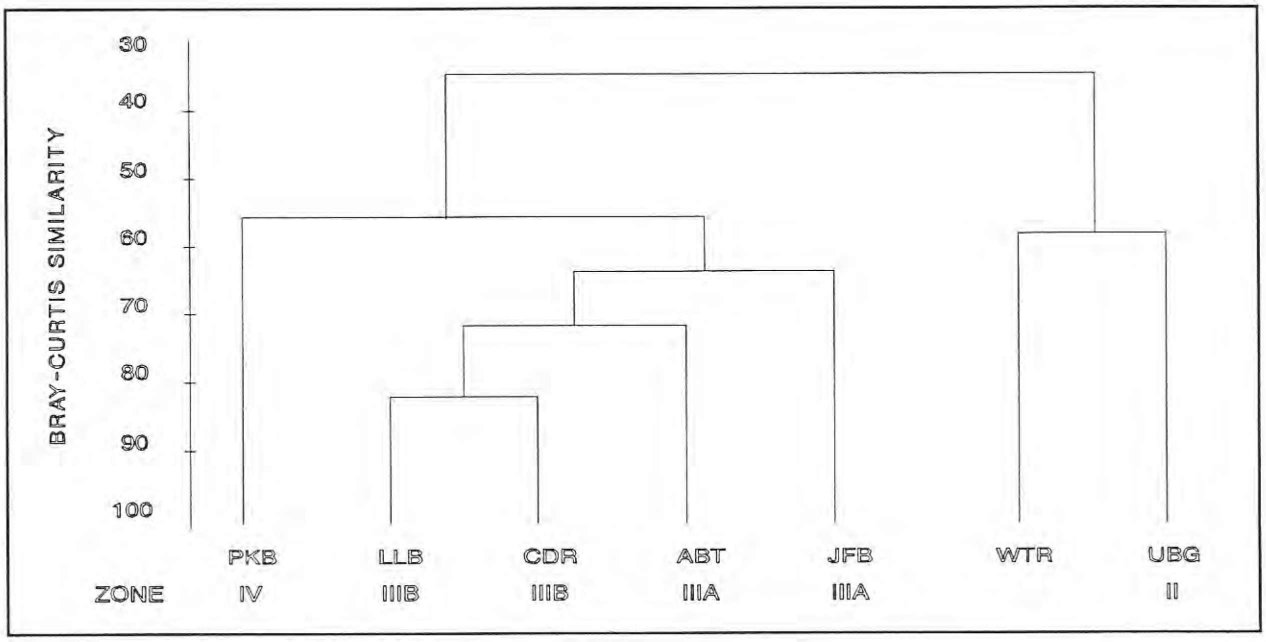


Figure 32.4.2. Dendrogram showing classification of stones-in-current faunal samples collected at six stations on the Berg River and one station on the Wemmers Tributary in 1991.

Marginal vegetation 1951 (Figure 32.4.3) : Zone V (KFN) is distinct from the others, as is Gouda (GOU, Zone IV). The inflow pipe of Voëlvlei Dam was immediately above this station. The upper stations (UBG, ABT, JFB, SMD and CDR) above Paarl form one group and the lower stations (HRM, LLB, BRD, PKB, SNT) form another.

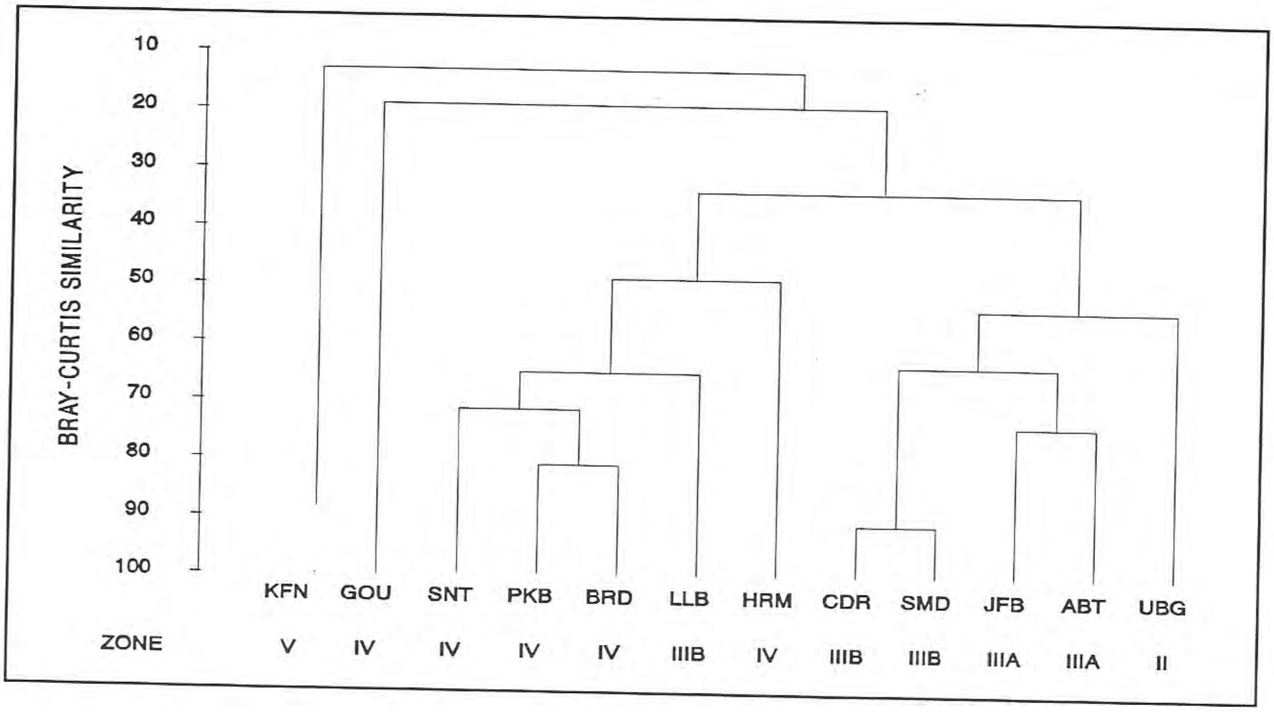


Figure 32.4.3 : Dendrogram showing classification of marginal vegetation faunal samples collected at 12 stations along the Berg River in 1951 (modified from Harrison & Elsworth, 1958)

Marginal vegetation 1991 (Figure 32.4.4) : KFN (Zone V), SNT and PKB (zone IV) are grouped together, GOU and HRM form a group, and the remaining stations, excluding the UBG which splits off at the 30% level, are grouped together.

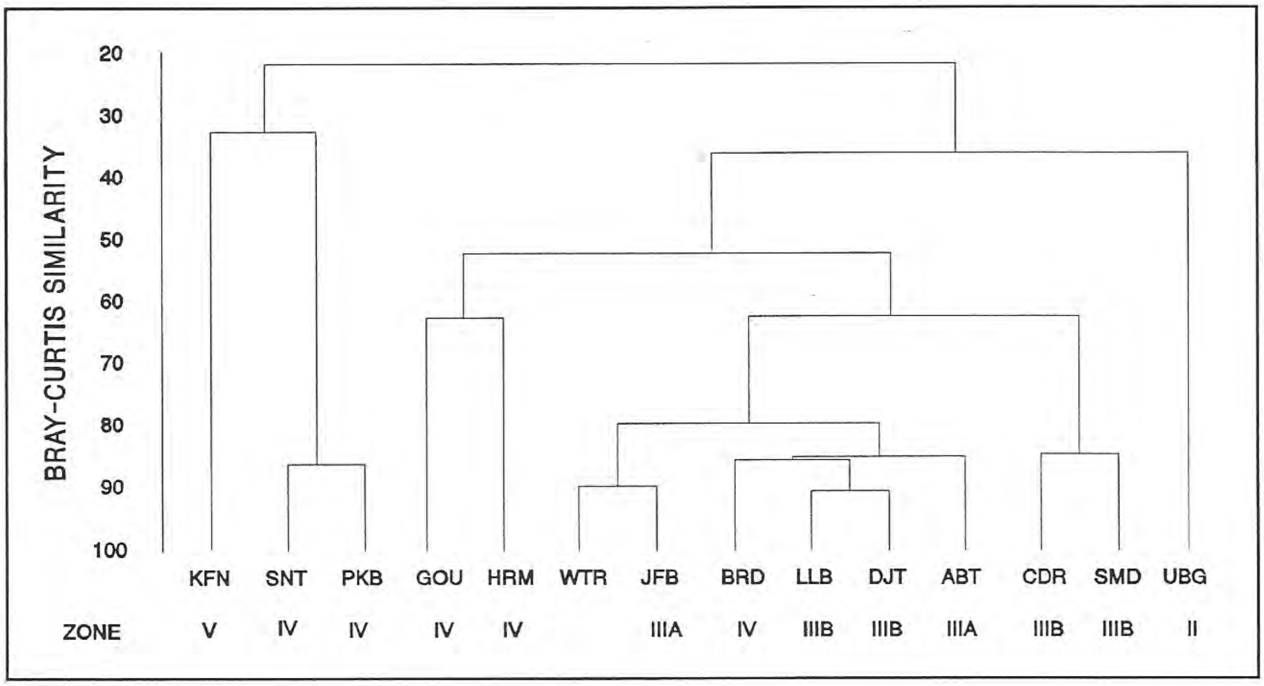


Figure 32.4.4 : **Dendrogram showing classification of marginal vegetation faunal samples collected at 13 stations along the Berg River and one station on the Wemmers Tributary in 1991**

Stones-in-current and marginal vegetation faunal samples for 1951 and 1991 were then analysed together and presented as a dendrogram (Figure 32.4.5) and as an MDS ordination plot (Figure 32.4.6). From both it is clear that the 1951 stones-in-current fauna and marginal vegetation fauna form separate groups. The distinction between fauna associated with these habitat types is less clear in 1991, possibly because of the overall decrease in abundance and change in the type of marginal vegetation and general increase in flow, especially in the upper reaches. Generally, 1951 stations are grouped separately from 1991 stations, with the exception of the Upper Berg River (UBG, both habitats) and the Wemmers Tributary (WTR, stones-in-current habitat), all of which show a tendency to be more similar to the faunal communities of 1951.

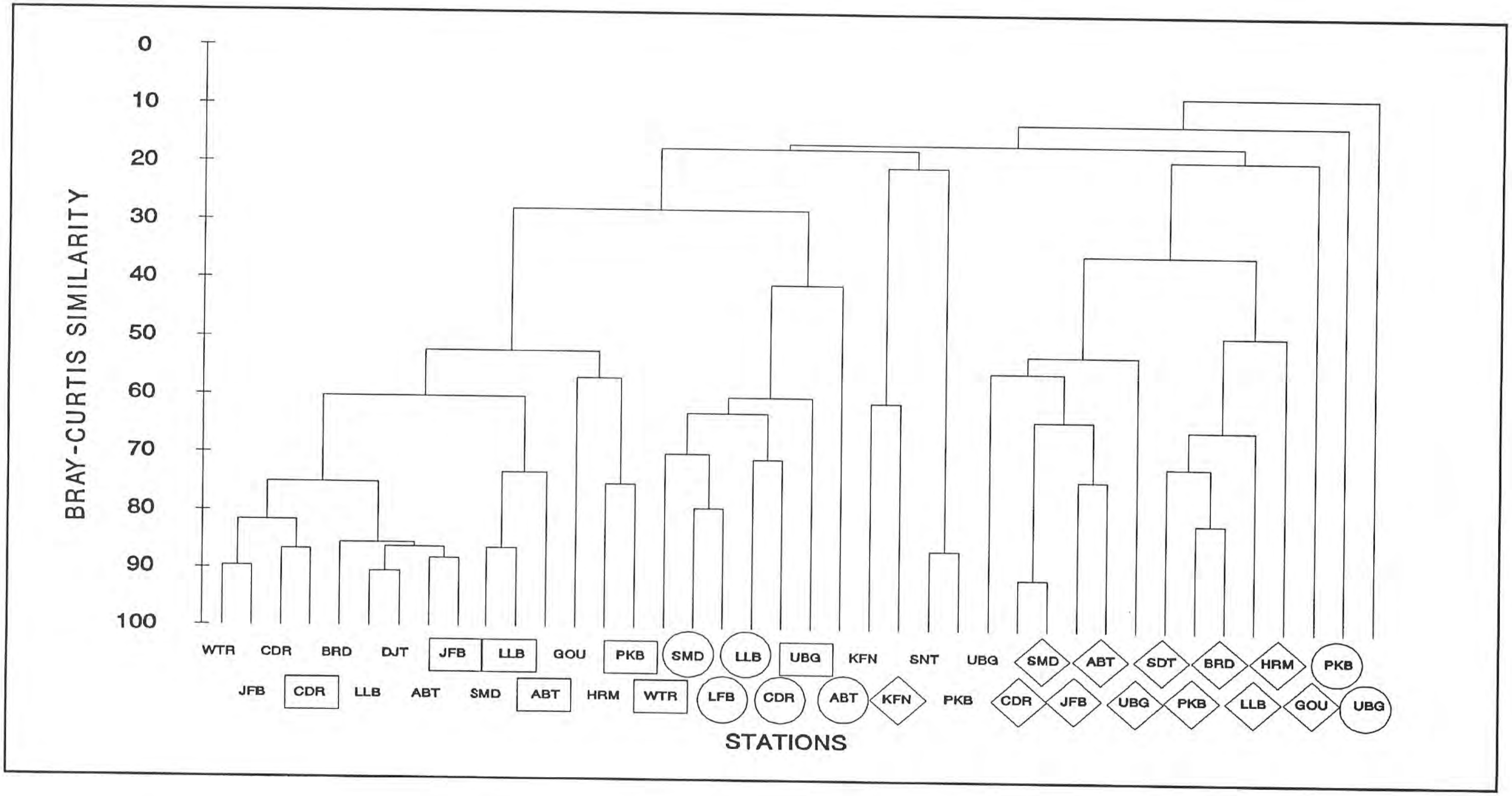


Figure 32.4.5 : Dendrogram showing classification of stones-in-current faunal samples collected in 1951: ○ and 1991: □ ; and marginal vegetation faunal samples collected in 1951 : ◇ and 1991 :

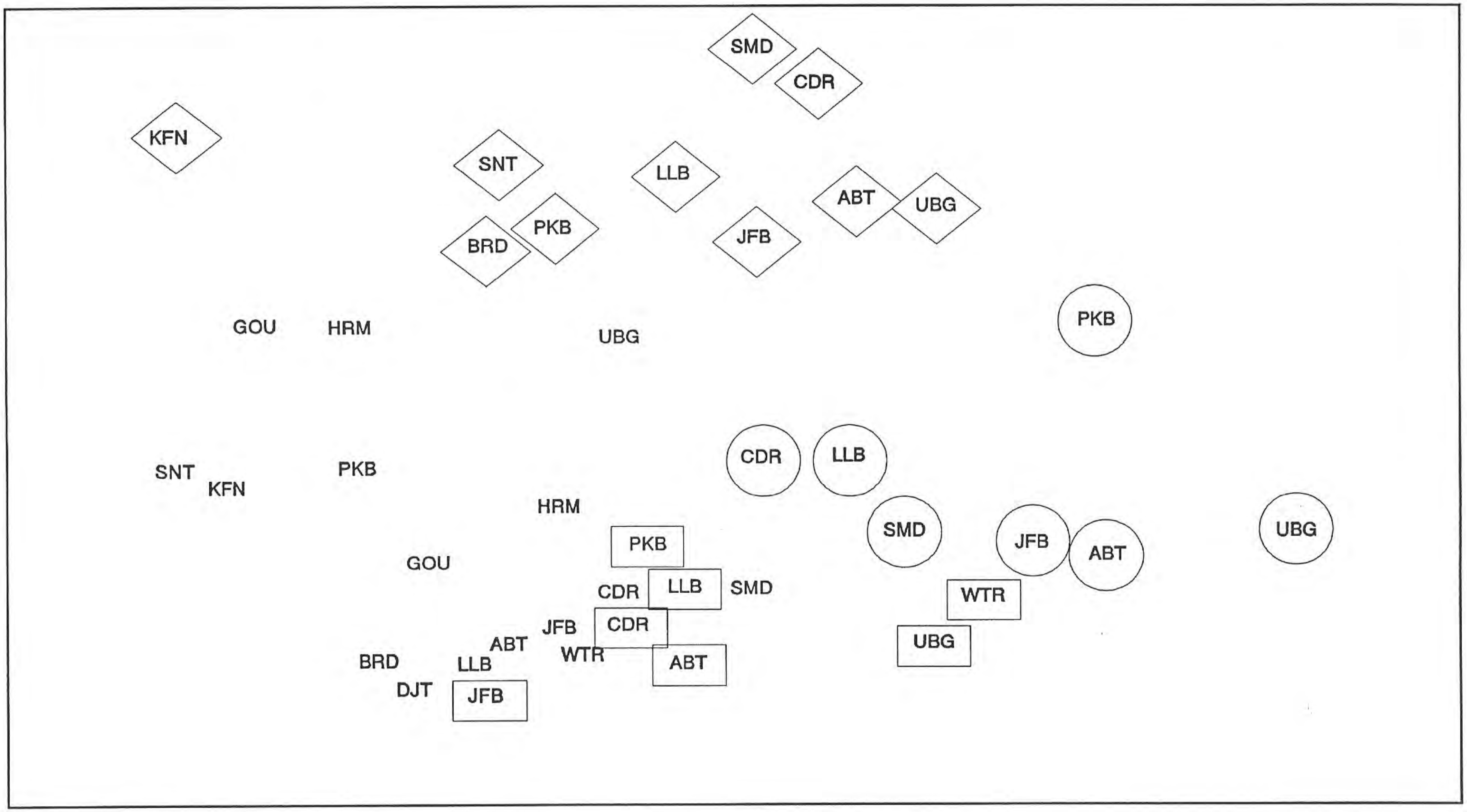


Figure 32.4.6 : MDS ordination of stones-in-current faunal samples collected in 1951: ○ and 1991: □ , and marginal vegetation faunal samples collected in 1951: ◇ and 1991:

32.4.3 Flow

In general, reduced flow affects the invertebrate fauna in the following manner :

(a) it reduces the surface area of the riffle biotope in which much of the fauna is found,
(b) it decreases the total submerged area,
(c) it can make marginal vegetation habitat inaccessible,
(d) it may lead to an increase in water temperature and a decrease in dissolved oxygen, both factors that would target the more sensitive species, and, lastly,
(e) it exacerbates the effects of pollution.

Increased flow may have the following effects :

(a) water temperature fluctuations may decrease resulting in higher minimum and lower maximum temperatures,
(b) turbidity may increase,
(c) habitat heterogeneity (dependent on channel morphology) may decrease,
(d) seasonal growth and availability of marginal vegetation as a habitat for the biota may decrease,
(e) cues for timing of various life cycle events, e.g. emergence, reproduction, etc, may be altered,
(f) the amount of habitat available for fish and fish migratory routes may be increased (advantageous if the fish are indigenous but deleterious if they are exotic),
(g) retention of detritus and debris (the base of the food chain) in the stream may decrease,
(h) and the relative contribution of groundwater may decrease.

A brief analysis of the flow data for four stations along the Berg River indicates that there has been an increase in water discharge below Theewaterskloof Tunnel (Table 32.4.1), and that this increase is more exaggerated in summer. In the middle reaches spring flow was slightly lower and summer flow higher. In the lower reaches of the river, flow has not changed much. Based on these flow records, it appears that water discharge has at no stage decreased from the 1950s to the 1980s and thus no comment can be made on the effects of reduced flow with respect to the invertebrates of the Berg River.

Table 32.4.1 : **Average monthly flow values ($m^3 \times 10^6$/month) for four stations along the Berg River. Simulated flow data for 1950 and patched observed flow data for 1980s. Spring values include the months of September, October and November; and summer values include the months of January, February and March.**

Station	Locality	Season	1950	1980s
G1M04	Driefontein, below tunnel	Spring	8,6	9,3
		Summer	1,6	6,3
G1M20	Noorder Paarl, immediately before Paarl	Spring	28,1	20,4
		Summer	2,5	5,6
G1M36	Vleesbank A, between Kompagnies & Fish tributaries	Spring	38,8	36,4
		Summer	2,6	7,1
G1M13	Driehewels, after Sandspruit tributary	Spring	67,5	59,0
		Summer	5,5	5,6

32.4.4 Water Quality

This has not been examined in detail since two studies (HRI and DWAF, already mentioned) are currently focusing on this issue. However, some comments can be made from examining the water quality data of Harrison & Elsworth (1958; Table 32.4.2) and those of the Department of Water Affairs and Forestry (Table 32.4.3).

There is a clear change in water quality, particularly pH, TDS and NO_2 + NO_3 in zone IIIA. Average monthly flow during spring increased from 8,6 to 9,3 $m^3 \times 10^6$/month in this zone. In zones IIIB and IV, both TDS and NO_2 + NO_3 have increased. In these zones average monthly flow during spring has decreased. Generally a reduction in water quantity exacerbates the effects of reduced water quality. The increases in pH, TDS and NO_2 + NO_3 may be responsible for the observed changes in the faunal communities.

Table 32.4.2 : Values for selected water quality analyses for Spring 1951 within each zone (from Harrison & Elsworth, 1958). (-) = no values given. TDS = total dissolved solids.

Zone	pH	TDS	$NO_2 + NO_3$	NH_4	PO_4
		mg l^{-1}	mg l^{-1}	mg l^{-1}	mgl^{-1}
II	4,8	16,5	0,14	0,007	0,003
IIIA	5,5	24,4	0,10	0,006	-
IIIB	6,8	37,0	0,10	0,030	-
IV	7,0	60,0	0,18	0,020	-
V	7,0	104,0	0,21	0,017	-

Table 32.4.3 : Values for selected water quality analyses for October 1989 at DWAF gauging stations in the respective zones. (-) = no values given. TDS = total dissolved solids.

Zone	Station	pH	TDS	$NO_2 + NO_3$	NH_4	PO_4
			mg l^{-1}	mg l^{-1}	mg l^{-1}	mgl^{-1}
II	-	-	-	-	-	-
IIIA	G1M04	7,0	62,0	1,44	0,050	0,020
IIIB	G1M20	7,4	72,0	1,07	0,046	0,197
IV	G1M13	7,0	133,0	0,82	0,070	0,031
V	-	-	-	-	-	-

32.5 CONCLUSIONS

From the invertebrate survey of the Berg River, it is clear that changes have occurred since the original study was undertaken in the 1950s by Harrison & Elsworth (1958). The Upper Berg Station (UBG) has changed the least and its faunal community is still similar to that found in 1951. The faunal community of the Wemmers Tributary was grouped with UBG, suggesting low impact of the dam. It should be noted, however, that this represents the "best-case-scenario" and in order to gain insight into the effect of the dam, further sampling should be conducted immediately after the dry period when spillage from the dam is zero or low.

The most obvious changes have occurred in zone IIIA, notably at the Jim Fouché Bridge station (JFB), where the complete dominance of the faunal community by chironomids is apparent. From this it is clear that pollution, mostly organic, which was previously absent above Paarl (Harrison & Elsworth 1958; Fourie & Steer 1971), is now prevalent. The middle reaches of the river, which have had a high organic loading since the 1950s, have not changed very much, except for a general increase in organic pollution and silt loading, as indicated by increases in the percentage composition of chironomids and oligochaetes. Changes in the faunal communities of the lower reaches, notably the rarity of certain mayfly species (e.g. *Tricorythus discolor), Baetis bellus,* and the presence of previously less common ones (*Baetis latus*), together with the presence of the estuarine amphipod *Afrochiltonia capensis* at Kersefontein, support the water quality data in demonstrating increased salinisation of the lower reaches.

With respect to flow and water quality, it seems probable that changes in the faunal communities of the upper reaches are related both to an increase in discharge from the Theewaterskloof Tunnel, and reduced water quality (e.g. increased agriculture, Theewaterskloof water, Dew Dale Trout Farm). In the lower reaches changes in flow are negligible, and thus the faunal changes noted in this survey presumably reflect changes in water quality over the past 40 years. It is not possible to predict the effects of low flow from these data.

According to O'Keeffe (1986) the Berg River may be roughly divided into the following areas with regard to its conservation status :

Upper catchment, Franschhoek Forest Reserve (FFR): "Slight but significant changes can be detected such as mild pollution, water regulation, the presence of alien animals or plants, increased siltation, disturbed catchment vegetation, etc."

Between FFR and Paarl, and between Gouda and the Atlantic: "Substantial changes are apparent such as locally severe pollution, dominant alien species, major water regulations, etc."

From Paarl to Gouda: "All natural aspects of the channel and catchments are badly degraded."

The present study reveals clear changes in invertebrate faunal assemblages in all but Zone II, which should be given high conservation status. Although most of the Berg River below this zone has been impacted, there are reaches which support an "ecologically healthy" invertebrate fauna, and thus every effort should be made to maintain the river in its current state or to improve conditions.

APPENDIX A

PERCENTAGE COMPOSITION OF INVERTEBRATE FAUNA SAMPLED IN THE

STONES-IN-CURRENT AND MARGINAL VEGETATION HABITATS IN "SPRING" 1951

AND NOVEMBER 1991

APPENDIX A. Percentage composition of invertebrate fauna sampled at all stations in 1951 and 1991. Habitat type (ST=stone-in-current; VEG=marginal vegetation) and sampling year: 1951 (Harrison & Elsworth 1958) and 1991. Station Name (UBG=Upper Berg River Franschoek Forest Reserve; ABT=Above Tunnel Franschoek Forest Reserve; JFB=Jim Fouche Bridge; SMD=Simondium; CDR=Cecilia's Drift; DJT=Daljasophat; LLB=Lady Loch Bridge; HRM=Hermon; GOU=Gouda; BRD=Bridgetown; PKB=Piketberg; SNT=Sandrift; KFN=Kersefontein; WTR=Wemmers Tributary.

				Habitat type and year	ST51	ST51	ST51	ST51	ST51	ST51	ST51
				Station Name	UBG	ABT	JFB	SMD	CDR	LLB	PKB
				Station Number	1	2	3	11	4	6	8
Phylum	Class	Order	Family	Genus species							
Coelenterata	Hydrozoa	Hydroida	Hydridae	Hydra sp.							
Platyhelminthes	Turbellaria		Dugesia?	spp.							
Nemertinea	Enopla	Hoplonemertea	Nemertini	Prostoma sp.		0.1				0.1	0.3
Mollusca	Gastropoda	Pulmonata	Lymnaeidae	Lymnaea columella							
			Lymnaeidae	Ferrissia sp.							
Annelida	Oligochaeta	Tubificida	Naididae	Nais sp.			0.6	10.0		0.5	0.1
			Naididae	Pristina sp							
			Naididae	Slavina appendiculata							
			Naididae	Stylaria fossularis							
		Lumbriculida		Lumbriculus spp.			0.2	0.2		0.9	
Arthropoda	Crustaceae	Amphipoda	Ceinidae	Afrochiltonia capensis							
	Insecta	Plecoptera	Notonemouridae	Aphanicerca spp.	8.1	2.4	0.7	0.2	0.2	0.7	
		Ephemeroptera	Heptageniidae	Afronurus harrisoni		0.4	0.1	0.5		0.3	
			Baetidae	Baetis harrisoni	3.5	15.3	52.4	52.7	43.2	31.7	4.1
			Baetidae	Baetis bellus							
			Baetidae	Baetis glaucus					0.1	0.1	23.7
			Baetidae	Baetis latus							
			Baetidae	Baetis capensis	4.8	0.9	0.5	1.4	3.5	1.1	
			Baetidae	Pseudocloeon vinosum		0.6	0.9	1.6	14.7	10.3	0.2
			Baetidae	Austrocloeon virgilidae							
			Baetidae	Centroptilim excisum							
			Baetidae	Centroptilim sudafricanum							
			Baetidae	Centroptilim sp. A							
			Leptophlebiidae	Aprionyx peterseni	8.4	0.9	0.1	0.1			
			Leptophlebiidae	Castanophlebia calida	17.8	1.1	0.6	0.2			
			Ephemerellidae	Lithogloea harrisoni	0.2	6.6	9.2	3.6	0.8	0.3	
			Ephemerellidae	Lestagella pennicillata	38.1	14.0	2.1	0.6	0.1	0.1	
			Tricorythidae	Tricorythus discolor							45.8
			Caenidae	Austrocaenis sp.				0.1		0.9	3.0
		Odonata	Zygoptera	Pseudagrion spp.							
			Anisoptera	spp.							
		Hemiptera	Notonectidae	Nychia limpida							
			Pleidae	Plea pullula							
			Naucoridae	Laccocoris limnogenus							
			Corixidae	Micronecta diminiata							
			Corixidae	Micronecta bleekiana							
			Corixidae	Micronecta scutellaris							
		Megaloptera		Chloroniella peringueyi							
		Trichoptera	General	spp.		2.4	8.4	1.0	0.1		6.8
			Sericostomatidae	Barbarochthon brunneum							
		Coleoptera	Dystiscidae	spp.							
			Hydraenidae	spp.				0.1			
			Helodidae	spp.	0.1	0.1	0.1				
			Dryopidae	Strina sp.			0.1				
			Elmidae	Elpidelmis capensis	0.4	17.6	2.8	0.3			
			Elmidae	Pelориolus granulosus	2.2	4.0	2.2	0.3	0.4	0.1	
		Diptera	Blepharoceridae	Elporia spp.	4.2	0.2	0.1				
			Dixidae	Dixa sp.							
			Chironomidae	spp.	0.6	1.6	3.0	11.4	25.6	12.6	6.5
			Ceratopogonidae	spp.							
			Ceratopogonidae	Atrichopogon virgilidae							
			Simulidae	spp.	4.8	19.3	14.1	13.6	7.7	25.5	4.6
			Rhagionidae	spp.							

APPENDIX A. Continued/

ST91	ST91	ST91	ST91	ST91	ST91	ST91	VEG51	VEG51	VEG51	VEG51	VEG51	VEG51	VEG51	VEG51	VEG51	VEG51
UBG	ABT	JFB	CDR	LLB	PKB	WTR	UBG	ABT	JFB	SMD	CDR	LLB	HRM	GOU	BRD	PKB
1	2	3	4	6	8	10	1	2	3	11	4	6	12	7	13	8
				0.6										3.6		
				0.7												
													0.2	20.6	1.2	1.0
													2.4	3.6		
				0.2	0.1								1.0	15.5	0.5	1.6
	5.5	0.8	0.7	2.7						0.1	0.8	5.1	2.4	1.8		0.6
	0.3		0.5	1.1												
		0.2														
																0.2
0.4			0.1			0.1										
0.6	0.3					0.3	11.9	0.4								
0.4																
49.0	22.3	2.4	15.4	25.9	3.9	50.0	2.3	2.0	2.3	0.8		4.8	0.1			0.6
1.2				0.1	0.8	0.0			2.8	1.3	0.2	28.8	62.9	9.1	19.9	26.7
					0.2											
					0.8										3.8	10.0
0.2																
							35.6	47.0	49.8	82.7	84.3	44.9	1.9	0.6	23.9	33.4
										1.5		0.4	1.9		6.0	3.4
							3.6		0.1		0.2					
							6.7	5.2	2.3	3.5		0.1				
3.5	12.0	0.1														
8.2																
0.4	0.3	0.3		0.1												
2.7																
				0.1	0.1											
							0.2		0.1	0.4			1.5	0.8	2.2	0.2
												1.2				1.2
										0.1						
													1.5			
0.1																
0.2	0.8		0.1	1.2	4.7	0.3		0.4	7.2	3.8	3.8	1.2	0.8	25.8		
		0.1					2.2	12.5								
						0.1	0.1									
11.2	6.3						1.1	0.2								
1.8	0.8	0.1	0.0	0.2		0.3										
4.9	1.9	0.3	0.1			0.1		0.1								
								0.1								
								1.4	6.7	0.3	0.4	0.3			1.0	
13.3	48.8	95.0	72.8	54.3	44.6	5.3	0.6	3.5	9.2	2.8	1.6	6.4	20.4	15.8	16.5	15.7
						0.1										
2.0	0.6	0.8	10.3	12.8	44.8	43.1	22.6	12.9	7.8	0.5	6.8	3.3	0.1			
						0.2										

APPENDIX A. Continued/

VEG51	VEG51	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91	VEG91
SNT	KFN	UBG	ABT	JFB	SMD	CDR	DJT	LLB	HRM	GOU	BRD	PKB	SNT	KFN	WTR
14	9	1	2	3	11	4	5	6	12	7	13	8	14	9	10
										1.9					
	1.8								0.8					3.0	
2.0				4.4				0.6		2.8		1.0			
				1.0			6.8	6.4	0.1	0.2					
				0.3			2.2		0.3	2.5					
1.4	3.1														
					0.3				0.5	1.3			0.3		
														9.1	
		0.5													
0.1		0.3		0.8	29.9	15.0		3.8		0.8					
31.9	7.1			0.1		1.0	1.5	1.9	3.7	0.8	2.4	0.6	0.2		
										0.2					
6.6	5.2		0.7							0.7		68.2	80.8	12.1	
20.1	2.2	43.7		0.1	0.2	0.2			0.6						
								0.6		0.5					
2.0	0.3	0.3													
		3.5													
		0.3													
			0.7		0.2	0.2									
		0.3													
													0.2		
					0.2				0.9	0.6					
	1.5	0.8				0.2	0.2	2.5	0.6	0.8			0.2	3.0	
								1.3							
12.4	5.5						0.2								
									0.5	7.6					
0.1									0.1				0.2		
	64.3								17.4	31.0	12.2			48.5	
	1.3														
	2.7								0.1						
0.3	0.3	2.9	4.6		0.2	0.3			0.1			0.6	1.0	3.0	
		4.8													
		1.9													
		1.1		0.1					0.2						3.0
		2.4													
		1.1													
		3.7	0.7												
10.8	2.9	31.5	86.8	79.3	47.4	61.2	88.8	82.2	37.9	45.4	85.4	21.9	16.2	21.2	75.8
			0.7												
0.6		1.1	5.9	13.8	21.7	21.9	0.2	0.6	36.2	4.2		7.7	1.1		21.2

APPENDIX B

AVERAGE MONTHLY RAINFALL (mm) FROM 1972 TO 1989 AT TWO STATIONS

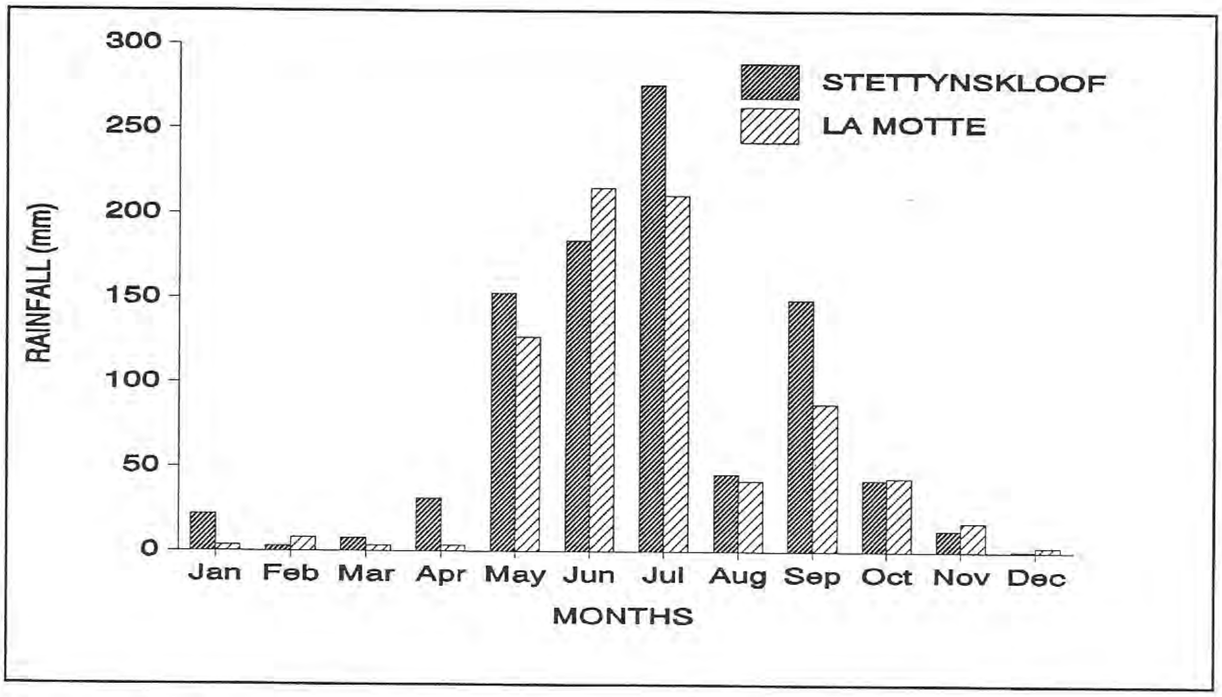
IN CLOSE PROXIMITY TO THE WEMMERS RIVER (CCWR),

AND THE AVERAGE MONTHLY INFLOW AND SPILLAGE ($m^3 \times 10^6$)

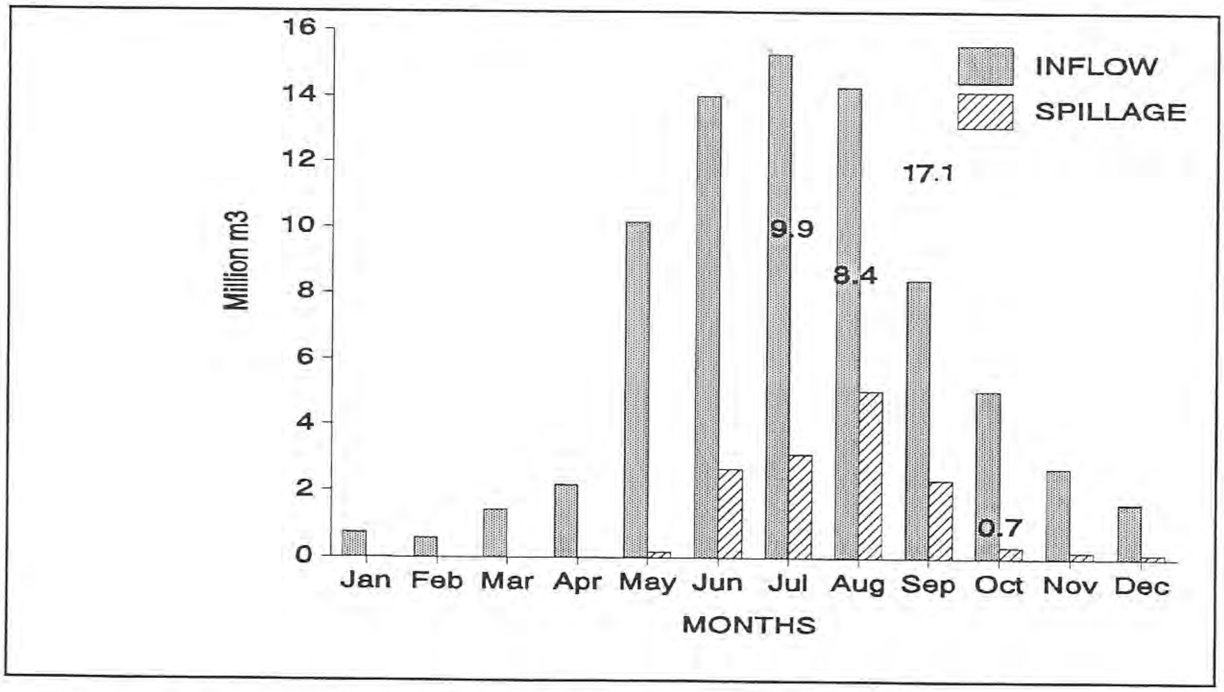
TO AND FROM WEMMERSHOEK DAM FOR THE YEARS 1972 TO 1989.

THE VALUES ABOVE THE MONTHS OF JULY, AUGUST, SEPTEMBER AND OCTOBER

ARE SPILLAGE VALUES FOR 1992, IMMEDIATELY PRIOR TO THIS STUDY.



Appendix B1 : Average monthly rainfall (mm) from 1972 to 1989 at two stations in close proximity to the Wemmers River (CCWR).



Appendix B2: Average monthly inflow and spillage (mill m^3) to and from Wemmershoek Dam for the years 1972 to 1989. The values above the months of Jul, Aug, Sept and Oct are spillage values for 1991, immediately prior to this study.

ACKNOWLEDGEMENTS

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TAXONOMIC ADDENDUM

Since the Harrison & Elsworth (1958) study the following taxonomic names have become available or changed:

Plecoptera	:	Nemouridae	-	Notonemouridae
Ephemeroptera	:	*Baetis* sp. A	-	Baetis glaucus
		Baetis sp. B	-	Baetis latus
		Acentrella capensis	-	Baetis capensis
		Austrocaenis sp.	-	*Caenis* sp.
Coleoptera	:	Helmidae Sp.6AA	-	*Elpidelmis capensis*
		Helmidae Sp.8J	-	*Peloriolus granulosus*
Crustacea	:	*Chiltonia capensis*	-	*Afrochiltonia capensis*

TERMS OF REFERENCE

The Freshwater Research Unit of the University of Cape Town was contracted to conduct a one-off survey of the invertebrate fauna of the Berg River in order to:

1. Determine the current status of the invertebrate fauna.
2. Compare our results with those of an earlier study by Harrison & Elsworth (1958).
3. Relate results to flow and water quality records with the view to providing a preliminary assessment of the flow regimes of macroinvertebrates.

GENERAL INDEX OF REPORTS

WESTERN CAPE SYSTEM ANALYSIS
GENERAL INDEX OF REPORTS

CATEGORY	NAME	DWAF REPORT NO.	WCSA SEQUENCE NO.
DATA REPORTS	Flow Gauging Stations : Calibration and Evaluation Vol I : Text Vol II - VIII : Particulars of Gauging Stations	P G000/00/1090	5
	Collection, Storage and Manipulation of Data Vol I : General Vol II : Riviersonderend Basin Vol III : Palmiet/Steenbras Basin Vol IV : Berg River Basin Vol V : Cape Town Basin	P G000/00/1190	6
	Description of Existing Urban Water Supply Infrastructure	P G000/00/1490	9
	Long-Term Urban Water Demand in the Western Cape Metropolitan Region 1990 - 2020	P G000/00/1590	10
	Development of Irrigation in the Riviersonderend and Palmiet/Steenbras Basins	P G000/00/1690	11
	Procedure for the Evaluation of Farm Dams	P G000/00/1790	12
	Analysis of the Potential for Further Irrigation Development in the Palmiet Basin	P G000/00/1891	13
	Sedimentation Study	P G000/00/2191	16
	A Comparison of the Relative Costs of Aerial Photography and Remote Landuse Mapping in the Western Cape	P G000/00/2291	17
	Water Quality Volume I : General Volume II : Data for Berg River Basin Volume III: Data for Eerste, Lourens, Steenbras, Palmiet, Riviersonderend and Diep River Basins	P G000/00/2891	23
	Vooruitskattings van Besproeiingswaterbehoeftes	P G000/00/3091	25
	Palmiet Worksessions : Impacts of the Development Options on the Ecological Environment	V G400/04/E024	50
	Palmiet Worksessions : Social Impact Assessment		51
	The Impact of Areas Inundated by Various Water Resource Development Options in the Palmiet River	P G000/00/4192	52
	Report on the Preliminary Berg River Environmental Assessment Worksession	P G000/00/1292	31
	Berg River Invertebrate Study	P G000/00/1392	32
	ROIPs	P G000/00/4293	35

WESTERN CAPE SYSTEM ANALYSIS

GENERAL INDEX OF REPORTS

CATEGORY	NAME	DWAF REPORT NO.	WCSA SEQUENCE NO.
REPORTS ON AVAILABLE WATER RESOURCES	Preliminary Report on the Yield of the Riviersonderend- Berg River Sub-system	P G000/00/0790	2
	Evaluation of the Stochastically Generated Flows for the Preliminary Riviersonderend Sub-system Analysis	P G000/00/2091	15
	Hydrology of the Palmiet/Steenbras River Basin	P G000/00/2391	18
	Hydrology of the Berg River Basin	P G000/00/2491	19
	A Review of the Groundwater Resources of the Western Cape	P G000/00/2591	20
	Hydrology of the Eerste, Lourens and Sir Lowry's Pass River Basins	P G000/00/2691	21
	Hydrology of the Riviersonderend Basin, Upper Molenaars and Elandspad River Catchments	P G000/00/2791	22
	Hydro-salinity Modelling of the Berg River Basin	P G000/00/3392	29
	The Fresh Water Requirements of the Palmiet Estuary - A First Assessment	P G000/00/3892	53
	Hydrology of the Diep River Basin	P G000/00/3593	30
	Analysis of Diversions for Use in the Monthly Water Resources Yield Model	P G000/00/3692	33
	RSE Sub-system Analysis	P G000/00/4093	34
	Palmiet/Steenbras Sub-system Analysis	P G000/00/4393	37
	Berg River Sub-system Analysis	P G000/00/4493	38
	Evaluation of the Stochastically Generated Flows	P G000/00/4593	39
	In Stream Flow Requirements Vol I : Proceedings of Worksession Vol II : Methodology and First Estimates	P G000/00/4793	41
	Water Requirements for the Maintenance of the Berg River Estuary Vol I : Report on Worksession Vol II : Compilation of Papers by Consultants	P G000/00/4993	43
	Integrated System Analysis	P G000/00/5093	44

WESTERN CAPE SYSTEM ANALYSIS

GENERAL INDEX OF REPORTS

CATEGORY	NAME	DWAF REPORT NO.	WCSA SEQUENCE NO.
REPORTS ON POTENTIAL DEVELOPMENTS	Ekonomiese Ontleding : Vergelyking van Alternatiewe Opgaareenhede in die Bo-Bergrivier en Volgorde van Infaseering van Toekomstige Waterbronne vir die Kaapse Metropolitaanse Gebied	P G000/00/3191	7
	Comparative Yield Analysis of Assegaaibos and Skuifraam Dam Schemes	P G000/00/1991	14
	Desalination Study Vol I : Seawater Desalination : Single Stage Reverse Osmosis Full and Phased Start-up Options Vol 2 : Seawater Desalination : Two Stage Reverse Osmosis Low Salinity Option Vol 3 : Desalination of Diep River Water Vol 4 : Reclamation of Potable Water by Reverse Osmosis from Secondary Sewage Effluent	P G000/00/3991	26
	Utilisation of Less Conventional Water Sources	P G000/00/3291	27
	Palmiet Phase II - Alternative Developments	P G000/00/3492	28
	Water Demand Management	P G000/00/4693	40
	Options for the Supply of Water in the Western Cape	P G000/00/4893	42
	Development of the Upper Berg River (Skuifraam Scheme)	P G000/00/5793	47
	Information Package I	P G000/00/5392	54
	Information Package II	P G000/00/5493	55
GENERAL	Proposal	P G000/00/0689	1
	Priority Classifications for Water Restrictions	P G000/00/3792	36
	Main Report	P G000/00/5193	45
	Summary Report	P G000/00/5293	46
	The Executive Summaries	P G000/00/5893	48

1993-11-04
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LIST OF STEERING COMMITTEE AND WORKING GROUP MEMBERS

WESTERN CAPE SYSTEM ANALYSIS

STEERING COMMITTEE

ORGANISATION	REPRESENTATIVE
DWAF : Project Planning	P H van Niekerk (Chairman) H Smit / P D Pyke J van Rooyen
Cape Town City Council : Waterworks Branch	J Saunders A Singels
DWAF : Western Cape	G van Zyl
DWAF : Water Quality Management	F van Zyl
DWAF : Environment Studies	J J Erasmus / C Bruwer
DWAF : Water Utilisation	P D Pyke / C Coetzer
DWAF : Hydrology	F Cornelius
DWAF : Geohydrology	P Seward
Dept of Agricultural Development	H Aab / I Scheepers / J C Venter
Winter Rainfall Region	J Piaget
DWAF : Hydrological Research Institute	M van Veelen / G Quibell
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Ninham Shand Inc.	M J Shand P R Little

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DWAF : Geohydrology	P Seward
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CCC : Scientific Services Branch	I R Morrison
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