RELATIONSHIPS BETWEEN LOW FLOWS AND THE RIVER FAUNA IN THE LETABA RIVER

by

F M Chutter and R G M Heath

Water Quality Information Systems Programme
Division of Water Technology, CSIR
P O Box 395, Pretoria, 0001, South Africa

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Division of Water Technology Project No. 670/33399

Report to the Water Research Commission on the Project "Relationships between Low Flows and the River Fauna in the Letaba River".

Divisional Director : Dr B M van Vliet
Project Leader : Dr F.M.Chutter

Pretoria
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WRC 293/1/93
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EXECUTIVE SUMMARY

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MOTIVATION AND BACKGROUND

The flow required in a river to maintain its ecological integrity has come to be regarded as the key issue in the management of the conservation status of South African aquatic ecosystems. The question is particularly acute in the Eastern Transvaal Lowveld, where there is a limited availability of water, a high rate of population growth, extensive development of intensive irrigation agriculture and the nation's major nature preservation area, the Kruger National Park, whose major rivers traverse the Lowveld before reaching the park.

The flow of the naturally perennial Letaba River as it crosses the Lowveld towards the Kruger National Park is regulated by the Fanie Botha Dam at Tzaneen. There were several successive years, at the height of the drought period of the middle 1980's, when the flow of the river ceased before it reached the western boundary of the Park. However, the flow of the river near Fanie Botha Dam never ceased during the drought, due to the fact that the river channel is used to carry water to the extensive irrigation areas downstream of the dam.

There is, therefore, a gradient of permanency of flow from west to east in this stretch of the river. The research project was based on the hypothesis that the composition of the fish and benthic macroinvertebrate fauna of the river is related to this gradient. The project's first aim was therefore to define the nature of this hypothesized biological gradient in terms of the tolerance of the various members of the communities to flow cessation and to the duration of the period over which flow ceased.

There are, in fact, two approaches to the manner in which answers to this question may be arrived at. The first is to record the composition of these (fish and benthic macroinvertebrate) components of the fauna at regular intervals over the gradient of permanency of flow. The longitudinal distribution of species might reveal which species are tolerant to flow interruption, which are not and which have intermediate tolerance.

The second approach is to record the composition of the fauna at close time intervals as the river dries up and again as it begins to flow. This would reveal the sequences in which species disappeared and re-appeared. Provided that these observations were related to physical conditions (depth, current speed, surface dimensions, etc) interpretations would be possible regarding the minimum flow tolerable to the sensitive taxa. This, however, presupposes that sufficient is known of the life cycles of at least the aquatic insects to allow their disappearance from the aquatic habitat to be properly interpreted.

It will be appreciated that the success with which the goals of a research project of this nature are achieved is subject to an important uncontrollable variable - the rainfall and its impact on the availability of water to sustain the flow of the river. If the river does not cease to flow during the study period some of the studies proposed may not be made. If the river has flowed permanently for some years, it is to be expected that the sensitive species will have re-established themselves where they had been previously eliminated by flow cessation.

The project was designed to focus on those benthic macroinvertebrates which are obligate dwellers in current, that is the community of parts of the river bed in which there are hard substrata in strong current (rapids, etc). These invertebrates would be the first to be impacted by declines in flow to very low levels. As fish are more mobile and probably more tolerant of a wider range of conditions (though a few species appear to be nearly restricted to fast-flowing water), it was decided to attempt to record the complete diversity of the fish fauna in the river.

PROJECT AIMS AND THEIR ACHIEVEMENT

An attempt was made to formalize the concepts contained within the motivation in the aims of the study, as agreed in the original contract between the Division of Water Technology, CSIR and the Water Research Commission. The aims are repeated below, with comment on whether they were achieved given in italics immediately after each aim:

1. To identify the combinations of minimal flow, depth and current speed in the Letaba River which allow the occurrence of a natural river fauna, taking water chemistry and temperature into account. The natural river fauna would be measured in terms of the species diversity and the occurrence of key species. *In the event, the drying out of the river could not be tracked, so that the minimal flow, depth and current speed, which allow the occurrence of a natural river fauna could not be identified.*

2. To compare the conditions identified in aim 1 to estimates of the natural (unmodified by man) flow and cross section of the river, to give a first estimate of minimal low flow requirements for habitat diversity and ecosystem maintenance as a proportion of the natural flow and river size. *Since aim 1 could not be achieved, it was impossible to achieve this aim.*

3. To collaborate with other researchers studying the ecology of rivers in the Eastern Transvaal and Kruger National Park by providing comparative data on a highly man-modified and regulated river. Impacts on the Letaba would, if possible, be used as a background for the prediction of ecological impacts on presently non-regulated rivers. *The information has been made available through this report, but mainly through logistical and financial constraints, active collaboration only took the form of presentations to Kruger National Park Workshops.*

4. To compare minimum flow requirements derived in this study with flow requirements, if available, arrived at by other workers (probably Dr J M King) using the Instream Flow Incremental Methodology (IFIM) or any other methods. *This aim was not achieved as this project did not yield minimum flow requirements and as the projects alluded to had not been concluded when this report was written.*

5. In collaboration with other researchers, to provide and update initial guidelines on the quantities of water and their pattern of flow required for the conservation of river ecosystems and water quality. *Again this was not achievable due to the fact that this was a two year duration project and the other projects were of three year's duration.*

It should be pointed out that these aims were agreed upon before the researchers had ever seen the Letaba River, so that they were uncertain whether or not the studies they had in mind would be possible in the river. It was assumed that the river fauna would reveal a gradient of declining diversity from the west, where the river flows permanently (albeit the flow is regulated) to the east, where the flow has previously ceased in the winter. Furthermore, at the request of the Water Research Commission, the aims were modified on the assumption that collaboration with other projects on the Kruger National Park rivers could be achieved within the constraints of the proposed budget.

Another important factor regarding the definition of the aims was that it was assumed that the lower Letaba River, near and in the Kruger National Park, would cease flowing during the latter part of the dry season and that the project team could arrange to be timeously informed when this occurred.

When the first Steering Committee Meeting for the project took place in March 1990, a helicopter survey had been made of the river and sampling sites had been selected. A research programme, involving regular quarterly visits to the river and visits at closer intervals immediately before and after the river ceased flowing, was agreed upon.

It was reported to the second Steering Committee Meeting, which considered the first year's results, that the species richness (or species diversity as it had earlier been called in the project proposal) of the benthic invertebrate community was greater in the stretch of river most exposed to low flows, than it was in the permanently flowing parts of the river. The river was not at that time known to have ceased flowing during the year and it had not been possible, nor did it look likely to be possible in the second year, to achieve aims 1 and 2 above. The Committee recommended that in view of the fact that the project was generating a potentially useful baseline of environmental information, the study should be continued for the second year with modifications to the choice of sampling points to allow for the inclusion of more upper river sites remote from major weirs.

MAJOR RESULTS AND CONCLUSIONS

The Letaba River was visited at 3 monthly intervals over a period of two years and samples of the water, the invertebrate communities of the rapids and of the fish population were collected. The quality of the Letaba River water was unimpaired in all respects other than that it had a high turbidity at times. Flow data only became available some time after the field work had been completed. In the event, the flow data showed that, contrary to what had been seen on field visits, there were two occasions during the study period when the flow of the river ceased. These occurred in November 1990 (3 consecutive days) and in August 1991 (11 consecutive days). In both cases scheduled sampling visits to the river took place within less than two weeks of the resumption of flow in the river.

In the first year, the invertebrate community was found to have a higher species richness near the Kruger National Park than upstream, which was a complete contradiction of what had been expected. This result was biased by the fact that many of the upstream sampling points were sited immediately below weirs, where conditions are ideal for collecting fish, but where the species richness of the invertebrate community is low. In the second year of the study, when other sampling sites, remote from weirs, were included in the sampling programme, a greater diversity of invertebrates was found in the upper river. Nevertheless, the lower part of the river maintained its greater species richness. In particular several tropical mayfly species which were absent upstream of Die Eiland were found in the lower river. In general there was a high level of species richness at all sampling points remote from weirs. Appendices to the report record all the invertebrate taxa collected by any method during the study.

Comparison of the invertebrate fauna data by means of objective mathematical analysis of similarity between sampling points, revealed that most of the species were collected at all sampling points. Proximity of sampling points to one another was always important, adjacent sampling points usually being more similar to one another than to other sampling points.

The effect of flow cessation on the rapid-dwelling invertebrates was carefully assessed by means of a thorough comparison of the communities collected before and after the event at sampling points, both where flow cessation was almost certain not to have occurred and where flow cessation almost certainly occurred. It would appear that the short period of flow cessation had no measurable impact on the species richness in the river, but a small impact on the relative abundance of Orthoclad Chironomidae (increased in abundance) and Tricorythid mayflies (decreased in abundance).

With the exception of the tiger fish, which can migrate into the Letaba River from the Olifants River, all fish species ever recorded from the study reach of Letaba River were recorded during the present study. There was no evidence that the several large weirs in the river formed barriers to the distribution of any species, though there are 11 known migratory species in the river. For the eleven migratory species, upstream spawning migrations over the weirs could only take place at very large flows, when there might be opportunity for passage over the weirs at the sides of the river.

It would appear that seasonal pools in sandy areas of the Letaba River bed form important refuges for many of the fish species when the flow of the river is very low. It is suspected that these pools are maintained by seepage of water through the sand. For this to occur it is necessary that there be movement of water down the river channel, albeit within the sand. High summer flows allow the fish to move back into the river from the seasonal pools. During the study there were two short periods (3 and 11 days) when the river ceased flowing near the Kruger National Park. When flow resumed there was no apparent loss of fish species diversity.

It was concluded that the present study showed that the present fauna of the river can survive under the present flow regime, including the short periods of flow cessation in the lower river which occurred during the study. This flow regime really came into effect in 1988, when, as a result of negotiations between the National Parks Board and the Letaba Irrigation Board, it was agreed to maintain a minimum flow of 0.5 m^3s^{-1} at the western boundary of the Kruger National Park. One important unanswered question is whether the present fauna of the river is representative of the original fauna or whether there have been species losses. It would appear that the only way in which this question can be answered is to compare the Letaba River fauna with that of the Sabie, when the Sabie results become available from a Water Research Commission sponsored study of that river.

A second important unanswered question relates to the role of large flows in maintaining the river channel in its present state. Were there to be radical changes to the river channel, such as colonisation by extensive reed beds, changes in the river fauna could be expected.

It was concluded that the fact that below Fanie Botha Dam the river is used to transport irrigation water to the irrigation areas, means that there is permanent flow in part of the river below the dam, which provides a refuge for many components of the river fauna at times of severe drought stress. It was further concluded that the current-dwelling components of both the invertebrate and the fish fauna have adaptations, which allow them to survive short periods when their preferred normal habitat is eliminated. A relatively short-term study such as this project can only provide information on short-term changes. It was concluded that it would be advisable to maintain low intensity surveillance of the Letaba River biota, lest there be important long term trends of change which have yet to be detected.

Knowledge of the biology of the migratory fish species in the Letaba River is deficient to ensure their continued presence. Key questions are whether they are able to spawn in all sections of the river separated by weirs and the size of the minimum flood in which they can make their way over the largest weirs. It may be that more fish ladders would have to be built to ensure that the eleven migratory species of fish can successfully recolonize the upper reaches of the study area. In such a situation, a careful assessment of whether or not access to the upper part of the river is essential to the continued survival of the species, would be necessary in deciding whether the cost of fish ladders and their flow requirements could be justified.

The study showed that a diverse fish and invertebrate fauna existed in the river. It was concluded from this that many components of the fauna can tolerate the present highly modified flow regime, even to the point where the river downstream of Letaba Ranch gauging weir ceased flowing for a period of eleven days. Gratifying as this observation is, it is concluded that it would be unwise to infer from this that river flows can freely be modified to the point where the river ceases flowing for eleven days on end. Although not part of this study, floods must be important in allowing fish migration, connecting seasonal pools to the main river and maintaining the form of the river channel. Long term studies on the response of the river ecosystem to the modified flow regime are needed if the flow pattern is to be managed for the continued maintenance of the present ecosystem.

RECOMMENDATIONS

The present intended minimum dry season flow of 0.5 m^3s^{-1} would appear to be sufficient to maintain the present species richness of the fauna, so this is the recommended minimum flow until such time as it is proved to be incorrect.

This should be an absolute daily minimum flow rather than a monthly mean minimum and the Groot Letaba Irrigation Board should manage the direct abstraction of irrigation water from the Letaba River so that the daily flow does not decline below 0.5 m^3s^{-1}.

Flow conditions during the wet season have an importance equal to the minimum dry season flow and they should not be ignored in the management of the flow of the river for maintenance of the ecosystem. The required wet season flow conditions have not been quantified and should enjoy research priority.

The migratory species of fish in the river need careful study to reveal whether the many weirs in the river prejudice their continued *short-term* survival. The flows required to allow their surmounting the highest weirs and the frequency of such flows should be analysed to determine whether the *long-term* survival of the natural genotypic variability of the migratory species is threatened.

It is recommended that the Letaba River ecosystem should be kept under carefully planned long term surveillance to reveal whether there are long term untoward trends of change in the ecosystem. Should such trends be detected, management actions to mitigate them should be instituted.

It is recommended that, when the reports on the fish and invertebrates of the Sabie River come to be written, results from this river should be compared with those from the Letaba River, to gain some appreciation of the extent of possible species loss that has taken place in the Letaba.

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"Relationships between low flows and the river fauna in the Letaba River."

The Steering Committee responsible for this project, consisted of the following persons:

Dr P C M Reid	Water Research Commission (Chairman)
Mr D Huyser	Water Research Commission (Secretary)
Mr D S van der Merwe	Water Research Commission
Mr C A Bruwer	Department of Water Affairs & Forestry
Dr P J Ashton	Division of Water Technology, CSIR
Dr F M Chutter	Division of Water Technology, CSIR
Prof B Davies	University of Cape Town
Dr J A Day	University of Cape Town
Dr J King	University of Cape Town

Dr C J Kleynhans	Department of Nature & Environmental Conservation, Transvaal
Mr A R Deacon	National Parks Board
Dr J H O'Keeffe	Rhodes University
Dr K H Rogers	University of the Witwatersrand
Prof W F van Riet	Pretoria University
Dr R D Walmsley	Foundation for Research Development

The Water Research Commission is gratefully thanked for its funding of the project, as are the members of the Steering Committee for their contribution to the project.

The Directorate of Nature and Environmental Conservation of the Transvaal Provincial Administration collaborated very actively in the fish study, by providing a scientist, a technician and a team of fishermen to help in the collection of fish and of benthic invertebrates. We greatly appreciate their support, without which it would have been well-nigh impossible to sample the fishes of the Letaba River.

Dr Peter Reid has supported the project very effectively, especially in its initial stages when he gave of his knowledge of the river and its surrounds to help in sample site selection.

Mr Tony Ravenhill of the Department of Water Affairs and Forestry at Tzaneen provided the flow data for the weir at Letaba Ranch.

Our thanks are due to the Department of Nature Conservation of the Gazankulu Government for permission to enter the Letaba Ranch conservation area and for the provision of guides. The National Parks Board provided accommodation and a ranger for the visits made to the river in the Kruger National Park in November 1990 and August 1991.

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1. INTRODUCTION

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It was reported to the second Steering Committee Meeting, which considered the first year's results, that the species richness (or species diversity as it had earlier been called in the project proposal) of the benthic invertebrate community was greater in the stretch of river most exposed to low flows, than it was in the permanently flowing parts of the river. The river was not at that time known to have ceased flowing during the year and it had not been possible, nor did it look likely to be possible in the second year, to achieve aims 1 and 2 above. The Committee recommended that in view of the fact that the project was generating a potentially useful baseline of environmental information, the study should be continued for the second year with modifications to the choice of sampling points to allow for the inclusion of more upper river sites remote from major weirs.

2. GENERAL DESCRIPTION OF THE STUDY AREA

Important features of the lower catchment of the Letaba River and position of the sites of the sampling points regularly used in the study are shown in **Figures 1** and **2**. Stations 10, 11 and 12 were used for fish studies only. The gradient of the Letaba River (**Figure 2**) is more or less constant along the study reach. The exact positions of the sampling points are given **Table 1**.

Irrigation agriculture is intensive from Tzaneen down to Station 6, the main crops being bananas (near Tzaneen), mangos, citrus and vegetables. Between Station 6 and Letaba Ranch subsistence agriculture (goat husbandry) is practised. In this area the densities of both goats and humans are very high.

While Letaba Ranch and Die Eiland are the only parts of the catchment in which the vegetation is in an undisturbed state, the riverine riparian vegetation is, broadly speaking, in fair condition. There are limited places between Stations 6 and 7 where subsistence agriculture impinges on the river banks.

A feature of the Letaba River is the number of weirs and small dams built to store and divert the flow of the river. The height of the larger of these is shown in **Table 2**, where it may be seen that there are particularly high weirs at Stations 1 (The Junction), 4 (Prieska) and 7 (The Slab) and Engelhardt Dam at Station 11. The present-day function of the large weirs is obscure for they are considerably silted and are not apparently designed to provide irrigation head. Other than Engelhardt Dam in the Kruger National Park (**Figure 1**) none is provided with a fish ladder. Several sampling points were sited in and immediately below some of these weirs (**Table 2**).

Exotic water weeds are not presently conspicuous in the Letaba River. There has been a persistent narrow fringe of *Salvinia* (Kariba weed) just above the weir at Station 3. Weeds such as *Pistia* (water lettuce) and *Eichhornia* (water hyacinth) were not seen on sampling visits.

The present-day hippopotamus population is present in an upstream direction at least as far as Station 1. Crocodiles are also present in the river, but they were seen no further upstream than Station 3 during the study.

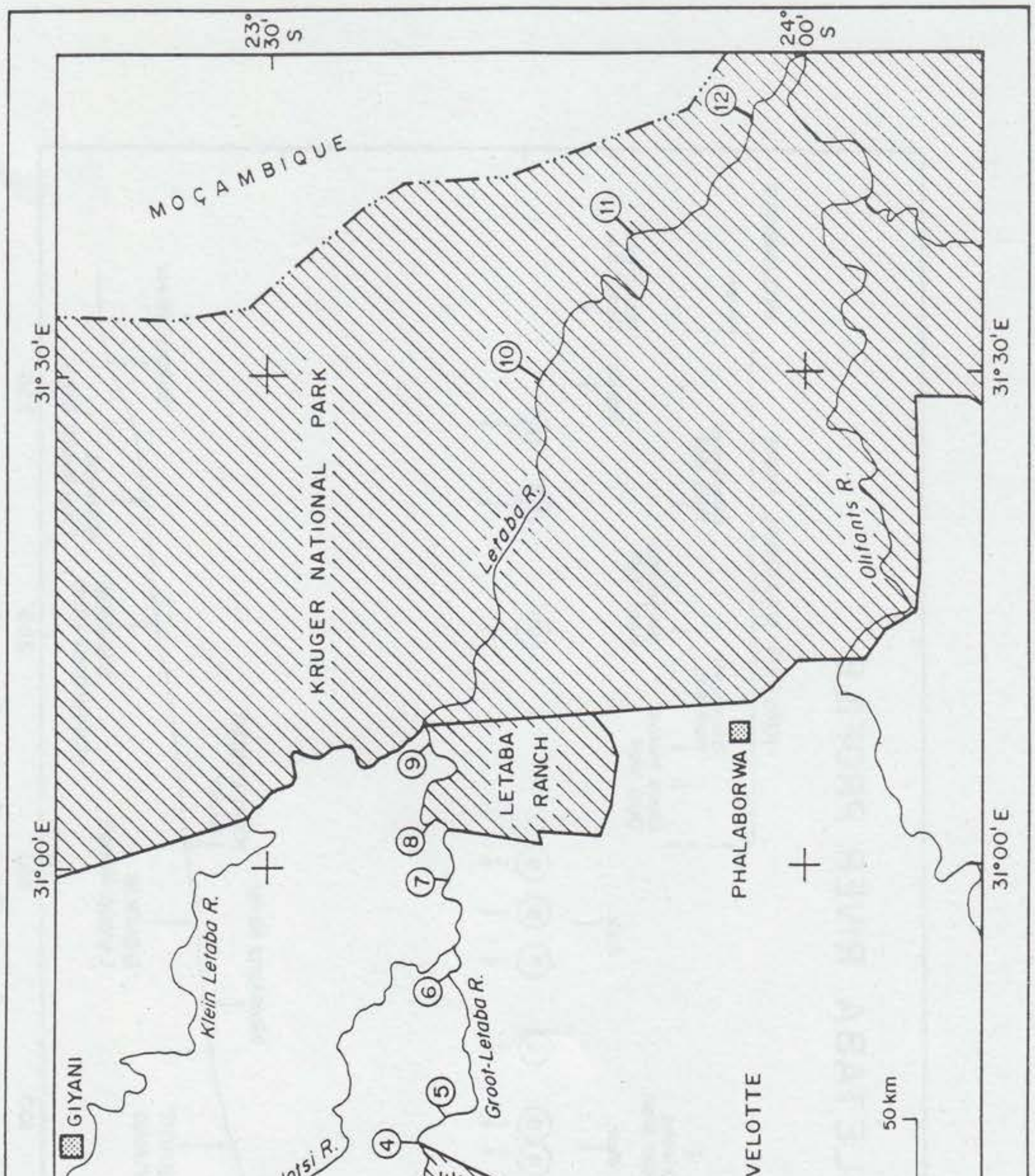


Figure 1: A map of the study area, showing sampling points.

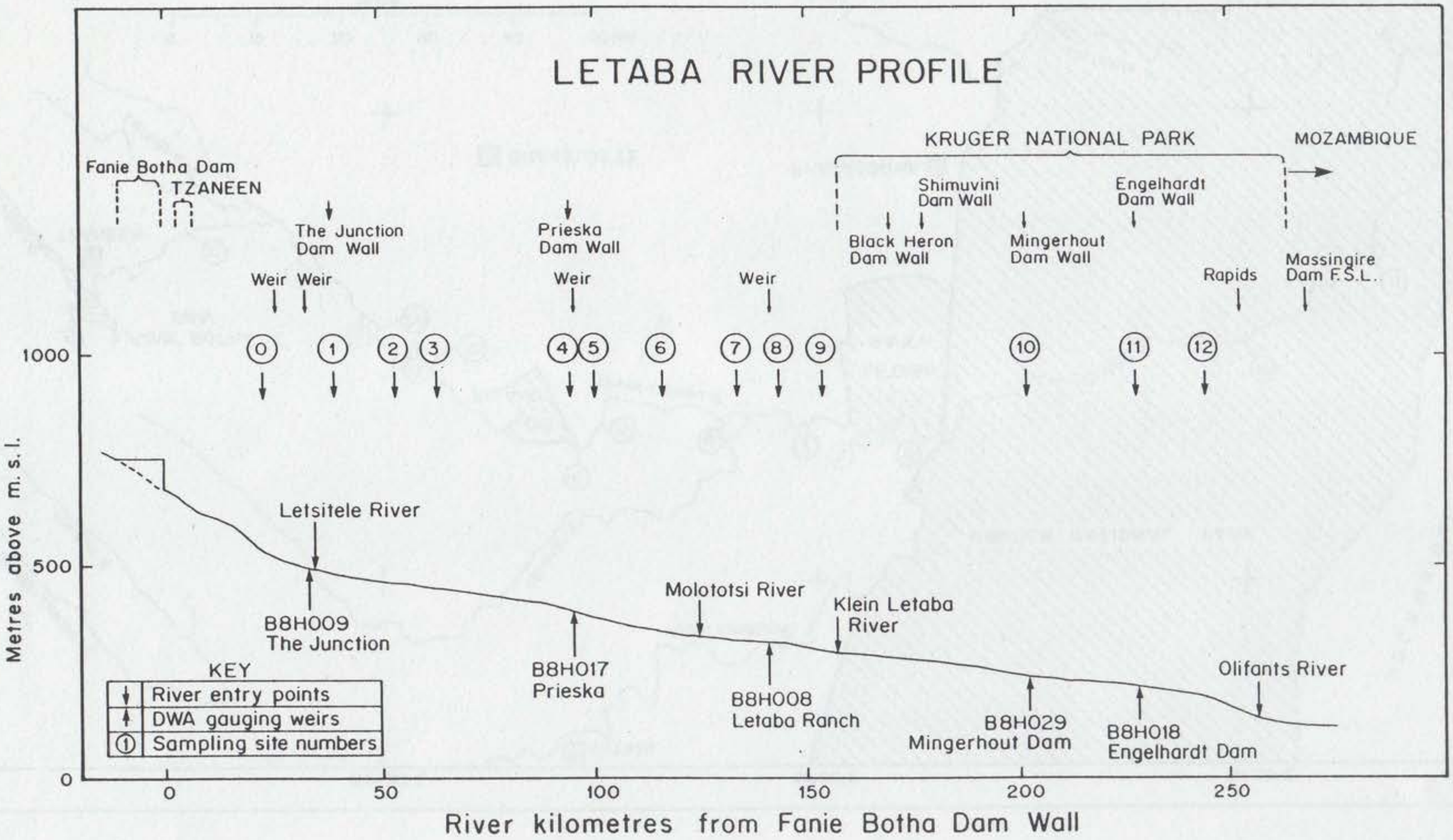


Figure 2: A profile of the Letaba River from Fanie Botha Dam to the confluence with the Olifants River.

Table 1: Letaba River. The coordinates of sampling points.

Station Number	Locality	Longitude S Deg	Min	Sec	Latitude E Deg	Min	Sec
0	Letsitele	23	52	18	30	16	18
1	The Junction	23	51	36	30	23	33
2	Nagude	23	47	26	30	28	09
2A	Laborie	23	45	33	30	29	27
3	Pump Station	23	00	21	30	32	19
3A	Gunyula	23	43	47	30	33	25
4	Prieska Weir	23	38	42	30	43	09
5	Prieska Farm	23	39	57	30	44	58
6	Nondweni	23	41	21	30	50	51
7	The Slab	23	40	11	30	59	24
8	Camp 3[1]	23	38	42	31	02	44
9	Camp 16[1]	23	39	47	31	06	54
10	Below Mingerhout Dam	23	45	05	31	29	16
11	Below Engelhardt Dam	23	50	53	31	44	56
12	Between Engelhardt Dam and Olifants R.	23	56	23	31	38	30

1. Letaba Ranch

Table 2: Letaba River. The dams and larger weirs between Fanie Botha Dam and the Olifants River confluence, in downstream order.

Name of Weir/Dam	Height (m)	Sampling point number
The Junction	12.5	1
Pump Station	2.5	3
Prieska	10.0	4
The Slab	2.5	7
Letaba Ranch B8H008	~2.5	-
Black Heron	7.0	-
Shimuvani	3.0	-
Mingerhout	3.5	10
Engelhardt	13.0	11

3. A REVIEW OF THE HISTORICAL FLOW RECORD

The Letaba Catchment covers some 13 400 km^2. More than 60 percent of the catchment area is located outside the Kruger National Park and all major tributaries rise outside the park. The last time that perennial flow was experienced in the lower 100 km of the Letaba River within the Kruger National Park was at the end of the prolonged drought of the 1960's. The Letaba River was originally a perennial river which, due to major exploitation of its water resources, has been seasonal for the most of the past twenty years.

The reduction in the flow of the Letaba River and its causes have been analysed and reported on in Department of Water Affairs (1990). In this report hydrological models were used to produce a simulated historical flow record from which **Figure 3**, showing the simulated historical flow record at Letaba Ranch (weir B8H008), has been drawn. **Figure 3** shows that there was a substantial dry season flow up to 1956, whereafter dry season flows were often insufficient to appear when plotted on the scale of **Figure 3**. The simulated record suggested that there was no flow at Letaba Ranch for an unbroken 16 month period in 1981/82/83. However, the actual flow recorded showed that this was not the case (see below).

Below Fanie Botha Dam water is diverted into irrigation canals at three points and there is controlled direct abstraction of water from the river at many places. It is estimated that more than the scheduled 8671 ha are irrigated in the Groot Letaba below Fanie Botha Dam. The volume of water allocated for irrigation purposes in this part of the valley is 87.6 x 10^6 m^{3}a^{-1}.

The completion of Fanie Botha Dam in 1977 allowed the regulation of the flow of the Letaba River. This flow modification has resulted in enhanced dry season flow of the river immediately downstream of the dam, but large volumes of water are abstracted from the river for irrigation. The consequence of this is that the flow is considerably reduced in the lower river in the spring and early summer.

Measured flow data for weir B8H008 (built in 1959 and with a catchment area of 4 710 km^2) at Letaba Ranch (**Figures 1, 2**) were obtained from the Department of Water Affairs and Forestry for the period 1981 to 1991. The monthly flows for this period (**Figure 4**) show that until 1988, the flow at Letaba Ranch ceased in most dry seasons for as long as five consecutive months. From 1988, the Groot Letaba Irrigation Board, at the request of the National Parks Board, undertook to ensure a minimum flow of 0.5 m^{3}s^{-1} at the western boundary of the Kruger National Park (F J Venter, pers. comm.).

Figure 4 also shows the intensity of the drought in summers 1981/1982, 1982/1983, 1985/1986 and 1986/1987 when the summer (rainy season) flow was very low. It is noteworthy that although summer flows were moderately high in 1983/1984 and 1984/1985,

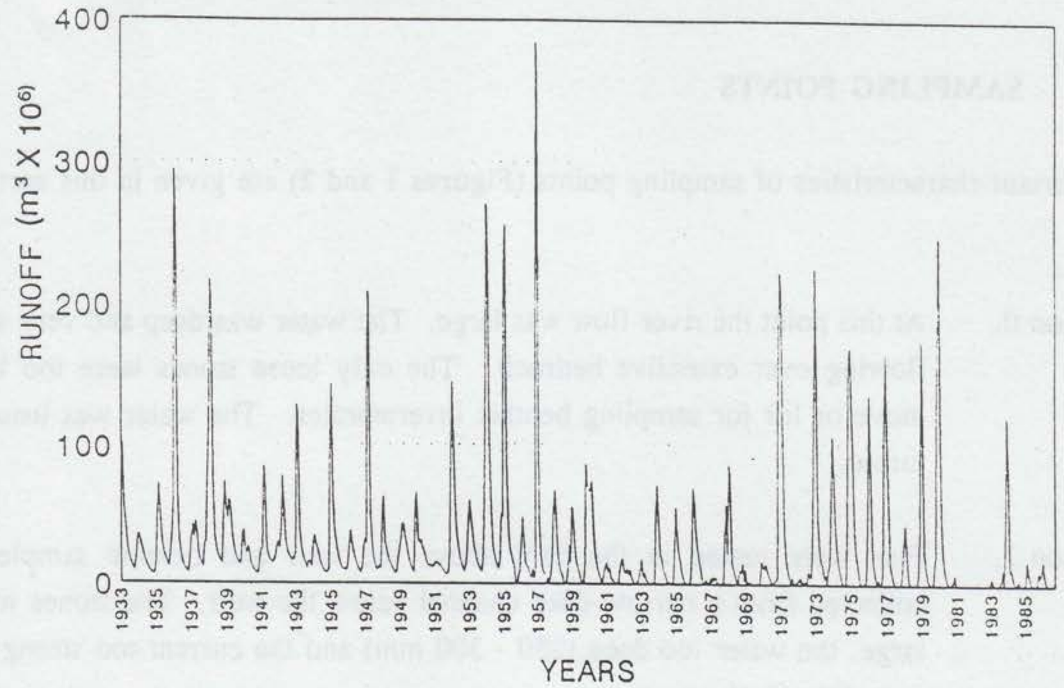


Figure 3: The simulated historical flow of the Letaba River at Letaba Ranch, 1933 to 1986 (from DWA 1990).

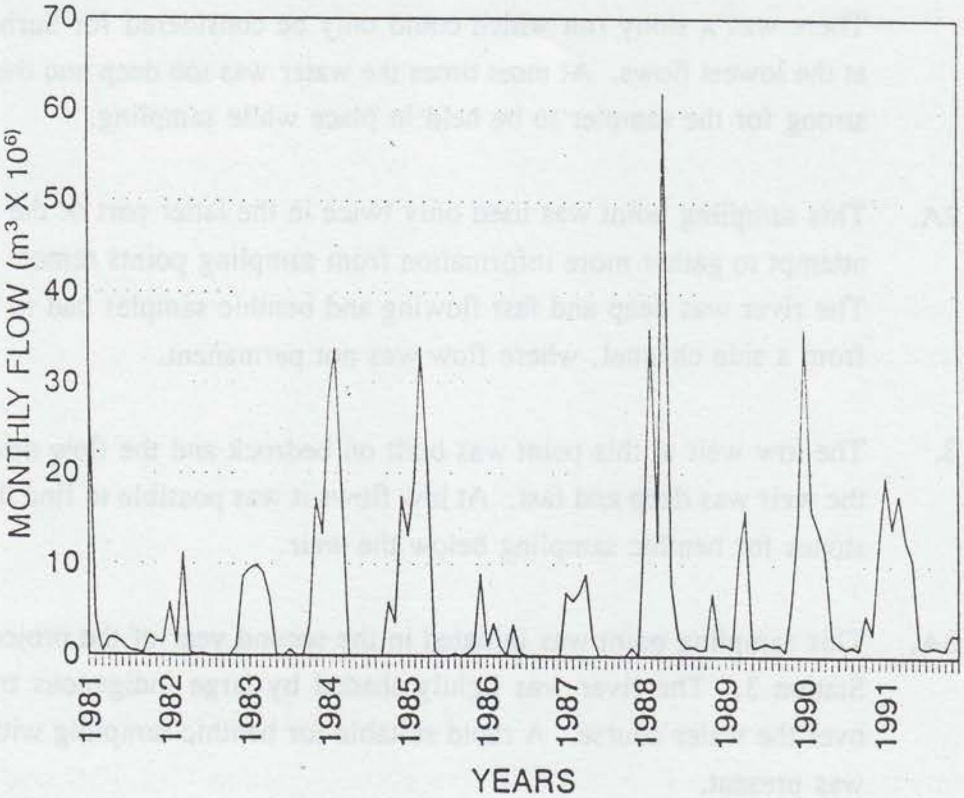


Figure 4: The monthly flow of the Letaba River at Letaba Ranch, 1981 to 1991.

there was still a five month period of no flow at Letaba Ranch in winter 1984. Also, although flows were very low in 1981/82/83, there was some flow, but not none (cf **Figure 3** above), for most of the period covered by these years.

4. SAMPLING POINTS

Important characteristics of sampling points (**Figures 1** and **2**) are given in this section.

Station 0. At this point the river flow was large. The water was deep and very strongly flowing over extensive bedrock. The only loose stones were too large to move or lift for sampling benthic invertebrates. The water was usually not turbid.

Station 1. Fish were netted in the dam above the weir and benthic samples were collected from a narrow deep channel below the weir. The stones were too large, the water too deep (250 - 300 mm) and the current too strong for the use of the Surber sampler.

Station 2. At this site a low concrete causeway has been built over concrete piping to form a low-level bridge. The river bed was braided with tall riparian trees. There was a stony run which could only be considered for Surber sampling at the lowest flows. At most times the water was too deep and the current too strong for the sampler to be held in place while sampling.

Station 2A. This sampling point was used only twice in the latter part of the study, in an attempt to gather more information from sampling points remote from weirs. The river was deep and fast flowing and benthic samples had to be collected from a side channel, where flow was not permanent.

Station 3. The low weir at this point was built on bedrock and the flow downstream of the weir was deep and fast. At low flows it was possible to find the odd loose stones for benthic sampling below the weir.

Station 3A. This sampling point was initiated in the second year of the project to replace Station 3. The river was lightly shaded by large indigenous trees hanging over the water course. A rapid suitable for benthic sampling with a hand net was present.

Station 4. Prieska Weir is built on a large slab of bedrock. When the river flow was insufficient to top the weir, water was released to one side of the river channel, where the flow was again deep and fast. Quantitative benthic sampling was not possible here.

Station 5. The river bottom here was mainly bedrock and there were no man-made structures in the river bed. At the bottom of narrow clefts in the bedrock there were some stones whose benthic invertebrate fauna was collected with a hand net.

Station 6. This was the site of another concrete causeway built over concrete pipes. The bed material in the rapid was loose stones suitable for benthic invertebrate sampling.

Station 7. This sampling point consisted of two substations, separated by about 200 m of river. The upstream site was used only for fish sampling and was above and immediately below a low weir. The downstream site was used for fish and benthic invertebrate sampling. Conditions for benthic sampling of the river were not altogether satisfactory because at high flows only a coarse and loose gravel bed was available.

Station 8. There were no man-made structures in the vicinity of this sampling point. The river bottom was bedrock with areas of loose stones.

Station 9. Bedrock predominated at this sampling point and extensive areas of loose stones were only seasonally inundated. Benthic sampling was never easy at low flows, as there were limited numbers of loose stones in the channels in the bed rock.

In this account of the sampling points emphasis has been placed on their suitability for sampling the benthic invertebrates. It is known that obstructions such as tall weirs have an impact on the composition of the benthic fauna immediately downstream. On the other hand, due to the upstream migratory tendencies of many fish species, they accumulate in large numbers below weirs which are then good places to collect fish. The sampling points initially chosen in this study were a compromise between the requirements of fishing and of collecting benthic invertebrates.

On two occasions the fish fauna was collected at three points within the Kruger National Park. These were as follows:

Station 10. About 5 km downstream of Mingerhout Dam. River bed predominately sand and gravel with *Phragmites* invasion. Water depth very limited and fish collected mainly from a shallow pool disconnected from the main channel.

Station 11. At and below the fish ladder at Engelhardt Dam. Fish were collected in and below the ladder.

Station 12. The Letaba River at the concrete causeway a few kilometres upstream of the confluence of the Letaba and Olifants Rivers. The river bed is mainly shallow and sandy here and has been invaded by *Phragmites*.

5. METHODS

Two water samples for chemical analysis were collected at each sampling point on each sampling occasion. One sample was kept unpreserved and the other, for nitrogen species and orthophosphate determinations, was preserved by the addition of 1% by volume of a saturated mercuric chloride solution.

Unfiltered water samples were analysed in the laboratory following the methods described in National Institute for Water Research (1974). In most cases the automated methods described in the guide were used. Turbidity was measured using a Hach meter and a formazin polymer standard.

Temperature, pH and conductivity were measured in the field using hand-held electronic meters. Current speeds were measured at 40% (measured from the bottom) of the height of the water column, using an Ott propeller driven current meter, Type C2 "10.150". Where depths were measured, a steel meter ruler was used.

On the initial sampling visit benthic invertebrates were collected using a Surber square foot sampler and thereafter, a circular (250 mm diameter) hand net. Three Surber samples were collected at each site where the apparatus could be used. After the initial visit to the river, it was concluded that the Surber sampler was of limited usefulness due to the depth and speed of the current in the rapids and to the limited numbers of loose stones in several of them. Both the Surber sampler and the hand net were fitted with 300μ pore size nylon bolting cloth. In the field, using either sampling method, stones were lifted from the river bottom into a 10ℓ plastic bucket (in the case of the hand net, with the net held behind the stone)with some water in it.

When sampling was complete the bucket was taken to the side of the river where the animals were cleaned off the stones into the bucket. They were then poured through the sampling net, put into plastic bags, preserved with Formalin and returned to the laboratory for enumeration of the species present and their abundance. The hand net samples cannot be regarded as giving quantitative results, though from the fact that the same bucket was filled with stones at each sampling location, the broad picture of invertebrate numerical abundance is contained within the total numbers of animals collected at each sampling point.

A rectangular (400 mm horizontal, 300 mm vertical) net fitted with 1 mm pore size nylon bolting cloth was used to collect invertebrates shocked or disturbed into the water column during electro-fishing. Opportunity of field work in the Letaba River was also taken to collect Simuliidae from fringing vegetation where they were particularly abundant, to compare collections made using 300μ and 1000μ nets and to experiment with the BMWP method (Hellawell, 1986) for evaluating stream conditions from the benthic fauna. These extra studies are not part of the study of the impact of low flow, but they have made more extensive information on the diversity of the river fauna available. This information has been used in this report.

Several methods were used to collect fish. These depended on river conditions at the sampling points. An electro-shocker was used in riffles, a gill-net in the deeper water upstream of weirs and a mosquito seine net in the stagnant, shallow (<1 m deep) pools which were adjacent to the river at some stations. The distribution of these habitat types from Station to Station is summarised in **Table 3**.

Table 3: Letaba River. Methods used to catch fish by sampling station. E - electro-shocker, G - gill-nets, M - mosquito seine net.

Station	0	1	2	3	4	5	6	7	8	9	10	11	12
Riffle	E	E	E	E	E	E	E	E	E	E	E	E	E
Pool	M	M	M	-	M	M	-	M	-	-	M	M	-
Dam	-	G	-	G	G	G	-	G	-	-	-	G	-

The collected fish were identified and counted by species. A representative sample of each species was measured (standard length in cm).

Physical features of riffles and rapids of importance to fish are summarised in **Table 4**. It should be noted that the depths at which the benthic invertebrates were collected were usually greater then those shown in **Table 4** for the fish. Depending on the flow of the river, stones were frequently 500 mm or more below the surface at Stations 2, 4, 5, 8 and 9.

Table 4: Letaba River. Physical conditions in the riffles and rapids at the sampling points. B - bedrock, L - large boulders (>30 cm), M - medium boulders (20-30 cm), S - stones (<20 cm), R - reeds, Sa - sandy and G - grass.

Physical conditions	Sampling Point												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Substrate	L/B	L	M/L	B	B/M	L	S/M	L	L	L	B/S	L	S/Sa
% Overhead cover	30	0	90	-	-	70	80	50	50	0	0	0	0
Marginal vegetation	R	R	R	-	R	R	G/R	R	R	R	R	R	R
Riffle Fishing Depth (cm)	40	20	30	35	30	30	20	20	20	20	3	15	10

The composition of benthic and fish samples was compared from station to station and from month to month using the Czekanowski Index of Similarity (similarity due to joint occurrences of species in the samples compared) and Percentage Similarity (similarity due to shared dominant species) (Kemp *et al*, 1976). Results of these comparisons are graphically shown as dendrograms created using Group Average Sorting (also called UPGMA or unweighted pair-group method using arithmetic averages) of similarity matrices.

6. RESULTS

6.1 RIVER FLOW

During the study period (1990 and 1991) the total monthly flows at Letaba Ranch showed the same seasonal trends as the prior nine years, that is high summer flows and low winter flows (**Figure 4**). However, **Figure 4** also shows that from 1988, when a policy of attempting to ensure a minimum flow of 0.5 m^3s^{-1} was initiated, river flow did not cease in the dry season. A closer examination of the daily flow record showed that there were 3 consecutive days in November 1990 and 11 consecutive days in August 1991, when there was no flow at Letaba Ranch (**Table**

5). It is most probable that these two interruptions of flow were of insufficient duration to result in the entire river bed drying out, a conclusion which is supported by the fauna recorded on field trips shortly after the flow resumed. There were, in fact, six consecutive months in 1991 when the mean monthly flow was less than 0.5 m^3s^{-1}

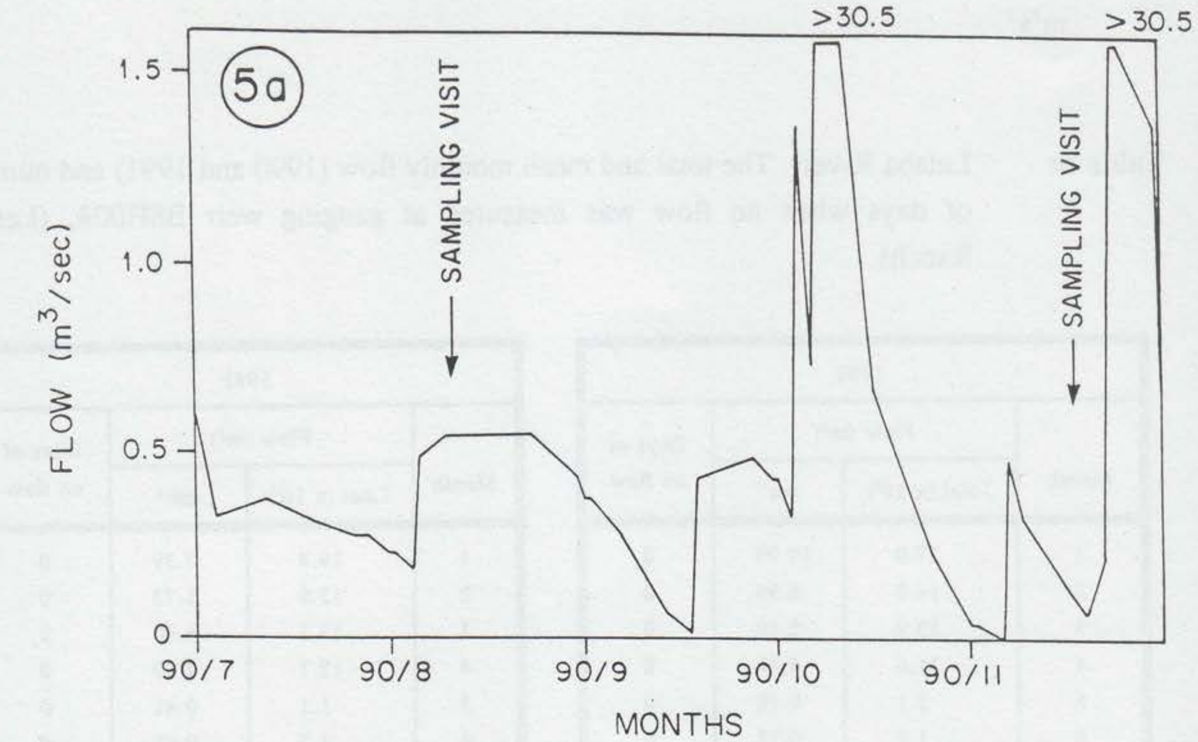
Table 5: Letaba River. The total and mean monthly flow (1990 and 1991) and number of days when no flow was measured at gauging weir B8H008, (Letaba Ranch).

1990			
Month	Flow (m^3) Total (x 10^6)	Flow (m^3) sec^{-1}	Days of no flow
1	27.0	10.09	0
2	16.0	6.59	0
3	13.9	5.19	0
4	11.6	4.49	0
5	2.1	0.78	0
6	1.4	0.55	0
7	0.9	0.33	0
8	1.2	0.46	0
9	0.7	0.28	0
10	4.7	1.75	0
11	2.4	0.95	3
12	11.8	4.42	0

1991			
Month	Flow (m^3) Total (x 10^6)	Flow (m^3) sec^{-1}	Days of no flow
1	19.8	7.39	0
2	13.9	5.73	0
3	17.7	6.60	0
4	12.7	4.90	0
5	1.1	0.41	0
6	1.2	0.46	0
7	0.9	0.32	0
8	1.2	0.46	11
9	1.0	0.40	0
10	0.8	0.30	0
11	2.6	1.00	0
12	2.3	0.88	0

November 1990 and August 1991 were both months in which field sampling was undertaken. In November 1990 the field trip took place 2 weeks after flow had resumed, and in August 1991 the sampling points downstream of Letaba Ranch were visited only seven days after flow had resumed. The daily flow record at Letaba Ranch for the low flow period prior to these sampling visits is of considerable importance to the biological findings and is shown in detail in **Figure 5**.

The maximum flow that can be measured at the Weir at Letaba Ranch is 30.5 m^3s^{-1}. The 1990 flow record for this weir (**Figure 5a**) reveals that within three weeks in October/November 1990 the flow of the Letaba rose to exceed the weir capacity and then fell to nothing. In September the river flow fell below 0.1 m^3s^{-1} for six days. The flow of the river was less than 0.5 m^3s^{-1} for about half the time period shown in **Figure 5**.



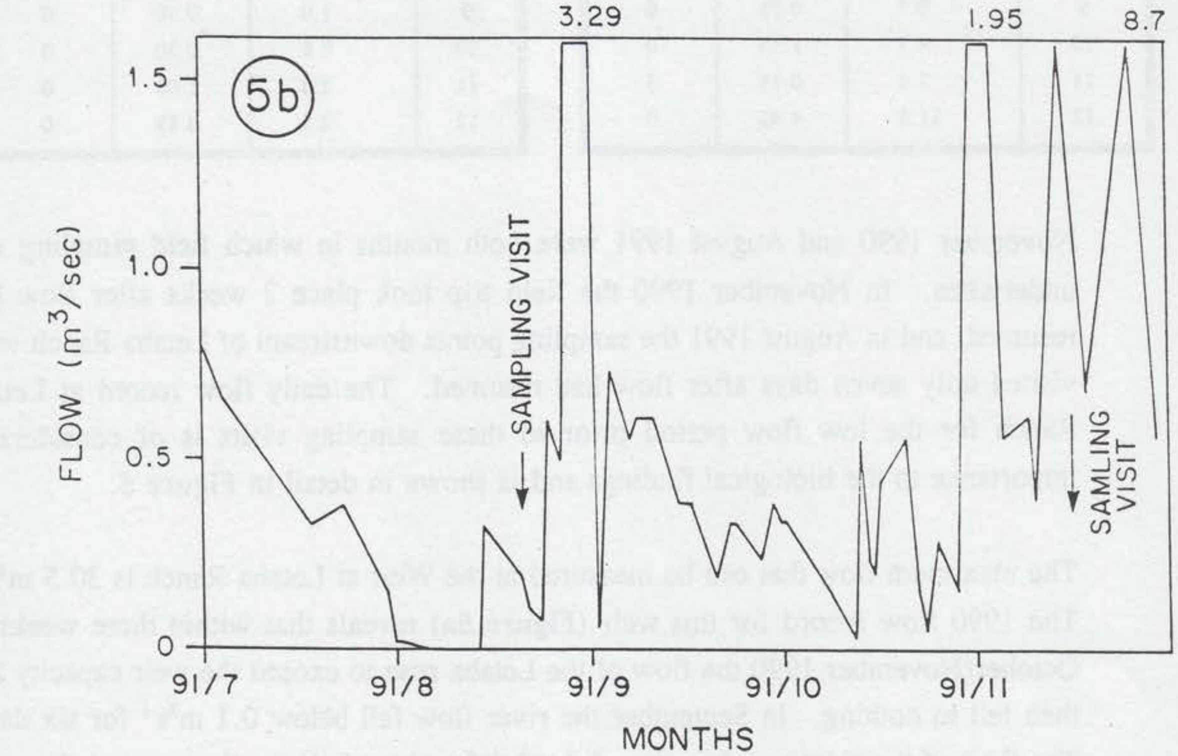


Figure 5: The daily flow of the Letaba River at Letaba Ranch, July to November 1990 (Fig. 5a) and 1991 (Fig. 5b). Data supplied by the Department of Water Affairs and Forestry.

In the spring and early summer of 1991, the river flow was never as great as it had been in 1990 (**Figure 5b**). It was, if anything more variable in 1991 than in 1990 and there were, in addition to the eleven days in August when there was no flow, three further occasions when the flow was less than 0.1 m^3s^{-1}.

It is clearly evident from **Figure 5** that the abstraction of water from the Letaba River for irrigation purposes is highly erratic. It cannot be assumed that the management objective to ensure a minimum flow of 0.5 m^3s^{-1} in the Kruger National Park will result in a constant flow in the Park, even though the mean monthly flow may approximate 0.5 m^3s^{-1}.

6.2 WATER TEMPERATURES

The data presented here (**Table 6**) was recorded during visits to the river. The day-time water temperature ranged between 17 and 24°C in winter (August), between 21 and 23°C in autumn (May) and, except at Station 0 where there may have been an impact due to the release of cold hypolimnetic water from Fanie Botha Dam, was above 25°C in summer (November and February). A remarkably high temperature of 37°C was measured in November 1990 at Station 10 in the mid afternoon of the day when the water was 10°C cooler at Station 11 and 12 in the morning. Factors which may have contributed to the large temperature difference were the time of the day, the presence of the large body of water in Engelhardt Dam which would tend to damp temperature fluctuations and the exposure and bottom material (black rock) of the river bed at Station 10.

6.3 CURRENT SPEEDS

The objective of measuring current speeds was to provide some quantification for subjective assessments of the current speed as fast or otherwise. Given the very variable current speed conditions at most sampling points and the aims of the study, it was not intended to characterize the current speed of the stones sampled to the extent that the impact of current speed on the composition of benthic invertebrate populations could be elucidated in detail. Indeed, current speeds were not measured at Stations 0 and 3, where benthic invertebrates could not be properly collected or at Station 2A which was a temporary rapid. Only one measurement was made at Station 1, where the current speed could be seen to be very high.

Table 6: Letaba River. Water temperatures in °C.

Station	Date 1990 Feb	May	Aug	Nov	1991 Feb	May	Aug	Nov
0		22	17	24	25	19	17	21
1		21	17	26	26	20	19	29
2	28	21	18	25	26	20	18	24
3		21	20	27	29	20	18	28
4	27	21	20	29	27	20	19	27
5	29	23	19	27	26	21	18	30
6		22	18	28	27	21	19	28
7	29	22	21	29		23	20	30
8	30	22	20	29	27	21	18	31
9		22	20	29	27	21	19	28
10				37			18	
11				27			18	
12				26			24	

The results of a statistical analysis of the current speed data are presented in **Table 7**. Maximum current speeds were high (above about 1.4 ms^{-1}) at Stations 1, 2, 4 and 6, and intermediate (0.85 to 1.15 ms^{-1}) at the remaining Stations. When considering mean current speeds, Station 1 where only one measurement was made, cannot be included. The remaining sampling points fell into the same groups arrived at from the maximum current speed, except that Station 9 stood alone with a low mean current speed.

Table 7: Letaba River. Current speeds in ms^{-1} by sampling point.

Sampling point	Number of measurements	Mean current speed	Standard deviation of mean	Maximum current speed	Minimum current speed
1	1	1.52	-	-	-
2	10	0.73	0.41	1.67	0.34
3A	8	0.65	0.14	0.85	0.45
4	5	0.82	0.33	1.38	0.54
5	8	0.68	0.20	1.04	0.30
6	10	0.87	0.39	1.38	0.44
7	12	0.63	0.23	0.97	0.18
8	8	0.75	0.29	1.15	0.46
9	6	0.46	0.34	1.12	0.26

6.4 WATER CHEMISTRY

The lowest conductivity values were recorded at Station 0 (**Table 8**) and conductivity values increased in a downstream direction. The highest conductivities were measured in August and November 1990, both months in which the flow was at times very low (**Table 5**). When the lower river was visited in August 1991, only a week after it had ceased flowing for 11 days, the conductivities recorded would seem, by comparison with August 1990 conductivities, to indicate that the water released from Fanie Botha Dam to supplement the river flow had reached Station 9. Conductivities were lowest in February of both study years.

Table 8: Letaba River. Conductivity (mSm^{-1} at 25°C) values recorded in the field.

Station	Month							
	1990				1991			
	Feb	May	Aug	Nov	Feb	May	Aug	Nov
0		5	6	4	12	7	5	5
1		15	11	4	12	16	12	12
2	16	27	23	12	16	23	19	8
3		26	30	16	14	26	17	14
4	16	27	37	21	16	27	21	17
5	16	27	40	23	18	26	22	18
6		33	51	41	21	33	39	21
7	20	33	55	58		31	44	22
8	22	34	67	61	19	34	52	26
9		32	66	69	21	27	41	27
10				44			33	
11				48			30	
12				32			34	

As is shown in **Table 9**, at most times the Letaba River water was alkaline in the pH range 7.2 to 8.4 (outlying values were 6.9 and 8.6).

Table 9: Letaba River. pH values recorded in the field.

Station	Month							
	1990				1991			
	Feb	May	Aug	Nov	Feb	May	Aug	Nov
0		7.6	7.4	7.5	7.7	7.9	7.7	7.7
1		7.6	7.7	8.2	7.9	7.5	7.4	7.7
2	6.9	7.8	7.3	7.9	7.8	7.5	7.2	7.8
3		7.5	7.2	8.2	8.3	7.8	7.6	8.1
4	7.6	7.4	8.1	8.1	7.9	7.7	7.8	8.1
5	7.7	8.0	7.7	8.0	7.9	7.8	7.8	8.0
6		7.8	7.7	8.0	7.9	7.8	7.8	7.8
7	7.8	8.1	8.0	8.3		8.0	8.0	8.0
8	7.7	7.9	7.5	8.2	8.0	7.7	7.8	7.6
9		7.7	7.7	8.4	7.8	7.8	7.8	8.1
10				8.6			7.9	
11				7.6			7.8	
12				7.5			8.0	

In common with many other rivers whose catchments are heavily populated, the Letaba was more turbid in the rainy season (February) than at other times (**Table 10**). Station 0 water consisted solely of water released from Fanie Botha Dam in May, August and November 1990 and in May and August 1991, which accounts for the very low turbidity of the water at this station at these times.

Table 10: Letaba River. Turbidity (NTU).

Station	Month						
	1990				1991		
	Feb	May	Aug	Nov	Feb	May	Aug
0		3	3	4	52	2	
1		5	20	5	67	4	
2	28	25	10		82	3	10
3		18			34	3	10
4	47				32	6	3
5	116	18	4		29	2	4
6	77			4	27	4	8
7	136	24	8		48	2	5
8	136	25		20	39	5	3
9		42	10		78	7	5
10				15			
11							27
12				22			

Orthophosphate concentrations (**Table 11**) in the river were low, considering that the Letaba River is a lowland river with intensive and extensive irrigation development. No seasonal or longitudinal trends of concentration change are evident from the data given in the table. An exceptionally high value was recorded from Station 9 in August 1991.

Table 11: Letaba River. Orthophosphate ($\mu g \ell^{-1}$)

Station	Month						
	1990				1991		
	Feb	May	Aug	Nov	Feb	May	Aug
0		32	38	52	74	85	
1		50	82	23	70	89	
2	65		60				41
3		40			73	80	34
4	89						38
5	69	44	58				39
6	95			19	56	76	32
7	117	47	39				30
8	105			36	63	86	40
9		53	52		69	93	223
10				91			
12				103			44

The recorded concentrations of nitrogen species (**Table 12**) also reveal no seasonal or longitudinal trends of change. These concentrations were low and indeed the total nitrogen concentration (Kjeldahl N + NO_2 + NO_3) was seldom greater than 1 $mg\ell^{-1}$.

Concentrations of the major ions (**Table 13**) were low at Station 0, and, with the exception of potassium, rose gradually down the course of the river. As might be expected, concentration increases down the course of the river were greater during low flow conditions (August 1990, November 1990 and August 1991) than at other times.

Table 12: Letaba River. Nitrogen species ($\mu g \ell^{-1}$).

Determinand & Sampling Station		Month						
		1990				1991		
		Feb	May	Aug	Nov	Feb	May	Aug
Kjeldahl N	0		199	153	333	292	269	
	1		224	302	219	315	324	
	2	< 15		263				
	3	0	230					
	4					256		518
	5	230	169	409				403
	6	201			263	231	266	406
	7	628	200	214				396
	8	254			259	228	298	396
	9	213	230	386		269	321	462
	10				337			
	11							602
	12				437			
Ammonia N	0		92	21	103	95	57	
	1		80	75	71	187	52	
	2	71		48				
	3		70			69		
	4	154						69
	5	86	67	86				51
	6	222			97	51	50	49
	7	140	62	29				25
	8	134			98	62	58	50
	9		83	84		66	56	74
	10				76			
	11							199
	12				105			
NO_3+NO_3 N	0		274	308	378	555	362	
	1		291	446	363	313	347	
	2	283		563				
	3		357			358		
	4	263						209
	5	307	303	208				245
	6	303			94	213	164	156
	7	318	301	62				132
	8	337			79	235	182	180
	9		439	94		267	57	160
	10				93			
	11							390
	12				91			

Table 13: Letaba River. The concentrations of major ions in the water in $mg\ell^{-1}$, alkalinity as $CaCO_3$.

Date & Determinand	Station Number													
	0	1	2A	3	3A	4	5	6	7	8	9	10	11	12
Aug. 1990														
Sodium	6										37			
Potassium	1										2			
Calcium	4										33			
Magnesium	1										11			
Sulphate	9										6			
Chloride	7										65			
Alkalinity	21										151			
Nov. 1990														
Sodium	4	9						47		56		22		41
Potassium	<1	1						1		2		2		2
Calcium	2	3						15		24		18		18
Magnesium	2	2						12		16		11		14
Sulphate	4	6						20		39		6		6
Chloride	6	7						44		81		23		47
Alkalinity	19	22						129		113		128		144
Feb. 1991														
Sodium	9	10		11			9		15	14	21			
Potassium	3	3		2			2		2	2	2			
Calcium	10	9		8			12		11	9	11			
Magnesium	3	3		4			6		6	6	6			
Sulphate	30	23		22			27		19	8	20			
Chloride	15	15		17			18		22	20	24			
Alkalinity	25	29		28			42		54	53	57			

Continued/....

Table 13 continued

Date & Determinand	Station Number													
	0	1	2A	3	3A	4	5	6	7	8	9	10	11	12
May 1991														
Sodium	4	10			22		23		32		29			
Potassium	1	1			1		1		2		2			
Calcium	5	12			18		17		17		16			
Magnesium	2	6			10		10		10		10			
Sulphate	< 5	< 5			5		< 5		< 5		5			
Chloride	11	17			32		35		42		38			
Alkalinity	22	60			87		87		100		96			
Aug. 1991														
Sodium			18		20	22	23	51	54	63	46		28	
Potassium			< 1		< 1	< 1	< 1	1	< 1	1	1		1	
Calcium			12		13	14	15	20	22	27	22		22	
Magnesium			6		7	18	8	13	14	19	13		12	
Sulphate			< 5		8	10	13	24	14	9	7		5	
Chloride			24		30	29	31	53	62	76	58		34	
Alkalinity			67		76	77	84	139	137	203	133		124	
Nov. 1991														
Sodium		11	12		11		14		19		23			
Potassium		< 1	< 1		< 1		< 1		< 1		< 1			
Calcium		4	5		6		8		9		10			
Magnesium		2	3		3		4		5		7			
Sulphate		5	< 5		< 5		< 5		5		6			
Chloride		9	15		15		19		24		31			
Alkalinity		37	45		48		57		71		85			

6.5 BENTHIC INVERTEBRATE FAUNA

6.5.1 Longitudinal distribution

The full list of taxa collected by any method in the Letaba River by sampling point is given in **Appendix Table A1**. This table reveals the level to which the various groups of benthic invertebrates were identified.

Many taxa, particularly among the Ephemeroptera (mayflies) were found mainly from Station 4 downstream. These taxa included *Afrobaetodes* sp., *Ophelmatostoma* sp., *Pseudopannota* sp. nov. and *Elassoneuria* sp., all of which are found in South Africa mainly in sub-tropical and tropical rivers. *Ecnomus* sp., *Leptelmis* sp., *Simulium bovis*, *S. impukane* and *S. ruficorne* were also more frequently encountered in the lower part of the river (below Prieska Weir, Station 4) than in the upper part of the river. There were only two species, *Simulium cervicornutum* and *S. unicornutum* which were found only upstream of Station 4.

The greater number of species found mainly in the lower river explains in part the apparent greater species richness of the lower river (number of taxa given at the foot of **Table A1**). Sampling intensity was far lower at Stations 0, 2A, 3 and 3A than at the downstream Stations. Station 1 was sampled in a very fast current immediately below a high weir which would account for the restricted number of species found there. In sampling frequency and suitability of habitat, only station 2 from the upper river (above Station 4) was comparable with the sampling points downstream of Prieska Weir. At Station 2 only 56 taxa were found, as compared with the 67 to 81 taxa found at Stations 7 to 9 (Table A1).

It is interesting that *S.ruficorne*, a very widespread species, should have been found in that part of the river most prone to drying up (Station 8 and 9). This species specializes in very small streams of shallow water and has been found in streamlets at oases in the Sahara.

Many of the trends in species richness found by taking all available data are confirmed when a more stringent selection of samples is made (**Table 14**). The selection was of those samples collected with a 300μ net in the stones in current, that is the samples collected in order to make station to station comparisons.

The number of samples taken from Station 2 was inflated by the fact that, on the first sampling trip, replicate samples were collected using a Surber sampler. It is well-known that the larger the numbers of samples and of benthic invertebrates collected, the greater the number of taxa likely to be collected. Examination of **Table 14** reveals that, in relation to the number of animals collected, the species richness at Station 1 was low, while it was high at Stations 8 and 9. Results from Stations 2 and 5 were comparable. Too few samples were collected at Stations 2A, 3 and 3A to allow for comparison of numbers of species found with other Stations. Rather low numbers of animals were collected from Station 4, but species richness was about 20% lower at Station 4 than at Station 9, where a similar number of animals was collected. There is no evidence from **Table 14** that the species richness in the stones in current of the lower part of the river was lower than that of the upper part of the river.

The information in **Table 14** does, however, show that the number of species recorded was low at Stations 1 and 4, which were immediately downstream of high weirs.

Table 14: Letaba River. Stones in current samples collected with 300μ nets. A summary table showing the numbers of samples taken, the numbers of taxa found and the numbers of individual animals collected by sampling point.

Station	Number of samples	Number of taxa	Number of individuals
1	6	43	29 562
2	10	60	11 777
2A	2	48	6 267
3	1	21	2 621
3A	3	44	6 134
4	6	48	7 055
5	8	59	11 279
6	8	65	30 809
7	8	61	20 343
8	8	71	19 361
9	7	58	7 651
Totals	67	102	152 859

6.5.2 Seasonal variation

The recorded occurrence of all the taxa collected in the regular 300μ net samples by sampling month is given in **Appendix Table A2**, from which the data given in **Table 15** has been extracted. In 1990 there was remarkably little difference in the numbers of taxa collected from month to month. 1991 collections contained greater numbers of taxa in May, August and November and low numbers in February. August 1991 was the month in which the river ceased flowing at Letaba Ranch for 11 days. (Flow cessation would have occurred at Stations 8 and 9 for certain, possibly at Station 7 and almost certainly not at Station 6). From the content of **Table 15**, there is no evidence that this resulted in a decline in the invertebrate species richness of the river.

Table 15: Letaba River. The numbers of taxa collected in stones in current samples in each sampling month.

1990			
Feb.	May	Aug.	Nov.
56	60	56	56

1991			
Feb.	May	Aug.	Nov.
47	63	68	63

6.5.3 Faunal similarity between sampling points

The similarity of the benthic invertebrate fauna of the various sampling points due to the extent of occurrence of shared species is shown in **Figure 6**. In order the gain the broad picture of this similarity, combined data from various sampling points for various combinations of dates were used (see caption to **Figure 6**). This was done because there were no sampling visits when all sampling points were sampled.

The broad picture revealed by **Figure 6** is that there was considerable similarity between all sampling points as regards the species present. Omitting Station 1 in **Figure 6a**, 69% of the taxa recorded at each sampling point were also found at all other sampling points. To some degree this percentage is influenced by the extent to which the fauna can be identified. Nevertheless some interesting facts do emerge from the dendrograms in **Figure 6**. In all three dendrograms, Stations 8 and 9 and Stations 6 and 7 were more similar to one another than to other Stations. In two of

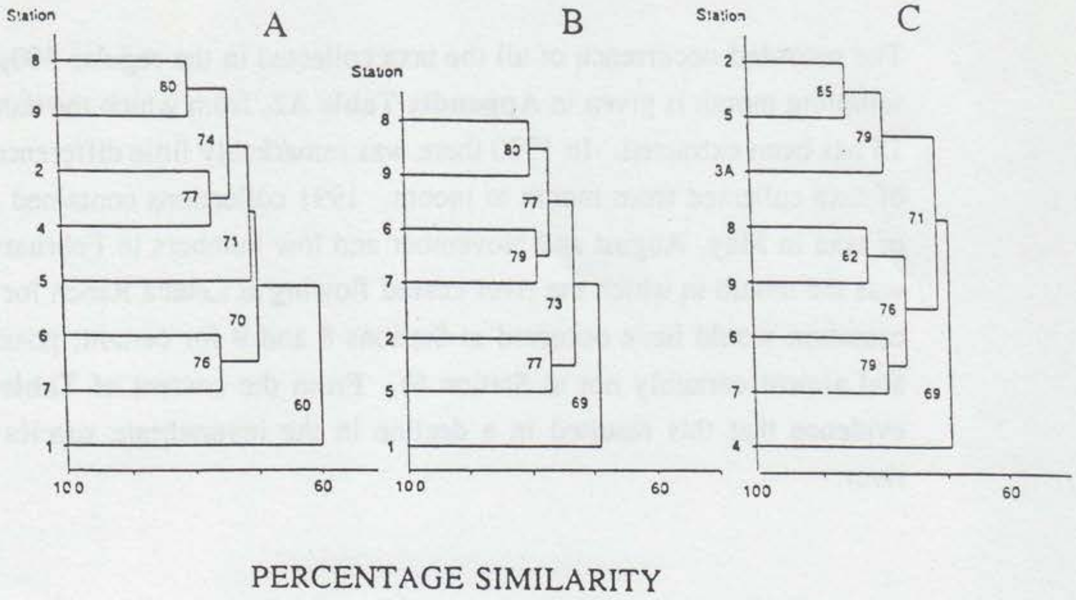


Figure 6: Dendrograms showing similarity between the fauna of various sampling points based on the shared occurrence of species. **Fig. 6a** based on data from 5/90, 2/91, 5/91 and 8/91. **Fig. 6b** based on data from 5/90, 8/90, 11/90, 2/91, 5/91 and 8/91. **Fig. 6c** based on data from 5/91, 8/91 and 11/91.

the three dendrograms (**Figures 6b** and **6c**), Stations 8 and 9 were more similar to Stations 6 and 7 than they were to any other Stations. **Figure 6c** shows the upper river stations (2, 3A and 5) in one cluster, the lower river stations (6, 7, 8 and 9) in another.

Data from Station 1 were included only in **Figures 6a** and **6b**. In each case Station 1 stands out as being less similar to the other stations than any other station. This was due to the rather low faunal diversity at this station (**Tables 14** and **A1**, note Ephemeroptera diversity), rather than to the occurrence of species only at Station 1.

The information contained in **Figure 6** may be summarised as indicating that the proximity of sampling points to one another was the major factor governing the degree to which their faunas were similar in respect of shared species.

Dendrograms representing similarity between sampling points based on the numerically dominant species within single samples are shown in **Figure 7**. Once again there was a tendency for sampling points geographically close to one another

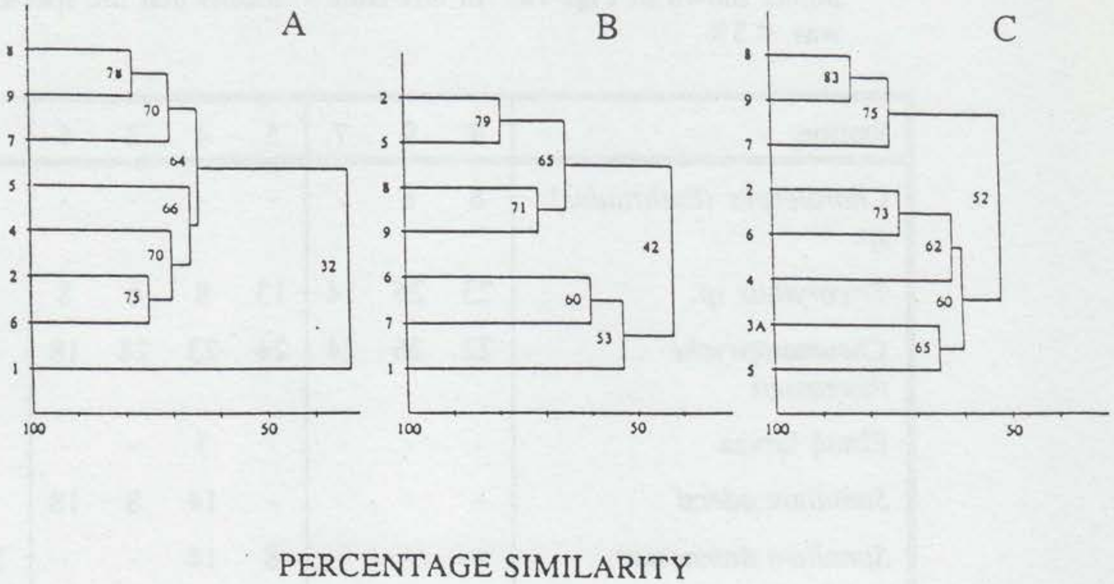


Figure 7: Dendrograms showing similarity between the fauna of various sampling points based on the numerically dominant species. **Fig. 7a** based on data from 5/90, 2/91, 5/91 and 8/91. **Fig. 7b** based on data from 5/90, 2/91, 8/90, 11/90, 5/91 and 8/91. **Fig. 7c** based on data from 5/91, 8/91 and 11/91.

to show greater similarity than those widely separated. Station 1 tended to be very different from the other stations.

The dominant species at Station 1 were different to those at all other Stations in the data set used to construct **Figure 7a (Table 16)**. *Tricorythus* sp. and *Cheumatopsyhe thomasseti* were very scarce and the Simuliidae were very abundant at Station 1 in contrast to the other sampling points where *C. thomasseti* and *Tricorythus* sp. were abundant and Simuliidae were few. *C. (Euthraulus)* sp. and *Tricorythus* sp. were more abundant at Stations 8 and 9 than elsewhere, thus accounting for the high percentage similarity between these two sampling points.

The dendrogram for the similarity between the sampling points shown in **Figure 7b** shows that they fell into two groups (Stations 2,5,8 and 9 and 1,6 and 7). The first of these groups had large numbers of *Tricorythus* sp. and of *C. thomasseti* **(Table 17)** while the second group was characterized by the abundance of *Simulium medusaeforme*. As in the dendrogram shown in **Figure 7a**, larger percentages of *C. (Euthraulus)* sp. and *Tricorythus* sp. were found at Stations 8 and 9 than the other stations.

Table 16: Percentages of species whose mean percentage was >5% for the sampling points shown in **Fig. 7a**. In this table - means that the species percentage was <5%.

Station	8	9	7	5	4	2	6	1
Choroterpes (Euthraulus) sp.	8	8	-	-	-	-	-	-
Tricorythus sp.	23	26	14	13	8	6	8	-
Cheumatopsyche thomasseti	22	26	24	24	23	28	18	6
Elmid larvae	-	-	-	-	5	-	-	-
Simulium adersi	-	-	-	-	14	8	18	-
Simulium damnosum	-	-	-	8	14	-	-	39
Simulium medusaeforme	-	-	-	-	7	-	-	28
Chironominae	-	-	6	5	-	-	-	-
Orthocladiinae	14	8	24	11	12	18	20	11
Eupera sp.	-	6	-	21	-	6	-	-

Table 17: Percentages of species whose mean percentage was >5% for the sampling points shown in **Fig. 7b**. In this table - means that the species percentage was <5%.

Station	2	5	8	9	6	7	1
Choroterpes (Euthraulus) sp.	-	-	5	8			
Tricorythus sp.	7	9	13	24		7	-
Amphipsyche scottae	-	-	7	-		6	-
Cheumatopsyche thomasseti	29	24	28	24	9	17	6
Simulium adersi	7	-	8	-	27	-	-
Simulium damnosum	-	-	-	-	-	-	37
Simulium medusaeforme	-	-	-	-	36	25	26
Orthocladiinae	18	19	12	9	9	22	12
Eupera sp.	6	14	-	5	-		5

In **Figure 7c**, where the lowest level of similarity in the dendrogram was a high 52%, differences between the dominant species along the river were less marked than they had been in **Figures 7a** and **7b**. Nevertheless Stations 7, 8 and 9 were more similar to one another than they were to the other sampling points (**Table 18**). The species mainly concerned were again *Tricorythus* sp., *C. (Euthraulus)* sp. and *A. scottae* (relatively abundant) and Simuliidae (relatively scarce) in this lower part of the river.

All in all, the comparisons between sampling points based on species diversity and on dominant species support the conclusion that the benthic invertebrate fauna of the stones in current and rapids of Stations 7, 8 and 9 differs somewhat from that of the river upstream of these sampling points. These are the sampling points which would be subject to the most stress due to flow cessation. It is therefore of considerable interest that the diversity of the invertebrate fauna was at least as great at these sampling points as it was further upstream. It included several unusual mayfly species, which are not commonly found in South Africa.

Table 18: Percentages of species whose mean percentage was >5% for the sampling points shown in **Fig. 7c**. In this table - means that the species percentage was <5%.

Station	8	9	7	2	6	4	3A	5
Choroterpes (Euthraulus) sp.	6	8	-	-	5	-	-	-
Tricorythus sp.	17	17	16	9	5	-	-	9
Caenidae	-	-	-	-	-	-	6	-
Amphipsyche scottae	29	24	18	-	-	-	-	-
Cheumatopsyche thomasseti	16	21	12	17	20	15	15	22
Catoxyethira pinheyi	-	-	-	9				
Elmid larvae	-	-	-	-	-	5	-	-
Simulium adersi	-	-	-	8	19	20	-	-
Simulium damnosum	-	-	-	-	-	18	33	9
Simulium medusaeforme	-	-	-	-	-	10	-	-
Chironominae	-	-	5	5	5	-	6	6
Pentaneura sp.					5			
Orthocladiinae	13	8	15	23	20	13	13	12
Eupera sp.	-	6	-	6	-	-	9	18

6.5.4 Flow cessation and the benthic fauna

As has been described in Section 6.1, River Flow, the river ceased flowing at the Letaba Ranch gauging weir on two occasions during the study. In November 1990 the river flow ceased for 3 days, two weeks prior to the sampling visit to the river. In August 1991 the river ceased flowing for 11 days and commenced flowing again only a week before the sampling visit. As previously mentioned, it is considered highly unlikely that these two periods of interrupted flow resulted in a drying out of the entire river channel.

In order to identify possible impacts of flow cessation on the benthic fauna, full records of sample composition for Stations 6 (where the river is almost certain not to have ceased flowing), 8 and 9 are given in **Appendix Tables A3** to **A5**. Information showing major differences between the fauna of comparable months in years in which river flow ceased or did not cease has been abstracted from these Appendix tables and is given in **Tables 19** (Station 6), **20** (Station 8) and **21** (Station 9).

A feature of all three of these tables is that the mayfly, *Tricorythus* sp., was absent or present only in very low numbers in August. This taxon has a well defined life-cycle in which only stragglers among the larvae are still in this stage in August, the greater part of the population being either in the adult or egg stage at this time (Chutter 1968). (Strictly speaking this seasonal cycle does not appear to apply to the species of *Tricorythus* sp. which occurs in mountain streams. Larvae of this species can be found in large numbers all the year round).

At Station 6 (**Table 19**), the greatest number of species in a single monthly sample was collected in November 1990, the month when, downstream, the river ceased flowing for 3 days (see above **Figure 5**). Faunal diversity was lower in August 1991, the second month that flow ceased, but was greater than it had been in February and May 1990 (**Table A3**).

Comparing species composition at Station 6 in August 1990 (no flow cessation) with that in August 1991 (flow ceased) reveals only two taxa in which there were major abundance changes. *Simulium medusaeforme* was abundant in 1990 and scarce in 1991 and Chironomidae (Chironominae, *Pentaneura* sp. and Orthocladinae) were abundant in 1991 and scarce in 1990. Similarly in November 1990 (flow ceased) and November 1991 the relative abundance of the Orthocladiinae was higher in the year that flow ceased. It would appear from the November data that low flows were detrimental to *Tricorythus* sp., but were tolerated by *C. thomasseti*.

These differences between years at Station 6 should be ascribed to low flow conditions rather than to a complete cessation of flow, as Station 6 was in an area where the flow was unlikely to have ceased completely.

Table 19: Station 6. Number of species and individual animals and percentages of those species whose percentages differed greatly between months in which there was flow cessation and months in which there was not flow cessation.

	Flow cessation months		No flow cessation months	
	Aug. '91	Nov '90	Aug. '90	Nov. '91
Number of species	28	35	32	31
Number of individuals	3765	2446	17886	1626
Tricorythus sp.	-	4	p	17
C.thomasseti	5	46	p	28
S. medusaeforme	3	-	56	-
Chironominae	8	p	1	1
Pentaneura sp.	9	1	p	2
Orthocladiinae	24	23	2	11

Stations 8 and 9 were downstream of the Letaba Ranch flow gauging weir, so that the flow ceased at these points in November 1990 and August 1991. At station 8 (**Table 20**) a greater variety of species was recorded in the months when the river was sampled just after flow had resumed, than in the months when flow had been continuous. Somewhat fewer animals were collected in August 1991 than in August 1990.

At Station 8 the relative abundance of Orthocladiinae was greater in the both months when flow ceased and *C. (Euthraulus)* sp. and *C. thomasseti* percentages were higher in one of the two months when flow ceased (**Table 20**). Species whose percentages were low when flow ceased were *Tricorythus* sp., *A. scottae* (November only) and Simuliidae (August only).

Changes in the number of species present at Station 9 in relation to flow cessation were inconsistent from year to year. Sampling one week after the 11 day flow cessation in 1991 resulted in many more species being found than a year previously, whereas sampling two weeks after the 3 day flow cessation in November 1990 resulted in many less species being found than in 1991 when flow was unbroken

(Table 21). Sample size as number of individuals was very low after the periods of flow cessation, but it was also low in August 1990.

Table 20: Station 8. Number of species and individual animals and percentages of those species whose percentages differed greatly between months in which there was flow cessation and months in which there was not flow cessation.

	Flow cessation months		No flow cessation months	
	Aug. '91	Nov '90	Aug. '90	Nov. '91
Number of species	40	31	32	32
Number of individuals	1283	3641	2155	3797
*C. (Euthraulus)*sp.	18	p	6	p
Tricorythus sp.	-	4	p	27
A. scottae	3	15	1	49
C.thomasseti	7	54	2	10
S. adersi	3	3	37	1
S. damnosum	1	4	8	-
S. medusaeforme	1	1	13	1
S. ruficorne	-	-	10	-
Orthocladiinae	29	9	12	3

Table 21: Station 9. Number of species and individual animals and percentages of those species whose percentages differed greatly between months in which there was flow cessation and months in which there was not flow cessation.

	Flow cessation months		No flow cessation months	
	Aug. '91	Nov '90	Aug. '90	Nov. '91
Number of species	32	22	25	36
Number of individuals	498	219	439	2047
Hirudinea	14	29	1	4
Tricorythus sp.	-	p	-	16
A. scottae	1	14	4	57
Elmid larvae	14	15	2	1
Eupera sp.	19	3	1	5

Species whose percentages showed large increases after flow resumption were Hirudinea (or leeches), Elmid larvae and *Eupera* sp. (August only), while *Tricorythus* sp. and *A. scottae* were less abundant after flow resumption.

The most surprising aspect of the response of the benthic fauna to flow cessation was that, within a week of flow resumption after a period of 11 days with no flow (August 1991), faunal diversity was apparently back to normal levels.

6.6 THE ICHTHYFAUNA

The species of fish present in the Letaba River below the Fanie Botha Dam and above the confluence with the Olifants River, (**Figure 1**) as well as their distribution during the 1990 and 1991 study period, will be reported on in this section.

6.6.1 Species present

During the eight field trips undertaken during 1990 and 1991 a total of 33 species of fish, representing nine families, were caught (**Table 22**). Eleven of these species are known to make summer upstream migrations and twenty-one species occur in seasonal pools.

6.6.2 Species distribution

The occurrence and distribution of the species of fish caught at the 13 sampling stations (**Figure 1**) in 1990 and 1991 can be seen in **Table 23**. The numbers of species that occurred at each station in 1990 and 1991 are shown in **Figure 8** and the total number of species that occurred at each station during the study period appear in **Figure 9.**

6.6.3 The total numbers of each species caught by station

The total numbers of each fish species caught per station can be seen in **Table 24.** A total of 16 644 individual fish were caught using all the types of fishing methods (gill and seine nets, and electro-shocker) during the eight sampling trips of 1990 and 1991.

Table 22: Letaba River. The family, common and scientific names of species of fish caught below Fanie Botha Dam during 1990 and 1991.

Family	Common name	Species		
Anguillidae	Longfinned Eel	*Anguilla mossambica*		✓
Characidae	Spot-tailed Robber	*Brycinus imberi*	*	
	Silver Robber	*Micralestes acutidens*	*	
Mormyridae	Bulldog	*Marcusenius macrolepidotus*	*	✓
	Churchill	*Petrocephalus catostoma*		
Cyprinidae	Hamilton's Barb	*Barbus afrohamiltoni*	*	
	Broadstriped Barb	*Barbus annectens*	*	
	Banded Orangefinned Barb	*Barbus eutaenia*		✓
	Spotted Minnow	*Barbus lineomaculatus*		
	Large-scale Yellowfish	*Barbus marequensis*	*	✓
	Straightfin Barb	*Barbus paludinosus*	*	
	Beira Barb	*Barbus radiatus*	*	
	Broadstriped Barb	*Barbus toppini*	*	✓
	Three-spot Barb	*Barbus trimaculatus*	*	✓
	Longbearded Barb	*Barbus unitaeniatus*	*	
	Bow-stripe Barb	*Barbus viviparus*		
	Purple Mudsucker	*Labeo congoro*		
	Red-eye Labeo	*Labeo cylindricus*		✓
	Plumbeous Labeo	*Labeo molybdinus*	*	✓
	Red-nosed Labeo	*Labeo rosae*	*	✓
	Silver Labeo	*Labeo ruddi*	*	
	River Sardine	*Mesobola brevianalis*	*	
Clariidae	Sharp-tooth Catfish	*Clarias gariepinus*	*	✓
Shilibeidae	Butter Catfish	*Shilbe intermedius*	*	
Mochokidae	Sawfin Rock Catlet	*Chiloglanis paratus*		✓
	Limpopo Rock Catlet	*Chiloglanis pretoriae*		
	Lowveld Catlet	*Chiloglanis swierstrai*		
	Brown Squeaker	*Synodontis zambezensis*		
Cichlidae	MoÇambique Tilapia	*Oreochromis mossambicus*	*	
	Dwarf Tilapia	*Pseudocrenilabrus philander*	*	
	Southern Redbreasted Tilapia	*Tilapia rendalli*	*	
	Banded Tilapia	*Tilapia sparrmanii*		
Gobiidae	Tank Goby	*Glossogobius giuris*	*	

Footnotes: * = Also collected in seasonal pools ; ✓ = Migratory species of fish

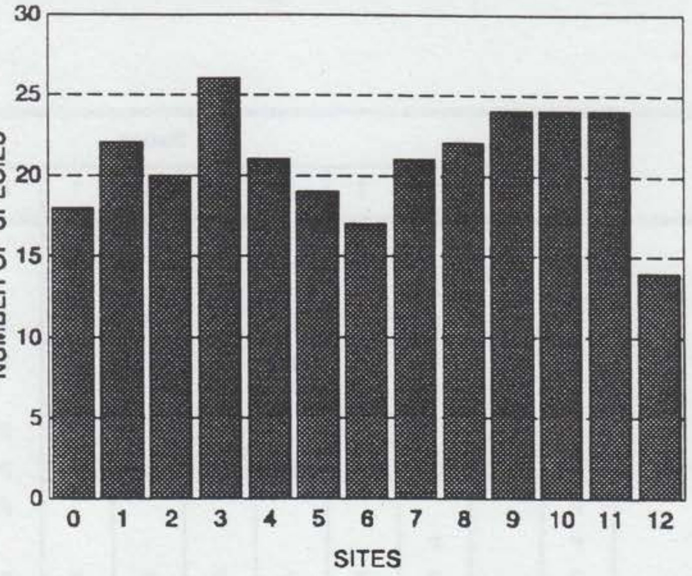


Figure 8: A comparison of the total number of fish species recorded by station in 1990 and 1991.

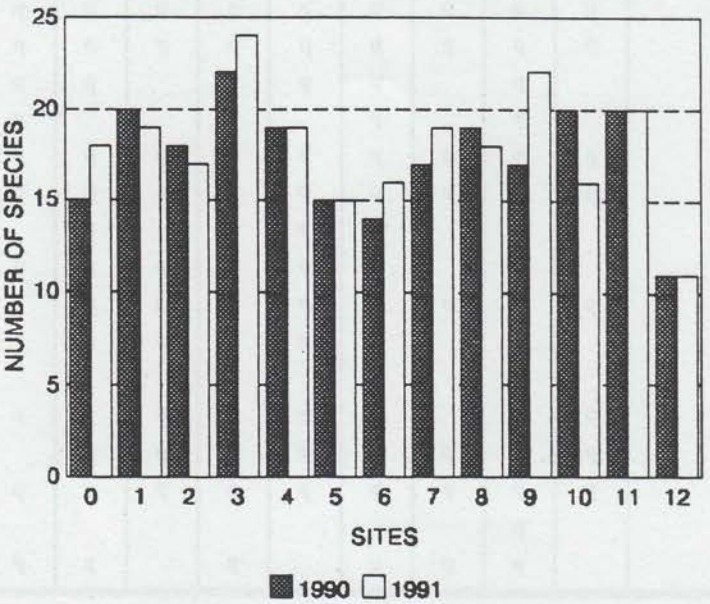


Figure 9: The total number of fish species recorded at each station during 1990 and 1991.

Table 23: Letaba River. The occurrence and distribution of fish species caught at all stations using gill nets, seine nets and an electro-shocker during 1990 and 1991. (p = presence at station).

Species	Station												
	0	1	2	3	4	5	6	7	8	9	10	11	12
A. mossambica		p				p							
B. imberi			p	p				p		p	p	p	
M. acutidens	p	p	p	p	p	p	p	p	p	p	p	p	
M. macrolepidotus	p	p	p	p	p	p	p		p	p	p	p	
P. catostoma		p	p	p									
B. afrohamiltoni									p	p	p	p	p
B. annectens	p	p	p	p	p	p		p	p	p	p	p	
B. eutaenia	p								p		p		
B. lineomaculatus	p		p										
B. marequensis	p		p	p	p	p	p	p	p	p	p	p	p
B. paludinosus			p	p	p					p		p	
B. radiatus										p	p	p	
B. toppini	p	p	p	p	p	p	p	p	p	p	p	p	p
B. trimaculatus	p	p	p	p	p	p	p	p	p	p	p	p	p
B. unitaeniatus	p	p	p	p	p	p	p	p	p	p	p	p	p
B. viviparus	p	p	p	p	p	p	p	p	p	p	p	p	p
L. congoro					p								
L. cylindricus	p	p	p	p	p	p	p	p	p	p	p	p	p
L. molybdinus	p	p	p	p	p	p	p	p	p	p	p	p	p
L. rosae		p		p	p			p	p	p	p	p	
L. ruddi		p		p					p	p	p	p	
M. brevianalis	p	p	p	p	p	p	p	p	p	p	p	p	p
C. gariepinus	p	p	p	p	p	p	p	p	p	p	p		p
S. intermedius		p		p	p			p		p	p	p	
C. paratus		p		p	p	p	p	p	p	p	p	p	p
C. pretoriae	p	p	p	p	p	p	p	p	p	p		p	p
C. swierstrai				p	p		p	p	p				
S. zambezensis				p									
O. mossambicus	p	p		p	p	p	p	p	p	p	p	p	p
P. philander	p		p	p	p	p	p	p			p	p	
T. rendalli	p	p	p	p	p	p	p	p	p	p	p	p	p
T. sparrmanii		p											
G. giuris		p	p	p		p		p	p	p	p	p	

The abundance ranking of the species caught (1 = most abundant) is also shown in **Table 24.** The most common species of fish was *Chiloglanis pretoriae* (Limpopo Rock Catlet), followed by *Mesobola brevianalis* (River sardine).

Table 24: Letaba River. The presence and total number of each fish species per sampling trip in 1990 and 1991.

Species	1990				1991				Total	Rank
	Feb	May	Aug	Nov	Feb	May	Aug	Nov		
A. mossambica			1		1	2	2	1	7	29
B. imberi	2	1	17	6					26	24
M. acutidens	69	183	58	175	113	181	56	68	903	7
M. macrolepidotus	3	6	2	1	7	2	7	8	36	22
P. catostoma	1	2			1			2	6	30
B. afrohamiltoni		2		45		7	24	1	79	20
B. annectens	2			324		43	20	49	438	14
B. eutaenia	12	3	2	2		15	5		39	21
B. lineomaculatus							1	2	3	31
B. marequensis	14	102	151	193	77	137	217	172	1063	6
B. paludinosus			7	2		2			11	26
B. radiatus				8		1		1	10	28
B. toppini	14	78	23	173	41	31	38	54	452	13
B. trimaculatus	91	236	75	138	82	136	307	31	1090	5
B. unitaeniatus	85	95	7	148	48	41	91	7	522	12
B. viviparus	23	47	81	141	72	37	120	159	680	9
L. congoro					1				1	33
L. cylindricus	25	13	50	76	112	89	109	48	522	11
L. molybdinus	119	160	119	136	180	151	227	95	1187	3
L. rosae	4		13	193	2	28	33	2	275	16
L. ruddi	2	1	10	1	4		11	1	30	23
M. brevianalis	230	345	27	199	33	276	36	44	1190	2
C. gariepinus	13	12	24	9	20	20	35	21	154	18
S. intermedius	3	4	7	6	1	2	29	4	560	10
C. paratus	7	68	86	43	30	94	50	38	416	15
C. pretoriae	74	478	859	532	368	1258	772	681	5022	1
C. swierstrai		2	9		1	3	1	1	17	25
S. zambezensis	2		8			1			11	26
O. mossambicus	71	29	124	110	189	78	373	131	1105	4
P. philander	5	9	35	23	27	17	1	12	129	19
T. rendalli	7	25	68	536	81	8	15	106	846	8
T. sparrmanii								2	2	32
G. giuris	6	5	7	55	31	46	64	26	240	17
Total catch	884	1906	1940	3275	1522	2706	2644	1767	16 644	

The differences between catch per unit effort for the different fishing methods were not taken into account for this data synthesis. All data were combined.

The maximum fish species diversity in 1990 and 1991 was recorded at station 3 with the lowest species diversity occurring at station 12 for both years (**Figure 8**). The same trend was apparent when the species diversity per station was combined for the study period, with 26 species being recorded at station 3 and only 14 recorded at station 12 (**Figure 9**).

6.6.4 Relative abundance of species caught

The relative abundance of each species of fish caught per sampling trip expressed as percentage of the total catch per sampling trip can be seen in **Table 25**.

Table 25: The relative abundance of each fish species as a percentage of the total catch per sampling trip (percentages <1 not shown).

Species	1990				1991				Mean
	Feb	May	Aug	Nov	Feb	May	Aug	Nov	
A. mossambica									
B. imberi			1	5	7	7	2	4	5
M. acutidens	8	10	3						
M. macrolepidotus									
P. catostoma									
B. afrohamiltoni				1			1	3	3
B. annectens				10		2	1		
B. eutaenia	1					1			
B. lineomaculatus									
B. marequensis	2	8	8	6	5	5	8	10	6
B. paludinosus									
B. radiatus									
B. toppini	2	4	1	5	3	1	1	3	3
B. trimaculatus	10	12	4	4	5	5	12	5	7
B. unitaeniatus	10	5		4	3	1	3		3
B. viviparus	3	2	4	4	5	1	4	9	4
L. congoro									
L. cylindricus	3	1	3	2	7	3	4	3	3
L. molybdinus	13	8	6	4	12	6	9	5	7
L. rosae			1	6		1	1		2
L. ruddi									
M. brevianalis	26	18	1	6	2	10	1	2	7
C. gariepinus	1				1	1	1	1	1
S. intermedius							1		
C. paratus	1	4	4	1	2	3	2	2	2
C. pretoriae	8	25	44	16	24	46	29	38	30
C. swierstrai									
S. zambezensis									
O. mossambicus	8	1	6	3	12	3	14	7	7
P. philander	1		2	1	2	1		1	1
T. rendalli	1	1	3	16	5		1	6	5
T. sparrmanii									
G. giuris	1			2	2	2	2	1	1

There were large seasonal variations in the relative abundance of each species especially *Tilapia rendalli* (range of 0,3% to 16,4% of the total catch per sampling site) and *M. brevianalis* (range of 1,4% to 26,0% of the total catch).

6.6.5 The fishing effort and catch per unit effort (CPUE)

The fishing methods and fishing efforts used per station during the sampling period of 1990 and 1991 are shown in **Table 26**.

Table 26: Letaba River. The fishing methods and fishing efforts used per station during the sampling period of 1990 to 1991.

Station	Method	Year and month							
		1990				1991			
		Feb	May	Aug	Nov	Feb	May	Aug	Nov
0	S	6	6	5	5	6	15	10	10
	Se	1	1	4		1	1	1	1
1	S	3	6.5	5	5	10	10	6	6
	G	210	240	280	180	400	330	270	290
	Se	1	1						
2	S	5	8	10	7	12	8	17	10
	Se	1							
3	S	5	7	9	5	10	7	10	12
	G	315		1080		470	1030	300	390
4	S	10	10	17	10	20	15	8	12
	G	160	1030	975	1	420	325	840	930
	Se	1	1				1		
5	S	3	11	12	5	10	10	10	10
	G		240						
6	S	5	3	10	7	6	15	10	10
7	S	3	4	6	12	12	10	10	10
	G	300	305	450	360	330	300	300	300
	Se	1	1			1			
8	S	5	20	8	12	12	10	15	2
9	S		315	17	10	20	20	6	10
	Se			1		1	1		
10	S				12			8	
	Se				1			1	
11	S				19			14	
	G				70			1	
	Se				2				
12	S				8			10	
	Se							1	

Key: S = Shocker (minutes) G = Gill net (minutes) Se = Seine net (no. of pulls)

The catch per unit effort (CPUE) indicates the number of fish caught, divided by the fishing effort(minutes) for the shocking and gillnet methods (**Table 27**).

Table 27: Letaba River. The catch per unit effort (CPUE) for gillnets and shockers used to catch fish. **A:** CPUE for 1990. **B:** CPUE for 1991

A.

Station	Feb		May		Aug		Nov	
	Shocker	Gillnet	Shocker	Gillnet	Shocker	Gillnet	Shocker	Gillnet
0	5.00		2.17		0.40		8.60	
1	18.33	0.15	5.54		28.20	0.03	58.20	0.03
2	7.80	0.00	41.25		5.40		27.00	
3	25.80	0.04	11.28		7.22	0.04	75.20	
4	1.70		12.20	0.03	7.24	0.02	6.50	
5	3.66		9.64	0.02	12.66		14.20	
6	4.60	0.04	63.00		41.80		39.86	
7	7.00		30.75	0.03	23.50	0.04	18.08	0.05
8	7.20		6.55		22.13		7.33	
9	3.9		20.00		5.24		13.20	
10							27.25	
11							16.37	4.54
12							22.50	

B.

Station	Feb		May		Aug		Nov	
	Shocker	Gillnet	Shocker	Gillnet	Shocker	Gillnet	Shocker	Gillnet
0	5.30		6.47		5.80		1.10	
1	15.40	0.02	38.3	0.02	62.33	0.03	14.00	0.01
2	16.58		12.13		5.76		13.90	
3	19.20	0.01	18.14	0.08	5.23	0.03	3.33	0.18
4	5.60	0.07	10.66	0.04	5.50	0.08	8.25	0.03
5	4.20		13.50		16.30		15.70	
6	19.50		33.66		12.50		44.30	
7	5.50	0.02	16.90	0.14	16.30	0.07	13.30	0.12
8	7.90		23.90		5.87		85.50	
9	4.40		12.40		21.66		13.70	
10					11.00			
11					11.86			
12					4.70			

The CPUE for the shocker varied seasonally with the highest CPUE's occurring in November for both 1990 and 1991 and the lowest in February for both years (**Table 27, Figure 10**).

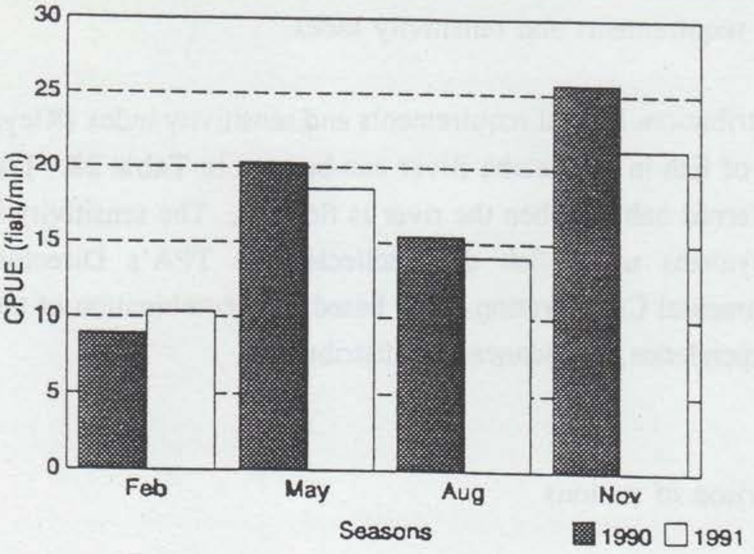


Figure 10: The mean seasonal shocker catch per unit effort for 1990 and 1991.

The mean CPUE's for the shocker (number of fish caught per minute of shocking) per station for 1990 and 1991 indicate a large variation between stations with Station O having a mean CPUE of 4,3 and Station 6 a mean CPUE of 32,4 (**Figure 11**).

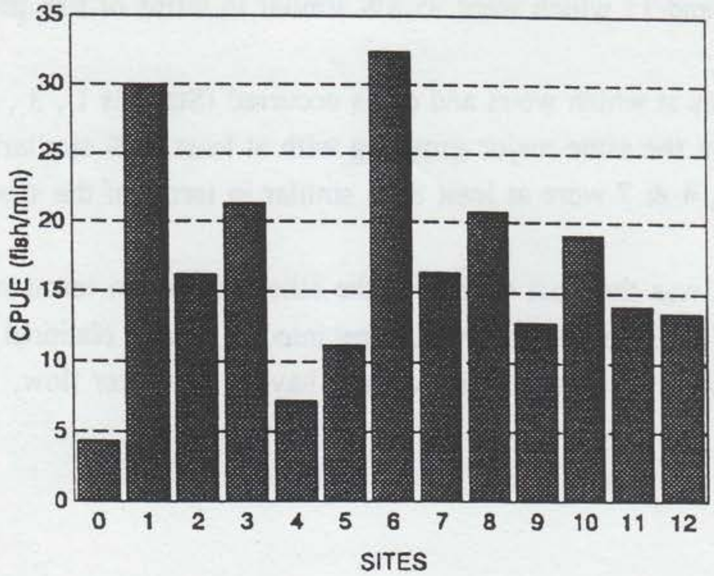


Figure 11: The mean shocker catch per unit effort per station for 1990 and 1991.

The CPUE's for the gillnets (number of fish caught per minute of netting) are low varying from 0 to 4,5 (**Table 27**).

6.6.6 Habitat requirements and sensitivity index

The distribution, habitat requirements and sensitivity index (Kleynhans, 1991) for the species of fish in the Letaba River can be seen in **Table 28**. The habitat indicated is the preferred habitat when the river is flowing. The sensitivity index was developed by Kleynhans using fish data collected by TPA's Directorate of Nature and Environmental Conservation. It is based on a combination of temperature tolerance, flow dependence, abundance and distribution.

6.6.7 Comparison of stations

The results of the cluster analysis undertaken can be seen in **Figure 12**. There was at least 70% similarity between all stations and Station 12 differed from the other stations.

Stations 0, 2, 5 and 6 were most different from the other stations even though they themselves were similar to one another. Stations 3, 4 and 7 were tightly clustered and consequently similar. The closest similarity between stations was between stations 9 and 11 which were 95,8% similar in terms of fish present.

The stations at which weirs and dams occurred (Stations 1 , 3 , 4 , 7 & 11) were all clustered in the same major grouping with at least 81% similarity between stations. Stations 3, 4 & 7 were at least 87% similar in terms of the species of fish present.

Station 12 was the least similar to the other stations in terms of the species of fish recorded. This station was the furthest into the Kruger National Park, had the lowest flow and was the most likely station to have a no winter flow.

Table 28: Letaba River. Distribution, preferred habitat and sensitivity index (Kleynhans, 1991) of fish species of fish caught.

Species	Distribution	Preferred Habitat	Sensitivity Index
A. mossambica	L	R	1
B. imberi	L	R	2
M. acutidens	M	P/R	1
M. macrolepidotus	L	P/R	2
P. catostoma	L	R	2
B. afrohamiltoni	L	P/D	2
B. annectens	L	P	2
B. eutaenia	M	P/R	4
B. lineomaculatus	M	P/R	3
B. marequensis	E/M/L	P/R/D	1
B. paludinosus	M/L	R	2
B. radiatus	L	P/R	2
B. toppini	M/L	P/R	2
B. trimaculatus	M/L	P/R	1
B. unitaeniatus	M/L	P/R	1
B. viviparus	M/L	P/R	3
L. congoro	L	R	2
L. cylindricus	M/L	P/R	1
L. molybdinus	M/L	P/R	1
L. rosae	L	R/D	1
L. ruddi	L	P/D	2
M. brevianalis	M	P/R	1
C. gariepinus	M/L	R/D	1
S. intermedius	L	P/D	1
C. paratus	L	R	2
C. pretoriae	E/M	P/R	3
C. swierstrai	L	R	4
S. zambezensis	L	R/D	2
O. mossambicus	M/L	P/D	1
P. philander	E/M/L	P/R	1
T. rendalli	M/L	P/R	1
T. sparrmanii	E/M/L	P/R	1
G. giuris	L	P	3

KEY:-

E = Escarpment M = Middleveld L = Lowveld
P = Pools* R = Rapids D = Man-made impoundments
1 = Tolerant 2 = Less tolerant 3 = intermediate sensitivity
4 = sensitive 5 = very sensitive

* mainstream reaches of river with slow or no flow

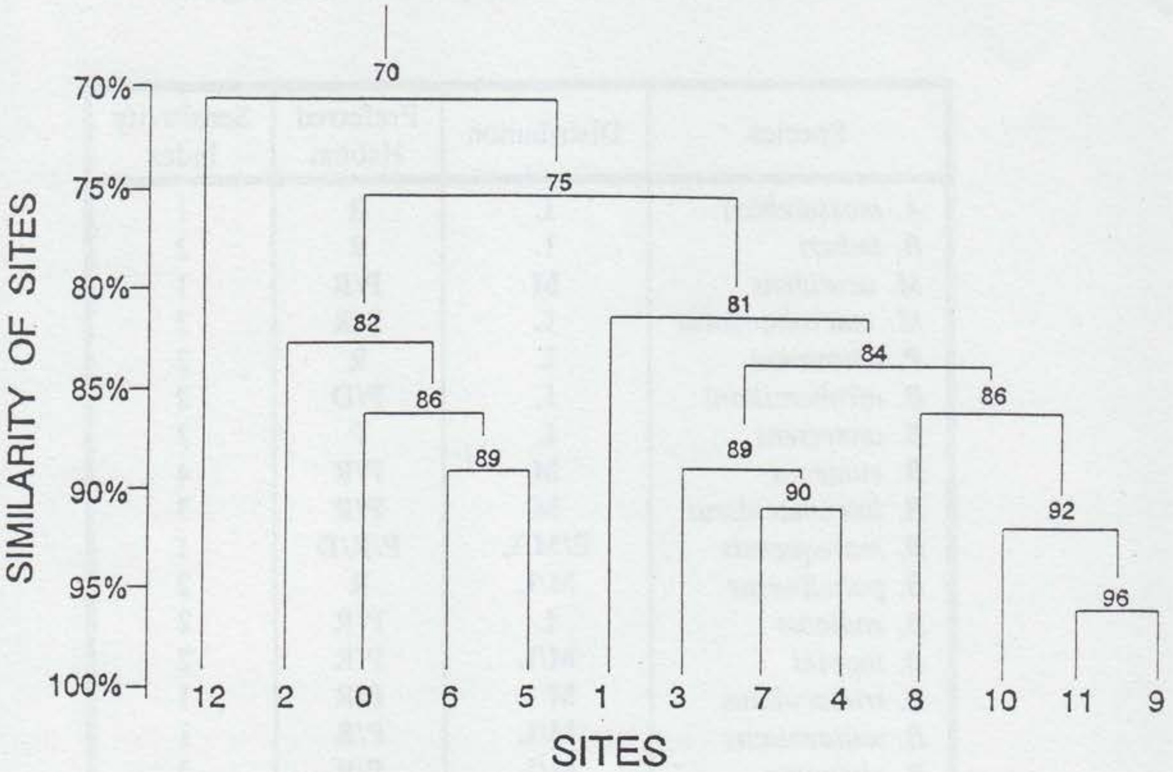


Figure 12: A dendrogram showing the similarity between sampling points based on dominant fish species.

6.6.8 Seasonal pools

During the survey, two seasonal pools (i.e. pools that are isolated from the main flow of the river or pools that persist when the main river has ceased flowing and are maintained by subsurface river flows) were netted by means of a mosquito seine net. A pool at Station 9, which was only inundated during high flow periods (which never corresponded to our field visits), was seine netted in August 1990 and in February, May and November 1991. A pool below Station 10 was netted in November 1990 and August 1991. This pool had a coarse gravel sediment, was 50% covered by overhead vegetation, was 5 to 20 cm deep, and had a maximum recorded water temperature of 38 °C at 14:00 on 19 November 1990.

A total of twenty one species of fish was recorded in these seasonal pools (Table 22).

7. DISCUSSION

7.1 WATER CHEMISTRY

The nature of the water chemistry recorded in the Letaba River in the study area is not such as to be likely to restrict the occurrence of benthic invertebrate or fish species. The characteristic of the water most likely to have an impact, either direct or indirect due to its consequences for primary production, is the turbidity. Turbidity would appear to be elevated by comparison with a river such as the Sabie.

7.2 BENTHOS

In contrast to the conclusions reached by Moore and Chutter (1988), the Letaba River would appear to be presently supporting a reasonably diverse fauna. The only invertebrate animal that was conspicuously absent is the Plecopteran, *Neoperla spio*. It is unlikely that the river is presently suitable for another interesting animal, the mayfly *Machadorythus* sp.. This animal lives in the thin layers of loose organic silt which accumulate under quiet current conditions on bedrock in the Sabie River. Such conditions were not seen in the Letaba, but then the water was seldom sufficiently transparent to allow the surface of underwater stones to be inspected.

It is only through comparisons of Letaba River benthos with the benthos of a river such as the Sabie, which is generally recognised among river ecologists as being the Lowveld river least impacted by human activities, that it will be possible to decide whether or not the loss of species diversity in the Letaba River benthos extends beyond the loss of *N. spio* and *Machadorythus* sp.. The data, which will allow a comparison to be made between the Sabie and the Letaba Rivers so that the extent of degradation of the Letaba may be better quantified, is presently being collected in another study sponsored by the Water Research Commission. However, the interpretation of absence of taxa as being due to "degradation" of the ecosystem will have to cautious, for too little is known about the minutiae of the environmental requirements of most of the benthos to make categorical statements.

In a recent consideration of the recovery of stream ecosystems from various forms of stress, Cairns (1990) listed the following six factors which contribute to the speed of recovery:

(a) existence of nearby epicentres for providing organisms to reinvade a damaged ecosystem,

(b) transportability or mobility of dissemules (eggs, larvae, flying adults, etc),

(c) condition of habitat following stress,

(d) presence and persistence of residual toxicants following pollutional stress,

(e) chemical-physical environmental quality following pollutional stress, and

(f) potential of management agencies or other organisations to assist in remediation of the damaged area.

It is relevant to consider the benthic invertebrates of the Letaba River in relation to some of these factors. The Letaba channel is used for the distribution of water downstream of Fanie Botha Dam. This means that there has always been an area below the dam, where the river has always flowed. This would be an important epicentre (factor a) from which the lower river could be re-colonised.

However, an interesting point arises from a consideration of the results. They indicate (**Tables 12** and **A1**) that the species richness of the benthos is no lower in that part of the study area which was most severely stressed as a result of the river ceasing to flow than it is where flow is permanent. Indeed, several mayfly species were found only in the downstream part of the river.

These facts might indicate that stresses of other kinds are restricting the natural diversity of the benthic fauna nearer to Fanie Botha Dam. For some sampling points, the stress could be the proximity of high weirs.

The Letaba flow is undoubtedly much lower than its virgin flow. Nevertheless, the fauna is reasonably diverse and, on present evidence, is as diverse in that part of the river which was most severely stressed due to flow cessation (see above) as it is anywhere. This suggests that too much emphasis may be being placed on the flow as the prime factor limiting the diversity of the river fauna. It should not be overlooked that there are other stresses on the biota of the river. For instance, the use of biocides is essential in modern intensive agriculture and it is to be expected that biocides may sporadically find their way into the river. While no single event may be sufficient to decimate the river fauna and to be recorded due to its prominence, the cumulative impact of small events may be sufficient to lower the species richness of the river biota. Also, from personal observations, it is clearly apparent that turbidity levels in the Letaba River below the Letsitele confluence are higher than in the Sabie River. Inorganic suspensoids can stress aquatic invertebrates directly through interfering with their respiratory organs or by lowering the feeding efficiency of species (particularly the predatory species), which rely on sight in feeding. Indirect effects of turbidity include reduction of macrophytic and algal growth in the river and thus of the diversity of food resources of some taxa.

Going back to Cairn's factors, factor (f) has had an effect on the recovery of the Letaba River, through the fruitful negotiations of the National Parks Board officials with the Letaba Irrigation Board. These have improved the dry season flow of the lower river in recent years - but these have been years of relatively high rainfall. Even so, control over abstraction of water from the river is still inadequate, as evidenced by the fact that flow ceased once in each year of this study.

There is no room for complacency about the future of the biota of the Letaba River, for the number of epicentres for re-invasion is doubtlessly becoming less and less. The Letaba is now itself an epicentre for the recovery of its tributaries, many of which have been degraded through the destruction of their riparian zones and the over-extraction of water (Ashton, P J, personal communication).

Nearly every fish species that has ever been recorded in the Letaba River has been collected during this study (see below). In view of the fact that fish populations recover from environmental stresses more slowly than invertebrate populations because their life cycles are of longer duration, it could be argued that the invertebrate fauna is now as diverse as it is ever likely to be. Since the invertebrate fauna of the river, when it was perennial, is unknown, there is no way to test this hypothesis.

Data from Stations 8 and 9 collected after the river ceased flowing at Letaba Ranch have to be interpreted with some caution. In the presentation of results, three assumptions have been made. It has been assumed that, because there was no flow at the weir, there was no flow at the downstream sampling points. It has been assumed that the duration of flow cessation was the same at the weir and the downstream sampling points and that the riverine pools did not dry out. Notwithstanding this, the flow of the lower river, if any, must have been very low when there was no flow at Letaba Ranch. There are no perennial tributaries to the Letaba River downstream of Letaba Ranch and upstream of the Klein Letaba confluence.

Quite clearly the great majority of the species present at Stations 8 and 9 survived this period of low flow. Such is the nature of the Letaba River channel in these lower reaches, with short rapids and long pools, that it is unlikely that apparent survival was due to re-invasion by drift. Re-colonisation by egg-laying adults could have been a factor contributing to the higher percentages of fast-growing Orthocladiinae (see above, 6.5.4). Specimens of the other insect taxa, too large to have recently hatched, were present.

It is interesting that the one taxon, *Tricorythus* sp., was consistently adversely affected by the flow cessation or extremely low flows below Letaba Ranch. This species has been seen to be the stream insect slowest to recover from a toxic spill which temporarily eradicated a stream fauna (Chutter, F M -personal records).

It must never be forgotten that South Africa is an arid country subject to prolonged droughts. This problem has been faced by the indigenous aquatic fauna as it has evolved. It must have successful survival and recolonisation strategies to have remained to the present day.

7.3 FISH

The Letaba river channel has considerable physical variability and includes sand-banks, backwaters, mainstream pools with barely perceptible flow and obviously flowing sections such as rapids, runs and waterfalls. Since separate elements of the fish fauna have become specialized to live in parts of a river, managed flow regimes have to maintain current speed and stream bed diversity to ensure continued biological diversity.

7.3.1 Comparison of stations

Figure 12 showed that Station 12 differed from the other stations. The probable reasons for this are a combination of the habitat, the effects of regulated flow with periods of zero flow, during winter months and the limited fishing effort. This station's winter flow, being downstream of Engelhardt Dam, is dependent on over flow down the fish ladder. There are several months during periods of drought that this station has no surface flow due to the sandy nature of the river bed substrate (A. Deacon, personal communication). Consequently the fish at this station would be affected and their numbers reduced by the seasonal flow variations. This station was only visited on two field trips and the fishing effort was limited to shocking and two seine net pulls. The fishing efforts were limited by the lack of flowing water and the habitat at this station.

The cluster analysis was unable to differentiate between riffles, pool and dam habitats or the fishing methods used at each station. For example, Stations 2, 5, 6, 8 and 9 were riffles at which mainly shocking was used to catch the fish. These stations were, however, not grouped together by the cluster analysis (**Figure 12**). The cluster analysis did, however, group the sampling stations below weirs together.

The flow modifications, in the form of reduced flows and changed flow patterns, have possibly resulted in similar fish species assemblages at these stations.

7.3.2 The diversity and distribution of the fish fauna of the Letaba River.

There are no fish species in the Letaba River threatened by extinction (Skelton, 1987).

Development in the catchment of the Letaba River, especially large areas of irrigated crops, has resulted in alterations of flow volumes, river regulation, large dams and weirs being built, increase in turbidity and pollution levels and the proliferation of exotic aquatic macrophytes (Russell and Rogers, 1989).

According to the official Transvaal Provincial Administration (TPA) Nature and Environmental Conservation records (Kleynhans, personal communications), thirty nine species of fish have historically been recorded in the Letaba River. The present study recorded thirty three species of fish from below Fanie Botha Dam to above the confluence with the Olifants River within the Kruger National Park. The species not recorded in this study are listed in **Table 29.**

Table 29: Letaba River. Fish species that have previously been recorded but not recorded in the present study (Kleynhans, personal communication).

Species	Common Name
Amphillius uranoscopis	Rock catlet
Anguilla mormorata	Madagascar mottled eel
Barbus polylepis	Small-scaled yellowfish
Hydrocynus vittatus	Tigerfish
Opsaridium zambezensis	Barred minnow
Platygobius aenofuscus	Goby

Amphillius uranoscopis, *Barbus polylepis* and *Opsaridium zambezensis* are restricted to cool highveld-escarpment waters and consequently these species have only been recorded above Fanie Botha Dam. This reach of the Letaba River was not included in the present study. The only distribution records of *Platygobius aenofuscus* in the Letaba River are from the large gorge at the confluence with the Olifants River, which was not sampled during the present study. Records of *Hydrocynus vittatus* have been limited in past years to mainly below the Engelhardt Dam. A study presently being undertaken by Rand Afrikaans University has recorded *H. vittatus* in pools in the Letaba River, directly below Engelhardt Dam and down to the Olifants River confluence (1991 and 1992, G. Steyn, personal communication). The present study did not use the fishing equipment required to collect *H. vittatus* below Engelhardt Dam.

The Madagascar mottled eel (*Anguilla mormorata*) was not recorded in this study but was recorded by Russell and Rogers (1989) in the Letaba River within the Kruger National Park. Although the distribution of this species has probably been least affected by the building of weirs and dams within the Kruger National Park, it is not easy to catch even when it is abundant.

Russell and Rogers (1989) reported on a three year survey of the Letaba River within the Kruger National Park and compared their results to Gaigher (1969). Direct comparisons of the results from Russell and Rogers (1989) are difficult to make due to the limited study area of overlap (only the Kruger National Park stations), their surveys were undertaken in post drought years, they used different stations, different seasons and different fishing methods. According to their survey *Barbus annectens*, a previously widespread species, was not present in the Letaba River. In the present study this species was found through the study area and its relative abundance ranked at 14 (N = 438, **Tables 23** and **24**). *Chiloglanis swierstrai*, also previously widespread (Russell and Rogers, 1989), was not found in the Kruger National Park in the present study but it was present at five stations outside the Kruger National Park.

The other species that Russell and Rogers (1989) suggested had disappeared from the Letaba River, *Labeo congoro*, was only found at station 4 during the present study. The distribution of this species would seem to be severely limited at present in the Letaba River.

Curle (1986) surveyed the Letaba River fish west of the Kruger National Park and all the species that he recorded were also recorded in the present study.

The species diversity at each station along the length of the study area (**Table 23; Figures 9** and **10**), indicated a range of 14 to 26 species of fish, but no clear trends were evident. What was more significant was that the stations (6 and 12) with lowest species diversity had limited available habitat for fish further limiting the fishing effort.

Station 12 was only sampled twice (November 1990 and August 1991) as was stations 10 and 11. The low seasonal flow from the Engelhardt Dam and the broad sandy river bed at station 12 resulted in the surface flow of this station most likely ceasing in winter. This reduced seasonal flow would account for the low species diversity at this station.

The high fish species diversity in the study area, excluding station 12, shows that many species are capable of surviving despite the greatly modified flow, the years of drought and the obstructions due to weirs and dams.

At least twenty six of the species of fish recorded in this study had a wide distribution and occurred throughout the study area (**Table 23**). *Barbus afrohamiltoni* and *B. radiatus* were only recorded at the lower end of the study area (Station 8 down), which agrees with their lowveld distribution (**Table 28**). The Spotted Minnow (*B. lineomaculatus*) was only recorded at Stations 0 and 2 which is in keeping with their Middleveld distribution (**Table 28**). There is no evidence that weirs formed effective barriers to species distribution in the area studied.

There is no difference in the fish species diversity of the Letaba and Olifants rivers, within the Kruger National Park, (Russell and Rogers 1989, Directorate of Nature and Environmental Conservation, Transvaal Provincial Administration, records). This is not surprising, since the Letaba River flows into the Olifants. Consequently each river can serve as an epicentre (or refuge) for re-invasion of the other. The threat to the biota of the Olifants lies in both water quality and flow reduction, while in the Letaba the threat arises out of only flow reduction. This must increase the probability that the biota of both rivers will survive.

From the monthly flow records at Letaba Ranch it would seem that the Letaba River had a reasonably high flow in 1988 due to a high summer rainfall. If the river ceased flowing through the period prior to the study, it was only for a short period of time (possibly November 1990 and August 1991). The fish species diversity and distribution along the Letaba River during the study period has possibly improved since Russell and Rogers' 1989 report. This is probably due to a more regular flow enabling the fish species to recover and recolonize their preferred habitats.

7.3.3 Seasonal pools

The Letaba River bed within the Kruger National Park is largely sandy. The seasonal pools that occur in the sandy bed of the river are essential for maintenance of the river fish species diversity in its present state, especially during winter months. These seasonal pools are also very important for large aquatic mammals and reptiles (hippopotamus and crocodiles). Terrestrial mammals also use these pools as sources of drinking and bathing water. Consequently the fish have to share this limited resource which may become highly eutrophied.

In the Letaba River the seasonal pools sampled during the low flow periods yielded twenty-one species of fish. All of these species are usually found in placid pools, slower quiet water or in vegetated pools (Pienaar, 1978). These seasonal pools play an important role in restocking a seasonal river as they harbour species of fish during no flow periods. The Letaba River has been reduced to a seasonal river due to the increased water demands caused by land usage changes in the upper catchment outside the Kruger National Park.

7.3.4 Flow requirements for maintaining fish populations

In order to maintain fish populations the flow of the Letaba River must be sufficient to ensure habitat diversity, to maintain pools, to maintain riparian vegetation, control excessive reed encroachment and to allow fish migration where it is needed to complete life cycles. The flow requirements for fish migration vary according to the magnitude of man-made obstacles (dams and weirs) and seasonally high flow. The higher the obstacle the larger the flow needed to 'flatten' these obstacles. In the study area of the Letaba River, fish migration is impeded by at least four dams with walls greater than 7 m high (viz. Engelhardt, Black Heron, Prieska and Junction) as well as numerous weirs that are at least one meter high. Only the Engelhardt Dam has a fish ladder. The effectiveness of this fish ladder is questionable due to its siting not being in the natural maximum stream flow.

Even when the highest flows were recorded (February 1990, **Figure 5**) the dams in the Letaba River impeded the upstream migration and recolonization of the 11 migratory species of fish. This, in effect could result in the fish community of the Letaba River being made up of isolated populations of fish. Downstream migration is not impeded which will enable genetic diversity to be maintained downstream of these barriers. Isolation of the upstream populations could lead to species of fish being lost in the Letaba River. Even though the downstream populations might be genetically secure the seasonally reduced flows of the river in the lower reaches will cause these populations to be severely stressed in the winter months and especially in times of drought.

The fish fauna of impounded and regulated rivers, will be characterized by extinctions of some faunal elements, but changes in the faunal composition, biomass and diversity, will also be apparent (Petts, 1984; Plumstead, 1990). Consequently if the flows are not large enough to allow fish migration upstream by 'flattening' the effects of the dams and weirs, as in the Letaba River, breeding and recruitment will be limited, resulting in the fish composition changes referred to above.

The migratory species of fish in the Letaba River, apart from *B. trimaculatus* and *L. molybdinus*, are the least abundant in the river. This implies that the effects of droughts, river regulation and man made obstructions are taking their toll on these fish species.

During the field visit in August 1991, a new station, Station 2a, above Station 3 was visited (**Figure 2**). At this station the river was divided into two channels, the main and a secondary channel. At the time of the visit (20 August) there was a strong flow in both channels. The secondary riffle channel had a pebble bed, was *ca.* 3 m wide, had 100% overhead vegetation and the water depth was *ca.* 20 cm. This was considered to be perfect habitat for at least eight species of fish which were present at Stations 2 and 3 that day. After twenty minutes of intensive shocking no fish were caught. There was, however, a rich species assemblage of macro-invertebrates at this station. Questioning a local farmer about the flow at this station revealed that this secondary channel had not flowed for two weeks at the beginning of August and had only flowed again for the past four to five days. This flow pattern is consistent with the flows recorded at Letaba Ranch for August 1991 (**Figure 5**).

On returning to this station in November 1991, nine species of fish were caught with a CPUE of 17,4.

The low CPUE's for the shocker in August 1991 (**Table 27**) can be related to the 11 days of no recorded flow at the Letaba Ranch gauging station weir prior to the August field trip (**Table 4, Figure 4**). The stations that were particularly effected were stations 8 and 12. Station 8 is a shallow riffle interlinking two slow flowing mainstream reaches of the river. Station 12 is a sandy bottomed riffle whose winter flow is dependant on the Engelhardt Dam being full enough to have an overflow via the fish ladder. Low or zero flow will first effect these stations as the last potential regulatory outflow point is Prieska weir.

In August 1991 the shocker CPUE's at Stations 2, 3 and 4 were very low (**Table 27**). These riffle stations are dependent on a continued flow to maintain the fish faunal diversity. The lowest CPUE's in both years corresponded with the lowest flows (**Figures 4** and **5**). The riffle dwellers, *Chiloglanis paratus*, the fifteenth ranked species (**Table 24**) and *C. swierstrai* (25th ranked), are most vulnerable during low flow periods. The shocker CPUE was used because it is a relatively quantitative method of surveying for the presence of riffle dwelling species of fish, especially in relatively shallow depths.

The ability of fish populations to recover or recolonize reaches of rivers that have dried out, as discussed for Station 2a, is a slower process when compared to the ability of macroinvertebrate populations to recover (Yount and Niemi, 1990). It can take several years of 'continued' flow before the fish population recovers. The successful recovery of fish populations depends on several factors.

Firstly, an 'epi-centre' for recruitment must be present in which the fish can survive during periods of drought or regulation (seasonal pools, dams and perennial tributaries can be used as epi-centres for recruitment).

Secondly, the flow must vary seasonally with early summer high flows in order to provide for fish upstream migrations. Eleven of the species of fish in the Letaba River, adults or juveniles, require summer floods for upstream migration. These migrations are either for spawning, moving away from turbid water in search of food, or the juveniles moving away from predatory pressures.

Thirdly, there must be sufficient flow in order to ensure that the habitats required for fish to complete their life cycles are available. These habitat requirements differ from species to species. In the Letaba River the river channel characteristics, and consequently available habitat, differ inside and outside of the Kruger National Park. These habitats are diverse, with the 'draw down zone' or marginal vegetation being the most sensitive to flow reduction. Marginal vegetation is important as it is the first habitat to be isolated from the river when flows decrease. This habitat is especially important for fish breeding and protection of juveniles from predation. Consequently, sufficient seasonal flow surges are required in order to flood the required habitats needed for the fish species recruitment and survival.

Detenbeck, *et al.*(1992) reviewed 49 case histories of the recovery of temperate stream fish communities from disturbance. Species within the rock-substratum/nest spawning guilds required significantly longer time periods to either recolonize or re-establish pre-disturbed population densities than did species within other reproductive groups. Recovery was enhanced by the presence of refugia but was delayed by barriers to migration, especially when source populations (epi-centres) for recolonization were relatively distant. Recovery was slowest if disturbance was immediately after spawning.

In contrast to floods, drying of stream channels normally occurs gradually, allowing time for behaviourial adaptations (Yount and Niemi, 1990). Where droughts are predictable, many species have evolved life history or behavioral characteristics that enhance their survival and recovery. Where avoidance or adaptation is impossible, organisms are eliminated and, if the drought is widespread, recolonization sources might be reduced as well.

The dependence of recovery time on generation time has been explicitly recognised for fishes (Yount and Niemi, 1990). Recovery time, i.e. if there is no further disturbance, will depend on the specific species spawning or life history strategy. Species composition, species richness, and total density of fish populations in disturbed rivers exhibited a wide recovery time duration, varying from one year to greater than 52 years (Detenbeck, 1992). The greater the disturbance of the habitat quality the longer the recovery period.

Russell and Rogers (1989) recorded that there was a reduction in the fish species diversity and distribution in the Letaba River after the 1982/1983 and 1986/1987 droughts which led to greatly reduced flows in the river. The present study indicates that the fish species have, to a greater or lesser extent, been able to recover in the Letaba River after good rains in 1988 and continued flows through to 1991.

The major components of fish habitat are water quality, water quantity, food producing areas, spawning grounds, egg incubation areas and cover (Wesche, 1985). For a community of fish to survive in a river all these components must be present. Each of these habitat components can be, to a lesser or greater extent, affected by the building of an impoundment, weir or by river regulation.

With the ongoing conflict between man and ecological water demands in the Letaba River, and man's increasing demands, many of the sensitive species of fish will eventually decrease in distribution and disappear unless the seasonal variation in managed flow to some extent mimics the natural variation. According to Kleynhans (1991) these sensitive species include *B. eutaenia* and *C. swierstrai*, which is confirmed by Russell and Rogers (1989) observations and the low relative abundance of these species in this study **(Table 25)**.

7.4 "ECOLOGICAL" FLOW REQUIREMENTS OF RIVERS

The original broad objective of this study was to provide information which would help to define the minimum flow required to maintain the species richness of the benthos and fish fauna of the Letaba River. The hoped-for opportunity to measure the response of the fauna to the gradual desiccation and rapid re-wetting of the river channel did not arise, due to the unexpected rapidity with which the flow ceased and to communication difficulties with a remote corner of the country.

Nevertheless, as reported in section 6.1 above, there were two short periods when the flow of the river did cease. In both cases scheduled field visits were made soon after the flow resumed and measured impacts on both the fish and benthos were very minor. The conclusion, that may be drawn from these observations, is that the present fauna of the lower Letaba River (Stations 8 and 9, **Figure 1**) is capable of surviving short (up to 11 days) breaks in the river flow. The relevance of this conclusion for the impact of short flow interruptions in otherwise perennial rivers depends on the "naturalness" of the fauna found during this study. This in turn can only be measured against the fauna of the Sabie River, which is still under study. It is certain that the impact of one short break in the continuity of river flow each dry season would be very much less than the impact of several short breaks in the season or of single breaks of longer duration.

Inconclusive as this may be, it is important that the Letaba River currently supports a diverse invertebrate and fish fauna, despite the great modification to the natural flow regime. What is apparent is that the present intended minimum flow of 0.5 m^3s^{-1} at the western boundary of the Kruger National Park would appear to be sufficient to support the present river fauna in the dry season. It is possible, that should this minimum flow be more completely achieved (see **Figure 5** for levels of achievement during the study) species richness in the invertebrates might increase and the numbers of individuals fish species rare in the Letaba River might also increase. For this reason, the authors feel that the only flow recommendation that their studies permit is that the minimum dry season flow should be maintained at 0.5 m^3s^{-1}.

The fish species diversity of the Letaba River has increased since the extremely dry periods of 1982/83 and 1986/87 (Russell & Rogers 1989) and this increase is coincident with higher summer flows and sustained winter flows (**Figure 4**) since 1988. The study showed that a river flow of 0.5 m^3s^{-1} was sufficient to maintain stony flowing water biotopes (rapids, riffles, runs). In the sandy bedded sections of the river, isolated dry season pools in the river channel, which were shown to be important refuges for many species of river fish, are very probably maintained by sub-surface flow, which is due to the 0.5 m^3s^{-1} flow at the western boundary of the Kruger National Park.

It is inadvisable to focus too narrowly on the impact of the very lowest periods of flow, important as they may be for the survival of the river fauna. Equally important are the flows which shape the river channel, the relationship between these large flows and the flow of suspended material into the river channel and the flow required for upstream migration by fish. River channel characteristics appeared to be stable during the short study period. Nevertheless the rate of change of river channel characteristics is variable, depending on the frequency and size of large flows. It is very possible that long term channel changes are taking place in the Letaba River and that these might be detrimental to the river biota.

Although it was not shown that the distribution of any fish species is presently limited by any weir or dam in the Letaba River, the size of flood required to allow upstream migration by the eleven known migratory fish species over the larger weirs is presently unknown. The size and frequency of high flows are extremely important in determining the nature of a river ecosystem and they cannot be ignored in the management of water for ecosystem conservation.

It follows that the impact of present flow management (in its totality of low, intermediate and uncontrolled large flows) on the Letaba River biota cannot be determined from short-term studies. There is therefore good reason to maintain low intensity surveillance of the Letaba River biota, to establish whether a river from which so much water is abstracted continues to support present levels of species richness.

8. CONCLUSIONS

It is concluded that the invertebrate and fish fauna of the Letaba River has recovered rapidly from the severe drought of the mid 1980's. It would appear that the permanently flowing section of the river, immediately downstream of the Fanie Botha Dam, is an important epicentre for the re-colonisation of the dried-up sections of the river, when flow resumes.

There are several aquatic insects, particularly among the mayflies, which only occur in the lower part of the river, which is subject to occasional flow cessation. These insects are apparently able to survive such conditions.

The present benthic invertebrate fauna of the Letaba River is, for the most part, capable of surviving short (up to 11 days) periods of flow cessation without drying out of pools. It is reasonably possible that the invertebrates which cannot tolerate flow cessation have already disappeared from the Letaba River. The most susceptible common insect in the present fauna would appear to be the mayfly *Tricorythus* sp.. This susceptibility may be linked to the fact that its life cycle is synchronized so that annual adult emergence and egg-laying take place over a short period. If the larval population is eradicated before it has emerged from the water to the adult stage, there is no egg-laying adult stage. In these circumstances the re-establishment of the *Tricorythus* sp. population would be dependent on either drift from upstream or re-colonisation through egg deposition by adults. Of course, if the river were to be devoid of the oviposition sites (? stones in the current) when egg-laying was due to take place, re-colonisation would be delayed for a further year.

The study showed that seasonally isolated pools in sandy reaches of the river are important dry season refuges for many fish species. The river flow must be sufficient to maintain these pools in the dry season through subsurface flow. In the wet season flows of sufficient magnitude to connect the pools to the river must occur. Only in this way are the pools able to fulfil their essential role in the continued survival of the fish population.

Knowledge of the biology of the migratory fish species in the Letaba River is deficient to ensure their continued presence. Key questions are whether they are able to spawn in all sections of the river separated by weirs and the size of the minimum flood in which they can make their way over the largest weirs. It may be that more fish ladders would have to be built to ensure that the eleven migratory species of fish can successfully recolonize the upper reaches of the study area. In such a situation, a careful assessment of whether or not access to the upper part of the river is essential to the continued survival of the species, would be necessary in deciding whether the cost of fish ladders and their flow requirements could be justified.

The study showed that a diverse fish and invertebrate fauna existed in the river. It was concluded from this that many components of the fauna can tolerate the present highly modified flow regime, even to the point where the river downstream of Letaba Ranch gauging weir ceased flowing for a period of eleven days. Gratifying as this observation is, it is concluded that it would be unwise to infer from this that river flows can freely be modified to the point where the river ceases flowing for eleven days on end. Although not part of this study, floods must be important in allowing fish migration, connecting seasonal pools to the main river and maintaining the form of the river channel. Long term studies on the response of the river ecosystem to the modified flow regime are needed if the flow pattern is to be managed for the continued maintenance of the present ecosystem.

9. RECOMMENDATIONS

9.1 The present intended minimum dry season flow of 0.5 m^3s^{-1} would appear to be sufficient to maintain the present species richness of the fauna, so this is the recommended minimum flow until such time as it is proved to be incorrect.

9.2 This should be an absolute daily minimum flow rather than a monthly mean minimum and the Groot Letaba Irrigation Board should manage the direct abstraction of irrigation water from the Letaba River so that the daily flow does not decline below 0.5 m^3s^{-1}.

9.3 Flow conditions during the wet season have an importance equal to the minimum dry season flow and they should not be ignored in the management of the flow of the river for maintenance of the ecosystem. The required wet season flow conditions have not been quantified and should enjoy research priority.

9.4 The migratory species of fish in the river need careful study to reveal whether the many weirs in the river prejudice their continued *short-term* survival. The flows required to allow their surmounting the highest weirs and the frequency of such flows should be analysed to determine whether the *long-term* survival of the natural genotypic variability of the migratory species is threatened.

9.5 It is recommended that the Letaba River ecosystem should be kept under carefully planned long term surveillance to reveal whether there are long term untoward trends of change in the ecosystem. Should such trends be detected, management actions to mitigate them should be instituted.

9.6 It is recommended that, when the reports on the fish and invertebrates of the Sabie River come to be written, results from this river should be compared with those from the Letaba River, to gain some appreciation of the extent of possible species loss that has taken place in the Letaba.

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Table A1. A complete distribution table of all invertebrate taxa collected by any method from all sampling points in the Letaba River at any time. N.B. sampling effort from station to station was by no means uniform.

		STATION NUMBER											
		0	1	2	2A	3	3A	4	5	6	7	8	9
Coelenterata	Hydra sp.											p	
Platyhelminthes	Planariidae	p	p	p	p	p	p	p	p	p	p	p	p
Nematoda	Mermithidae		p	p	p		p	p	p	p	p	p	p
	Other Nematoda		p	p	p		p	p	p	p	p	p	p
Annelida	Branchiura sowerbyi				p				p	p	p	p	p
	Nais sp.	p	p	p	p	p		p	p	p	p	p	p
	Other Oligochaeta	p				p		p	p	p	p	p	p
	Hirudinea		p		p	p	p	p	p	p	p	p	p
Crustacea	Cladocera											p	
	Ostracoda		p	p		p		p		p	p	p	p
	Copepoda							p				p	
	Potamonautes juv.			p									
	Caridina nilotica					p				p		p	
Arachnea	Hydrachnellae	p	p	p	p		p	p	p	p	p	p	p
Ephemeroptera	Polymitarcidae		p	p				p	p				p
	Afrobaetodes sp.							p				p	p
	Baetis bellus			p						p	p	p	p
	B. glaucus	p	p	p	p	p	p	p	p	p	p	p	p
	B. harrisoni	p		p		p		p		p		p	
	B. latus	p		p							p		
	Afroptilum excisum			p				p		p		p	p
	A. flavum	p		p				p	p	p	p	p	p
	A. medium	p		p		p			p	p	p	p	p
	A. varium	p						p		p	p		
	Cloeon africanum							p		p			p
	Ophelmatostoma sp.								p	p		p	

continued/...

Table A1 continued/...

		STATION NUMBER											
		0	1	2	2A	3	3A	4	5	6	7	8	9
	Pseudopannota maculosum	p										p	
	Pseudopannota sp. nov.											p	
	Pseudocloeon vinosum	p		p						p	p		p
	Centoptilum bifasciatum	p						p					
	C. spinulosa	p		p				p	p	p	p	p	p
	Baetid juv.	p	p	p	p	p	p	p	p	p	p	p	p
	Elassoneuria sp.			p				p	p	p	p	p	p
	Afronurus sp.	p		p	p	p	p	p	p	p	p	p	p
	Notonurus sp.			p	p				p		p	p	p
	Castanophlebia sp.			p									
	Choroterpes (Euthraulus) sp.		p	p	p		p	p	p	p	p	p	p
	C. (Choroterpes) sp.			p				p	p	p		p	
	Leptophlebiidae juv.	p	p	p				p	p	p	p	p	p
	Tricorythus sp.	p	p	p	p	p	p	p	p	p	p	p	p
	Caenidae	p	p	p	p	p	p	p	p	p	p	p	p
Zygoptera	Zygoptera juv.	p		p	p		p	p	p	p	p	p	p
Anisoptera	Aeschna sp.	p							p				
	Gomphidae		p			p		p	p		p	p	
	Syncordulia sp.										p		
	Libellulidae	p	p	p	p	p	p	p	p	p	p	p	p
Hemiptera	Notonectidae												p
	Naucoridae									p	p		p
	Belostomatidae												p
	Corixidae											p	p
	Veliidae			p								p	p
Neuroptera	Sisyridae		p	p		p	p	p	p			p	

continued/...

Table A1 continued/...

		STATION NUMBER											
		0	1	2	2A	3	3A	4	5	6	7	8	9
Lepidoptera	Nymphulidae		p	p	p		p	p	p	p			p
Trichoptera	Aethaloptera maxima			p	p		p	p		p	p	p	p
	Amphipsyche scottae	p	p	p		p	p	p	p	p	p	p	p
	Cheumatopsyche thomasseti	p	p	p	p	p	p	p	p	p	p	p	p
	C. afra						p						
	Macrostemum sp.	p		p							p	p	
	Hydropsychidae juv.		p	p		p	p	p	p	p	p	p	p
	Chimarra sp.				p								
	Ecnomus sp.							p		p		p	p
	Ceraclea sp.						p		p	p			p
	Trichosetodes sp.			p	p		p		p	p		p	p
	Oecetis sp.	p		p			p		p	p	p	p	p
	Other Leptoceridae			p		p	p			p	p	p	p
	Catoxyethira pinheyi	p	p	p	p	p	p	p	p	p	p	p	p
	Hydroptilia capensis	p	p	p	p	p		p	p	p		p	p
	Orthotrichia sp.	p	p	p		p	p	p	p	p	p	p	p
	Hydroptilidae juv.												p
Coleoptera	Gyrinidae							p		p		p	p
	Dytiscidae		p	p					p	p	p	p	p
	Helminthopsis sp.		p	p				p	p	p	p	p	
	Leptelmis sp.			p						p	p	p	p
	Microdinodes sp.		p			p	p	p		p	p	p	
	Pachyelmis sp.	p	p	p		p	p	p	p	p	p	p	p
	Stenelmis sp.	p	p	p	p	p	p	p	p	p	p	p	p
	Elmidae larvae	p	p	p	p	p	p	p	p	p	p	p	p
	Hydraenidae		p		p	p						p	
	Hydrophilidae		p				p	p		p	p	p	p

continued/...

Table A1 continued/...

		STATION NUMBER											
		0	1	2	2A	3	3A	4	5	6	7	8	9
Diptera	Tipulidae	p					p		p				
	Culicinae							p		p			
	Chaoborinae		p	p									
	Simulium adersi	p	p	p	p	p		p	p	p	p	p	p
	S. bovis			p				p	p				p
	S. bovis/chutteri			p				p	p	p	p	p	p
	S. cervicornutum						p						
	S. damnosum	p	p	p	p	p	p	p	p	p	p	p	p
	S. mcmahoni			p	p		p		p	p	p		p
	S. nigritarsis				p								
	S. ruficorne				p								
	S. medusaeformae	p	p	p		p	p	p	p	p	p	p	p
	S. unicornutum	p		p	p								
	S. vorax		p		p			p				p	
	Simuliidae juv.	p	p	p	p	p	p	p	p	p	p	p	p
	Chironominae	p	p	p	p	p	p	p	p	p	p	p	p
	Pentaneura sp.	p		p	p	p	p	p	p	p	p	p	p
	Orthocladiinae	p	p	p	p	p	p	p	p	p	p	p	p
	Coryoneura sp.			p	p		p	p	p		p	p	
	Limnophora sp.		p		p	p		p				p	p
	Bezzia sp.			p	p			p		p	p	p	p
	? Forcipomyia sp.				p				p		p		p
	Ephydridae				p								
	Rhagionidae	p		p	p		p	p	p	p	p	p	p
	Stratiomyidae			p									
	Tabanidae	p	p	p		p		p	p	p	p	p	p

continued/...

Table A1 continued/...

		STATION NUMBER											
		0	1	2	2A	3	3A	4	5	6	7	8	9
	Dolichopodidae										p		
	Empididae	p	p	p	p		p	p	p	p			
Gastropoda	Melanoides sp.		p	p	p	p	p	p				p	p
	Lymnaea sp.					p							
	? Physopsis sp.		p	p									
	Gyraulus sp.			p	p			p			p	p	
	Biomphalaria sp.									p			
	Burnupia sp.		p	p	p	p		p	p	p	p	p	p
Pelecypoda	Corbicula sp.		p	p	p	p	p	p	p	p	p	p	p
	Eupera sp.		p	p	p	p	p	p	p	p	p	p	p
	Pelecypoda juv.		p	p	p	p	p	p	p	p	p	p	p
Total number of taxa at sampling point		44	49	56	50	43	47	60	63	71	67	81	75

p - species present

Table A2. The seasonal occurrence of all taxa (other than the Cladocera, Copepoda and Ostracoda) collected in the stones in current benthic samples collected with the 300μ sampling net.

		SAMPLING DATE							
		2/90	5/90	8/90	11/90	2/91	5/91	8/91	11/91
Coelenterata	*Hydra* sp.				p	p			
Platyhelminthes	Planariidae	p	p	p	p	p	p	p	p
Nematoda	Mermithidae	p	p	p	p	p	p	p	p
	Other Nematoda	p	p	p	p	p	p	p	p
Annelida	*Branchiura sowerbyi*	p			p	p	p	p	p
	Nais sp.	p			p	p	p	p	p
	Other Oligochaeta	p	p		p		p	p	p
	Hirudinea	p		p		p	p	p	p
Crustacea	*Caridina nilotica*					p			
Arachnea	Hydrachnellae	p	p	p	p	p	p	p	p
Ephemeroptera	Polymitarcidae	p	p		p		p		p
	Afrobaetodes sp.		p						
	Baetis bellus	p				p			
	B. glaucus	p	p	p	p	p	p	p	p
	B. harrisoni	p	p				p		p
	B. latus								p
	Afroptilum excisum	p			p	p			
	A. flavum	p	p	p	p	p	p		p
	A. medium	p	p		p	p	p		p
	A. varium		p						
	Cloeon africanum					p		p	
	Ophelmatostoma sp.			p	p			p	
	Pseudopannota maculosum								p
	Pseudopannota sp. nov.		p	p					
	Pseudocloeon vinosum					p			
	Centroptiloides bifasciatum								p
	Centroptiloides spinulosa		p			p			p

Continued/...

Table A2 continued

		SAMPLING DATE							
		2/90	5/90	8/90	11/90	2/91	5/91	8/91	11/91
Ephemeroptera	*Elassoneuria* sp.	p	p		p	p	p		p
	Afronurus sp.	p	p	p	p	p	p	p	p
	Notonurus sp.							p	
	Castanophlebia sp.						p		
	Choroterpes (Euthraulus) sp.	p	p	p	p	p	p	p	p
	C. (Choroterpes) sp.	p		p		p	p		
	Tricorythus sp.	p	p	p	p	p	p	p	p
	Caenidae	p	p	p	p	p	p	p	p
Odonata	Zygoptera	p	p	p	p	p	p	p	p
	Aeschna sp.	p							
	Gomphidae	p			p		p	p	
	Corduliidae								p
	Libellulidae	p	p	p	p	p	p	p	p
Hemiptera	Corixidae			p	p				p
Neuroptera	Sisyridae	p	p	p	p	p	p	p	p
Trichoptera	*Aethaloptera maxima*	p	p		p	p	p	p	p
	Amphipsyche scottae	p	p	p	p	p	p	p	p
	Cheumatopsyche afra							p	p
	C. thomasseti	p	p	p	p	p	p	p	p
	Macrostemum sp.	p	p						
	Chimarra sp.							p	
	Ecnomus sp.			p			p	p	p
	Ceraclea sp.						p	p	p
	Trichosetodes sp.		p		p		p	p	p
	Triaenodes sp.			p				p	
	Leptocerus sp						p	p	
	Oecetis sp.	p	p	p			p	p	p

Continued/...

Table A2 continued

		SAMPLING DATE							
		2/90	5/90	8/90	11/90	2/91	5/91	8/91	11/91
Trichoptera	Other Leptoceridae		p	p			p	p	
	Catoxyethira pinheyi		p	p	p	p	p	p	p
	Hydroptila capensis	p	p	p	p		p	p	p
	Orthotrichia sp.	p	p	p	p	p	p	p	p
Lepidoptera	Nymphulidae		p	p	p	p	p		p
Coleoptera	Gyrinidae							p	
	Dytiscidae	p			p	p			p
	Helminthopsis sp.			p	p		p	p	p
	Leptelmis sp.	p		p		p	p	p	
	Microdinodes sp.		p	p	p	p	p		
	Pachyelmis sp.	p	p	p	p	p	p	p	p
	Stenelmis sp.	p	p	p	p	p	p	p	p
	Elmid larvae	p	p	p	p	p	p	p	p
	Hydraenidae		p	p		p		p	
	Hydrophilidae	p		p		p	p		p
Diptera	Tipulidae	p		p	p	p		p	
	Chaoborinae	p				p			
	Simulium adersi	p	p	p	p	p	p	p	p
	S. bovis	p	p	p		p	p		
	S. cervicornutum		p					p	
	S. damnosum	p	p	p	p	p	p	p	p
	S. impukane			p			p		
	S. mcmahoni		p	p			p	p	p
	S. medusaeforme		p	p	p	p	p	p	p
	S. nigritarsis							p	
	S. ruficorne		p	p				p	
	S. unicornutum		p					p	

Continued/...

Table A2 continued

		SAMPLING DATE							
		2/90	5/90	8/90	11/90	2/91	5/91	8/91	11/91
Diptera	*S. vorax*						p	p	
	Chironominae	p	p	p	p	p	p	p	p
	Pentaneura sp.	p	p	p	p	p	p	p	p
	Orthocladiinae	p	p	p	p	p	p	p	p
	Corynoneura sp.	p	p	p	p	p		p	p
	Bezzia sp.						p	p	p
	Forcipomyia sp.			p	p				p
	Ephydridae							p	
	Rhagionidae	p	p	p	p	p	p	p	p
	Stratiomyiidae	p							
	Tabanidae	p	p	p	p	p	p	p	p
	Dolichopodidae		p						
	Empididae	p	p	p	p	p	p	p	p
	Muscid - *Limnophora* sp.		p	p	p		p	p	
Gastropoda	*Melanoides* sp.		p	p	p	p	p	p	p
	? *Physopsis* sp.		p						
	Gyraulus sp.	p						p	p
	Burnupia sp.		p		p		p	p	p
Pelecypoda	*Corbicula* sp.	p	p	p	p	p	p	p	p
	Eupera sp.	p	p	p	p	p	p	p	p
Number of taxa recorded		56	60	56	56	47	63	68	63

p - species present

Table A3: The animals collected from the stones in current at Station 6 during the survey period. Species abundance as percentage of the total number of animals in each sample. P means present <0.5%.

Date \ Species	1990				1991			
	20.2	8.5	7.8	21.11	11.2	20.5	21.8	13.11
Planariidae	p	p	p	1	p	1	p	4
Mermithidae			p	p	p		1	p
Other Nematoda			p			p		
Branchiura sowerbyi								p
Nais sp.				1			p	
Other Oligochaeta				p		p	p	
Hirudinea			p	p		p		3
Caridina nilotica					p			
Hydrachnellae	p			p		p	p	p
Baetis bellus					26			
B. glaucus	7	5	p	1	13	1	p	1
Afroptilum excisum					p			
A. flavum				p	1			p
A. medium	p			p	p			1
Cloeon africanum					p			
Ophelmatostoma sp.			p	p				
Pseudocloeon vinosum					2			
Centroptiloides spinulosa		1						
Baetid sp. nov.					p			
Elassoneuria sp.	1	p			2	p		
Afronurus sp.	1	2			1	p		1
Choroterpes (Euthraulus) sp.	13	9	p	p	3	5	3	7
Tricorythus sp.	37	26	p	4	15	8		14
Caenidae	3	p	p	3	6	2	2	8
Zygoptera		p			p			
Libellulidae	p	1		p		p	p	
Corixidae								p
Aethaloptera maxima		p		1		2		p
Amphipsyche scottae			p	1		1	p	1
Cheumatopsyche thomasseti	14	18	p	46	16	42	5	28
Ecnomus sp.			p					
Ceraclea sp.								p
Trichosetodes sp.							p	p

Continued/...

Table A3 continued

Date / Species	1990				1991			
	20.2	8.5	7.8	21.11	11.2	20.5	21.8	13.11
Oecetis sp.			p					p
Catoxyethira pinheyi			p	3	p	1	1	1
Hydroptila capensis		1	p	p				
Orthotrichia sp.			p	p	1		p	
Nymphulidae								p
Dytiscidae	p			p	p			
Helminthopsis sp.			p	p		p	p	
Leptelmis sp.	p		p			p		
Microdinodes sp.			p	1				
Pachyelmis sp.		p		p	p	p		
Stenelmis sp.	1	1	p	p	1	1	p	p
Elmidae larvae	4	6	p	5	2	4	p	6
Hydrophilidae					p			
Simulium adersi	2	p	36	1		1	36	
S. bovis	1	p			1	1		
S. damnosum	10	9	3			1	5	p
S. impukane			p			p		
S. mcmahoni		p				1		
S. medusaeforme		p	56				3	
S. nigritarsis							p	
S. ruficorne			1					
Chironominae	p	3	1	p		1	8	1
Pentaneura sp.			p	1	p	2	9	2
Orthocladiinae	4	16	2	23	5	22	24	11
Bezzia sp.			p			p	p	
Rhagionidae	p					p	p	p
Tabanidae	p			p	p	p		p
Empididae		p	p					
Muscid - *Limnophora* sp.			p	p				
Burnupia sp.				p			p	
Corbicula sp.				5		2	1	3
Eupera sp.	p	2		2	p	1		8
Number of taxa	23	25	32	35	29	34	28	31
Number of individuals	1024	1091	17886	2446	1032	1957	3765	1626

Table A4: The animals collected from the stones in current at Station 8 during the survey period. Species abundance as percentage of the total number of animals in each sample. P means present <0.5%.

Date \ Species	1990				1991			
	20.2	8.5	7.8	20.11	11.2	21.5	21.8	13.11
Hydra sp.					P			
Planariidae							1	P
Mermithidae				P			P	P
Other Nematoda	1	P	P				P	
Branchiura sowerbyi	P							
Nais sp.	P			P			1	P
Other Oligochaeta	P							
Hirudinea	P		P	P	P	P	P	P
Hydrachnellae		P					1	P
Povilla adusta				P				P
Baetis glaucus	3	1	1	P	4	P		P
B. harrisoni								P
Afroptilum excisum	1							
A. flavum					1	1		P
A. medium	5				11	1		P
Ophelmatostoma sp.			P				P	
Pseudopannota maculosum								P
Pseudopannota sp. nov.		1	p					
Elassoneuria sp.	5	P		P	39	P		
Afronurus sp.	P		P			P		
Notonurus sp.							P	
Choroterpes *(Euthraulus)* sp.	P	1	6	P	2	10	18	P
C. (Choroterpes) sp.	P				2			
Tricorythus sp.	35	46	P	4	26	10		27
Caenidae	P		2	P		2	5	2
Zygoptera	P		P			P	P	P
Gomphidae	P			P				
Libellulidae	P	P	P		2	P	1	
Corixidae				P				

Continued/...

Table A4 continued

Date	1990				1991			
Species	20.2	8.5	7.8	20.11	11.2	21.5	21.8	13.11
Sisyridae							P	
Aethaloptera maxima		P			P	1		
Amphipsyche scottae	P	2	1	15		10	3	49
Cheumatopsyche thomasseti	12	24	2	54	6	30	7	10
Macrostemum sp.	P							
Ecnomus sp.			P			P		P
Trichosetodes sp.						p	1	P
Triaenodes sp.							P	
Leptocerus sp.						p		
Oecetis sp.						P	P	
Catoxyethira pinheyi				1		P	6	P
Hydroptila capensis		P					P	
Orthotrichia sp.	P		P	2	1	P	P	1
Gyrinidae							P	
Dytiscidae	1			1				P
Helminthopsis sp.				P				
Leptelmis sp.	P						P	
Microdinodes sp.				P				
Pachyelmis sp.	P	P				P	P	
Stenelmis sp.		P	P	1	P	P	P	P
Elmidae larvae	P	3	1	1	1	3	5	1
Hydraenidae			P					
Hydrophilidae			P					
Simulium adersi	4	P	37	3		1	3	
S. bovis	28	10				P		
S. damnosum		5	8	4	1		1	
S. medusaeforme		P	13	1	1		1	
S. ruficorne			10					
Chironominae	1	1	3	P		2	4	1
Pentaneura sp.	P		2	2	3	4	9	

Continued/...

Table A4 continued

Date	1990				1991			
Species	20.2	8.5	7.8	20.11	11.2	21.5	21.8	13.11
Orthocladiinae	3	4	12	9	1	19	29	3
Corynoneura sp.	P	P						
Bezzia sp.						P	1	P
Rhagionidae			P	P			P	P
Tabanidae		P	P	1		P	1	P
Limnophora sp.							P	
Melanoides sp.			P	P			P	
Gyraulus sp.							P	P
Burnupia sp.				1			P	P
Corbicula sp.	P	P	1			1	2	
Eupera sp.	P	1	1	1		3	P	4
Number of species	33	26	32	31	19	32	40	32
Number of individuals	3548	2371	2155	3641	353	2300	1283	3797

Table A5. The animals collected from the stones in current at Station 9 during the survey period. Species abundance as percentage of the total number of animals in each sample. P means present <0.5%.

Date	1990			1991			
Species	8.5	7.8	20.11	11.2	21.5	21.8	13.11
Planariidae			1			1	P
Mermithidae	P		1			P	P
Other Nematoda		P					
Branchiura sowerbyi			1				P
Nais sp.						1	
Other Oligochaeta			2		P		
Hirudinea		1	29			14	4
Hydrachnellae						P	
Povilla adusta							2
Baetis glaucus	7	P		4	1		
Afroptilum flavum	2	P		3	1		1
A. medium	3			11	P		P
Ophelmatostoma sp.							p
Pseudopannota sp. nov.		1					p
Cloeon africanum						1	
Elassoneuria sp.	P			4	P		
Afronurus sp.	P			2			
Choroterpes (*Euthraulus*) sp.	1	14	2	2	11	11	1
Tricorythus sp.	49		P	30	20		16
Caenidae	P	3	6		1	7	1
Zygoptera							P
Libellulidae	1	P		2	1	2	P
Corixidae		P					
Aethaloptera maxima			1	2			P
Amphipsyche scottae	1	4	14	7	4	1	57
Cheumatopsyche thomasseti	15	8	10	25	35	2	4
Ecnomus sp.						P	P
Ceraclea sp.					p	2	P
Trichosetodes sp.			p		p	2	P

Continued/...

Table A5 continued

Species \ Date	1990			1991			
Species	8.5	7.8	20.11	11.2	21.5	21.8	13.11
Triaenodes sp.		P				2	
Leptocerus sp.						1	
Oecetis sp.	P	P				1	
Other Leptoceridae		P			P	p	
Catoxyethira pinheyi						P	1
Hydroptila capensis						P	
Orthotrichia sp.	p			P	P	1	P
Nymphulidae					P		
Dytiscidae			1				P
Leptelmis sp.		P				1	
Pachyelmis sp.	P				P		
Stenelmis sp.			1		P		P
Elmidae larvae	P	2	15	P	1	14	1
Hydrophilidae					P		
Simulium adersi		8	4		P		
S. bovis	13				p		
S. damnosum	P	6	1	2	4	P	P
S. medusaeforme		7				1	P
Chironominae		5	P		1	2	1
Pentaneura sp.		3		1	3	2	1
Orthocladiinae	4	30	2	6	9	11	5
Bezzia sp.						P	
Forcipomyia sp.							P
Rhagionidae		P					P
Tabanidae	P	P	2				P
Melanoides sp.			1			P	1
Burnupia sp.			P				
Corbicula sp.	P				P	1	
Eupera sp.	2	1	3	P	5	19	5
Number of species	22	25	22	17	28	32	36
Number of individuals	1348	439	219	266	2907	498	2047